IMPLEMENTATION OF ENERGYPLUS OBJECTS IN SAPTOOL

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CODE DEVELOPMENT

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INTRODUCTION

In the scope of the Ren4EEnIEQ project (https://ren4eenieq.wordpress.com/) a comprehensive BIM add-on tool for the improvement of energy efficiency and indoor environment quality in renovation of buildings (SAPTool) was developed. This tool – developed in Java – allows to produce alternative building geometries, from the same user requirements and preferences, and then evaluate their energy performance using dynamic simulation. The latter is performed by the coupled simulation engine EnergyPlus.

This manual describes the implementation methodology of selected EnergyPlus objects in the SAPTool – internal gains, HVAC systems, DHW and water systems, air contaminants, daylighting controls, window shading, and electric generation systems – and how to generate the corresponding outputs. These objects properties are mainly defined in a specific database (SAPTool_SQLite database) and their simulation is performed with the EnergyPlus engine (version 9.2). Refer to the EnergyPlus *Input-Output Reference* for additional details on each EnergyPlus object (available in https://bigladdersoftware.com/epx/docs/9-2/input-output-reference/).

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1. ZONES

The zone objects are assigned to the building's zones in the **Zone** table in the database:

- id – object ID;
- name – zone name, for guidance.
- daylightingControlsID – ID of the lighting controls assigned to the zone, defined in section **18**;
- airFlowNetworkMultiZoneZoneID – ID of the zone's airflow network system, defined in section **2.2**;
- sizingZoneID – ID of the zone sizing specifications, defined in section **13.2.2**;
- zoneControlThermostatID – ID of the control thermostat assigned to the zone, defined in section **7.2.1**;
- zoneControlHumidistatID – ID of the control humidistat assigned to the zone, defined in section **7.2.2**;
- zoneControlContaminantControllerID – ID of the contaminant controller assigned to the zone, defined in section **7.2.3**;
- ventilationIDs – IDs of the ventilation specifications assigned to the zone, defined in section **2.1.2**;
- infiltrationIDs – IDs of the infiltration specifications assigned to the zone, defined in section **2.1.1**;
- thermalComfortLimitsID – ID of the thermal comfort limits assigned to the zone, defined in section **16**;
- peopleID – ID of the people specifications assigned to the zone, defined in section **4.1**;
- lightsID – ID of the lights specifications assigned to the zone, defined in section **4.2**;
- zoneEquipmentIDs – IDs of the equipment assigned to the zone, defined in section **4.3**;
- contaminantSourceAndSinkIDs – IDs of the contaminant source and sink specifications assigned to the zone, defined in section **4.4**;
- description – optional object description, for guidance.

2. VENTILATION

Regarding the building's ventilation, the user can select a simplistic Zone Airflow (**2.1**) or a more detailed Airflow Network system (**2.2**). Only one of the options can be selected.

2.1. Zone Airflow

This simplistic zone airflow mode allows to assign different ventilation and infiltration objects to the building's zones. The ventilation and infiltration objects for each zone are assigned in the database, in the 'ventilationIDs' and 'infiltrationIDs' columns of the **Zone** table (**0**), respectively. Multiple ventilation and infiltration objects can be assigned to a single zone. These objects are defined in the sections **2.1.1** and **2.1.2**, respectively.

In this case, the Airflow Network option must be deactivated (**AIRFLOW_NETWORK = false**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables, in order to activate the Zone Airflow option (**INFILTRATION = !AIRFLOW_NETWORK**, **VENTILATION = !AIRFLOW_NETWORK**).

2.1.1. Zone Infiltration

The Zone Infiltration objects assigned to the zones are defined in the **ZoneInfiltration** table in the database:

- id – object ID;
- type – infiltration specification in the corresponding Type table. Currently, only one Zone Infiltration Type is available: 'DesignFlowRate' (**ZoneInfiltrationDesignFlowRate** table in the database – **2.1.1.1**);
- infiltrationID – infiltration type ID in the corresponding table.

2.1.1.1. Design Flow Rate

The following fields are present in the **ZoneInfiltrationDesignFlowRate** table in the database, corresponding to the ZoneInfiltration:DesignFlowRate object in EnergyPlus:

- id – object ID;
- designFlowRateCalculationMethod – 'Flow_Zone', 'Flow_Area', 'Flow_ExteriorArea' or 'AirChanges_Hour';
- designFlowRate – full design volume flow rate [m3/s]. Used only if designFlowRateCalculationMethod = Flow_Zone;
- flowPerZoneFloorArea – flow per zone floor area [m3/s.m2]. Used only if designFlowRateCalculationMethod = Flow_Area;
- flowPerExteriorSurfaceArea – flow per exterior surface area [m3/s.m2]. Used only if designFlowRateCalculationMethod = Flow_ExteriorArea;
- airChangesPerHour – air changes per hour. Used only if designFlowRateCalculationMethod = AirChanges_Hour;
- constantTermCoefficient – parameter A in the infiltration equation[1];

[1] Infiltration = Idesign * FSchedule * (A + B*|(Tzone-Todb)| + C*WindSpeed + D*WindSpeed**2)

- temperatureTermCoefficient – parameter B in the infiltration equation;
- velocityTermCoefficient – parameter C in the infiltration equation;
- velocitySquaredTermCoefficient – parameter D in the infiltration equation;
- scheduleID – infiltration schedule ID, defined in the **Schedules** table in the database (**21**);
- type – 'WithExteriorOpenings', 'WithoutExteriorOpenings' or blank:
  A - In the cases where the user does not know in advance if a zone has exterior openings or not, this allows to specify two infiltration objects, with different infiltration rates, schedules, etc. for each type. Both objects must be assigned to the zone, but only one will be used, depending on the presence or absence of exterior openings in the zone. Example: by assigning an infiltration object with type = WithExteriorOpenings and with 0.3 ACH, and an infiltration object with type = WithoutExteriorOpenings and with 0.1 ACH to a zone, if the zone has exterior openings the infiltrations will be 0.3 ACH; otherwise, the infiltrations will be 0.1 ACH;
  B - If the zone exterior openings type is known, the user can select the proper type and assign a single infiltration object to the zone;
  C - And, finally, if an infiltration object must be assigned, independently of the openings type, the user must leave this field blank (NULL) and assign the infiltration object to the zone;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "INFILTRATION" + Zone Name;
- Zone Name – name of the zone for which the infiltration object is assigned.

2.1.2. Zone Ventilation

The Zone Ventilation objects assigned to the zones are defined in the **ZoneVentilation** table in the database:

- id – object ID;
- type – ventilation specification in the corresponding Type table. Currently, there are three Zone Ventilation Types available: 'DesignFlowRate' (**ZoneVentilationDesignFlowRate** table in the database – **2.1.2.1**), 'WindAndStackOpenArea' (**ZoneVentilationWindAndStackOpenArea** table in the database – **2.1.2.2**), and 'Mixing' (**ZoneVentilationMixing** table in the database – **2.1.2.3**);
- ventilationID – ventilation type ID in the corresponding table.

2.1.2.1. Design Flow Rate

This is a simple ventilation type, where the air entering the space is <u>always</u> assumed to come from <u>outdoors</u>. For air entering the space from other zones see the Zone Mixing Ventilation section (**2.1.2.3**).
The following fields are present in the **ZoneVentilationDesignFlowRate** table in the database, corresponding to the ZoneVentilation:DesignFlowRate object in EnergyPlus:

- id – object ID;

- designFlowRateCalculationMethod – ‘Flow_Zone’, ‘Flow_Area’, ‘Flow_Person’ or ‘AirChanges_Hour’;
- designFlowRate – full design volume flow rate [m3/s]. Used only if designFlowRateCalculationMethod = Flow_Zone;
- flowPerZoneFloorArea – flow per zone floor area [m3/s.m2]. Used only if designFlowRateCalculationMethod = Flow_Area;
- flowPerPerson – flow per person [m3/s.person]. Used only if designFlowRateCalculationMethod = Flow_Person;
- airChangesPerHour – air changes per hour. Used only if designFlowRateCalculationMethod = AirChanges_Hour;
- ventilationType – ‘Natural’, ‘Exhaust’, ‘Intake’ or ‘Balanced’. For Natural and Exhaust ventilation, the conditions of the air entering the space are assumed to be equivalent to outside air conditions. For Intake and Balanced ventilation, an appropriate amount of fan heat is added to the entering air stream.
  A natural ventilation object is only assigned to a zone if exterior openable openings are present. For the remaining ventilation types this is not valid, as the air flow is produced by a fan, thus not depending on the presence of any openings. However, some care must be taken while defining the field ‘type’ below;
- fanPressureRise – pressure rise experienced across the fan in Pa. Used if ventilationType ≠ Natural;
- fanTotalEfficiency – overall efficiency of the fan, i.e., the ratio of the power delivered to the fluid to the electrical input power. Used if ventilationType ≠ Natural;
- constantTermCoefficient – parameter A in the ventilation equation[2];
- temperatureTermCoefficient – parameter B in the ventilation equation;
- velocityTermCoefficient – parameter C in the ventilation equation;
- velocitySquaredTermCoefficient – parameter D in the ventilation equation;
- minimumIndoorTemperature – indoor temperature in Celsius below which ventilation is shutoff (optional);
- minimumIndoorTemperatureScheduleID – minimum indoor temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- maximumIndoorTemperature – indoor temperature in Celsius above which ventilation is shutoff (optional);
- maximumIndoorTemperatureScheduleID – maximum indoor temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- deltaTemperature – temperature difference in Celsius between the indoor and outdoor air dry-bulb temperatures below which ventilation is shutoff (optional);
- deltaTemperatureScheduleID – delta temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- minimumOutdoorTemperature – outdoor temperature in Celsius below which ventilation is shutoff (optional);
- minimumOutdoorTemperatureScheduleID – minimum outdoor temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- maximumOutdoorTemperature – outdoor temperature in Celsius above which ventilation is shutoff (optional);

[2] Ventilation = Vdesign * FSchedule * (A + B*|(Tzone-Todb)| + C*WindSpeed + D*WindSpeed**2)

- maximumOutdoorTemperatureScheduleID – maximum outdoor temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- maximumWindSpeed – wind speed [m/s] above which ventilation is shut off (optional);
- scheduleID – ventilation schedule ID, defined in the **Schedules** table in the database (**21**);
- type – 'WithExteriorOpenings', 'WithoutExteriorOpenings' or blank. <u>This is only valid for ventilationType ≠ Natural (i.e., mechanical ventilation)</u>:
  A - In the cases where the user does not know in advance if a zone has exterior openings or not, this allows to specify two ventilation objects, with different ventilation rates, schedules, etc. for each type. In this way, the object is assigned or not to the zone, depending on the presence or absence of exterior openings. Example 1: by defining a natural ventilation object (type = blank, as it is not valid for natural ventilation) and an exhaust ventilation object with type = WithoutExteriorOpenings for a zone, if the zone has exterior openings, only the natural ventilation object will be assigned; otherwise, only the exhaust ventilation object will be assigned. Example 2: by defining a natural ventilation object (type = blank, as it is not valid for natural ventilation) and an intake ventilation object with type = WithExteriorOpenings for a zone, if the zone has exterior openings, both the natural ventilation and the intake ventilation objects will be assigned; otherwise, no object will be assigned;
  B - If the zone exterior openings type is known, the user can select the proper type and assign a single ventilation object to the zone;
  C - And, finally, if a mechanical ventilation object must be assigned, independently of the openings type, the user must leave this field blank (NULL) and assign the ventilation object to the zone;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "VENT_DFR" + Zone Name + ventID (ventID – ventilation type ID);
- Zone Name – name of the zone for which this object is assigned.

2.1.2.2. Wind and Stack Open Area

With this object, the ventilation air flow rate is a function of wind speed and thermal stack effect, along with the opening area. When active in a zone, this object is assigned to all its exterior openings (one Wind and Stack Open Area object for each opening).
The following fields are present in the **ZoneVentilationWindAndStackOpenArea** table in the database, corresponding to the ZoneVentilation:WindandStackOpenArea object in EnergyPlus:

- id – object ID;
- openingAreaFractionScheduleID – opening area fraction schedule ID, defined in the **Schedules** table in the database (**21**);
- openingEffectiveness – opening effectiveness (Cw) in the ventilation rate driven by wind[3]. 'autocalculate' option is available;
- heightDifference – height difference between the midpoint of the lower opening and the neutral pressure level in meters;

[3] Ventilation Wind = Cw * Opening Area * Schedule * WindSpeed

- dischargeCoefficientForOpening – discharge coefficient for the opening (Cd) in the ventilation rate due to stack effect equation[4]. 'autocalculate' option is available;
- minimumIndoorTemperature – indoor temperature in Celsius below which ventilation is shutoff (optional);
- minimumIndoorTemperatureScheduleID – minimum indoor temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- maximumIndoorTemperature – indoor temperature in Celsius above which ventilation is shutoff (optional);
- maximumIndoorTemperatureScheduleID – maximum indoor temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- deltaTemperature – temperature difference in Celsius between the indoor and outdoor air dry-bulb temperatures below which ventilation is shutoff (optional);
- deltaTemperatureScheduleID – delta temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- minimumOutdoorTemperature – outdoor temperature in Celsius below which ventilation is shutoff (optional);
- minimumOutdoorTemperatureScheduleID – minimum outdoor temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- maximumOutdoorTemperature – outdoor temperature in Celsius above which ventilation is shutoff (optional);
- maximumOutdoorTemperatureScheduleID – maximum outdoor temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- maximumWindSpeed – wind speed above which ventilation is shut off [m/s] (optional).

Automatic filling fields in EnergyPlus:

- Name – "VENT_WSOA" + Zone Name + "OPEN" + openingID (openingID – ID of the opening for which this object is assigned);
- Zone Name – name of the zone for which this object is assigned;
- Opening Area – area of the opening [m2];
- Effective Angle – normal angle of the opening area.

2.1.2.3. Zone Mixing

This is a simple air exchange between zones, where the air entering the receiving zone is always assumed to be originated from other zones or zones.

This option should be used for zone ventilation purposes where the air entering the space does not come from outdoors, but, instead, from a neighbor zone or zones. This is useful for exhaust zones, like bathrooms or kitchens, where the entering air is provided from neighbor zones.

If this object is assigned to a zone (receiving zone), this zone will receive air from all its neighbor zones (source zones), as long as there is an opening between the source and the receiving zones. It will automatically assign a Zone Mixing object for each opening.
The specified total flow rate entering the receiving zone is divided for each Zone Mixing object, according to the number of neighbor zones and the corresponding opening areas. A complementary Zone Ventilation Design Flow Rate object will be assigned to each source zone,

[4] Ventilation Stack = Cd * Opening Area * Schedule * SQRT(2 * g * DH * (|(Tzone-Todb)|/Tzone))

with the correspondent resulting flow rate. The user is able to specify all the source zone ventilation parameters (see below).

The following fields are present in the **ZoneVentilationMixing** table in the database, corresponding to the ZoneMixing object in EnergyPlus:

- id – object ID;
- scheduleID – ventilation schedule ID, defined in the **Schedules** table in the database (**21**);
- designFlowRateCalculationMethod – 'Flow_Zone', 'Flow_Area', 'Flow_Person' or 'AirChanges_Hour';
- designFlowRate – full design volume flow rate [m3/s]. Used only if designFlowRateCalculationMethod = Flow_Zone;
- flowPerZoneFloorArea – flow per zone floor area [m3/s.m2]. Used only if designFlowRateCalculationMethod = Flow_Area;
- flowPerPerson – flow per person [m3/s.person]. Used only if designFlowRateCalculationMethod = Flow_Person;
- airChangesPerHour – air changes per hour. Used only if designFlowRateCalculationMethod = AirChanges_Hour;
- deltaTemperature – temperature value in Celsius that controls when mixing air from the source zone is sent to the receiving zone (optional);
- deltaTemperatureScheduleID – delta temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- minimumZoneTemperatureScheduleName – schedule ID, defined in the **Schedules** table in the database (**21**), which contains the minimum receiving zone temperature in Celsius below which mixing is shutoff as a function of time (optional);
- maximumZoneTemperatureScheduleName – schedule ID, defined in the **Schedules** table in the database (**21**), which contains the maximum receiving zone temperature in Celsius above which mixing is shutoff as a function of time (optional);
- minimumSourceZoneTemperatureScheduleName – schedule ID, defined in the **Schedules** table in the database (**21**), which contains the minimum source zone temperature in Celsius below which mixing is shutoff as a function of time (optional);
- maximumSourceZoneTemperatureScheduleName – schedule ID, defined in the **Schedules** table in the database (**21**), which contains the maximum source zone temperature in Celsius above which mixing is shutoff as a function of time (optional);
- minimumOutdoorTemperatureScheduleName – schedule ID, defined in the **Schedules** table in the database (**21**), which contains the minimum outdoor temperature in Celsius below which mixing is shutoff as a function of time (optional);
- maximumOutdoorTemperatureScheduleName – schedule ID, defined in the **Schedules** table in the database (**21**), which contains the maximum outdoor temperature in Celsius above which mixing is shutoff as a function of time (optional);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "VENT_MIX" + Zone Name + ventID + adjZoneID (ventID – ventilation type ID; adjZoneID – adjacent zone number ID);
- Zone Name – name of the zone for which this object is assigned (Receiving Zone Name);
- Source Zone Name – name of the adjacent (source) zone.

The following fields represent the complementary Zone Ventilation: Design Flow Rate object specifications that will be created for each source zone:

- sourceZoneVentilationType – 'Natural', 'Exhaust', 'Intake' or 'Balanced'. For Natural and Exhaust ventilation, the conditions of the air entering the space are assumed to be equivalent to outside air conditions. For Intake and Balanced ventilation, an appropriate amount of fan heat is added to the entering air stream.
  In this mixing case, and opposed to the original Zone Ventilation Design Flow Rate (**2.1.2.1**), a natural ventilation object can be assigned to a source zone even if exterior openable openings are not present. This allows to simulate the effect of outdoor air entering the zone through other ventilation devices (other than doors or windows), without taking in account any fan electric consumption (e.g., an ideal loads air system);
- sourceZoneFanPressureRise – pressure rise experienced across the fan in Pa. Used if sourceZoneVentilationType ≠ Natural;
- sourceZoneFanTotalEfficiency – overall efficiency of the fan, i.e., the ratio of the power delivered to the fluid to the electrical input power. Used if sourceZoneVentilationType ≠ Natural;
- sourceZoneConstantTermCoefficient – parameter A in the ventilation equation[5];
- sourceZoneTemperatureTermCoefficient – parameter B in the ventilation equation;
- sourceZoneVelocityTermCoefficient – parameter C in the ventilation equation;
- sourceZoneVelocitySquaredTermCoefficient – parameter D in the ventilation equation;
- sourceZoneMinimumIndoorTemperature – indoor temperature in Celsius below which ventilation is shutoff (optional);
- sourceZoneMinimumIndoorTemperatureScheduleID – minimum indoor temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- sourceZoneMaximumIndoorTemperature – indoor temperature in Celsius above which ventilation is shutoff (optional);
- sourceZoneMaximumIndoorTemperatureScheduleID – maximum indoor temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- sourceZoneDeltaTemperature – temperature difference in Celsius between the indoor and outdoor air dry-bulb temperatures below which ventilation is shutoff (optional);
- sourceZoneDeltaTemperatureScheduleID – delta temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- sourceZoneMinimumOutdoorTemperature – outdoor temperature in Celsius below which ventilation is shutoff (optional);
- sourceZoneMinimumOutdoorTemperatureScheduleID – minimum outdoor temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- sourceZoneMaximumOutdoorTemperature – outdoor temperature in Celsius above which ventilation is shutoff (optional);
- sourceZoneMaximumOutdoorTemperatureScheduleID – maximum outdoor temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- sourceZoneMaximumWindSpeed – wind speed above which ventilation is shut off [m/s] (optional).

Automatic filling fields in EnergyPlus:

- Name – "VENT_DFR" + Source Zone Name + "MIX" + Receiving Zone Name;

[5] Ventilation = Vdesign * FSchedule * (A + B*|(Tzone-Todb)| + C*WindSpeed + D*WindSpeed**2)

- Zone Name – name of the adjacent (source) zone;
- Schedule Name – equivalent to the receiving zone schedule;
- Design Flow Rate Calculation Method – equivalent to the receiving zone method;
- designFlowRate – resulting design volume flow rate for this source zone [m3/s]. Used only if designFlowRateCalculationMethod = Flow_Zone;
- flowPerZoneFloorArea – resulting flow per zone floor area for this source zone [m3/s.m2]. Used only if designFlowRateCalculationMethod = Flow_Area;
- flowPerPerson – resulting flow per person for this source zone [m3/s.person]. Used only if designFlowRateCalculationMethod = Flow_Person;
- airChangesPerHour – resulting air changes per hour for this source zone. Used only if designFlowRateCalculationMethod = AirChanges_Hour.

2.2. Airflow Network

This airflow mode allows to assign a detailed airflow network in the building zones (interzone and outdoors air exchange), depending on the surface types and openings presence and typology. The airflow network object for each zone (**2.2.2**) is assigned in the database, in the 'airflowNetworkMultiZoneZoneID' column of the **Zone** table (**0**).

In this case, the Airflow Network option must be activated (**AIRFLOW_NETWORK = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

2.2.1. Simulation Control

The specification of the Airflow Network Simulation Control is defined in the SAPTool_LSP building template, as follows:

AirflowNetworkSimulationControlSpec afnSimulationControlSpec= new AirflowNetworkSimulationControlSpec() – Airflow Network Simulation Control specification (named afnSimulationControlSpec in this example). With the following AirflowNetworkSimulationControlSpec() arguments:

- **x1** – ID of the Airflow Network Simulation Control in the database (**AirflowNetworkSimulationControl** table in the database);
- **db** – database unique ID.

The Airflow Network Simulation Control is defined in the **AirflowNetworkSimulationControl** table in the database, corresponding to the AirflowNetwork:SimulationControl object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- airflowNetworkControlType – 'MultizoneWithDistribution', 'MultizoneWithoutDistribution', 'MultizoneWithDistributionOnlyDuringFanOperation' or 'NoMultizoneOrDistribution';

- windPresureCoefficientType – ‘SurfaceAverageCalculation’. Currently, the ‘Input’ option is not implemented, as it would also require the specification of a Wind Pressure Coefficient Array, an External Node and the Wind Pressure Coefficient Values;
- heightSelectionForLocalWindSpeedCalculation – ‘ExternalNode’ or ‘OpeningHeight’;
- maximumNumberOfIterations – maximum number of iterations allowed in finding an AirflowNetwork solution;
- initializationType – ‘LinearInitializationMethod’ or ‘ZeroNodePressures’;
- relativeAirflowConvergenceTolerance – convergence criteria;
- absoluteAirflowConvergenceTolerance – convergence criteria;
- convergenceAccelerationLimit – convergence criteria;
- heightDependenceOfExternalNodeTemperature – ‘Yes’ or ‘No’ (blank = No).

Automatic filling fields in EnergyPlus:

- Name – “AIRFLOW_NETWORK_SIMULATION_CONTROL”;
- Building Type – automatically defined depending on the building typology;
- Azimuth Angle of Long Axis of Building – automatically defined depending on the building typology;
- Ratio of Building Width Along Short Axis to Width Along Long Axis – automatically defined depending on the building typology.

The object afnSimulationControlSpec must then be entered as the last argument in the layout specifications (LayoutSpecs()), in the end of the SAPTool_LSP building template.

2.2.2. Zone

This object allows control of natural ventilation through exterior and interior openings in a zone.

The Airflow Network Zone objects assigned to the zones (‘airflowNetworkMultiZoneZoneID’ column of the **Zone** table in the database – **0**) are defined in the **AirflowNetworkMultiZoneZone** table in the database, corresponding to the AirflowNetwork:MultiZone:Zone object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- ventilationControlModeType – ‘NoVent’, ‘Temperature’, ‘Enthalpy’, ‘Constant’, ‘ASHRAE55Adaptive’, ‘CEN15251Adaptive’, ‘ZoneLevel’, ‘AdjacentTemperature’ or ‘AdjacentEnthalpy’;
- minimumVentingOpenFactor – minimum venting open factor. Used only if ventilationControlModeType = Temperature or Enthalpy;
- indoorOutdoorTemperatureDifferenceLowerLimit – indoor and outdoor temperature difference lower limit. Used only if ventilationControlModeType = Temperature;
- indoorOutdoorTemperatureDifferenceUpperLimit – indoor and outdoor temperature difference upper limit. Used only if ventilationControlModeType = Temperature;
- indoorOutdoorEnthalpyDifferenceLowerLimit – indoor and outdoor enthalpy difference lower limit. Used only if ventilationControlModeType = Enthalpy;
- indoorOutdoorEnthalpyDifferenceUpperLimit – indoor and outdoor enthalpy difference upper limit. Used only if ventilationControlModeType = Enthalpy;

- ventilationControlZoneTemperatureSetpointScheduleID – ventilation control zone temperature setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Used only if ventilationControlModeType = Temperature or Enthalpy;
- ventingAvailabilityScheduleID – ventilation availability schedule ID, defined in the **Schedules** table in the database (**21**). If **null**, venting is always available. Not used if ventilationControlModeType = NoVent;
- airflowNetworkOccupantVentilationControlID – ID of the object used to perform advanced window opening control based on occupant conditions (see section **2.2.3**). When assigned, advanced window opening control is performed and, the ventilation control defined in the ventilationControlModeType field will be overridden;
- airflowNetworkMultiZoneComponentZoneExhaustFanID – allows to assign an exhaust fan to the zone. A Zone Exhaust Fan object (**2.2.4.3**) is assigned to one of the zone's surfaces (primarily a roof or, if not available, an exterior wall) as a leakage component.

Automatic filling fields in EnergyPlus:

- Name – "AF_NET_MZN_ZN" + Zone Name;
- Zone Name – name of the zone for which this object is assigned;
- Single Sided Wind Pressure Coefficient Algorithm – default value;
- Façade Width – default value.

2.2.3. Occupant Ventilation Control

This object provides control options with minimum opening and closing time checks and opening and closing probability values. It is defined in the **AirflowNetworkOccupantVentilationControl** table in the database, corresponding to the AirflowNetwork:OccupantVentilationControl object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- minimumOpeningTime – minimum time that windows will remain open [min];
- minimumClosingTime – minimum time that windows will remain closed [min];
- thermalComfortLowTemperatureCurveID – thermal comfort low temperature curve ID, defined in the **PerformanceCurve** table in the database (**22**);
- thermalComfortTemperatureBoundaryPoint – when there are two piecewise curves to represent thermal comfort temperature calculation, this field represents a boundary point of outdoor dry-bulb temperature [°C];
- thermalComfortHighTemperatureCurveID – thermal comfort high temperature curve ID, defined in the **PerformanceCurve** table in the database (**22**);
- maximumThresholdForPersonsDissatisfiedPPD – used to calculate the comfort band[6] as a function of predicted percentage of dissatisfied (PPD);
- occupancyCheck – '1' (Yes) or '0' (No);
- openingProbabilityScheduleID – opening probability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, opening is true;
- closingProbabilityScheduleID – closing probability schedule ID, defined in the **Schedules** table in the database (**21**). If blank closing is true.

[6] Comfort band = -0.0028*(100-PPD)**2 + 0.3419*(100-PPD) – 6.6275

Automatic filling fields in EnergyPlus:

- Name – "OVC" + Zone Name, when called by an Airflow Network Zone object; or "OVC" + Surface/Subsurface Name, when called by an Airflow Network Surface object. (Zone Name – name of the zone for which this object is assigned; Surface/Subsurface Name – surface/subsurface name for which this object is assigned)

2.2.4. Surface

The Airflow Network Surface object specifies the properties of a surface "linkage" through which air flows. This linkage is always associated with a heat transfer surface (wall, roof, floor or a ceiling) or subsurface (door, glass door or window) with both faces exposed to air.

The associated leakage component for this surface can be a crack in an exterior or interior heat transfer surface or subsurface or an exterior or interior window, door or glass door (heat transfer subsurface) that can be opened to allow air flow. Currently, only the following air leakage components are implemented: Surface Crack (**2.2.4.1**), Simple Opening (**2.2.4.2**), and Zone Exhaust Fan (**2.2.4.3**).

An Airflow Network Surface object is automatically assigned to each surface and subsurface in the zones where an airflow network is present. It is defined in the **AirflowNetworkMultiZoneSurface** table in the database, corresponding to the AirflowNetwork:MultiZone:Surface object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- ventilationControlModeType – 'NoVent', 'Temperature', 'Enthalpy', 'Constant', 'ASHRAE55Adaptive', 'CEN15251Adaptive', 'AdjacentTemperature' or 'AdjacentEnthalpy';
- minimumVentingOpenFactor – minimum venting open factor. Used only if ventilationControlModeType = Temperature or Enthalpy;
- indoorOutdoorTemperatureDifferenceLowerLimit – indoor and outdoor temperature difference lower limit. Used only if ventilationControlModeType = Temperature;
- indoorOutdoorTemperatureDifferenceUpperLimit – indoor and outdoor temperature difference upper limit. Used only if ventilationControlModeType = Temperature;
- indoorOutdoorEnthalpyDifferenceLowerLimit – indoor and outdoor enthalpy difference lower limit. Used only if ventilationControlModeType = Enthalpy;
- indoorOutdoorEnthalpyDifferenceUpperLimit – indoor and outdoor enthalpy difference upper limit. Used only if ventilationControlModeType = Enthalpy;
- ventilationControlZoneTemperatureSetpointScheduleID – ventilation control zone temperature setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Used only if ventilationControlModeType = Temperature or Enthalpy;
- ventingAvailabilityScheduleID – ventilation availability schedule ID, defined in the **Schedules** table in the database (**21**). If **null**, venting is always available. Not used if ventilationControlModeType = NoVent or ZoneLevel;
- airflowNetworkOccupantVentilationControlID – ID of the object used to perform advanced window opening control based on occupant conditions (see section **2.2.3**). When assigned, advanced window opening control is performed and, the ventilation control defined in the ventilationControlModeType field will be overridden;

- crackFactorOrOpeningFactor – multiplier for a crack, window or door. In the case of windows, if a pre-defined window type is specified in the zone, the opening factor is automatically assigned, independently of the value defined in this field: FIXED = 0.000001; TWO_SLIDING_OVERLAP = 0.45; PIVOT_DOUBLE, PIVOT_SINGLE, SLIDING_UP, SLIDING_INSIDE_WALL_TO_SIDE, SLIDING_OUTSIDE_WALL_TO_SIDE, or NONE = 0.9. Otherwise (non-pre-defined window type, doors and cracks), the value defined in this field is used.

Automatic filling fields in EnergyPlus:

- Surface Name – name of the surface for which this object is assigned;
- Leakage Component Name – depends on the surface or subsurface type or component: crack (**2.2.4.1**) for a wall, roof, floor or ceiling – "LKG" + Surface Name; simple opening (**2.2.4.2**) for a door, glass door or window – "LKG" + Opening Name (name of the door, glass door or window for which the simple opening is assigned); or zone exhaust fan (**2.2.4.3**), if one is assigned to the zone (airflowNetworkMultiZoneComponentZoneExhaustFanID in the Airflow Network Zone object – **2.2.2**) – "EXHAUST_FAN" + Zone Name (name of the zone for which the exhaust fan is assigned);
- External Node Name – considered blank, as it is only used if windPresureCoefficientType = Input in the Airflow Network Simulation Control object (**2.2.1**), which is not yet implemented;
- Equivalent Rectangle Method – default value;
- Equivalent Rectangle Aspect Ratio – default value.

2.2.4.1. Crack

This object specifies the properties of air flow through a crack and the associated measurement conditions. It is defined in the **AirflowNetworkMultiZoneSurfaceCrack** table in the database, corresponding to the AirflowNetwork:MultiZone:Surface:Crack object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- airMassFlowCoefficientAtReferenceConditions – value of the air mass flow coefficient Cq in the crack air flow equation[7];
- airMassFlowExponent – value of the exponent n in the crack air flow equation[7].

Automatic filling fields in EnergyPlus:

- Name – "LKG" + Surface Name (name of the surface for which the crack is assigned);
- Reference Crack Conditions – automatically filled, but must be defined once (equal for all crack objects; if not defined or defined more than once, then the default crack reference conditions will be used) in the **AirflowNetworkMultiZoneCrackReferenceConditions** table in the database, corresponding to the AirflowNetwork:MultiZone:Surface:ReferenceCrackConditions object in EnergyPlus. The following fields are present in the table:

[7] Crack air flow = (Crack factor)*Ct*Cq*dP**n. Ct is automatically computed, depending on the air density, the air kinetic viscosity and the exponent n.

- id – object ID;
- referenceTemperatureForCrackData – reference temperature in Celsius under which the Surface Crack Data were obtained;
- referenceBarometricPressureForCrackData – reference barometric pressure in Pa under which the Surface Crack Data were obtained;
- referenceHumidityRatioForCrackData – reference humidity ratio in kgWater/kgDryAir under which the Surface Crack Data were obtained.

Automatic filling fields in EnergyPlus:

- Name – "RCC" + Crack Name, when called by a Surface Crack object; or "RCC" + Fan Name, when called by a Zone Exhaust Fan object.

2.2.4.2. Simple Opening

This object specifies the properties of air flow through windows, doors and glass doors (heat transfer subsurfaces) when they are closed or open. The Airflow Network model assumes that open windows or doors are vertical or close to vertical. The second and third fields are similar to those for a Surface Crack object, when the window or door is closed, but additional information is required to describe the air flow characteristics when the window or door is open. It is defined in the **AirflowNetworkMultiZoneComponentSimpleOpening** table in the database, corresponding to the AirflowNetwork:MultiZone:Component:SImpleOpening object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- airMassFlowCoefficientWhenOpeningIsClosed – The value of the air mass flow coefficient Cq in the simple opening air flow equation[8] (used only when window or door is closed). Two values are required: for an interior opening and for an exterior opening;
- airMassFlowExponentWhenOpeningIsClosed – The value of the exponent n in the simple opening air flow equation (used only when window or door is closed). Two values are required: for an interior opening and for an exterior opening;
- minimumDensityDifferenceForTwoWayFlow – minimum density difference above which two-way or one-way flow may occur due to stack effect with the window being open. Two values are required: for an interior opening and for an exterior opening;
- dischargeCoefficient – discharge coefficient. Two values are required: for an interior opening and for an exterior opening;
- type – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "LKG" + Opening Name (name of the door, glass door or window for which the simple opening is assigned).

2.2.4.3. Zone Exhaust Fan

This object specifies the properties of air flow through an exterior heat transfer surface with a zone exhaust fan. The zone exhaust fan turns on or off based on the availability schedule defined

[8] Mass flow rate = Cq*dp**n

in the corresponding Fan Zone Exhaust object (see section **8.8**). When the exhaust fan mass flow rate is greater than zero, the airflow network model treats this object as a constant volume fan. When the fan is off based on the availability schedule, the model treats this object as a crack. This component is defined in the **AirflowNetworkMultiZoneComponentZoneExhaustFan** table in the database, corresponding to the AirflowNetwork:MultiZone:Component:ZoneExhaustFan object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- airMassFlowCoefficientWhenTheZoneExhaustFanIsOffAtReferenceConditions – value of the air mass flow coefficient Cq in the crack air flow equation (equivalent to a crack, when fan is off; see section **2.2.4.1**);
- airMassFlowExponentWhenTheZoneExhaustFanIsOff – value of the exponent, n in the crack air flow equation (equivalent to a crack, when fan is off; see section **2.2.4.1**).
- fanZoneExhaustID – ID of the Fan Zone Exhaust object (**8.8**), which specifies the fan properties when the fan is on.

Automatic filling fields in EnergyPlus:

- Name – "EXHAUST_FAN" + Zone Name (name of the zone for which the exhaust fan is assigned);
- Reference Crack Conditions – "RCC" + Fan Name, when called by a Zone Exhaust Fan object. Defined in the **AirflowNetworkMultiZoneCrackReferenceConditions** table in the database (used for all crack objects – **2.2.4.1**).

3. AIR CONTAMINANTS

The Zone Air Contaminant Balance object provides a way to select which contaminant type will be simulated. The Air Contaminant Balance option must be activated (**AIR_CONTAMINANT_BALANCE = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The Zone Air Contaminant Balance must be defined in the SAPTool_LSP building template in the last argument of the Dynamic Simulation specification object (DynamicSimulationSpec()). It is defined through a Zone Air Contaminant Balance specification object (**new ZoneAirContaminantBalanceSpec()**), corresponding to the ZoneAirContaminantBalance object in EnergyPlus, with the following arguments:

- **x** – ID of the Zone Air Contaminant Balance properties in the database (see below);
- **db** – database unique ID.

The Zone Air Contaminant Balance properties are defined in the **ZoneAirContaminantBalance** table in the database, corresponding to the ZoneAirContaminantBalance object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- carbonDioxideConcentration – If Yes (1), simulation of carbon dioxide concentration levels will be performed. If No (0), simulation of carbon dioxide concentration levels will not be performed;
- outdoorCarbonDioxideScheduleID – outdoor carbon dioxide schedule ID, defined in the **Schedules** table in the database (**21**);
- genericContaminantConcentration – If Yes (1), simulation of generic contaminant concentration levels will be performed. If No (0), simulation of generic contaminant concentration levels will not be performed;
- outdoorGenericContaminantScheduleID – outdoor generic contaminant schedule ID, defined in the **Schedules** table in the database (**21**).

An outdoor air node (named “Contaminant_Balance_Outdoor_Air_Node") is automatically defined with the OutdoorAir:Node object in EnergyPlus, in order to define the CO_2 and/or generic contaminant concentration output(s).

4. INTERNAL GAINS

4.1. People

The People option must be activated (**PEOPLE = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The people objects are assigned to each zone in the database, in the 'peopleID' column of the **Zone** table (**0**), and are defined in the **People** table in the database, corresponding to the People object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- scheduleID – number of people schedule ID, defined in the **Schedules** table in the database (**21**);
- numberOfPeopleCalculationMethod – 'People', 'People_Area' or 'Area_Person';
- numberOfPeople – maximum number of people in a zone that is then multiplied by a schedule fraction. Used if numberOfPeopleCalculationMethod = People;
- peoplePerZoneFloorArea – used along with the Zone Floor Area to determine the maximum number of people, that is then multiplied by a schedule fraction [person/m2]. Used if numberOfPeopleCalculationMethod = People_Area;
- zoneFloorAreaperPerson – used along with the Zone Floor Area to determine the maximum number of people, that is then multiplied by a schedule fraction [m2/person]. Used if numberOfPeopleCalculationMethod = Area_Person;
- fractionRadiant – fraction representing the amount of long wavelength radiation gain from human beings in the zone;
- sensibleHeatFraction – fixed sensible fraction for the heat gain due to people in the zone. 'autocalculate' option is available (default if blank);
- activityLevelScheduleID – activity level schedule ID, defined in the **Schedules** table in the database (**21**). It determines the amount of heat gain per person in the zone under design conditions;
- carbonDioxideGenerationRate – carbon dioxide generation rate per person [m3/s.W]. This field is only used if the CO_2 concentration simulation is active in the Zone Air Contaminant Balance object (**3**);
- meanRadiantTemperatureCalculationType – 'ZoneAveraged' (default if blank), 'SurfaceWeighted' or 'AngleFactor'. Currently, only the ZoneAveraged option is implemented;
- surfaceNameAngleFactorListID – ID of the Surface or the Angle Factor List for the mean radiant temperature calculation. Only used if meanRadiantTemperatureCalculationType = SurfaceWeighted or AngleFactor, which are not yet implemented;
- workEfficiencyScheduleID – work efficiency schedule ID, defined in the **Schedules** table in the database (21). It determines the efficiency of energy usage within the human body that will be used for thermal comfort calculations. Only required if thermalComfortModelTypes = Fanger, Pierce or KSU;
- clothingInsulationCalculationMethod – 'ClothingInsulationSchedule' (default if blank), 'DynamicClothingModelASHRAE55' or 'CalculationMethodSchedule';
- clothingInsulationCalculationMethodScheduleID – clothing insulation calculation method schedule ID, defined in the **Schedules** table in the database (**21**). 1 - ClothingInsulationSchedule method, 2 - DynamicClothingModelASHRAE55 method. If

blank, the specified clothing insulation calculation method will be used and not changed during the simulation. Only required if clothingInsulationCalculationMethod = CalculationMethodSchedule;

- clothingInsulationScheduleID – clothing insulation schedule ID, defined in the **Schedules** table in the database (**21**) It defines the amount of clothing being worn by a typical zone occupant during various times in the simulation period. Only required if clothingInsulationCalculationMethod = ClothingInsulationSchedule and if thermalComfortModelTypes = Fanger, Pierce or KSU;
- airVelocityScheduleID – air velocity schedule ID, defined in the **Schedules** table in the database (**21**). It approximates the amount of air movement in the space as a function of time throughout the simulation period. Only required if thermalComfortModelTypes = Fanger, Pierce or KSU;
- thermalComfortModelTypes – 'Fanger', 'Pierce', 'KSU', 'AdaptiveASH55' or 'AdaptiveCEN15251'. This field is optional and up to 5 types are simultaneous allowed;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "PEOPLE" + Zone Name;
- Zone Name – name of the zone for which the people object is assigned.

4.2. Lights

The Lights option must be activated (**LIGHTS = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The lighting objects are assigned to each zone in the database, in the 'lightsID' column of the **Zone** table (**0**), and are defined in the **Lights** table in the database, corresponding to the Lights object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- scheduleID – lighting power design level schedule ID, defined in the **Schedules** table in the database (**21**);
- designLevelCalculationMethod – 'LightingLevel', 'Watts_Area' or 'Watts_Person';
- lightingLevel – maximum electrical power input to lighting in a zone that is multiplied by the schedule fraction [W]. Only used if designLevelCalculationMethod = LightingLevel;
- wattsPerZoneFloorArea – used along with the Zone Floor Area to determine the maximum lighting level that is multiplied by the schedule fraction [W/m2]. Only used if designLevelCalculationMethod = Watts_Area;
- wattsPerPerson – used along with the number of occupants to determine the maximum lighting level that is multiplied by the schedule fraction [W/person]. Only used if designLevelCalculationMethod = Watts_Person;
- returnAirFraction – fraction of the heat from lights that goes into the zone return air;
- fractionRadiant – fraction of heat from lights that goes into the zone as long-wave (thermal) radiation;
- fractionVisible – fraction of heat from lights that goes into the zone as visible (short-wave) radiation;

- fractionReplaceable – used as an on/off flag for dimming controls if daylighting control is specified for the zone (see section **18**);
- endUseSubCategory – user-defined end-use subcategory;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – “LIGHTS” + Zone Name;
- Zone Name – name of the zone for which the lighting object is assigned.

4.3. Equipment

The equipment objects are assigned to each zone in the database, in the ‘zoneEquipmentIDs’ column of the **Zone** table (**0**).
Multiple equipment objects can be assigned to a single zone, in the **ZoneEquipment** table in the database:

- id – object ID;
- name – equipment name;
- zoneElectricEquipmentID – zone electric equipment ID in the corresponding table (**4.3.1**);
- zoneWaterUseEquipmentID – zone water use equipment ID in the corresponding table (**5.1**);
- zoneGasEquipmentID – zone gas equipment ID in the corresponding table (**4.3.2**);
- zoneSteamEquipmentID – zone steam equipment ID in the corresponding table (**4.3.3**);
- endUseSubcategory – user-defined end-use subcategory;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

In the **ZoneEquipment** table is possible to define a multi-type object. For example, a washing machine, which is an electric equipment and a water use equipment, can be defined by assigning to the same ID a zone electric equipment object (zoneElectricEquipmentID; washing machine electric part) and a zone water use equipment object (zoneWaterUseEquipmentID; washing machine water use part).

4.3.1. Electric Equipment

The Electrical Equipment option must be activated (**ELECTRICAL_EQUIPMENT = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The zone electric equipment objects are defined in the **ZoneElectricEquipment** table in the database, corresponding to the ElectricEquipment object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- calculationMethod – ‘EquipmentLevel’, ‘Watts_Area’ or ‘Watts_Person’;
- designLevel – maximum electrical input to equipment in a zone [W]. Used if calculationMethod = EquipmentLevel;

- wattsArea – maximum equipment level in W/m2. Used if calculationMethod = Watts_Area;
- wattsPerson – maximum equipment level in W/person. Used if calculationMethod = Watts_Person;
- fractionLatent – amount of latent heat given off by electric equipment in a zone;
- fractionRadiant – amount of long-wave radiant heat being given off by electric equipment in a zone;
- fractionLost – amount of “lost” heat being given off by electric equipment in a zone;
- scheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). This schedule modifies the design level parameter for electric equipment;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – electricEquipmentName = Zone Name + equipmentName + equipmentID:
  - equipmentName – equipment name defined in the **ZoneEquipment** table;
  - equipmentID – ID of the equipment in the zone.
- Zone Name – name of the zone for which the electric equipment is assigned;
- End-Use Subcategory – endUseSubcategory defined in the **ZoneEquipment** table.

4.3.2. Gas Equipment

The Gas Equipment option must be activated (**GAS_EQUIPMENT = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The zone gas equipment objects are defined in the **ZoneGasEquipment** table in the database, corresponding to the GasEquipment object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- calculationMethod – ‘EquipmentLevel’, ‘Watts_Area’ or ‘Watts_Person’;
- designLevel – maximum electrical input to equipment in a zone [W]. Used if calculationMethod = EquipmentLevel;
- powerArea – maximum equipment level in W/m2. Used if calculationMethod = Watts_Area;
- powerPerson – maximum equipment level in W/person. Used if calculationMethod = Watts_Person;
- fractionLatent – amount of latent heat given off by gas equipment in a zone;
- fractionRadiant – amount of long-wave radiant heat being given off by gas equipment in a zone;
- fractionLost – amount of “lost” heat being given off by gas equipment in a zone;
- scheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). This schedule modifies the design level parameter for electric equipment;
- carbonDioxideGenerationRate – carbon dioxide generation rate in m3/s.W;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – gasEquipmentName = Zone Name + equipmentName + equipmentID:
    - equipmentName – equipment name defined in the **ZoneEquipment** table;
    - equipmentID – ID of the equipment in the zone.
- Zone Name – name of the zone for which the gas equipment is assigned;
- End-Use Subcategory – endUseSubcategory defined in the **ZoneEquipment** table.

4.3.3. Steam Equipment

The Steam Equipment option must be activated (**STEAM_EQUIPMENT = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The zone steam equipment objects are defined in the **ZoneSteamEquipment** table in the database, corresponding to the SteamEquipment object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- calculationMethod – ‘EquipmentLevel’, ‘Watts_Area’ or ‘Watts_Person’;
- designLevel – maximum electrical input to equipment in a zone [W]. Used if calculationMethod = EquipmentLevel;
- powerArea – maximum equipment level in W/m2. Used if calculationMethod = Watts_Area;
- powerPerson – maximum equipment level in W/person. Used if calculationMethod = Watts_Person;
- fractionLatent – amount of latent heat given off by steam equipment in a zone;
- fractionRadiant – amount of long-wave radiant heat being given off by steam equipment in a zone;
- fractionLost – amount of “lost” heat being given off by steam equipment in a zone;
- scheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). This schedule modifies the design level parameter for steam equipment;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – steamEquipmentName = Zone Name + equipmentName + equipmentID:
    - equipmentName – equipment name defined in the **ZoneEquipment** table;
    - equipmentID – ID of the equipment in the zone.
- Zone Name – name of the zone for which the steam equipment is assigned;
- End-Use Subcategory – endUseSubcategory defined in the **ZoneEquipment** table.

4.4. Zone Contaminant Source and Sink

The Air Contaminant Balance option must be activated (**AIR_CONTAMINANT_BALANCE = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The contaminant source and sink objects are assigned to each zone in the database, in the 'contaminantSourceAndSinkIDs' column of the **Zone** table (**0**).
Multiple equipment objects can be assigned to a single zone, in the **ZoneContaminantSourceAndSink** table in the database:

- id – object ID;
- type – contaminant source and sink specification in the corresponding Type table: 'CarbonDioxide' (**ZoneContaminantSourceAndSinkCarbonDioxide** table in the database – **4.4.1**), 'GenericConstant' (**ZoneContaminantSourceAndSinkGenericConstant** table in the database – **4.4.2.1**), 'GenericCutoffModel' (**ZoneContaminantSourceAndSinkGenericCutoffModel** table in the database – **4.4.2.2**), 'GenericDecaySource' (**ZoneContaminantSourceAndSinkGenericDecaySource** table in the database – **4.4.2.3**), or 'GenericDepositionRateSink' (**ZoneContaminantSourceAndSinkGenericDepositionRateSink** table in the database – **4.4.2.4**);
- contaminantSourceAndSinkID – contaminant source and sink type ID in the corresponding table.

4.4.1. Carbon Dioxide

The dioxide concentration simulation must be active in the Zone Air Contaminant Balance object (**3**). The carbon dioxide source and sink objects are defined in the **ZoneContaminantSourceAndSinkCarbonDioxide** table in the database, corresponding to the ZoneContaminantSourceAndSink:CarbonDioxide object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- designGenerationRate – design carbon dioxide generation rate [m^3/s]. The design value is modified by the schedule fraction. The rate can be either positive or negative. A positive value represents a source rate (CO_2 addition to the zone air) and a negative value represents a sink rate (CO_2 removal from the zone air);
- scheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). This schedule (0-1) modifies the design carbon dioxide generation rate;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "SOURCE_SINK_CO2" + Zone Name;
- Zone Name – name of the zone for which the carbon dioxide source and sink object is assigned.

4.4.2. Generic

The generic contaminant simulation must be active in the Zone Air Contaminant Balance object (**3**).

4.4.2.1. Constant

The generic contaminant source and sink constant objects are defined in the **ZoneContaminantSourceAndSinkGenericConstant** table in the database, corresponding to the

ZoneContaminantSourceAndSink:Generic:Constant object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- designGenerationRate – full generic contaminant design generation rate [m^3/s]. It is the maximum amount of generic contaminant expected at design conditions. The design value is modified by the schedule fraction;
- generationScheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). This schedule (0-1) modifies the maximum design generation rate;
- designRemovalCoefficient – full generic contaminant design removal coefficient [m^3/s]. It is the maximum amount of generic contaminant expected at design conditions times the generic contaminant concentration in the same zone. The design value is modified by the schedule fraction;
- removalScheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). This schedule (0-1) modifies the maximum design removal rate;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "SOURCE_SINK_GEN_CONST" + Zone Name;
- Zone Name – name of the zone for which the generic contaminant source and sink constant object is assigned.

4.4.2.2. Cutoff Model

The generic contaminant source and sink cutoff model objects are defined in the **ZoneContaminantSourceAndSinkGenericCutoffModel** table in the database, corresponding to the ZoneContaminantSourceAndSink:Generic:CutoffModel object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- designGenerationRateCoefficient – full generic contaminant design generation rate [m^3/s]. It is the maximum amount of generic contaminant expected at design conditions. The design value is modified by the schedule fraction;
- scheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). This schedule (0-1) modifies the maximum design generation rate;
- cutoffGenericContaminantAtWhichEmissionCeases – generic contaminant cutoff concentration level where the source ceases its emission [ppm];
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "SOURCE_SINK_GEN_CUTOFF" + Zone Name;
- Zone Name – name of the zone for which the generic contaminant source and sink cutoff model object is assigned.

4.4.2.3. Decay Source

The generic contaminant source and sink decay source objects are defined in the **ZoneContaminantSourceAndSinkGenericDecaySource** table in the database, corresponding to the ZoneContaminantSourceAndSink:Generic:DecaySource object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- initialEmissionRate – initial generic contaminant design emission rate [m^3/s]. The generation is controlled by a schedule, as defined in the next field. Generic contaminant emission begins when the schedule changes from a zero to a non-zero value (between 0 and 1). The initial emission rate is equal to the schedule value times the initial generation rate. A single schedule may be used to initiate several emissions at different times;
- scheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). This schedule (0-1) modifies the maximum design emission rate;
- decayTimeConstant – time at which the generation rate reaches 0.37 of the original rate [s];
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "SOURCE_SINK_GEN_DECAY" + Zone Name;
- Zone Name – name of the zone for which the generic contaminant source and sink decay source object is assigned.

4.4.2.4. Deposition Rate Sink

The generic contaminant source and sink deposition rate sink objects are defined in the **ZoneContaminantSourceAndSinkGenericDepositionRateSink** table in the database, corresponding to the ZoneContaminantSourceAndSink:Generic:DepositionRateSink object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- depositionRate – deposition rate to the zone [m/s];
- scheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). This schedule (0-1) modifies the maximum design removal rate;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "SOURCE_SINK_GEN_DEPOS_RATEOURCE_SINK_GEN_DECAY" + Zone Name;
- Zone Name – name of the zone for which the generic contaminant source and sink deposition rate sink object is assigned.

5. WATER SYSTEMS

5.1. Water Use Equipment

The Water Use option must be activated (**WATER_USE = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The zone water use equipment objects are defined in the **ZoneWaterUseEquipment** table in the database, corresponding to the WaterUse:Equipment object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- peakFlowRate – peak demanded hot water flow rate [m3/s];
- flowRateFractionScheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). This schedule specifies the flow rate fraction relative to the Peak Flow Rate. If blank, = 1;
- targetTemperatureScheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). Specifies the target water temperature [°C]. If blank, the target temperature defaults to the hot water supply temperature;
- hotWaterSupplyTemperatureScheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). Specifies the hot water temperature [°C]. This field is ignored if the object is used with the Water Use Connections object (field waterUseConnectionsID);
- coldWaterSupplyTemperatureScheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). This schedule specifies the cold water temperature [°C]. If blank, water temperatures are calculated by the Water Mains Temperature object (**22.1)**. This field is ignored if the object is used with the Water Use Connections object (field waterUseConnectionsID);
- sensibleFractionScheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). Specifies the fraction of the maximum possible sensible heat gain (based on inlet water conditions and ambient zone conditions) that is added to the zone;
- latentFractionScheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). Specifies the fraction of the maximum possible latent heat gain (based on inlet water conditions and ambient zone conditions) that is added to the zone;
- waterUseConnectionsID – ID of the Water Use Connections object to which the current equipment is assigned, if any (**5.2**).

Automatic filling fields in EnergyPlus:

- Name – waterUseEquipmentName = Zone Name + equipmentName + equipmentID:
  - equipmentName – equipment name defined in the **ZoneEquipment** table;
  - equipmentID – ID of the equipment in the zone.
- End-Use Subcategory – endUseSubcategory defined in the **ZoneEquipment** table;
- Zone Name – name of the zone for which the water use equipment is assigned.

The water use equipment can operate in stand-alone mode or coupled to a Water Use Connections object (by assigning a waterUseConnectionsID), which represents a subsystem that groups together multiple Water Use Equipment components (**5.2**).

5.2. Water Use Connections

The zone water use connection objects are defined in the **WaterUseConnections** table in the database, corresponding to the WaterUse:Equipment object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – water use connections name;
- hotWaterSupplyTemperatureScheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). Specifies the hot water temperature [°C]. If blank in stand-alone mode, the hot water supply temperature defaults to the cold water supply temperature. This field (even if blank) overrides the Hot Water Supply Temperature Schedule in all of the Water Use Equipment objects assigned to this connection;
- coldWaterSupplyTemperatureScheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). This schedule specifies the cold water temperature [°C]. If blank, water temperatures are calculated by the Water Mains Temperature object (**22.1**). This field (even if blank) overrides the Cold Water Supply Temperature Schedule in all of the Water Use Equipment objects assigned to this connection;
- drainWaterHeatExchangerType – ‘None’, ‘Ideal’, ‘CounterFlow’ or ‘CrossFlow’;
- drainWaterHeatExchangerDestination – ‘Plant’, ‘Equipment’, ‘PlantAndEquipment’ or blank;
- drainWaterHeatExchangerUFactorTimesArea – heat transfer coefficient for the heat exchanger [W/K];
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment, if it is assigned to a loop – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – stand-alone mode: waterUseConnectionsName = connectionsName + connectionsID; coupled to a loop: waterUseConnectionsName = loopName&ID + loopSide + equipmentID + connectionsName + connectionsID;
  - connectionsName – connections name defined in the **WaterUseConnections** table;
  - connectionsID – ID of the connections object in the zone;
  - loopName&ID – loop name and ID for which the water use connections object is assigned (see section **9.3**);
  - loopSide – loop side for which the water use connections object is assigned (= DEMAND, as a water use connections object is always a demand side equipment) (see section **9.3**);
  - equipmentID – water use connections position on the branch equipment list of the loop (see section **9.3**).
- Inlet Node Name – waterUseConnectionsName + “Inlet_node”. Only defined if coupled to a loop;
- Outlet Node Name – waterUseConnectionsName + “Outlet_node”. Only defined if coupled to a loop;
- Supply Water Storage Tank Name – reference to a Water Use Storage object (**5.3**) that supplies cold water to the Water Use Equipment assigned to the current Water Use Connections object. See section **5.3** for details on the assignment of a Supply Water

Storage Tank to the Water Use Connections. If there is no Supply Water Storage Tank assignment or the tank is empty, fresh water is supplied from the water mains;

- Reclamation Water Storage Tank Name – reference to a Water Use Storage object (**5.3**) that stores the resulting graywater from the Water Use Equipment assigned to the current Water Use Connections object. See section **5.3** for details on the assignment of a Reclamation Water Storage Tank to the Water Use Connections. If there is no Reclamation Water Storage Tank assignment, the graywater is not reclaimed;
- Water Use Equipment X Name – the names of the Water Use Equipment assigned to the current Water Use Connections object.

The Water Use Connections object can be used stand-alone or coupled with a plant loop. In stand-alone mode, the Hot and Cold Water Supply Temperature Schedules override the values for the listed Water Use Equipment objects. When coupled to the plant, the Hot Water Supply Temperature Schedule is overridden by the actual plant loop inlet water temperature. In this case, the Water Use Connections specification must be defined in the SAPTool_LSP building template, as follows, in order to be added to the plant loop (**9.3**):

PlantLoopZoneWaterUseConnectionsSpec waterUseConnectionsSpec = new PlantLoopZoneWaterUseConnectionsSpec() – Water Use Connections specification (named waterUseConnectionsSpec in this example). With the following PlantLoopZoneWaterUseConnectionsSpec() argument:

- **DBWaterUseConnectionType.ABC.getID()** – ID of the Water Use Connections properties in the database, defined using the DBWaterUseConnectionType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here.

5.3. Water Use Storage

The specification of a Water Use Storage is defined in the SAPTool_LSP building template, as follows:

WaterUseStorageSpec waterUseStorageSpec = new WaterUseStorageSpec() – Water Use Storage specification (named waterUseStorageSpec in this example). With the following WaterUseStorageSpec() arguments:

- **DBWaterUseStorageType.ABC.toString()** – storage name, defined using the DBWaterUseStorageType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **x1** – name of the Overflow Destination storage, which is defined in another WaterUseStorageSpec(). **null** if nonexistent;
- **x2** – name of the Other Tank, which is defined in another WaterUseStorageSpec(). **null** if nonexistent;
- **DBWaterUseStorageType.ABC.getID** – ID of the Water Use Storage properties in the database, defined using the DBWaterUseStorageType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Water Use Storage is specified using the WaterUseStorageSpec() object and then must be assigned to the HVAC detailed systems specifications – HVACSpec() (named hVACSpec in this example), in the SAPTool_LSP building template, as follows:

hVACSpec.addWaterUseStorageSpec(waterUseStorageSpec) – assignment of Water Use Storage specification (named waterUseStorageSpec in this example) to the hVACSpec object.

The water use storage objects are defined in the **WaterUseStorage** table in the database, corresponding to the WaterUse:Storage object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- waterQualitySubcategory – describes the quality of the water contained in the tank. Used for reporting and to check that the uses and supply match the category of water quality;
- maximumCapacity – maximum volumetric capacity of the water tank [m^3]. If blank, this field defaults to unlimited capacity;
- initialVolume – volume of water in the storage tank at the beginning of each simulation environmental period [m^3];
- designInFlowRate – design flow rate of fittings that provide water into the tank from external sources [m^3/s]. If blank, this field defaults to unlimited rate;
- designOutFlowRate – design flow rate of fittings that withdraw water from the tank to end uses [m^3/s]. If blank, this field defaults to unlimited rate;
- typeOfSupplyControlledByFloatValve – 'None', 'Mains', 'GroundwaterWell' or 'OtherTank';
- floatValveOnCapacity – volumetric capacity of the water tank when a floating valve would turn on to allow filling the tank [m^3];
- floatValveOffCapacity – volumetric capacity of the water tank when a floating valve would turn off after having been filling the tank [m^3];
- backupMainsCapacity – volumetric capacity of the tank that indicates where a secondary float valve will maintain the volume by calling for mains water. If left blank or equal 0.0, then there is no mains water backup;
- waterThermalMode – 'ScheduledTemperature' or 'ThermalModel';
- waterTemperatureScheduleID – schedule ID, defined in the **Schedules** table in the database (**21**). Specifies the temperature of the water in the tank [°C];
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – defined in the first argument of the WaterUseStorageSpec() above;
- Overflow Destination – name of a second Water Use Storage that would receive overflow (if any), defined in the argument x1 of the WaterUseStorageSpec() above;
- Other Tank Name – name of other Water Use Storage (if any), defined in the argument x2 of the WaterUseStorageSpec() above, and only used if typeOfControlledSupply =

OtherTank and the current tank is to be configured to be supplied by a second tank in response to a float valve.

Note: the fields 'Ambient Temperature Indicator', 'Ambient Temperature Schedule Name', 'Zone Name', 'Tank Surface Area', 'Tank U Value' and 'Tank Outside Surface Material Name' are not yet implemented in EnergyPlus, as they are reserved for future use according to the EnergyPlus manual.

Up to two Water Use Storage tanks can be assigned to a Water Use Connections object to serve as Supply Water Storage Tank and Reclamation Water Storage Tank (see section **5.2**). This is defined in the SAPTool_LSP building template, as follows:

WaterUseConnectionsStorageTanksSpec waterUseConnectionsStorageTanksSpec = new WaterUseConnectionsStorageTanksSpec() – Water Use Connections Storage Tanks specification (named waterUseConnectionsStorageTanksSpec in this example). With the following WaterUseConnectionsStorageTanksSpec() arguments:

- **DBWaterUseConnectionType.ABC.getID** – ID of the Water Use Connections in the database, defined using the DBWaterUseConnectionType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **x1** – name of the Supply Water Storage Tank [defined with the WaterUseStorageSpec()] to assign to the Water Use Connections 'ABC'. **null** if nonexistent;
- **x2** – name of the Reclamation Water Storage Tank [defined with the WaterUseStorageSpec()] to assign to the Water Use Connections 'ABC'. **null** if nonexistent.

6. HVAC TEMPLATE

All template zone systems are implemented: Ideal Loads Air System (**6.3**), Baseboard Heat (**6.4**), Fancoil (**6.5**), PTAC (**6.6**), PTHP (**6.7**), Water-to-Air Heat Pump (**6.8**), Unitary (**6.9**), Dual Duct (**6.10**), VRF (**6.11**), Constant Volume (**6.12**), VAV (**6.13**), and Dedicated Outdoor Air System (**6.14**). For each template, a thermostat needs to be assigned (**6.2**).

In addition, three template plant heating and cooling equipment – Template Plant Boiler (**6.16.1**), Template Plant Chiller (**6.16.2**), and Template Plant Tower (**6.16.3**) – and three plant water loops – Template Plant Loop Hot Water (**6.15.2**), Template Plant Loop Chilled Water (**6.15.1**), and Template Plant Loop Mixed Water (**6.15.3**) – are implemented.

Note: It is not possible to simultaneously assign a Zone HVAC Template and a Zone HVAC Equipment (**7.1**) to the same zone. Refer to section **7.1.9** for details.

6.1. Specification

The assignment of the plant objects and non-zone systems to the building's HVAC template system is defined in the SAPTool_LSP building template, as follows:

HVACTemplateSpec hvacTemplateSpec = new HVACTemplateSpec() – object comprising the specifications of the template plant water loops, template heating and cooling equipment, template cooling towers, and non-zone template HVAC systems. With the following HVACTemplateSpec() arguments:

- **x1** – Template Plant Loop Chilled Water specification (named hvacTemplatePlantChilledWaterLoopSpec in the example presented in section **6.15.1**);
- **x2** – Template Plant Loop Hot Water specification (named hvacTemplatePlantHotWaterLoopSpec in the example presented in section **6.15.2**);
- **x3** – Template Plant Loop Mixed Water specification (named hvacTemplatePlantMixedWaterLoopSpec in the example presented in section **6.15.3**).

The assignment of objects with possible multiple specifications to the building's HVAC template system is performed as follows, and should be repeated for each object addded:

- **hvacTemplateSpec.addPlantBoilerSpec(x4)** – addition of a plant boiler (named hvacTemplatePlantBoilerSpec in section **6.16.1**) to the building's HVAC template system;
- **hvacTemplateSpec.addPlantChillerSpec(x5)** – addition of a plant chiller (named hvacTemplatePlantChillerSpec in section **6.16.2**) to the building's HVAC template system;
- **hvacTemplateSpec.addPlantTowerSpec(x6)** – addition of a plant tower (named hvacTemplatePlantTowerSpec in section **6.16.3**) to the building's HVAC template system;
- **hvacTemplateSpec.addSystemUnitarySpec(x7)** – addition of a system unitary (named hvacTemplateSystemUnitarySpec in section **6.9.1**) to the building's HVAC template system;
- **hvacTemplateSpec.addSystemUnitarySystemSpec(x8)** – addition of a system unitary system (named hvacTemplateSystemUnitarySystemSpec in section **6.9.1**) to the building's HVAC template system;

- **hvacTemplateSpec.addSystemUnitaryHeatPumpAirToAirSpec(x9)** – addition of a system unitary heat pump air-to-air (named hvacTemplateSystemUnitaryHPSpec in section **6.9.1**) to the building's HVAC template system;
- **hvacTemplateSpec.addSystemConstantVolumeSpec(x10)** – addition of a contant volume system (named hvacTemplateSystemConstantVolumeSpec in section **6.12.1**) to the building's HVAC template system;
- **hvacTemplateSpec.addSystemVAVSpec(x11)** – addition of a VAV system (named hvacTemplateSystemVAVSpec in section **6.13.1**) to the building's HVAC template system;
- **hvacTemplateSpec.addSystemPackagedVAVSpec(x12)** – addition of a packaged VAV system (named hvacTemplateSystemPackagedVAVSpec in section **6.13.1**) to the building's HVAC template system;
- **hvacTemplateSpec.addSystemDualDuctSpec(x13)** – addition of a dual duct system (named hvacTemplateSystemDualDuctSpec in section **6.10.1**) to the building's HVAC template system;
- **hvacTemplateSpec.addSystemVRFSpec(x14)** – addition of a VRF system (named hvacTemplateSystemVRFSpec in section **6.11.1**) to the building's HVAC template system;
- **hvacTemplateSpec.addDedicatedOutdoorAirSystemSpec(x15)** – addition of a dedicated outdoor air system (named hvacTemplateSystemDedicatedOutdoorAirSpec in section **6.14**) to the building's HVAC template system;

The object hvacTemplateSpec must then be entered as the 13th argument in the layout specifications (LayoutSpecs()), in the end of the SAPTool_LSP building template.

6.2. Thermostat

The HVAC Template Thermostat properties are defined in the **HVACTemplateThermostat** table in the database, corresponding to the HVACTemplate:Thermostat object in EnergyPlus, and then assigned to the desired template system in its specification. The following fields are present in the table:

- id – object ID;
- heatingSetpointScheduleID – heating setpoint schedule ID, defined in the **Schedules** table in the database (**21**). If blank, a constant setpoint is used (defined in the next field);
- constantHeatingSetpoint – constant heating setpoint temperature in Celsius;
- coolingSetpointScheduleID – cooling setpoint schedule ID, defined in the **Schedules** table in the database (**21**). If blank, a constant setpoint is used (defined in the next field);
- constantCoolingSetpoint – constant cooling setpoint temperature in Celsius.

Automatic filling fields in EnergyPlus:

- Name – "THERMOSTAT" + Zone Name (Zone Name – name of the zone for which the thermostat is assigned).

6.3. Ideal Loads Air System

The HVAC Template Ideal Loads Air System is defined in the SAPTool_LSP building templates for each desired space (SAPTool_LSP>SourcePacakges>lsp.templates), while the properties for each object are defined in the database. The HVAC Template Ideal Loads Air System option must be active (**HVAC_TEMPLATE_ZONE_IDEAL_LOADS_AIR_SYSTEM = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The specification of the Ideal Loads Air System for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_LivingRoom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_LivingRoom and defined for the Living Room space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateIdealLoadsAirSystemSpec(x, db)** – specification of the space Ideal Loads Air System, defined in the ID *x* of the table **HVACTemplateIdealLoadsAirSystem** in the database db (see below);
- **null** – used only for HVAC Template zone system specifications.

This zone HVAC template specification (hvacTemplateSpec_LivingRoom) must then be assigned to the space, by entering it as the first argument in the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Living Room, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_LivingRoom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living Room, in this example);
- **db** – database unique ID.

The HVAC Template Ideal Loads Air System properties are defined in the **HVACTemplateIdealLoadsAirSystem** table in the database, corresponding to the HVACTemplate:Zone:IdealLoadsAirSystem object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**);
- maximumHeatingSupplyAirTemperature – maximum air temperature of the air used for heating the zone [°C];
- minimumCoolingSupplyAirTemperature – minimum air temperature of the air used for cooling the zone [°C];

- maximumHeatingSupplyAirHumidityRatio – maximum humidity ratio of the hot supply air [kgWater/kgDryAir];
- minimumCoolingSupplyAirHumidityRatio – minimum humidity ratio of the cold supply air [kgWater/kgDryAir];
- heatingLimitType – ‘LimitFlowRate’, ‘LimitCapacity’, ‘LimitFlowRateAndCapacity’ or ‘NoLimit’;
- maximumHeatingAirflowRate – maximum heating supply air flow rate in m3/s, if heatingLimitType = LimitFlowRate or LimitFlowRateAndCapacity. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- maximumSensibleHeatingCapacity – maximum allowed sensible heating capacity in W, if heatingLimitType = LimitCapacity or LimitFlowRateAndCapacity. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- coolingLimitType – ‘LimitFlowRate’, ‘LimitCapacity’, ‘LimitFlowRateAndCapacity’ or ‘NoLimit’;
- maximumCoolingAirflowRate – maximum cooling supply air flow rate in m3/s, if coolingLimitType = LimitFlowRate or LimitFlowRateAndCapacity. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- maximumTotalCoolingCapacity – maximum allowed sensible cooling capacity in W, if coolingLimitType = LimitCapacity or LimitFlowRateAndCapacity. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- heatingAvailabilityScheduleID – heating availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, heating and humidification are always available;
- coolingAvailabilityScheduleID – cooling availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, cooling and dehumidification are always available;
- dehumidificationControlType – ‘None’, ‘Humidistat’, ‘ConstantSensibleHeatRatio’ or ‘ConstantSupplyHumidityRatio’;
- coolingSensibleHeatRatio – Sensible Cooling divided by Total Cooling (sensible plus latent). Only used if dehumidificationControlType = ConstantSensibleHeatRatio;
- dehumidificationSetpoint – zone humidistat relative humidity setpoint for dehumidification in percent (0 to 100). Only used if dehumidificationControlType = Humidistat;
- humidificationControlType – ‘None’, ‘Humidistat’ or ‘ConstantSupplyHumidityRatio’;
- humidificationSetpoint – zone humidistat relative humidity setpoint for humidification in percent (0 to 100). Only used if humidificationControlType = Humidistat;
- outdoorAirMethod – ‘None’, ‘Flow_Person’, ‘Flow_Area’, ‘Flow_Zone’, ‘Sum’, ‘Maximum’ or ‘DetailedSpecification’;
- outdoorAirflowRatePerPerson – design outdoor air flow rate per person for this zone in m3/s. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [m3/s.m2]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;

- outdoorAirflowRatePerZone – design outdoor air flow rate for this zone in m3/s. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this system, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- demandControlledVentilationType – 'None', 'OccupancySchedule' or 'CO2Setpoint'. For CO2Setpoint, the minimum outdoor air flow rate may be increased if necessary to maintain the level of indoor CO_2 at or below the setpoint defined in the Contaminant Controller object (**7.2.3**);
- outdoorAirEconomizerType – 'DifferentialDryBulb', 'DifferentialEnthalpy' or 'NoEconomizer';
- heatRecoveryType – 'None', 'Sensible' or 'Enthalpy';
- sensibleHeatRecoveryEffectiveness – change in supply temperature divided by the difference in entering supply and relief air temperatures;
- latentHeatRecoveryEffectiveness – change in supply humidity ratio divided by the difference in entering supply and relief air humidity ratios;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template Thermostat Name – name of the thermostat assigned to the zone, defined in the first argument of the ZoneHVACTemplateSpec() above.

The corresponding detailed version of this template object can be defined as presented in section **7.1.1** (Zone HVAC Ideal Loads Air System).

An example of this template object usage can be found in the SingleStoreyFamilyHouse_HVACT_ZoneIdealLoads template in the SAPTool_LSP.

An example of this template object usage with air contaminants concentration can be found in the SingleStoreyFamilyHouse_HVACT_ZoneIdealLoads_CO2AndGenericContaminant template in the SAPTool_LSP.

6.4. Baseboard Heat

The HVAC Template Zone Baseboard Heat option must be active (**HVAC_TEMPLATE_ZONE_BASEBOARD_HEAT = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

If the Baseboard Heating type is 'Hot Water', a Template Plant Hot Water Loop (**6.15.2**), a Template Plant Chilled Water Loop (**6.15.1**), one or more Template Plant Boilers (**6.16.1**), and one or more Template Plant Chillers (**6.16.2**) must be defined (see section **6.1**). In addition, optional Template Dedicated Outdoor Air Systems (**6.14**) can be defined to serve the fancoil units for which they are assigned (see section **6.1**).

The specification of the baseboard heat units for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_LivingRoom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_LivingRoom and defined for the Living Room space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneBaseboardHeatSpec()** – specification of the baseboard heat unit for this space, defined in the table **HVACTemplateZoneBaseboardHeat** in the database (see below), and with the following arguments:
  - **x** – name of the Dedicated Outdoor Air system which supplies this baseboard heat unit – defined in the section **6.14** (named systemDedicatedOutdoorAirName in that example). If a Dedicated Outdoor Air system is not defined or is not assigned to this unit, this field must be set as **null**;
  - **DBHVACTemplateZoneBaseboardHeatType.ABC.getID()** – ID of the HVAC Template baseboard heat properties in the database, defined using the DBHVACTemplateZoneBaseboardHeatType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
  - **db** – database unique ID;
- **null** – used only for HVAC Template zone system specifications.

This zone HVAC template specification (hvacTemplateSpec_LivingRoom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Living Room, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_LivingRoom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living Room, in this example);
- **db** – database unique ID.

The HVAC Template Baseboard Heat properties are defined in the **HVACTemplateZoneBaseboardHeat** table in the database, corresponding to the HVACTemplate:Zone:BaseboardHeat object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating load will be multiplied by the number input in this field when baseboardHeatingCapacity = autosize. If blank, the Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- baseboardHeatingType – 'HotWater' or 'Electric';

- baseboardHeatingAvailabilityScheduleID – baseboard heating availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the baseboard heating is always available;
- baseboardHeatingCapacity – maximum amount of heat that the baseboard heating can deliver [W]. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- outdoorAirMethod – 'Flow_Person', 'Flow_Area', 'Flow_Zone', 'Sum', 'Maximum' or 'DetailedSpecification';
- outdoorAirFlowRatePerPerson – design outdoor air flow rate per person for this zone in m3/s. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [m3/s.m2]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirFlowRatePerZone – design outdoor air flow rate for this zone in m3/s. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this system, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationZoneAirID – ID of the object which specifies the zone air distribution requirements and schedule for this system, defined in table **DesignSpecificationZoneAirDistribution** in the database (see section **13.1.2**). Only used if outdoorAirMethod = DetailedSpecification;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template Thermostat Name – name of the thermostat assigned for the zone, defined in the first argument of the ZoneHVACTemplateSpec() above;
- Dedicated Outdoor Air System Name – name of the Dedicated Outdoor Air System assigned for this baseboard heat unit (if any), defined defined in section **6.14**.

The corresponding detailed version of this template object can be defined as presented in sections **7.1.3.1** (Zone HVAC Baseboard Convective Water) and **7.1.3.2** (Zone HVAC Baseboard Convective Electric).

An example of this template object usage can be found in the SingleStoreyFamilyHouse_HVACT_BaseboardHeat template in the SAPTool_LSP.

6.5. Fancoil

The HVAC Template Zone Fancoil option must be active (**HVAC_TEMPLATE_ZONE_FANCOIL = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

A Template Plant Hot Water Loop (**6.15.2**), a Template Plant Chilled Water Loop (**6.15.1**), one or more Template Plant Boilers (**6.16.1**) and one or more Template Plant Chillers (**6.16.2**) must be defined (see section **6.1**). In addition, optional Template Dedicated Outdoor Air Systems (**6.14**) can be defined to serve the fancoil units for which they are assigned (see section **6.1**).

The specification of the fancoil units for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_LivingRoom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_LivingRoom and defined for the Living Room space, in this example). With the following **ZoneHVACTemplateSpec**() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneFancoilHeatSpec()** – specification of the fancoil unit for this space, defined in the table **HVACTemplateZoneFancoil** in the database (see below), and with the following arguments:
    - **x** – name of the Dedicated Outdoor Air system which supplies this fancoil unit – defined in the section **6.14** (named systemDedicatedOutdoorAirName in that example). If a Dedicated Outdoor Air system is not defined or is not assigned to this unit, this field must be set as **null**;
    - **DBHVACTemplateZoneFancoilType.ABC.getID()** – ID of the HVAC Template fancoil properties in the database, defined using the DBHVACTemplateZoneFancoilType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
    - **db** – database unique ID.
- **null** – used only for HVAC Template zone system specifications.

This zone HVAC template specification (hvacTemplateSpec_LivingRoom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Living Room, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_LivingRoom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living Room, in this example);
- **db** – database unique ID.

The HVAC Template Fancoil properties are defined in the **HVACTemplateZoneFancoil** table in the database, corresponding to the HVACTemplate:Zone:FanCoil object in EnergyPlus. The following fields are present in the table:

- id – object ID;

- supplyAirMaximumFlowRate – maximum supply air flow rate into the zone in m3/s. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**) and a thermostat must be specified for the zone. If a value is entered it is used as the maximum supply air flow rate into the zone, and it will be multiplied by the Supply Air Sizing Factor and by zone multipliers;
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- zoneCoolingSizingFactor – zone level cooling sizing ratio. The zone design cooling air flow rate and load load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Cooling Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- outdoorAirMethod – ‘Flow_Person’, ‘Flow_Area’, ‘Flow_Zone’, ‘Sum’, ‘Maximum’ or ‘DetailedSpecification’;
- outdoorAirFlowRatePerPerson – design outdoor air flow rate per person for this zone in m3/s. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [m3/s.m2]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirFlowRatePerZone – design outdoor air flow rate for this zone in m3/s. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;
- systemAvailabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the system is always available;
- supplyFanTotalEfficiency – total efficiency of the supply fan, i.e., the ratio of the power delivered to the fluid to the electrical input power. This input value must be between 0 and 1;
- supplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions (20 °C at sea level, 101325 Pa);
- supplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed. Must be greater than 0 and less than or equal to 1;
- supplyFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream. A value of 0 means that the motor is completely outside the air stream. A value of 1 means that all of the motor heat will go into the air stream and act to cause a temperature rise;
- coolingCoilType – ‘ChilledWater’, ‘ChilledWaterDetailedFlatModel’ or ‘HeatExchangerAssistedChilledWater’;
- coolingCoilAvailabilityScheduleID – cooling coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- coolingCoilDesignSetpoint – design supply air temperature used to size the cooling supply air flow and the cooling coil [°C]. Only used when zoneCoolingDesignSupplyAirTemperatureInputMethod = SupplyAirTemperature;
- heatingCoilType – ‘HotWater’ or ‘Electric’;
- heatingCoilAvailabilityScheduleID – heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;

- heatingCoilDesignSetpoint – design supply air temperature used to size the heating supply air flow and the heating coil [°C]. Only used when zoneHeatingDesignSupplyAirTemperatureInputMethod = SupplyAirTemperature;
- zoneCoolingDesignSupplyAirTemperatureInputMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneCoolingDesignSupplyAirTemperatureDifference – temperature difference between the cooling design supply air temperature and the zone air temperature for the zone cooling design air flow rate calculation and cooling coil sizing [°C]. Only used when zoneCoolingDesignSupplyAirTemperatureInputMethod = TemperatureDifference';
- zoneHeatingDesignSupplyAirTemperatureInputMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneHeatingDesignSupplyAirTemperatureDifference – temperature difference between the heating design supply air temperature and the zone air temperature for the zone heating design air flow rate calculation and cooling coil sizing [°C]. Only used when zoneHeatingDesignSupplyAirTemperatureInputMethod = TemperatureDifference';
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this system, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationZoneAirDistributionID – ID of the object which specifies the zone air distribution requirements and schedule for this system, defined in table **DesignSpecificationZoneAirDistribution** in the database (see section **13.1.2**). Only used if outdoorAirMethod = DetailedSpecification;
- fanCoilCapacityControlMethod – 'ConstantFanVariableFlow', 'CyclingFan', 'VariableFanVariableFlow', 'VariableFanConstantFlow', 'MultiSpeedFan' or 'ASHRAE90VariableFan'. If this field is left blank, it will default to CyclingFan if a Dedicated Outdoor Air System is specified (see above), otherwise it will default to ConstantFanVariableFlow;
- lowSpeedSupplyAirFlowRatio – ratio of the low speed flow rate to the maximum supply air flow rate. Its value should be less than mediumSpeedSupplyAirFlowRatio. This field is ignored if fanCoilCapacityControlMethod ≠ CyclingFan;
- mediumSpeedSupplyAirFlowRatio – ratio of the medium speed flow rate to the maximum supply air flow rate. Its value should be greater than the lowSpeedSupplyAirFlowRatio but less than 1. This field is ignored if fanCoilCapacityControlMethod ≠ CyclingFan;
- outdoorAirScheduleID – schedule ID of values (0.0 to 1.0) used as multipliers to alter the outdoor air flow rate, defined in the **Schedules** table in the database (**21**). If blank, the values will default to 1.0. This schedule is ignored if the zone is served by an HVACTemplate dedicated outdoor air system (see below);
- baseboardHeatingType – 'HotWater', 'Electric' or 'None';
- baseboardHeatingAvailabilityScheduleID – baseboard heating availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the baseboard heating is always available;
- baseboardHeatingCapacity – maximum amount of heat that the baseboard heating can deliver [W]. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);

- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template Thermostat Name – name of the thermostat assigned for the zone, defined in the first argument of the ZoneHVACTemplateSpec() above;
- Dedicated Outdoor Air System Name – name of the Dedicated Outdoor Air System assigned for this baseboard heat unit (if any), defined in section **6.14**.

The corresponding detailed version of this template object can be defined as presented in section **7.1.4** (Zone HVAC Four Pipe Fancoil).

An example of this template object usage can be found in the SingleStoreyFamilyHouse_HVACT_Fancoil template in the SAPTool_LSP.

6.6. PTAC

The HVAC Template Zone PTAC option must be active (**HVAC_TEMPLATE_ZONE_PTAC = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

If the PTAC heating coil type and/or baseboard heating type is 'Hot Water', a Template Plant Hot Water Loop (**6.15.2**) and one or more Template Plant Boilers (**6.16.1**) must be defined (see section **6.1**). In addition, optional Template Dedicated Outdoor Air Systems (**6.14**) can be defined to serve the PTAC units for which they are assigned (see section **6.1**).

The specification of the PTAC units for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_LivingRoom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_LivingRoom and defined for the Living Room space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZonePTACSpec()** – specification of the PTAC unit for this space, defined in the table **HVACTemplateZonePTAC** in the database (see below), and with the following arguments:
    - **x** – name of the Dedicated Outdoor Air system which supplies this PTAC unit – defined in the section **6.14** (named systemDedicatedOutdoorAirName in that example). If a Dedicated Outdoor Air system is not defined or is not assigned to this unit, this field must be set as **null**;
    - **DBHVACTemplateZonePTACType.ABC.getID()** – ID of the HVAC Template PTAC properties in the database, defined using the DBHVACTemplateZonePTACType list

object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
    - **db** – database unique ID.
- **null** – used only for HVAC Template zone system specifications.

This zone HVAC template specification (hvacTemplateSpec_LivingRoom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Living Room, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_LivingRoom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living Room, in this example);
- **db** – database unique ID.

The HVAC Template PTAC properties are defined in the **HVACTemplateZonePTAC** table in the database, corresponding to the HVACTemplate:Zone:PTAC object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- coolingSupplyAirFlowRate – supply air flow rate when the DX cooling coil is operating [m^3/s]. 'autosize' option is available;
- heatingSupplyAirFlowRate – supply air flow rate when the heating coil is operating [m^3/s]. 'autosize' option is available;
- noLoadSupplyAirFlowRate – supply air flow rate when neither cooling nor heating is required (i.e., DX coil and heater are off but the supply air fan operates). This field is only used when the supply air fan operating mode schedule specifies continuous fan operation. 'autosize' option is available;
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating air flow rate and load will be multiplied by the number input in this field when heatingSupplyAirFlowRate = autosize. If blank, the Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- zoneCoolingSizingFactor – zone level cooling sizing ratio. The zone design cooling air flow rate and load load will be multiplied by the number input in this field when coolingSupplyAirFlowRate = autosize. If blank, the Cooling Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- outdoorAirMethod – 'Flow_Person', 'Flow_Area', 'Flow_Zone', 'Sum', 'Maximum' or 'DetailedSpecification';
- outdoorAirFlowRatePerPerson – design outdoor air flow rate per person for this zone in m3/s. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [m3/s.m2]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirFlowRatePerZone – design outdoor air flow rate for this zone in m3/s. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;

- systemAvailabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the system is always available;
- supplyFanOperatingModeScheduleID – supply air fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). Schedule values of 0 denote that the supply air fan and the heating or cooling coil cycle on and off together to meet the heating or cooling load (a.k.a. auto fan). Schedule values other than 0 denote that the supply fan runs continuously while the heating or cooling coil cycles to meet the load. If blank, a schedule of always zero (cycling fan) will be used;
- supplyFanPlacement – 'DrawThrough' or 'BlowThrough';
- supplyFanTotalEfficiency – total efficiency of the supply fan, i.e., the ratio of the power delivered to the fluid to the electrical input power. This input value must be between 0 and 1;
- supplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions (20 °C at sea level, 101325 Pa);
- supplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed. Must be greater than 0 and less than or equal to 1;
- coolingCoilType – 'SingleSpeedDX';
- coolingCoilAvailabilityScheduleID – cooling coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- coolingCoilGrossRatedTotalCapacity – full load gross cooling capacity, including both sensible and latent capacity, of the DX coil unit at rated conditions [W]. 'autosize' option is available, which lets the automatic sizing algorithm determine the cooling coil gross capacity based on the maximum cooling loads during the cooling design day;
- coolingCoilGrossRatedSensibleHeatRatio – ratio of the sensible capacity divided by total cooling capacity of the DX cooling coil at rated conditions. 'autosize' option is available, which allows the sizing algorithm to determine the sensible heat ratio based on the rated capacity and air flow rate;
- coolingCoilGrossRatedCoolingCOP – coefficient of performance defined as the gross cooling coil capacity in watts divided by electrical power input in watts of the DX cooling coil unit at rated conditions;
- heatingCoilType – 'Electric', 'HotWater' or 'Gas';
- heatingCoilAvailabilityScheduleID – heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- heatingCoilCapacity – maximum amount of heat that the coil can deliver [W]. 'autosize' option is available, allowing the sizing algorithm to determine the proper capacity required based on the loads experienced during the heating design day;
- gasHeatingCoilEfficiency – gas burner efficiency as a decimal. Only used if heatingCoilType = Gas;
- gasHeatingCoilParasiticElectricLoad – parasitic electric load associated with the gas heating coil operation [W]. Only used if heatingCoilType = Gas;
- zoneCoolingDesignSupplyAirTemperatureInputMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneCoolingDesignSupplyAirTemperature – supply air temperature in for the zone cooling design air flow rate calculation and cooling coil sizing [°C]. Only used when zoneCoolingDesignSupplyAirTemperatureInputMethod = SupplyAirTemperature;
- zoneCoolingDesignSupplyAirTemperatureDifference – temperature difference between the cooling design supply air temperature and the zone air temperature for the zone

cooling design air flow rate calculation and cooling coil sizing [°C]. Only used when zoneCoolingDesignSupplyAirTemperatureInputMethod = TemperatureDifference;

- zoneHeatingDesignSupplyAirTemperatureInputMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneHeatingDesignSupplyAirTemperature – supply air temperature in for the zone heating design air flow rate calculation and heating coil sizing [°C]. Only used when zoneCoolingDesignSupplyAirTemperatureInputMethod = SupplyAirTemperature;
- zoneHeatingDesignSupplyAirTemperatureDifference – temperature difference between the heating design supply air temperature and the zone air temperature for the zone heating design air flow rate calculation and cooling coil sizing [°C]. Only used when zoneHeatingDesignSupplyAirTemperatureInputMethod = TemperatureDifference;
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this system, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationZoneAirDistributionID – ID of the object which specifies the zone air distribution requirements and schedule for this system, defined in table **DesignSpecificationZoneAirDistribution** in the database (see section **13.1.2**). Only used if outdoorAirMethod = DetailedSpecification;
- baseboardHeatingType – 'HotWater', 'Electric' or 'None';
- baseboardHeatingAvailabilityScheduleID – baseboard heating availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the baseboard heating is always available;
- baseboardHeatingCapacity – maximum amount of heat that the baseboard heating can deliver [W]. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- capacityControlMethod – 'None' or 'SingleZoneVAV';
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template Thermostat Name – name of the thermostat assigned for the zone, defined in the first argument of the ZoneHVACTemplateSpec() above;
- Dedicated Outdoor Air System Name – name of the Dedicated Outdoor Air System assigned for this baseboard heat unit (if any), defined in section **6.14**.

The corresponding detailed version of this template object can be defined as presented in section **7.1.5.1** (Zone HVAC Packaged Terminal Air Conditioner).

An example of this template object usage can be found in the SingleStoreyFamilyHouse_HVACT_PTAC template in the SAPTool_LSP.

6.7. PTHP

The HVAC Template Zone PTHP option must be active (**HVAC_TEMPLATE_ZONE_PTHP = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

If the PTHP supplemental heating coil type and/or baseboard heating type is 'Hot Water', a Template Plant Hot Water Loop (**6.15.2**) and one or more Template Plant Boilers (**6.16.1**) must be defined (see section **6.1**). In addition, optional Template Dedicated Outdoor Air Systems (**6.14**) can be defined to serve the PTAC units for which they are assigned (see section **6.1**).

The specification of the PTHP units for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_LivingRoom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_LivingRoom and defined for the Living Room space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZonePTHPSpec()** – specification of the PTHP unit for this space, defined in the table **HVACTemplateZonePTHP** in the database (see below), and with the following arguments:
  - **x** – name of the Dedicated Outdoor Air system which supplies this PTHP unit – defined in the section **6.14** (named systemDedicatedOutdoorAirName in that example). If a Dedicated Outdoor Air system is not defined or is not assigned to this unit, this field must be set as **null**;
  - **DBHVACTemplateZonePTHPType.ABC.getID()** – ID of the HVAC Template PTHP properties in the database, defined using the DBHVACTemplateZonePTHPType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
  - **db** – database unique ID.
- **null** – used only for HVAC Template zone system specifications.

This zone HVAC template specification (hvacTemplateSpec_LivingRoom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Living Room, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_LivingRoom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living Room, in this example);
- **db** – database unique ID.

The HVAC Template PTHP properties are defined in the **HVACTemplateZonePTHP** table in the database, corresponding to the HVACTemplate:Zone:PTHP object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- coolingSupplyAirFlowRate – supply air flow rate when the DX cooling coil is operating [m^3/s]. 'autosize' option is available;
- heatingSupplyAirFlowRate – supply air flow rate when the heating coil is operating [m^3/s]. 'autosize' option is available;
- noLoadSupplyAirFlowRate – supply air flow rate when neither cooling nor heating is required (i.e., DX coil and heater are off but the supply air fan operates). This field is only used when the supply air fan operating mode schedule specifies continuous fan operation. 'autosize' option is available;
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating air flow rate and load will be multiplied by the number input in this field when heatingSupplyAirFlowRate = autosize. If blank, the Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- zoneCoolingSizingFactor – zone level cooling sizing ratio. The zone design cooling air flow rate and load load will be multiplied by the number input in this field when coolingSupplyAirFlowRate = autosize. If blank, the Cooling Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- outdoorAirMethod – 'Flow_Person', 'Flow_Area', 'Flow_Zone', 'Sum', 'Maximum' or 'DetailedSpecification';
- outdoorAirFlowRatePerPerson – design outdoor air flow rate per person for this zone in m3/s. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [m3/s.m2]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirFlowRatePerZone – design outdoor air flow rate for this zone in m3/s. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;
- systemAvailabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the system is always available;
- supplyFanOperatingModeScheduleID – supply air fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). Schedule values of 0 denote that the supply air fan and the heating or cooling coil cycle on and off together to meet the heating or cooling load (a.k.a. auto fan). Schedule values other than 0 denote that the supply fan runs continuously while the heating or cooling coil cycles to meet the load. If blank, a schedule of always zero (cycling fan) will be used;
- supplyFanPlacement – 'DrawThrough' or 'BlowThrough';
- supplyFanTotalEfficiency – total efficiency of the supply fan, i.e., the ratio of the power delivered to the fluid to the electrical input power. This input value must be between 0 and 1;
- supplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions (20 °C at sea level, 101325 Pa);
- supplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed. Must be greater than 0 and less than or equal to 1;
- coolingCoilType – 'SingleSpeedDX';

- coolingCoilAvailabilityScheduleID – cooling coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- coolingCoilGrossRatedTotalCapacity – full load gross cooling capacity, including both sensible and latent capacity, of the DX coil unit at rated conditions [W]. 'autosize' option is available, which lets the automatic sizing algorithm determine the cooling coil gross capacity based on the maximum cooling loads during the cooling design day;
- coolingCoilGrossRatedSensibleHeatRatio – ratio of the sensible capacity divided by total cooling capacity of the DX cooling coil at rated conditions. 'autosize' option is available, which allows the sizing algorithm to determine the sensible heat ratio based on the rated capacity and air flow rate;
- coolingCoilGrossRatedCoolingCOP – coefficient of performance defined as the gross cooling coil capacity in watts divided by electrical power input in watts of the DX cooling coil unit at rated conditions;
- heatingCoilType – 'SingleSpeedDXHeatPump';
- heatingCoilAvailabilityScheduleID – heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- heatPumpHeatingCoilGrossRatedCapacity – full load gross heating capacity, in watts of the DX heat pump unit at rated condition. 'autosize' option is available, which lets the automatic sizing algorithm determine the heat pump heating coil gorss rated capacity based on the maximum heating loads during the heating design day;
- heatPumpHeatingCoilGrossRatedCOP – coefficient of performance defined as the gross heating coil capacity in watts divided by electrical power input of the DX heating coil unit at rated conditions [W];
- heatPumpHeatingMinimumOutdoorDryBulbTemperature – minimum outdoor dry-bulb temperature in degrees Celsius for PTHP compressor operation [°C];
- heatPumpDefrostMaximumOutdoorDryBulbTemperature – outdoor air dry-bulb temperature above which outdoor coil defrosting is disabled [°C];
- heatPumpDefrostStrategy – 'ReverseCycle' or 'Resistive';
- heatPumpDefrostControl – 'Timed' or 'OnDemand';
- heatPumpDefrostTimePeriodFraction – fraction of compressor runtime when the defrost cycle is active. Only applies if heatPumpDefrostControl = Timed;
- supplementalHeatingCoilType – 'Electric', 'HotWater' or 'Gas';
- supplementalHeatingCoilAvailabilityScheduleID – supplemental heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- supplementalHeatingCoilCapacity – maximum amount of heat that the supplemental heating coil can deliver [W]. 'autosize' option is available, which allows the sizing algorithm to determine the proper capacity required based on the loads experienced during the heating design day;
- supplementalHeatingCoilMaximumOutdoorDryBulbTemperature – outdoor air dry-bulb temperature above which the supplemental heating coil is disabled [°C];
- supplementalGasHeatingCoilEfficiency – supplemental heating coil gas burner efficiency as a decimal. Only used if supplementalHeatingCoilType = Gas;
- supplementalGasHeatingCoilParasiticElectricLoad – parasitic electric load associated with the gas supplemental heating coil operation. Only used if supplementalHeatingCoilType = Gas;

- zoneCoolingDesignSupplyAirTemperatureInputMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneCoolingDesignSupplyAirTemperature – supply air temperature in for the zone cooling design air flow rate calculation and cooling coil sizing [°C]. Only used when zoneCoolingDesignSupplyAirTemperatureInputMethod = SupplyAirTemperature;
- zoneCoolingDesignSupplyAirTemperatureDifference – temperature difference between the cooling design supply air temperature and the zone air temperature for the zone cooling design air flow rate calculation and cooling coil sizing [°C]. Only used when zoneCoolingDesignSupplyAirTemperatureInputMethod = TemperatureDifference;
- zoneHeatingDesignSupplyAirTemperatureInputMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneHeatingDesignSupplyAirTemperature – supply air temperature in for the zone heating design air flow rate calculation and heating coil sizing [°C]. Only used when zoneCoolingDesignSupplyAirTemperatureInputMethod = SupplyAirTemperature;
- zoneHeatingDesignSupplyAirTemperatureDifference – temperature difference between the heating design supply air temperature and the zone air temperature for the zone heating design air flow rate calculation and cooling coil sizing [°C]. Only used when zoneHeatingDesignSupplyAirTemperatureInputMethod = TemperatureDifference;
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this system, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationZoneAirDistributionID – ID of the object which specifies the zone air distribution requirements and schedule for this system, defined in table **DesignSpecificationZoneAirDistribution** in the database (see section **13.1.2**). Only used if outdoorAirMethod = DetailedSpecification;
- baseboardHeatingType – 'HotWater', 'Electric' or 'None';
- baseboardHeatingAvailabilityScheduleID – baseboard heating availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the baseboard heating is always available;
- baseboardHeatingCapacity – maximum amount of heat that the baseboard heating can deliver [W]. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- capacityControlMethod – 'None' or 'SingleZoneVAV';
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template Thermostat Name – name of the thermostat assigned for the zone, defined in the first argument of the ZoneHVACTemplateSpec() above;
- Dedicated Outdoor Air System Name – name of the Dedicated Outdoor Air System assigned for this baseboard heat unit (if any), defined in section **6.14**.

The corresponding detailed version of this template object can be defined as presented in section **7.1.5.2** (Zone HVAC Packaged Terminal Heat Pump).

An example of this template object usage can be found in the SingleStoreyFamilyHouse_HVACT_PTHP template in the SAPTool_LSP.

6.8. Water-to-Air Heat Pump

The HVAC Template Zone Water-to-Air Heat Pump option must be active (**HVAC_TEMPLATE_ZONE_WATER_TO_AIR_HEAT_PUMP = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

A Template Plant Mixed Water Loop (**6.15.3**), one or more Template Plant Boilers (**6.16.1**), and one or more Template Plant Towers (**6.16.3**) must be defined (see section **6.1**). If the Water-to-Air Heat Pump supplemental heating coil type and/or baseboard heating type is 'Hot Water', a Template Plant Hot Water Loop (**6.15.2**) and a Template Plant Boiler (**6.16.1**) must be defined (see section **6.1**). In addition, optional Template Dedicated Outdoor Air Systems (**6.14**) can be defined to serve the Water-to-Air Heat Pump units for which they are assigned (see section **6.1**).

The specification of the Water-to-Air Heat Pump units for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_LivingRoom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_LivingRoom and defined for the Living Room space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneWaterToAirHeatPumpSpec()** – specification of the Water-to-Air Heat Pump unit for this space, defined in the table **HVACTemplateZoneWaterToAirHeatPump** in the database (see below), and with the following arguments:
  - **x** – name of the Dedicated Outdoor Air system which supplies this PTHP unit – defined in the section **6.14** (named systemDedicatedOutdoorAirName in that example). If a Dedicated Outdoor Air system is not defined or is not assigned to this unit, this field must be set as **null**;
  - **DBHVACTemplateZoneWaterToAirHeatPumpType.ABC.getID()** – ID of the HVAC Template Water-to-Air Heat Pump properties in the database, defined using the DBHVACTemplateZoneWaterToAirHeatPumpType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
  - **db** – database unique ID.
- **null** – used only for HVAC Template zone system specifications.

This zone HVAC template specification (hvacTemplateSpec_LivingRoom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Living Room, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_LivingRoom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living Room, in this example);
- **db** – database unique ID.

The HVAC Template Water-to-Air Heat Pump properties are defined in the **HVACTemplateZoneWaterToAirHeatPump** table in the database, corresponding to the HVACTemplate:Zone:WaterToAirHeatPump object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- coolingSupplyAirFlowRate – supply air flow rate when the DX cooling coil is operating [m^3/s]. 'autosize' option is available;
- heatingSupplyAirFlowRate – supply air flow rate when the heating coil is operating [m^3/s]. 'autosize' option is available;
- noLoadSupplyAirFlowRate – supply air flow rate when neither cooling nor heating is required (i.e., DX coil and heater are off but the supply air fan operates). This field is only used when the supply air fan operating mode schedule specifies continuous fan operation. 'autosize' option is available;
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating air flow rate and load will be multiplied by the number input in this field when heatingSupplyAirFlowRate = autosize. If blank, the Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- zoneCoolingSizingFactor – zone level cooling sizing ratio. The zone design cooling air flow rate and load load will be multiplied by the number input in this field when coolingSupplyAirFlowRate = autosize. If blank, the Cooling Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- outdoorAirMethod – 'Flow_Person', 'Flow_Area', 'Flow_Zone', 'Sum', 'Maximum' or 'DetailedSpecification';
- outdoorAirFlowRatePerPerson – design outdoor air flow rate per person for this zone in m3/s. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [m3/s.m2]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirFlowRatePerZone – design outdoor air flow rate for this zone in m3/s. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;
- systemAvailabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the system is always available;
- supplyFanOperatingModeScheduleID – supply air fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). Schedule values of 0 denote that the supply air fan and the heating or cooling coil cycle on and off together to meet the

heating or cooling load (a.k.a. auto fan). Schedule values other than 0 denote that the supply fan runs continuously while the heating or cooling coil cycles to meet the load. If blank, a schedule of always zero (cycling fan) will be used;

- supplyFanPlacement – 'DrawThrough' or 'BlowThrough';
- supplyFanTotalEfficiency – total efficiency of the supply fan, i.e., the ratio of the power delivered to the fluid to the electrical input power. This input value must be between 0 and 1;
- supplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions (20 °C at sea level, 101325 Pa);
- supplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed. Must be greater than 0 and less than or equal to 1;
- coolingCoilType – 'Coil_Cooling_WaterToAirHeatPump_EquationFit;
- coolingCoilGrossRatedTotalCapacity – full load gross cooling capacity, including both sensible and latent capacity, of the DX coil unit at rated conditions [W]. 'autosize' option is available, which lets the automatic sizing algorithm determine the cooling coil gross capacity based on the maximum cooling loads during the cooling design day;
- coolingCoilGrossRatedSensibleHeatRatio – ratio of the sensible capacity divided by total cooling capacity of the DX cooling coil at rated conditions. 'autosize' option is available, which allows the sizing algorithm to determine the sensible heat ratio based on the rated capacity and air flow rate;
- coolingCoilGrossRatedCOP – coefficient of performance defined as the gross cooling coil capacity in watts divided by electrical power input in watts of the DX cooling coil unit at rated conditions;
- heatPumpHeatingCoilType – 'Coil_Heating_WaterToAirHeatPump_EquationFit;
- heatPumpHeatingCoilGrossRatedCapacity – full load heating capacity of the DX heat pump unit at rated conditions [W]. 'autosize' option is available, which lets the automatic sizing algorithm determine the heat pump heating coil gross capacity based on the maximum heating loads during the heating design day;
- heatPumpHeatingCoilGrossRatedCOP – coefficient of performance defined as the gross heating coil capacity divided by electrical power input in watts of the DX heating coil unit at rated conditions [W];
- supplementalHeatingCoilAvailabilityScheduleID – supplemental heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- supplementalHeatingCoilCapacity – maximum amount of heat that the supplemental heating coil can deliver [W]. 'autosize' option is available, which allows the sizing algorithm to determine the proper capacity required based on the loads experienced during the heating design day;
- maximumCyclingRate – maximum on-off cycling rate for the compressor, which occurs at 50% run time fraction [cycles/h];
- heatPumpTimeConstant – time constant for the cooling coil's capacity to reach steady state after startup [s];
- fractionOfOnCyclePowerUse – fraction of on-cycle power use to adjust the part load fraction based on the off-cycle power consumption due to crankcase heaters, controls, fans, and etc.;
- heatPumpFanDelayTime – time delay for the heat pump supply air fan to shut off after compressor cycle off [s];

- supplementalHeatingCoilType – ‘Electric’ or ‘HotWater’;
- zoneCoolingDesignSupplyAirTemperatureInputMethod – ‘SupplyAirTemperature’ or ‘TemperatureDifference’;
- zoneCoolingDesignSupplyAirTemperature – supply air temperature in for the zone cooling design air flow rate calculation and cooling coil sizing [°C]. Only used when zoneCoolingDesignSupplyAirTemperatureInputMethod = SupplyAirTemperature;
- zoneCoolingDesignSupplyAirTemperatureDifference – temperature difference between the cooling design supply air temperature and the zone air temperature for the zone cooling design air flow rate calculation and cooling coil sizing [°C]. Only used when zoneCoolingDesignSupplyAirTemperatureInputMethod = TemperatureDifference;
- zoneHeatingDesignSupplyAirTemperatureInputMethod – ‘SupplyAirTemperature’ or ‘TemperatureDifference’;
- zoneHeatingDesignSupplyAirTemperature – supply air temperature in for the zone heating design air flow rate calculation and heating coil sizing [°C]. Only used when zoneCoolingDesignSupplyAirTemperatureInputMethod = SupplyAirTemperature;
- zoneHeatingDesignSupplyAirTemperatureDifference – temperature difference between the heating design supply air temperature and the zone air temperature for the zone heating design air flow rate calculation and cooling coil sizing [°C]. Only used when zoneHeatingDesignSupplyAirTemperatureInputMethod = TemperatureDifference;
- heatPumpCoilWaterFlowMode – ‘Cycling’, ‘Constant’ or ‘ConstantOnDemand’;
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this system, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationZoneAirDistributionID – ID of the object which specifies the zone air distribution requirements and schedule for this system, defined in table **DesignSpecificationZoneAirDistribution** in the database (see section **13.1.2**). Only used if outdoorAirMethod = DetailedSpecification;
- baseboardHeatingType – ‘HotWater’, ‘Electric’ or ‘None’;
- baseboardHeatingAvailabilityScheduleID – baseboard heating availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the baseboard heating is always available;
- baseboardHeatingCapacity – maximum amount of heat that the baseboard heating can deliver [W]. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template Thermostat Name – name of the thermostat assigned for the zone, defined in the first argument of the ZoneHVACTemplateSpec() above;
- Dedicated Outdoor Air System Name – name of the Dedicated Outdoor Air System assigned for this baseboard heat unit (if any), defined in section **6.14**.

The corresponding detailed version of this template object can be defined as presented in section **7.1.6** (Zone HVAC Water-to-Air Heat Pump).

An example of this template object usage can be found in the SingleStoreyFamilyHouse_HVACT_WaterToAirHP template in the SAPTool_LSP.

6.9. Unitary

The HVAC Template Zone Unitary System option must be active (**HVAC_TEMPLATE_ZONE_UNITARY = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

Prior to the zone terminal units' definition, their supply system(s) must also be defined. If the unitary system is intended to serve multiple zone units, it must be defined in the building's HVAC template system (**6.9.1**). Otherwise, if the unitary system is intended to serve a single zone unit, it must be defined in the zone (**6.9.2**).

6.9.1. Unitary system supplying multiple zone units

The assignment of the supply system(s) to the building's HVAC template system is defined in the SAPTool_LSP building template, as demonstrated in section **6.1**. There, the hvacTemplateSpec's arguments should be defined as 'null' if the unitary systems' and zones' coils (or baseboards) are not water heated/chilled; otherwise, the adequate plant loop(s) and plant heating and/or cooling equipment specifications must be properly assigned.

Systems

There are 3 unitary supply system types that can be assigned to zone units: Unitary, Unitary System, and Unitary Heat Pump Air-to-Air:

a) Unitary

The HVAC Template System Unitary name must be defined as follows:

String systemUnitaryName = DBHVACTemplateSystemUnitaryType.ABC.toString() – unitary system name, defined using the DBHVACTemplateSystemUnitaryType list object ('ABC', in this case). Alternatively, a string can be directly inputted here (e.g., **"ABC"**).

The specification of each unitary is defined in the SAPTool_LSP building template, as follows:

HVACTemplateSystemUnitarySpec hvacTemplateSystemUnitarySpec = new HVACTemplateSystemUnitarySpec() – unitary system specification (named hvacTemplateSystemUnitarySpec in this example), defined in the table **HVACTemplateSystemUnitary** in the database (see section **6.9.3** below). With the following HVACTemplateSystemUnitarySpec() arguments:

- **systemUnitaryName** – unitary system's name, defined above;

- **x1** – ID of the control zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template;
- **x2** – ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
- **x3** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
- **x4** – ID of the night cycle control zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if night cycle control is zone controlled (nightCycleControl = CycleOnControlZone, in the table **HVACTemplateSystemUnitary** in the database). **null** if nonexistent;
- **x5** – ID of the humidifier control zone for controlling humidification, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if humidification control is active (humidifierType = ElectricSteam, in the table **HVACTemplateSystemUnitary** in the database). **null** if nonexistent;
- **DBHVACTemplateSystemUnitaryType.ABC_BedroomsUnit.getID()** – ID of the unitary system properties in the database, defined using the DBHVACTemplateSystemUnitaryType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The above defined HVAC Template System Unitary is then added to the building's HVAC template system (named hvacTemplateSpec in this example) as follows:

hvacTemplateSpec.addSystemUnitarySpec(hvacTemplateSystemUnitarySpec) – addition of the unitary system (hvacTemplateSystemUnitarySpec) to the building's HVAC template system.

To add more unitary systems, one should repeat the above process, by defining new unitary system names, their specifications (with the HVACTemplateSystemUnitarySpec()), and adding them to the building's HVAC template system.

An example of this system usage can be found in the SingleStoreyFamilyHouse_HVACT_Unitary template in the SAPTool_LSP.

The corresponding detailed version of this template object can be defined as presented in section **10.4.3** (Air Loop HVAC Unitary Furnace Heat Cool).

b) <u>Unitary System</u>

The HVAC Template System Unitary System name must be defined as follows:

String systemUnitaryName = DBHVACTemplateSystemUnitarySystemType.ABC.toString() – unitary system name, defined using the DBHVACTemplateSystemUnitarySystemType list object ('ABC', in this case). Alternatively, a string can be directly inputted here (e.g., **"ABC"**).

The specification of each unitary system is defined in the SAPTool_LSP building template, as follows:

HVACTemplateSystemUnitarySystemSpec hvacTemplateSystemUnitarySystemSpec = new HVACTemplateSystemUnitarySystemSpec() – unitary system specification (named hvacTemplateSystemUnitarySystemSpec in this example), defined in the table

HVACTemplateSystemUnitarySystem in the database (see section **6.9.3** below). With the following HVACTemplateSystemUnitarySystemSpec() arguments:

- **systemUnitaryName** – unitary system's name, defined above;
- **x1** – ID of the control zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if the system is zone controlled (controlType = Load, in the table **HVACTemplateSystemUnitarySystem** in the database). Otherwise, it may be **null**;
- **x2** – ID of the humidifier control zone for controlling humidification, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if humidification control is active (humidifierType = ElectricSteam, in the table **HVACTemplateSystemUnitarySystem** in the database). **null** if nonexistent;
- **x3** – ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
- **x4** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
- **DBHVACTemplateSystemUnitarySystemType.ABC_BedroomsUnit.getID()** – ID of the Unitary System properties in the database, defined using the DBHVACTemplateSystemUnitarySystemType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The above defined HVAC Template System Unitary System is then added to the building's HVAC template system (named hvacTemplateSpec in this example) as follows:

hvacTemplateSpec.addSystemUnitarySystemSpec(hvacTemplateSystemUnitarySystemSpec) – addition of the unitary system (hvacTemplateSystemUnitarySystemSpec) to the building's HVAC template system.

To add more unitary systems, one should repeat the above process, by defining new unitary system names, their specifications (with the HVACTemplateSystemUnitarySystemSpec()), and adding them to the building's HVAC template system.

An example of this system usage can be found in the SingleStoreyFamilyHouse_HVACT_UnitarySystem template in the SAPTool_LSP.

The corresponding detailed version of this template object can be defined as presented in section **10.4.1** (Air Loop HVAC Unitary System).

c) Unitary Heat Pump Air-to-Air

The HVAC Template System Unitary Heat Pump Air-to-Air name must be defined as follows:

String systemUnitaryName = DBHVACTemplateSystemUnitaryHeatPumpAirToAirType.ABC.toString() – unitary system heat pump air-to-air name, defined using the DBHVACTemplateSystemUnitaryHeatPumpAirToAirType list object ('ABC', in this case). Alternatively, a string can be directly inputted here (e.g., **"ABC"**).

The specification of each unitary is defined in the SAPTool_LSP building template, as follows:

HVACTemplateSystemUnitaryHeatPumpAirToAirSpec hvacTemplateSystemUnitaryHPSpec = new HVACTemplateSystemUnitaryHeatPumpAirToAirSpec() – unitary system heat pump air-to-air specification (named hvacTemplateSystemUnitaryHPSpec in this example), defined in the table **HVACTemplateSystemUnitaryHeatPumpAirToAir** in the database (see section **6.9.3** below). With the following HVACTemplateSystemUnitaryHeatPumpAirToAirSpec() arguments:

- **systemUnitaryName** – unitary heat pump air-to-air's name, defined above;
- **x1** – ID of the control zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template;
- **x2** – ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
- **x3** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
- **x4** – ID of the night cycle control zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if night cycle control is zone controlled (nightCycleControl = CycleOnControlZone, in the table **HVACTemplateSystemUnitaryHeatPumpAirToAir** in the database). **null** if nonexistent;
- **x5** – ID of the humidifier control zone for controlling humidification, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if humidification control is active (humidifierType = ElectricSteam, in the table **HVACTemplateSystemUnitaryHeatPumpAirToAir** in the database). **null** if nonexistent;
- **DBHVACTemplateSystemUnitaryHeatPumpAirToAirType.ABC_BedroomsUnit.getID()** – ID of the unitary heat pump air-to-air properties in the database, defined using the DBHVACTemplateSystemUnitaryHeatPumpAirToAirType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The above defined HVAC Template System Unitary Heat Pump Air-to-Air is then added to the building's HVAC template system (named hvacTemplateSpec in this example) as follows:

hvacTemplateSpec.addSystemUnitarySpec(hvacTemplateSystemUnitaryHPSpec) – addition of the unitary heat pump air-to-air (hvacTemplateSystemUnitaryHPSpec) to the building's HVAC template system.

To add more unitary heat pump air-to-air systems, one should repeat the above process, by defining new unitary system names, their specifications (with the HVACTemplateSystemUnitaryHeatPumpAirToAirSpec()), and adding them to the building's HVAC template system.

An example of this system usage can be found in the SingleStoreyFamilyHouse_HVACT_UnitaryHP template in the SAPTool_LSP.

The corresponding detailed version of this template object can be defined as presented in section **10.4.2** (Air Loop HVAC Unitary Heat Pump Air-to-Air).

Zone units

The specification of the zone terminal units for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneUnitarySpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneUnitary** in the database (see section **6.9.3** below), and with the following arguments:
  - **systemUnitaryName** – name of the unitary system defined above outside the zone (unitary, unitary system or unitary heat pump air-to-air) that can supply multiple units;
  - **x1 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
  - **x2 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **DBHVACTemplateZoneUnitaryType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneUnitaryType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
  - **db** – database unique ID.
- **null** – this terminal zone unit is supplied by a unitary system (unitary, unitary system or unitary heat pump air-to-air – named 'systemUnitaryName') that can supply multiple units and is defined outside the zone.

This zone HVAC template specification (hvacTemplateSpec_SingleBedroom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Single Bedroom, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_SingleBedroom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.SINGLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Single Bedroom, in this example);
- **db** – database unique ID.

The corresponding detailed version of this zone template object can be defined as presented in section **7.1.8.1** (Air Terminal Single Duct Uncontrolled).

6.9.2. Unitary system supplying a single zone unit (zone system)

If the unitary system is intended to serve a single zone unit, it must be defined in the zone. The specification of the zone system for each space is defined in the SAPTool_LSP building template, as follows (for the 3 different supply system types), immediately prior to that zone specification (RoomSpec()):

a) **Unitary**

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneUnitarySpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneUnitary** in the database (see section **6.9.3** below), and with the following arguments:
  - **null** – since this terminal unit is supplied by a single unitary system (unitary) specific to this unit (defined in the zone). In this case, the unitary system name is automatically assigned ("SystemUnitary" + Zone Name).
  - **x1 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
  - **x2 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **DBHVACTemplateZoneUnitaryType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneUnitaryType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
  - **db** – database unique ID.
- **new HVACTemplateSystemUnitarySpec()** – specification of the zone system for this space (unitary), defined in the table **HVACTemplateSystemUnitary** in the database (see section **6.9.3** below), and with the following arguments:
  - **null** – unitary system's name. As this system is specific to a zone unit (and, therefore, defined in the zone), its name is automatically assigned ("SystemUnitary" + Zone Name);
  - **null** – ID of the control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the control zone;
  - **x2** – ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **x3** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
  - **null** – ID of the night cycle control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the night cycle control zone;
  - **null** – ID of the humidifier control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the humidifier control zone;

- **x6** – ID of the unitary system properties in the database, defined using the DBHVACTemplateSystemUnitaryType list object or directly with the proper database ID;
- **db** – database unique ID.

An example of this zone system usage can be found in the SingleStoreyFamilyHouse_HVACT_Unitary template in the SAPTool_LSP.

b) <u>Unitary System</u>

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneUnitarySpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneUnitary** in the database (see section **6.9.3** below), and with the following arguments:
  - **null** – since this terminal unit is supplied by a single unitary system (unitary system) specific to this unit (defined in the zone). In this case, the unitary system name is automatically assigned ("SystemUnitary" + Zone Name).
  - **x1 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
  - **x2 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **DBHVACTemplateZoneUnitaryType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneUnitaryType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
  - **db** – database unique ID.
- **new HVACTemplateSystemUnitarySystemSpec ()** – specification of the zone system for this space (unitary system), defined in the table **HVACTemplateSystemUnitarySystem** in the database (see section **6.9.3** below), and with the following arguments:
  - **null** – unitary system's name. As this system is specific to a zone unit (and, therefore, defined in the zone), its name is automatically assigned ("SystemUnitary" + Zone Name);
  - **null** – ID of the control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the control zone;
  - **null** – ID of the humidifier control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the humidifier control zone;
  - **x3** – ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;

- **x4** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
- **x5** – ID of the Unitary System properties in the database, defined using the DBHVACTemplateSystemUnitarySystemType list object or directly with the proper database ID;
- **db** – database unique ID.

An example of this zone system usage can be found in the Brazil_Simple_MultiStoreyT3T2ApartmentsWithStores template in the SAPTool_LSP.

c) <u>Unitary Heat Pump Air-to-Air</u>

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneUnitarySpec()** – specification of the zone terminal unit for this space (unitary heat pump air-to-air), defined in the table **HVACTemplateZoneUnitary** in the database (see section **6.9.3** below), and with the following arguments:
  - **null** – since this terminal unit is supplied by a single unitary system (unitary) specific to this unit (defined in the zone). In this case, the unitary system name is automatically assigned ("SystemUnitary" + Zone Name).
  - **x1 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
  - **x2 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **DBHVACTemplateZoneUnitaryType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneUnitaryType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
  - **db** – database unique ID.
- **new HVACTemplateSystemUnitaryHeatPumpAirToAirSpec()** – specification of the zone system for this space, defined in the table **HVACTemplateSystemUnitaryHeatPumpAirToAir** in the database (see section **6.9.3** below), and with the following arguments:
  - **null** – unitary system's name. As this system is specific to a zone unit (and, therefore, defined in the zone), its name is automatically assigned ("SystemUnitary" + Zone Name);
  - **null** – ID of the control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the control zone;
  - **x2** – ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;

- **x3** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
- **null** – ID of the night cycle control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the night cycle control zone;
- **null** – ID of the humidifier control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the humidifier control zone;
- **x6** – ID of the unitary system properties in the database, defined using the DBHVACTemplateSystemUnitaryHeatPumpAirToAirType list object or directly with the proper database ID;
- **db** – database unique ID.

An example of this zone system usage can be found in the SingleStoreyFamilyHouse_HVACT_UnitaryHP template in the SAPTool_LSP.

<u>**General**</u>

The zone HVAC template specification defined above (hvacTemplateSpec_SingleBedroom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Single Bedroom, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_SingleBedroom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.SINGLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Single Bedroom, in this example);
- **db** – database unique ID.

6.9.3. System and zone unit properties

<u>**System**</u>

There are 3 unitary supply system types that can be assigned to zone units: Unitary, Unitary System, and Unitary Heat Pump Air-to-Air:

a) <u>Unitary</u>

The HVAC Template System Unitary properties are defined in the **HVACTemplateSystemUnitary** table in the database, corresponding to the HVACTemplate:System:Unitary object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – system availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the system is always available;

- supplyFanMaximumFlowRate – maximum air-flow rate, it is the upper limit on system flow, even if the zone level air flow inputs sum to a greater value [m3/s]. 'autosize' option is available;
- supplyFanOperatingModeScheduleID – supply air fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). 0 - auto cycling fan, ≠ 0 - continuous fan. If blank, a schedule of always zero (cycling fan) will be used;
- supplyFanTotalEfficiency – total efficiency of the supply fan;
- supplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- supplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed;
- supplyFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- coolingCoilType – 'SingleSpeedDX' or 'None';
- coolingCoilAvailabilityScheduleID – cooling coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- coolingDesignSupplyAirTemperature – cooling supply air temperature in Celsius to be used for sizing the cooling coil and zone supply air flow rates;
- coolingCoilGrossRatedTotalCapacity – full load gross total cooling capacity, including both sensible and latent capacity, of the DX coil unit at rated conditions [W]. 'autosize' option is available, which lets the automatic sizing algorithm determine the cooling coil gross capacity based on the maximum cooling loads during the cooling design day;
- coolingCoilGrossRatedSensibleHeatRatio – ratio of the gross sensible capacity divided by the gross total cooling capacity of the DX cooling coil at rated conditions. 'autosize' option is available, which allows the sizing algorithm to determine the sensible heat ratio based on the gross rated capacity and air flow rate;
- coolingCoilGrossRatedCOP – coefficient of performance defined as the gross cooling coil capacity in watts divided by electrical power input in watts of the DX cooling coil unit at rated conditions;
- heatingCoilType – 'Gas', 'Electric' or 'HotWater'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- heatingCoilAvailabilityScheduleID – heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- heatingDesignSupplyAirTemperature – heating supply air temperature in Celsius to be used for sizing the heating coil and zone supply air flow rates;
- heatingCoilCapacity – maximum amount of heat that the coil can deliver [W]. 'autosize' option is available, which allows the sizing algorithm to determine the proper capacity required based on the loads experienced during the heating design day;
- gasHeatingCoilEfficiency – gas burner efficiency. Only used if heatingCoilType = Gas;
- gasHeatingCoilParasiticElectricLoad – parasitic electric load associated with the gas heating coil operation [W]. Only used if heatingCoilType = Gas;
- maximumOutdoorAirFlowRate – maximum outdoor air flow rate in m3/s. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- minimumOutdoorAirFlowRate – minimum outdoor air flow rate in m3/s. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);

- minimumOutdoorAirFlowScheduleID – minimum outdoor air schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the minimum outdoor air will be always the same;
- economizerType – 'NoEconomizer', 'FixedDryBulb', 'FixedEnthalpy', 'DifferentialDryBulb', 'DifferentialEnthalpy', 'FixedDewPointAndDryBulb', 'ElectronicEnthalpy' or 'DifferentialDryBulbAndEnthalpy';
- economizerLockout – 'NoLockout', 'LockoutWithHeating' or 'LockoutWithCompressor';
- economizerUpperTemperatureLimit – outdoor air temperature high limit for economizer operation [°C];
- economizerLowerTemperatureLimit – outdoor air temperature low limit for economizer operation [°C];
- economizerUpperEnthalpyLimit – outdoor air upper enthalpy limit for economizer operation [J/kg];
- economizerMaximumLimitDewpointTemperature – outdoor air dewpoint limit in Celsius for economizer operation. If blank, there is no outdoor air dewpoint limit control. Only used if economizerType = FixedDewPointAndDryBulb;
- supplyFanPlacement – 'BlowThrough' or 'DrawThrough';
- economizerMaximumLimitDryBulbTemperature – outdoor air temperature high limit in Celsius for economizer operation. If blank, there is no outdoor air temperature high limit control. Only used if economizerType = FixedDryBulb or FixedDewPointAndDryBulb;
- nightCycleControl – 'StayOff', 'CycleOnAny' or 'CycleOnControlZone';
- heatRecoveryType – 'None', 'Sensible' or 'Enthalpy';
- sensibleHeatRecoveryEffectiveness – sensible heat recovery effectiveness;
- latentHeatRecoveryEffectiveness – latent heat recovery effectiveness. Only used if heatRecoveryType = Enthalpy;
- dehumificationControlType – 'None', 'CoolReheatHeatingCoil' or 'CoolReheatDesuperheater';
- dehumidificationSetpoint – zone humidistat setpoint for dehumidification in percent;
- humidifierType – 'None' or 'ElectricSteam';
- humidifierAvailabilityScheduleID – humidifier availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, humidifier is always available;
- humidifierRatedCapacity – rated moisture output rate in m3/s;
- humidifierRatedElectricPower – electric power input at the rated capacity moisture output [W]. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- humidifierSetpoint – zone humidistat setpoint for humidification in percent;
- hasReturnFan – 'Yes' or 'No';
- returnFanTotalEfficiency – total efficiency of the return fan;
- returnFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- returnFanMotorEfficiency – shaft power of the return fan divided by the electrical power consumed;
- returnFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – name of the unitary system, defined in the first argument of the HVACTemplateSystemUnitarySpec() above;
- Control Zone or Thermostat Location Name – name of the control zone for which this object is assigned, defined in the argument x1 of the HVACTemplateSystemUnitarySpec() above;
- Supply Plenum Name – name of the zone that serves as a supply plenum for this system, defined in the argument x2 of the HVACTemplateSystemUnitarySpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x3 of the HVACTemplateSystemUnitarySpec() above;
- Night Cycle Control Zone Name – zone name where the night cycle control is located (if any), defined in the argument x3 of the HVACTemplateSystemUnitarySpec() above
- Humidifier Control Zone Name – zone name where the humidistat is located for controlling humidification (if any), defined in the argument x4 of the HVACTemplateSystemUnitarySpec() above.

Note: even when not setting any of the above fields to 'autosize', the "Do System Sizing Calculation" field should be set to Yes in the Simulation Control (x2 = true in section **17**). This is due to the fact that the HVAC Template System Unitary object is internally converted by EnergyPlus to an Air Loop HVAC object (with the expand file), for which an autosized field is assigned, thus requiring a system sizing. Moreover, as system sizing cannot be done without zone sizing, the "Do Zone Sizing Calculation" field should also be set to Yes in the Simulation Control (x1 = true in section **17**).

b) <u>Unitary System</u>

The HVAC Template System Unitary System properties are defined in the **HVACTemplateSystemUnitarySystem** table in the database, corresponding to the HVACTemplate:System:UnitarySystem object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – system availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the system is always available;
- controlType – 'Load' or 'SetPoint';
- coolingSupplyAirFlowRate – supply air flow rate when the cooling coil is operating [m3/s]. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- heatingSupplyAirFlowRate – supply air flow rate when the heating coil is operating [m3/s]. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- noLoadSupplyAirFlowRate – supply air flow rate when neither cooling nor heating is required [m3/s]. 'autosize' option is available, which sizes the supply flow rate to match the smaller of the cooling and heating flow rates, and for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- supplyFanOperatingModeScheduleID – supply air fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). 0 - auto cycling fan, ≠ 0 - continuous fan. If blank, a schedule of always zero (cycling fan) will be used;

- supplyFanPlacement – 'BlowThrough' or 'DrawThrough';
- supplyFanTotalEfficiency – total efficiency of the supply fan;
- supplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- supplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed;
- supplyFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- coolingCoilType – 'SingleSpeedDX', 'TwoSpeedDX', 'MultiSpeedDX', 'TwoStageDX', 'TwoStageHumidityControlDX', 'HeatExchangerAssistedDX', 'SingleSpeedDXWaterCooled', 'ChilledWater', 'ChilledWaterDetailedFlatModel', 'HeatExchangerAssistedChilledWater' or 'None'. SingleSpeedDXWaterCooled requires an HVAC Template Plant Mixed Water Loop to serve as the water source (**6.15.3**), with one or more HVAC Template Plant Boilers (**6.16.1**) and HVAC Template Plant Towers (**6.16.3**). All the chilled water types require an HVAC Template Plant Chilled Water Loop (**6.15.1**), with one or more HVAC Template Plant Chillers (**6.16.2**) and (if present) HVAC Template Plant Towers (**6.16.3**);
- numberOfSpeedsForCooling – number of cooling speeds if coolingCoilType = MultiSpeedDX;
- coolingCoilAvailabilityScheduleID – cooling coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- coolingDesignSupplyAirTemperature – cooling supply air temperature in Celsius to be used for sizing the cooling coil and zone supply air flow rates;
- dxCoolingCoilGrossRatedTotalCapacity – full load gross total cooling capacity, including both sensible and latent capacity, in W of the DX coil unit at rated conditions. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**). Only used if coolingCoilType = SingleSpeedDX, TwoSpeedDX, MultiSpeedDX, TwoStageDX, TwoStageHumidityControlDX, HeatExchangerAssistedDX or SingleSpeedDXWaterCooled;
- dxCoolingCoilGrossRatedSensibleHeatRation – ratio of the gross sensible capacity divided by gross total cooling capacity of the DX cooling coil at rated conditions. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**). Only used if coolingCoilType = SingleSpeedDX, TwoSpeedDX, MultiSpeedDX, TwoStageDX, TwoStageHumidityControlDX, HeatExchangerAssistedDX or SingleSpeedDXWaterCooled;
- dxCoolingCoilGrossRatedCOP – coefficient of performance defined as the gross cooling coil total capacity in W divided by electrical power input in W of the DX cooling coil unit at rated conditions. Only used if coolingCoilType = SingleSpeedDX, TwoSpeedDX, MultiSpeedDX, TwoStageDX, TwoStageHumidityControlDX, HeatExchangerAssistedDX or SingleSpeedDXWaterCooled;
- heatingCoilType – 'Gas', 'Electric', 'HotWater', 'SingleSpeedDXHeatPumpAirSource', 'MultiSpeedDXHeatPumpAirSource', 'SingleSpeedDXHeatPumpWaterSource', 'MultiStageElectric', 'MultiStageGas' or 'None'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**). SingleSpeedDXHeatPumpWaterSource requires an HVAC Template Plant Mixed Water Loop to serve as the water source (**6.15.3**), with one

or more HVAC Template Plant Boilers (**6.16.1**) and HVAC Template Plant Towers (**6.16.3**);

- numberOfSpeedsForHeating – number of heating speeds if heatingCoilType = MultiSpeedDXHeatPumpAirSource, MultiStageElectric or MultiStageGas;
- heatingCoilAvailabilityScheduleID – heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- heatingDesignSupplyAirTemperature – heating supply air temperature in Celsius to be used for sizing the heating coil and zone supply air flow rates;
- heatingCoilGrossRatedCapacity – heating coil gross capacity [W]. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- gasHeatingCoilEfficiency – gas burner efficiency. Only used if heatingCoilType = Gas;
- gasHeatingCoilParasiticElectricLoad – parasitic electric load associated with the gas heating coil operation [W]. Only used if heatingCoilType = Gas;
- heatPumpHeatingCoilGrossRatedCOP – coefficient of performance defined as the gross heating coil capacity in W divided by electrical power input in W of the DX heat pump heating coil unit at rated conditions;
- heatPumpHeatingMinimumOutdoorDryBulbTemperature – minimum outdoor dry-bulb temperature in Celsius for compressor operation;
- heatPumpHeatingMaximumOutdoorDryBulbTemperature – outdoor air dry-bulb temperature in Celsius above which outdoor coil defrosting is disabled;
- heatPumpDefrostStrategy – 'ReverseCycle' or 'Resistive';
- heatPumpDefrostControl – 'Timed' or 'OnDemand';
- heatPumpDefrostTimePeriodFraction – fraction of compressor runtime when the defrost cycle is active. Only used if heatPumpDefrostControl = Timed;
- supplementalHeatingOrReheatCoilType – None', 'Electric', 'Gas', 'HotWater' or 'DesuperHeater'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- supplementalHeatingOrReheatCoilAvailabilityScheduleID – supplemental heating or reheat coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- supplementalHeatingOrReheatCoilCapacity – maximum amount of heat that the supplemental heating coil can deliver in W. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- supplementalHeatingOrReheatCoilMaximumOutdoorDryBulbTemperature – outdoor air dry-bulb temperature in Celsius above which the supplemental heating coil is disabled;
- supplementalGasHeatingOrReheatCoilEfficiency – supplemental heating coil gas burner efficiency. Only used if supplementalHeatingOrReheatCoilType = Gas;
- supplementalGasHeatingOrReheatCoilParassiticElectricLoad – parasitic electric load associated with the gas supplemental heating coil operation [W]. Only used if supplementalHeatingOrReheatCoilType = Gas;
- maximumOutdoorAirFlowRate – maximum outdoor air flow rate in m3/s. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);

- minimumOutdoorAirFlowRate – minimum outdoor air flow rate in m3/s. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- minimumOutdoorAirFlowScheduleID – minimum outdoor air schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the minimum outdoor air will be always the same;
- economizerType – 'NoEconomizer', 'FixedDryBulb', 'FixedEnthalpy', 'DifferentialDryBulb', 'DifferentialEnthalpy', 'FixedDewPointAndDryBulb', 'ElectronicEnthalpy' or 'DifferentialDryBulbAndEnthalpy';
- economizerLockout – 'NoLockout', 'LockoutWithHeating' or 'LockoutWithCompressor';
- economizerMaximumLimitDryBulbTemperature – outdoor air temperature high limit in Celsius for economizer operation. If blank, there is no outdoor air temperature high limit control. Only used if economizerType = FixedDryBulb or FixedDewPointAndDryBulb;
- economizerMaximumLimitEnthalpy – outdoor air upper enthalpy limit in J/kg for economizer operation. If blank or zero, there is no outdoor air enthalpy limit control;
- economizerMaximumLimitDewpointTemperature – outdoor air dewpoint limit in Celsius for economizer operation. If blank, there is no outdoor air dewpoint limit control. Only used if economizerType = FixedDewPointAndDryBulb;
- economizerMinimumLimitDryBulbTemperature – outdoor air temperature low limit in Celsius for economizer operation. If blank, there is no outdoor air temperature low limit control;
- heatRecoveryType – 'None', 'Sensible' or 'Enthalpy';
- sensibleHeatRecoveryEffectiveness – sensible heat recovery effectiveness;
- latentHeatRecoveryEffectiveness – latent heat recovery effectiveness. Only used if heatRecoveryType = Enthalpy;
- heatRecorveryHeatExchangerType – 'Plate' or 'Rotary';
- heatRecorveryFrostControlType – 'None', 'ExhaustAirRecirculation', 'ExhaustOnly' or 'MinimumExhaustTemperature';
- dehumificationControlType – 'None', 'CoolReheat' or 'Multimode';
- dehumificationRelativeHumiditySetpoint – zone humidistat setpoint for dehumidification. This field is ignored if a schedule is specified in the next field;
- dehumificationRelativeHumiditySetpointScheduleID – dehumification relative humidity setpoint schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the constant value specified in the previous field will be used;
- humidifierType – 'None' or 'ElectricSteam';
- humidifierAvailabilityScheduleID – humidifier availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, humidifier is always available;
- humidifierRatedCapacity – rated moisture output rate in m3/s;
- humidifierRatedElectricPower – electric power input at the rated capacity moisture output [W]. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- humidifierRelativeHumiditySetpoint – zone humidistat setpoint for humidification. This field is ignored if a schedule is specified in the next field;
- humidifierRelativeHumiditySetpointScheduleID – humidifier relative humidity setpoint schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the constant value specified in the previous field will be used;
- sizingOption – 'NonCoincident' or 'Coincident';

- hasReturnFan – ‘Yes’ or ‘No’;
- returnFanTotalEfficiency – total efficiency of the return fan;
- returnFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- returnFanMotorEfficiency – shaft power of the return fan divided by the electrical power consumed;
- returnFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – name of the unitary system, defined in the first argument of the HVACTemplateSystemUnitarySystemSpec() above;
- Control Zone Name – name of the control zone for which this object is assigned, defined in the argument x1 of the HVACTemplateSystemUnitarySystemSpec() above;
- Supply Plenum Name – name of the zone that serves as a supply plenum for this system, defined in the argument x3 of the HVACTemplateSystemUnitarySystemSpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x4 of the HVACTemplateSystemUnitarySystemSpec() above;
- Humidifier Control Zone Name – zone name where the humidistat is located for controlling humidification (if any), defined in the argument x2 of the HVACTemplateSystemUnitarySystemSpec() above.

Note: even when not setting any of the above fields to ‘autosize’, the “Do System Sizing Calculation" field should be set to Yes in the Simulation Control (x2 = true in section **17**). This is due to the fact that the HVAC Template System Unitary System object is internally converted by EnergyPlus to an Air Loop HVAC object (with the expand file), for which an autosized field is assigned, thus requiring a system sizing. Moreover, as system sizing cannot be done without zone sizing, the “Do Zone Sizing Calculation" field should also be set to Yes in the Simulation Control (x1 = true in section **17**).

c) <u>Unitary Heat Pump Air-to-Air</u>

The HVAC Template System Unitary Heat Pump Air-to-Air properties are defined in the **HVACTemplateSystemUnitaryHeatPumpAirToAir** table in the database, corresponding to the HVACTemplate:System:UnitaryHeatPump:AirToAir object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – system availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the system is always available;
- coolingSupplyAirFlowRate – supply air flow rate when the DX cooling coil is operating [m3/s]. ‘autosize’ option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- heatingSupplyAirFlowRate – supply air flow rate when the heating coil is operating [m3/s]. ‘autosize’ option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);

- noLoadSupplyAirFlowRate – supply air flow rate when neither cooling nor heating is required [m3/s]. ‘autosize’ option is available, which sizes the supply flow rate to match the smaller of the cooling and heating flow rates, and for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- supplyFanOperatingModeScheduleID – supply air fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). 0 - auto cycling fan, ≠ 0 - continuous fan. If blank, a schedule of always zero (cycling fan) will be used;
- supplyFanPlacement – ‘BlowThrough’ or ‘DrawThrough’;
- supplyFanTotalEfficiency – total efficiency of the supply fan;
- supplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- supplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed;
- supplyFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- coolingCoilType – ‘SingleSpeedDX’;
- coolingCoilAvailabilityScheduleID – cooling coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- coolingDesignSupplyAirTemperature – cooling supply air temperature in Celsius to be used for sizing the cooling coil and zone supply air flow rates;
- coolingCoilGrossRatedTotalCapacity – full load gross total cooling capacity, including both sensible and latent capacity, of the DX coil unit at rated conditions [W]. ‘autosize’ option is available, which lets the automatic sizing algorithm determine the cooling coil gross capacity based on the maximum cooling loads during the cooling design day;
- coolingCoilGrossRatedSensibleHeatRatio – ratio of the gross sensible capacity divided by the gross total cooling capacity of the DX cooling coil at rated conditions. ‘autosize’ option is available, which allows the sizing algorithm to determine the sensible heat ratio based on the gross rated capacity and air flow rate;
- coolingCoilGrossRatedCOP – coefficient of performance defined as the gross cooling coil capacity in watts divided by electrical power input in watts of the DX cooling coil unit at rated conditions;
- heatPumpHeatingCoilType – ‘SingleSpeedDXHeatPump’;
- heatingDesignSupplyAirTemperature – supply air temperature to be used for sizing the heating coil and zone supply air flow rates [°C];
- heatPumpHeatingCoilAvailabilityScheduleID – heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- heatPumpHeatingCoilGrossRatedCapacity – full load gross heating capacity, in watts of the DX heat pump unit at rated conditions. ‘autosize’ opetion is available, which lets the automatic sizing algorithm determine the heat pump heating coil gross capacity based on the maximum heating loads during the heating design day;
- heatPumpHeatingCoilGrossRatedCOP – coefficient of performance defined as the gross heating coil capacity in watts divided by electrical power input in watts of the DX heating coil unit at rated conditions;
- heatPumpHeatingMinimumOutdoorDryBulbTemperature – minimum outdoor dry-bulb temperature for compressor operation [°C];
- heatPumpDefrostMaximumOutdoorDryBulbTemperature – outdoor air dry-bulb temperature above which outdoor coil defrosting is disabled [°C];

- heatPumpDefrostStrategy – ‘ReverseCycle’ or ‘Resistive’;
- heatPumpDefrostControl – ‘Timed’ or ‘OnDemand’;
- heatPumpDefrostTimePeriodFraction – fraction of compressor runtime when the defrost cycle is active. Only used if heatPumpDefrostControl = Timed;
- supplementalHeatingCoilType – ‘Gas’, ‘Electric’ or ‘HotWater’. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- supplementalHeatingCoilAvailabilityScheduleID – supplemental heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- supplementalHeatingCoilCapacity – maximum amount of heat that the supplemental heating coil can deliver [W]. ‘autosize’ option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- supplementalHeatingCoilMaximumOutdoorDryBulbTemperature – outdoor air dry-bulb temperature above which the supplemental heating coil is disabled [°C];
- supplementalGasHeatingCoilEfficiency – supplemental heating coil gas burner efficiency. Only used if supplementalHeatingCoilCapacity = Gas;
- supplementalGasHeatingCoilParasiticElectricLoad – parasitic electric load associated with the gas supplemental heating coil operation [W]. Only used if supplementalHeatingCoilCapacity = Gas;
- maximumOutdoorAirFlowRate – maximum outdoor air flow rate in m3/s. ‘autosize’ option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- minimumOutdoorAirFlowRate – minimum outdoor air flow rate in m3/s. ‘autosize’ option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- minimumOutdoorAirFlowScheduleID – minimum outdoor air schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the minimum outdoor air will be always the same;
- economizerType – ‘NoEconomizer’, ‘FixedDryBulb’, ‘FixedEnthalpy’, ‘DifferentialDryBulb’, ‘DifferentialEnthalpy’, ‘FixedDewPointAndDryBulb’, ‘ElectronicEnthalpy’ or ‘DifferentialDryBulbAndEnthalpy’;
- economizerLockout – ‘NoLockout’, ‘LockoutWithHeating’ or ‘LockoutWithCompressor’;
- economizerMaximumLimitDryBulbTemperature – outdoor air temperature high limit in Celsius for economizer operation. If blank, there is no outdoor air temperature high limit control. Only used if economizerType = FixedDryBulb or FixedDewPointAndDryBulb;
- economizerMaximumLimitEnthalpy – outdoor air upper enthalpy limit in J/kg for economizer operation. If blank or zero, there is no outdoor air enthalpy limit control;
- economizerMaximumLimitDewpointTemperature – outdoor air dewpoint limit in Celsius for economizer operation. If blank, there is no outdoor air dewpoint limit control. Only used if economizerType = FixedDewPointAndDryBulb;
- economizerMinimumLimitDryBulbTemperature – outdoor air temperature low limit in Celsius for economizer operation. If blank, there is no outdoor air temperature low limit control;
- nightCycleControl – ‘StayOff’, ‘CycleOnAny’ or ‘CycleOnControlZone’;
- heatRecoveryType – ‘None’, ‘Sensible’ or ‘Enthalpy’;

- sensibleHeatRecoveryEffectiveness – sensible heat recovery effectiveness;
- latentHeatRecoveryEffectiveness – latent heat recovery effectiveness. Only used if heatRecoveryType = Enthalpy;
- humidifierType – ‘None’ or ‘ElectricSteam’;
- humidifierAvailabilityScheduleID – humidifier availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, humidifier is always available;
- humidifierRatedCapacity – rated moisture output rate in m3/s;
- humidifierRatedElectricPower – electric power input at the rated capacity moisture output [W]. ‘autosize’ option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- humidifierSetpoint – zone humidistat setpoint for humidification in percent;
- hasReturnFan – ‘Yes’ or ‘No’;
- returnFanTotalEfficiency – total efficiency of the return fan;
- returnFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- returnFanMotorEfficiency – shaft power of the return fan divided by the electrical power consumed;
- returnFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – name of the unitary system, defined in the first argument of the HVACTemplateSystemUnitaryHeatPumpAirToAirSpec() above;
- Control Zone or Thermostat Location Name – name of the control zone for which this object is assigned, defined in the argument x1 of the HVACTemplateSystemUnitaryHeatPumpAirToAirSpec() above;
- Supply Plenum Name – name of the zone that serves as a supply plenum for this system, defined in the argument x2 of the HVACTemplateSystemUnitaryHeatPumpAirToAirSpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x3 of the HVACTemplateSystemUnitaryHeatPumpAirToAirSpec() above;
- Night Cycle Control Zone Name – zone name where the night cycle control is located (if any), defined in the argument x3 of the HVACTemplateSystemUnitaryHeatPumpAirToAirSpec() above
- Humidifier Control Zone Name – zone name where the humidistat is located for controlling humidification (if any), defined in the argument x4 of the HVACTemplateSystemUnitaryHeatPumpAirToAirSpec() above.

Note: even when not setting any of the above fields to ‘autosize’, the “Do System Sizing Calculation" field should be set to Yes in the Simulation Control (x2 = true in section **17**). This is due to the fact that the HVAC Template System Unitary Heat Pump Air-to-Air object is internally converted by EnergyPlus to an Air Loop HVAC object (with the expand file), for which an autosized field is assigned, thus requiring a system sizing. Moreover, as system sizing cannot be done without zone sizing, the “Do Zone Sizing Calculation" field should also be set to Yes in the Simulation Control (x1 = true in section **17**).

Zone unit

There is one zone unit type (zone unitary).

The HVAC Template zone terminal unit properties are defined in the **HVACTemplateZoneUnitary** table in the database, corresponding to the HVACTemplate:Zone:Unitary object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- supplyAirMaximumFlowRate – maximum supply air flow rate into the zone in m3/s. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- zoneCoolingSizingFactor – zone level cooling sizing ratio. The zone design cooling air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Cooling Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- outdoorAirMethod – 'Flow_Person', 'Flow_Area', 'Flow_Zone', 'Sum', 'Maximum' or 'DetailedSpecification';
- outdoorAirFlowRatePerPerson – design outdoor air flow rate per person for this zone in m3/s. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [m3/s.m2]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirflowRatePerZone – design outdoor air flow rate for this zone in m3/s. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;
- baseboardHeatingType – 'None', 'HotWater' or 'Electric'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- baseboardHeatingAvailabilityScheduleID – baseboard heating availability schedule ID, defined in the Schedules table in the database (**21**). If blank, the baseboard heating is always available;
- baseboardHeatingCapacity – maximum amount of heat that the baseboard heating can deliver in W. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- zoneCoolingDesignAirTemperatureInputMethod – 'SystemSupplyAirTemperature', 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneCoolingDesignAirTemperature – supply air temperature in Celsius for the zone cooling design air flow rate calculation and cooling coil sizing. Only used if zoneCoolingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneCoolingDesignAirTemperatureDifference – temperature difference between the cooling design supply air temperature and the zone air temperature in Celsius for the zone cooling design air flow rate calculation and cooling coil sizing. Only used if zoneCoolingDesignAirTemperatureInputMethod = TemperatureDifference;

- zoneHeatingDesignAirTemperatureInputMethod – 'SystemSupplyAirTemperature', 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneHeatingDesignAirTemperature – supply air temperature in Celsius for the zone heating design air flow rate calculation and heating coil sizing. Only used if zoneHeatingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneHeatingDesignAirTemperatureDifference – temperature difference between heating design supply air temperature and zone air temperature in degrees Celsius for the zone heating design air flow rate calculation and heating coil sizing. Only used if zoneHeatingDesignAirTemperatureInputMethod = TemperatureDifference;
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this unit, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationZoneAirID – ID of the object which specifies the zone air distribution requirements and schedule for this unit, defined in table **DesignSpecificationZoneAirDistribution** in the database (see section **13.1.2**). Only used if outdoorAirMethod = DetailedSpecification;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template System Unitary Name – name of the unitary system serving this unit, defined in section **6.9.1**, entered as the first argument in the HVACTemplateZoneUnitarySpec() above;
- Template Thermostat Name – name of the thermostat assigned for the zone, defined in the first argument of the ZoneHVACTemplateSpec() above;
- Supply Plenum Name – name of the zone that serves as a supply plenum for this unit, defined in the argument x2 of the HVACTemplateZoneUnitarySpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x1 of the HVACTemplateZoneUnitarySpec() above.

Note: even when not setting any of the above fields to 'autosize', the "Do Zone Sizing Calculation" field should be set to Yes in the Simulation Control (x1 = true in section **17**). This is due to the fact that the HVAC Template Zone Unitary object is internally converted by EnergyPlus to an Air Terminal Single Duct Uncontrolled object (with the expand file), for which an autosized air flow rate field is assigned, thus requiring a zone sizing.

6.10. Dual Duct

The HVAC Template Zone Dual Duct option must be active (**HVAC_TEMPLATE_ZONE_DUAL_DUCT = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

An example of this system and zone objects usage can be found in the SingleStoreyFamilyHouse_HVACT_DualDuct template in the SAPTool_LSP.

Prior to the zone terminal units' definition, their supply system(s) must also be defined. If the dual duct system is intended to serve multiple zone units, it must be defined in the building's HVAC template system (**6.10.1**). Otherwise, if the dual duct system is intended to serve a single zone unit, it must be defined in the zone (**6.10.2**).

6.10.1. Dual duct system supplying multiple zone units

The assignment of the supply system(s) to the building's HVAC template system is defined in the SAPTool_LSP building template, as demonstrated in section **6.1**. There, the hvacTemplateSpec's arguments should be defined as 'null' if the constant volume systems' and zones' coils (or baseboards) are not water heated/chilled; otherwise, the adequate plant loop(s) and plant heating and/or cooling equipment specifications must be properly assigned.

__System__

The HVAC Template System Dual Duct name must be defined as follows:

String dualDuctSystemName = DBHVACTemplateSystemDualDuctType.ABC.toString() – dual duct system name, defined using the DBHVACTemplateSystemDualDuctType list object ('ABC', in this case). Alternatively, a string can be directly inputted here (e.g., **"ABC"**).

The specification of each dual duct system is defined in the SAPTool_LSP building template, as follows:

HVACTemplateSystemDualDuctSpec hvacTemplateSystemDualDuctSpec = new HVACTemplateSystemDualDuctSpec() – dual duct system specification (named hvacTemplateSystemDualDuctSpec in this example), defined in the table **HVACTemplateSystemDualDuct** in the database (see section **6.10.3** below). With the following HVACTemplateSystemDualDuctSpec() arguments:

- **dualDuctSystemName** – dual duct system's name, defined above;
- **x1** – ID of a zone that serves as cold supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
- **x2** – ID of a zone that serves as hot supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
- **x3** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
- **x4** – ID of the night cycle control zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if the night cycle is zone controlled (nightCycleControl = CycleOnControlZone, in the table **HVACTemplateSystemDualDuct** in the database). Otherwise, it may be **null**;
- **x5** – ID of the dehumidification control zone where the humidistat is located, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if dehumidification control is active (dehumidificationControlType = CoolReheat, in the table **HVACTemplateSystemDualDuct** in the database). Otherwise, it may be **null**;
- **x6** – ID of the humidifier control zone for controlling humidification, which corresponds to the order for which the zone is added to the spaceSpec list in the building template.

Only used if humidification control is active (humidifierType = ElectricSteam, in the table **HVACTemplateSystemConstantVolume** in the database). **null** if nonexistent;

- **DBHVACTemplateSystemDualDuctType.ABC_BedroomsUnit.getID()** – ID of the dual duct system properties in the database, defined using the DBHVACTemplateSystemDualDuctType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The above defined HVAC Template System Dual Duct is then added to the building's HVAC template system (named hvacTemplateSpec in this example) as follows:

hvacTemplateSpec.addSystemDualDuctSpec(hvacTemplateSystemDualDuctSpec) – addition of the dual duct system (hvacTemplateSystemDualDuctSpec) to the building's HVAC template system.

To add more dual duct systems, one should repeat the above process, by defining new dual duct names, their specifications (with the HVACTemplateSystemDualDuctSpec()), and adding them to the building's HVAC template system.

<u>Zone units</u>

The specification of the zone terminal units for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneDualDuctSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneDualDuct** in the database (see section **6.10.3** below), and with the following arguments:
    - **dualDuctSystemName** – name of the dual duct system defined above that can supply multiple units;
    - **x1 –** ID of a zone that serves as cold supply plenum for this system (optional). **null** if no cold supply plenum is to be modelled;
    - **x2 –** ID of a zone that serves as hot supply plenum for this system (optional). **null** if no hot supply plenum is to be modelled;
    - **x3 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
    - **DBHVACTemplateZoneDualDuctType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneDualDuctType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
    - **db** – database unique ID.

- **null** – this terminal unit is supplied by a dual duct system that can supply multiple units and is defined outside the zone.

This zone HVAC template specification (hvacTemplateSpec_SingleBedroom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Single Bedroom, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_SingleBedroom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.SINGLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Single Bedroom, in this example);
- **db** – database unique ID.

6.10.2. Dual duct system supplying a single zone unit (zone system)

If the dual duct system is intended to serve a single zone unit, it must be defined in the zone. The specification of the zone system for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneDualDuctSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneDualDuct** in the database (see section **6.10.3** below), and with the following arguments:
  - **null** – since this terminal unit is supplied by a single dual duct system specific to this unit (defined in the zone). In this case, the dual duct system name is automatically assigned ("DualDuctSystem" + Zone Name).
  - **x1 –** ID of a zone that serves as cold supply plenum for this system (optional). **null** if no cold supply plenum is to be modelled;
  - **x2 –** ID of a zone that serves as hot supply plenum for this system (optional). **null** if no hot supply plenum is to be modelled;
  - **x3 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
  - **DBHVACTemplateZoneDualDuctType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneDualDuctType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
  - **db** – database unique ID.

- **new HVACTemplateSystemDualDuctSpec()** – specification of the zone system for this space, defined in the table **HVACTemplateSystemDualDuct** in the database (see section **6.10.3** below), and with the following arguments:
  - **null** – dual duct system's name. As this system is specific to a zone unit (and, therefore, defined in the zone), its name is automatically assigned ("DualDuctSystem" + Zone Name);
  - **x1** – ID of a zone that serves as cold supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **x2** – ID of a zone that serves as hot supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **x3** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
  - **null** – ID of the night cycle control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the night cycle control zone;
  - **null** – ID of the dehumidification control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the dehumidification control zone;
  - **null** – ID of the humidifier control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the humidifier control zone;
  - **x7** – ID of the dual duct system properties in the database, defined using the DBHVACTemplateSystemDualDuctType list object or directly with the proper database ID;
  - **db** – database unique ID.

The zone HVAC template specification (hvacTemplateSpec_SingleBedroom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Single Bedroom, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_SingleBedroom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.SINGLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Single Bedroom, in this example);
- **db** – database unique ID.

6.10.3. System and zone unit properties

<u>**System**</u>

The HVAC Template System Dual Duct properties are defined in the **HVACTemplateSystemDualDuct** table in the database, corresponding to the HVACTemplate:System:DualDuct object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – system availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the system is always available;
- systemConfigurationType – 'SingleFanConstantVolume', 'DualFanConstantVolume', 'SingleFanVariableVolume' or 'DualFanVariableVolume';
- mainSupplyFanMaximumFlowRate – upper limit on system flow, even if the zone level air flow inputs sum to a greater value [m^3/s]. 'autosize' option is available, which sets the system maximum air-flow rate to the sum of the zone air flow rates;
- mainSupplyFanMinimumFlowFraction – minimum supply air flow fraction. Ignored if the system is constant volume;
- mainSupplyFanTotalEfficiency – total efficiency of the main supply fan;
- mainSupplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- mainSupplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed;
- mainSupplyFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- mainSupplyFanPartLoadPowerCoefficients – 'InletVaneDampers', 'OutletDampers', 'VariableSpeedMotor', 'ASHRAE90_1$1$2004AppendixG' or 'VariableSpeedMotorPressureReset';
- coldDuctSupplyFanMaximumFlowRate – upper limit on system flow, even if the zone level air flow inputs sum to a greater value. 'autosize' option is available, which sets the system maximum cold air-flow rate to the sum of the zone air flow rates;
- coldDuctSupplyFanMinimumFlowFraction – minimum cold duct air flow fraction. Ignored if the system is constant volume;
- coldDuctSupplyFanTotalEfficiency – total efficiency of the cold duct supply fan;
- coldDuctSupplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- coldDuctSupplyFanMotorEfficiency – shaft power of the cold duct supply fan divided by the electrical power consumed;
- coldDuctSupplyFanMotorInAirStreamFraction – fraction of the motor heat that is added to the cold duct air stream;
- coldDuctSupplyFanPartLoadPowerCoefficients – 'InletVaneDampers', 'OutletDampers', 'VariableSpeedMotor', 'ASHRAE90_1$1$2004AppendixG' or 'VariableSpeedMotorPressureReset';
- coldDuctSupplyFanPlacement – 'DrawThrough' or 'BlowThrough';
- hotDuctSupplyFanMaximumFlowRate – upper limit on system flow, even if the zone level air flow inputs sum to a greater value. 'autosize' option is available, which sets the system maximum hot air-flow rate to the sum of the zone air flow rates;
- hotDuctSupplyFanMinimumFlowFraction – minimum hot duct air flow fraction. Ignored if the system is constant volume;
- hotDuctSupplyFanTotalEfficiency – total efficiency of the hot duct supply fan;
- hotDuctSupplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- hotDuctSupplyFanMotorEfficiency – shaft power of the hot duct supply fan divided by the electrical power consumed;
- hotDuctSupplyFanMotorInAirStreamFraction – fraction of the motor heat that is added to the hot duct air stream;

- hotDuctSupplyFanPartLoadPowerCoefficients – 'InletVaneDampers', 'OutletDampers', 'VariableSpeedMotor', 'ASHRAE90_1$1$2004AppendixG' or 'VariableSpeedMotorPressureReset';
- hotDuctSupplyFanPlacement – 'DrawThrough' or 'BlowThrough';
- coolingCoilType – 'ChilledWater', 'ChilledWaterDetailedFlatModel' or 'None'. The chilled water types require an HVAC Template Plant Chilled Water Loop (**6.15.1**), with one or more HVAC Template Plant Chillers (**6.16.2**) and (if present) HVAC Template Plant Towers (**6.16.3**);
- coolingCoilAvailabilityScheduleID – cooling coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- coolingCoilSetpointControlType – 'FixedSetpoint', 'Scheduled', 'OutdoorAirTemperatureReset' or 'Warmest';
- coolingCoilDesignSetpointTemperature – cooling supply air temperature to be used for sizing the cooling coil and zone supply air flow rates [°C]. Used if coolingCoilSetpointScheduleID is not specified;
- coolingCoilSetpointScheduleID – cooling coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Leave blank, if a constant setpoint is to be specified (coolingCoilDesignSetpointTemperature);
- coolingCoilSetpointAtOutdoorDryBulbLow – cooling coil supply air setpoint temperature when the outdoor dry-bulb temperature is at or below the low limit (coolingCoilResetOutdoorDryBulbLow) [°C]. Only used if coolingCoilType = OutdoorAirTemperatureReset;
- coolingCoilResetOutdoorDryBulbLow – low limit of outdoor dry-bulb temperature for outdoor air reset control [°C]. Only used if coolingCoilType = OutdoorAirTemperatureReset;
- coolingCoilSetpointAtOutdoorDryBulbHigh – cooling coil supply air setpoint temperature when the outdoor dry-bulb temperature is at or above the high limit (coolingCoilResetOutdoorDryBulbHigh) [°C]. Only used if coolingCoilType = OutdoorAirTemperatureReset;
- coolingCoilResetOutdoorDryBulbHigh – high limit of outdoor dry-bulb temperature for outdoor air reset control [°C]. Only used if coolingCoilType = OutdoorAirTemperatureReset;
- heatingCoilType – 'HotWater', 'Electric', 'Gas' or 'None'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- heatingCoilAvailabilityScheduleID – heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- heatingCoilSetpointControlType – 'FixedSetpoint', 'Scheduled', 'OutdoorAirTemperatureReset' or 'Coldest';
- heatingCoilDesignSetpoint – heating supply air temperature to be used for sizing the heating coil and zone supply air flow rates [°C]. Used if heatingCoilSetpointScheduleID is not specified;
- heatingCoilSetpointScheduleID – heating coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Leave blank, if a constant setpoint is to be specified (heatingCoilDesignSetpoint);
- heatingCoilSetpointAtOutdoorDryBulbLow – heating coil supply air setpoint temperature when the outdoor dry-bulb temperature is at or below the low limit

(heatingCoilResetOutdoorDryBulbLow) [°C]. Used only when heatingCoilSetpointControlType = OutdoorAirTemperatureReset;

- heatingCoilResetOutdoorDryBulbLow – low limit of outdoor dry-bulb temperature for outdoor air reset control [°C]. Only used if heatingCoilSetpointControlType = OutdoorAirTemperatureReset;
- heatingCoilSetpointAtOutdoorDryBulbHigh – heating coil supply air setpoint temperature when the outdoor dry-bulb temperature is at or above the low limit (heatingCoilResetOutdoorDryBulbHigh) [°C]. Used only when heatingCoilSetpointControlType = OutdoorAirTemperatureReset;
- heatingCoilResetOutdoorDryBulbHigh – high limit of outdoor dry-bulb temperature for outdoor air reset control [°C]. Only used if heatingCoilSetpointControlType = OutdoorAirTemperatureReset;
- heatingCoilCapacity – maximum amount of heat that the coil can deliver [W]. 'autosize' option is available;
- gasHeatingCoilEfficiency – gas burner efficiency in decimal values;
- gasHeatingCoilParasiticElectricLoad – parasitic electric load associated with the gas heating operation [W];
- preheatCoilType – 'HotWater', 'Electric', 'Gas' or 'None'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- preheatCoilAvailabilityScheduleID – preheat coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the preheat coil is always available;
- preheatCoilDesignSetpoint – preheat supply air temperature to be used for sizing the preheat coil [°C]. Used if preheatCoilSetpointScheduleID is not specified;
- preheatCoilSetpointScheduleID – preheat coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Leave blank, if a constant setpoint is to be specified (preheatCoilDesignSetpoint);
- gasPreheatCoilEfficiency – gas burner efficiency in decimal values;
- gasPreheatCoilParasiticElectricLoad – parasitic electric load associated with the gas heating operation [W];
- maximumOutdoorAirFlowRate – maximum amount of outdoor air flow into the unit when the economizer is operating [m^3/s]. 'autosize' option is available, which means that 100% of the full supply flow may be taken from outdoor air;
- minimumOutdoorAirFlowRate – minimum amount of outdoor air that can enter the unit and be distributed to the zones [m^3/s]. 'autosize' option is available;
- minimumOutdoorAirControlType – 'ProportionalMinimum' or 'FixedMinimum';
- minimumOutdoorAirScheduleID – minimum outdoor air schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the minimum outdoor air to be the same for all hours in the entire year;
- economizerType – 'NoEconomizer', 'FixedDryBulb', 'FixedEnthalpy', 'DifferentialDryBulb', 'DifferentialEnthalpy', 'FixedDewPointAndDryBulb', 'ElectronicEnthalpy' or 'DifferentialDryBulbAndEnthalpy';
- economizerLockout – 'NoLockout';
- economizerUpperTemperatureLimit – outdoor air temperature high limit for economizer operation [°C]. If the outdoor air temperature is above this limit, the outdoor air flow rate will be set to the minimum and heat recovery will be enabled if available;

- economizerLowerTemperatureLimit – outdoor air temperature low limit for economizer operation [°C]. If the outdoor air temperature is below this limit, the outdoor air flow rate will be set to the minimum and heat recovery will be enabled if available;
- economizerUpperEnthalpyLimit – outdoor air upper enthalpy limit for economizer operation [J/kg]. If the outdoor air enthalpy is above this limit, the outdoor air flow rate will be set to the minimum and heat recovery will be enabled if available;
- economizerMaximumLimitDewpointTemperature – outdoor air dewpoint limit for economizer operation [°C]. If the outdoor air dewpoint temperature is above this limit, the outdoor air flow rate will be set to the minimum. Required (even if blank [no limit]) if economizerType = FixedDewPointAndDryBulb;
- nightCycleControl – 'StayOff', 'CycleOnAny' or 'CycleOnControlZone';
- heatRecoveryType – 'None', 'Sensible' or 'Enthalpy';
- sensibleHeatRecoveryEffectiveness – sensible heat recovery effectiveness;
- latentHeatRecoveryEffectiveness – latent heat recovery effectiveness. Only used if heatRecoveryType = Enthalpy;
- heatRecoveryHeatExchangerType – 'Plate' or 'Rotary';
- heatRecoveryFrostControlType – 'None', 'ExhaustAirRecirculation', 'ExhaustOnly or 'MinimumExhaustTemperature';
- dehumidificationControlType – 'None' or 'CoolReheat';
- dehumidificationRelativeHumiditySetpoint – zone humidistat setpoint for dehumidification in percent. This field is ignored if a schedule is specified in the next field;
- dehumidificationRelativeHumiditySetpointScheduleID – dehumification relative humidity setpoint schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the constant value specified in the previous field will be used;
- humidifierType – 'None' or 'ElectricSteam';
- humidifierAvailabilityScheduleID – humidifier availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, humidifier is always available;
- humidifierRatedCapacity – rated moisture output rate [m^3/s];
- humidifierRatedElectricPower – electric power input at the rated capacity moisture output [W]. 'autosize' option is available;
- humidifierRelativeHumiditySetpoint – zone humidistat setpoint for humidification in percent. This field is ignored if a schedule is specified in the next field;
- humidifierRelativeHumiditySetpointScheduleID – humidifier relative humidity setpoint schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the constant value specified in the previous field will be used;
- sizingOption – 'NonCoincident' or 'Coincident'
- hasReturnFan – 'Yes' or 'No';
- returnFanTotalEfficiency – total efficiency of the return fan;
- returnFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- returnFanMotorEfficiency – shaft power of the return fan divided by the electrical power consumed;
- returnFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- returnFanPartLoadPowerCoefficients – 'InletVaneDampers', 'OutletDampers', 'VariableSpeedMotor', 'ASHRAE90_1$1$2004AppendixG' or 'VariableSpeedMotorPressureReset';

- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – name of the dual duct system, defined in the first argument of the HVACTemplateSystemDualDuctSpec() above;
- Cold Supply Plenum Name – name of the zone that serves as a cold supply plenum for this system, defined in the argument x1 of the HVACTemplateSystemDualDuctSpec() above;
- Hot Supply Plenum Name – name of the zone that serves as a hot supply plenum for this system, defined in the argument x2 of the HVACTemplateSystemDualDuctSpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x3 of the HVACTemplateSystemDualDuctSpec() above;
- Night Cycle Control Zone Name – name of the night cycle control zone for which this object is assigned, defined in the argument x4 of the HVACTemplateSystemConstantVolumeSpec () above;
- Dehumidification Control Zone Name – zone name where the humidistat is located for controlling dehumidification (if any), defined in the argument x5 of the HVACTemplateSystemDualDuctSpec() above.
- Humidifier Control Zone Name – zone name where the humidistat is located for controlling humidification (if any), defined in the argument x6 of the HVACTemplateSystemDualDuctSpec() above.

Note: even when not setting any of the above fields to 'autosize', the "Do System Sizing Calculation" field should be set to Yes in the Simulation Control (x2 = true in section **17**). This is due to the fact that the HVAC Template System Dual Duct object is internally converted by EnergyPlus to an Air Loop HVAC object (with the expand file), for which an autosized field is assigned, thus requiring a system sizing. Moreover, as system sizing cannot be done without zone sizing, the "Do Zone Sizing Calculation" field should also be set to Yes in the Simulation Control (x1 = true in section **17**).

<u>Zone unit</u>

The HVAC Template zone terminal unit properties are defined in the **HVACTemplateZoneDualDuct** table in the database, corresponding to the HVACTemplate:Zone:DualDuct object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- supplyAirMaximumFlowRate – maximum supply air flow rate into the zone [m^3/s]. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- zoneCoolingSizingFactor – zone level cooling sizing ratio. The zone design cooling air flow rate and load will be multiplied by the number input in this field when

supplyAirMaximumFlowRate = autosize. If blank, the Cooling Sizing Factor from Sizing Parameters (**13.2.1**) will be used;

- zoneMinimumAirFlowFraction – minimum flow rate to the zone while the system is operating, specified as a fraction of the maximum air flow rate. Ignored if the system serving this zone is constant volume;
- outdoorAirMethod – ‘Flow_Person’, ‘Flow_Area’, ‘Flow_Zone’, ‘Sum’, ‘Maximum’ or ‘DetailedSpecification’;
- outdoorAirFlowRatePerPerson – design outdoor air flow rate per person for this zone [m^3/s]. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [$m^3/s.m^2$]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirflowRatePerZone – design outdoor air flow rate for this zone [m^3/s]. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;
- designSpecificationOutdoorAirForSizingID – ID of the object which specifies the outdoor air requirements for sizing and schedule for this unit, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationZoneAirDistributionID – ID of the object which specifies the zone air distribution requirements and schedule for this unit, defined in table **DesignSpecificationZoneAirDistribution** in the database (see section **13.1.2**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationOutdoorAirForControlID – ID of the object which specifies the outdoor air requirements for control and schedule for this unit, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**);
- baseboardHeatingType – ‘None’, ‘HotWater’ or ‘Electric’. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- baseboardHeatingAvailabilityScheduleID – baseboard heating availability schedule ID, defined in the Schedules table in the database (**21**). If blank, the baseboard heating is always available;
- baseboardHeatingCapacity – maximum amount of heat that the baseboard heating can deliver [W]. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- zoneCoolingDesignSupplyAirTemperatureInputMethod – ‘SystemSupplyAirTemperature’, ‘SupplyAirTemperature’ or ‘TemperatureDifference’;
- zoneCoolingDesignSupplyAirTemperature – supply air temperature for the zone cooling design air flow rate calculation and cooling coil sizing [°C]. Only used if zoneCoolingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneCoolingDesignSupplyAirTemperatureDifference – temperature difference between the cooling design supply air temperature and the zone air temperature for the zone cooling design air flow rate calculation and cooling coil sizing [°C]. Only used if zoneCoolingDesignAirTemperatureInputMethod = TemperatureDifference;
- zoneHeatingDesignSupplyAirTemperatureInputMethod – ‘SystemSupplyAirTemperature’, ‘SupplyAirTemperature’ or ‘TemperatureDifference’;

- zoneHeatingDesignSupplyAirTemperature – supply air temperature for the zone heating design air flow rate calculation and heating coil sizing [°C]. Only used if zoneHeatingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneHeatingDesignSupplyAirTemperatureDifference – temperature difference between heating design supply air temperature and zone air for the zone heating design air flow rate calculation and heating coil sizing [°C]. Only used if zoneHeatingDesignAirTemperatureInputMethod = TemperatureDifference;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template Dual Duct System Name – name of the dual duct system serving this unit, defined in section **6.10.1** or **6.10.2** and entered as the first argument in the HVACTemplateZoneDualDuctSpec() above;
- Template Thermostat Name – name of the thermostat assigned for the zone, defined in the first argument of the ZoneHVACTemplateSpec() above;
- Cold Supply Plenum Name – name of the zone that serves as a cold supply plenum for this unit, defined in the argument x1 of the HVACTemplateZoneDualDuctSpec() above;
- Hot Supply Plenum Name – name of the zone that serves as a hot supply plenum for this unit, defined in the argument x2 of the HVACTemplateZoneDualDuctSpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x3of the HVACTemplateZoneDualDuctSpec() above.

Note: even when not setting any of the above fields to 'autosize', the "Do Zone Sizing Calculation" field should be set to Yes in the Simulation Control (x1 = true in section **17**). This is due to the fact that the HVAC Template Zone Dual Duct object is internally converted by EnergyPlus to an Air Terminal Single Duct object (with the expand file), for which an autosized air flow rate field is assigned, thus requiring a zone sizing.

6.11. VRF

The HVAC Template Zone VRF option must be active (**HVAC_TEMPLATE_ZONE_VRF = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

An example of this system and zone objects usage can be found in the SingleStoreyFamilyHouse_HVACT_VRF template in the SAPTool_LSP.

Prior to the zone terminal units' definition, their supply system(s) must also be defined. If the VRF system is intended to serve multiple zone units, it must be defined in the building's HVAC template system (**6.11.1**). Otherwise, if the VRF system is intended to serve a single zone unit, it must be defined in the zone (**6.11.2**).

6.11.1. VRF system supplying multiple zone units

The assignment of the supply system(s) to the building's HVAC template system is defined in the SAPTool_LSP building template, as demonstrated in section **6.1**. There, the hvacTemplateSpec's arguments should be defined as 'null' if the constant volume systems' and zones' coils (or baseboards) are not water heated/chilled; otherwise, the adequate plant loop(s) and plant heating and/or cooling equipment specifications must be properly assigned.

System

The HVAC Template System VRF name must be defined as follows:

String vrfSystemName = DBHVACTemplateSystemVRFType.ABC.toString() – VRF system name, defined using the DBHVACTemplateSystemVRFType list object ('ABC', in this case). Alternatively, a string can be directly inputted here (e.g., **"ABC"**).

The specification of each VRF system is defined in the SAPTool_LSP building template, as follows:

HVACTemplateSystemVRFSpec hvacTemplateSystemVRFSpec = new HVACTemplateSystemVRFSpec() – VRF system specification (named hvacTemplateSystemVRFSpec in this example), defined in the table **HVACTemplateSystemVRF** in the database (see section **6.11.3** below). With the following HVACTemplateSystemVRFSpec() arguments:

- **vrfSystemName** – VRF system's name, defined above;
- **x1** – ID of the master thermostat location zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template;
- **DBHVACTemplateSystemVRFType.ABC_BedroomsUnit.getID()** – ID of the VRF system properties in the database, defined using the DBHVACTemplateSystemVRFType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The above defined HVAC Template System VRF is then added to the building's HVAC template system (named hvacTemplateSpec in this example) as follows:

hvacTemplateSpec.addSystemVRFSpec(hvacTemplateSystemVRFSpec) – addition of the VRF system (hvacTemplateSystemVRFSpec) to the building's HVAC template system.

To add more dual duct systems, one should repeat the above process, by defining new VRF names, their specifications (with the HVACTemplateSystemVRFSpec()), and adding them to the building's HVAC template system.

The corresponding detailed version of this template object can be defined with an Air Conditioner Variable Refrigerant Flow system (see section **11**).

Zone units

The specification of the zone terminal units for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneVRFSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneVRF** in the database (see section **6.11.3** below), and with the following arguments:
  - **vrfSystemName** – name of the VRF system defined above;
  - **x –** name of the Dedicated Outdoor Air system which supplies this VRF unit – defined in the section **6.14** (named systemDedicatedOutdoorAirName in that example). If a Dedicated Outdoor Air system is not defined or is not assigned to this unit, this field must be set as **null**;
  - **DBHVACTemplateZoneVRFType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneVRFType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
  - **db** – database unique ID.
- **null** – this terminal unit is supplied by a VRF system that can supply multiple units and is defined outside the zone.

This zone HVAC template specification (hvacTemplateSpec_SingleBedroom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Single Bedroom, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_SingleBedroom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.SINGLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Single Bedroom, in this example);
- **db** – database unique ID.

The corresponding detailed version of this template object can be defined as presented in section **7.1.7** (Zone HVAC Terminal Unit Variable Refrigerant Flow).

6.11.2. VRF system supplying a single zone unit (zone system)

If the VRF system is intended to serve a single zone unit, it must be defined in the zone. The specification of the zone system for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneVRFSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneVRF** in the database (see section **6.11.3** below), and with the following arguments:
    - **null** – since this terminal unit is supplied by a single VRF system specific to this unit (defined in the zone). In this case, the VRF system name is automatically assigned ("VRFSystem" + Zone Name).
    - **x –** name of the Dedicated Outdoor Air system which supplies this VRF unit – defined in the section **6.14** (named systemDedicatedOutdoorAirName in that example). If a Dedicated Outdoor Air system is not defined or is not assigned to this unit, this field must be set as **null**;
    - **DBHVACTemplateZoneVRFType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneVRFType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
    - **db** – database unique ID.
- **new HVACTemplateSystemVRFSpec()** – specification of the zone system for this space, defined in the table **HVACTemplateSystemVRF** in the database (see section **6.11.3** below), and with the following arguments:
    - **null** – VRF system's name. As this system is specific to a zone unit (and, therefore, defined in the zone), its name is automatically assigned ("VRFSystem" + Zone Name);
    - **null** – ID of the master thermostat location zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the master thermostat location zone;
    - **x2** – ID of the VRF system properties in the database, defined using the DBHVACTemplateSystemVRFType list object or directly with the proper database ID;
    - **db** – database unique ID.

The zone HVAC template specification (hvacTemplateSpec_SingleBedroom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Single Bedroom, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_SingleBedroom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.SINGLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Single Bedroom, in this example);
- **db** – database unique ID.

6.11.3. System and zone unit properties

System

The HVAC Template System VRF properties are defined in the **HVACTemplateSystemVRF** table in the database, corresponding to the HVACTemplate:System:VRF object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – system availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the system is always available;
- grossRatedTotalCoolingCapacity – gross rated total cooling capacity of the DX cooling coil [W]. 'autosize' option is available;
- grossRatedCoolingCOP – cooling coefficient of performance at rated conditions;
- minimumOutdoorTemperatureInCoolingMode – minimum outdoor dry-bulb temperature allowed for cooling operation [°C];
- maximumOutdoorTemperatureInCoolingMode – maximum outdoor dry-bulb temperature allowed for cooling operation [°C];
- grossRatedHeatingCapacity – gross total heat pump heating capacity at rated conditions [W]. 'autosize' option is available;
- ratedHeatingCapacitySizingRatio – ratio of gross heating to gross cooling capacity;
- grossRatedHeatingCOP – heating coefficient of performance at rated conditions;
- minimumOutdoorTemperatureInHeatingMode – minimum outdoor dry-bulb temperature allowed for heating operation [°C];
- maximumOutdoorTemperatureInHeatingMode – maximum outdoor dry-bulb temperature allowed for heating operation [°C];
- minimumHeatPumpPartLoadRatio – minimum operating part-load ratio (PLR) of the heat pump;
- masterThermostatPriorityControlType – 'MasterThermostatPriority', 'LoadPriority', 'ZonePriority', 'ThermostatOffsetPriority' or 'Scheduled';
- thermostatPriorityScheduleID – thermostat priority schedule ID, defined in the **Schedules** table in the database (**21**) (optional). 0 = cooling mode, 1 = heating mode. Only used if masterThermostatPriorityControlType = Scheduled;
- hasHeatPumpWasteHeatRecovery – 'Yes' or 'No';
- equivalentPipingLengthUsedForPipingCorrectionFactorInCoolingMode – equivalent pipe length in meters between the farthest terminal unit and the heat pump condenser [m];
- verticalHeightUsedForPipingCorrectionFactor – vertical pipe height in meters between the highest or lowest terminal unit and the heat pump condenser [m];
- equivalentPipingLengthUsedForPipingCorrectionFactorInHeatingMode – quivalent pipe length in meters between the farthest terminal unit and the heat pump condenser [m];
- crankcaseHeaterPowerPerCompressor – electrical power consumed by the crankcase heater in watts for each compressor;
- numberOfCompressors – number of compressors in the heat pump condensing unit and is used exclusively to determine the operating characteristics of the crankcase heater;
- ratioOfCompressorSizeToTotalCompressorCapacity – size of the first stage compressor to the total compressor capacity and is used exclusively for calculating crankcase heater energy [W/W];

- maximumOutdoorDryBulbTemperatureForCrankcaseHeater – maximum outdoor temperature below which the crankcase heater will operate [°C];
- defrostStrategy – 'Resistive' or 'ReverseCycle';
- defrostControl – 'Timed' or 'OnDemand';
- defrostTimePeriodFraction – fraction of compressor runtime when the defrost cycle is active;
- resistiveDefrostHeaterCapacity – capacity of the resistive defrost heating element [W]. 'autosize' option is available. Only used if defrostStrategy = Resistive;
- maximumOutdoorDryBulbTemperatureForDefrostOperation – outdoor air dry-bulb temperature above which outdoor coil defrosting is disabled [°C];
- condenserType – 'AirCooled', 'EvaporativelyCooled' or 'WaterCooled'. WaterCooled type requires an HVAC Template Plant Mixed Water Loop (**6.15.3**), with one or more HVAC Template Plant Boilers (**6.16.1**) and one or more HVAC Template Plant Towers (**6.16.3**);
- waterCondenserVolumeFlowRate – condenser water volume flow rate [m3/s]. 'autosize' option is available. Only used if condenserType = WaterCooled;
- evaporativeCondenserEffectiveness – effectiveness of the evaporative condenser, which is used to determine the temperature of the air entering the outdoor condenser coil: Tcond,in = Twb,o + (1 – ECE)*(Tdb,o – Twb,o)[9];
- evaporativeCondenserAirFlowRate – air volume flow rate entering the evaporative condenser [m3/s]. 'autosize' option is available. Not used when condenserType = AirCooled;
- evaporativeCondenserPumpRatedPowerConsumption – rated power of the evaporative condenser water pump [W]. 'autosize' option is available. Not used when condenserType = AirCooled;
- basinHeaterCapacity – capacity of the heat pump's electric basin heater [W/K]. Only used if condenserType = EvaporativelyCooled;
- basinHeaterSetpointTemperature – set point temperature for the basin heater [°C]. Only used if condenserType = EvaporativelyCooled;
- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the system is always available. Only used if condenserType = EvaporativelyCooled;
- fuelType – 'Electricity', 'NaturalGas', 'PropaneGas', 'Diesel', 'Gasoline', 'FuelOil_1', 'FuelOil_2', 'OtherFuel1' or 'OtherFuel2';
- minimumOutdoorTemperatureInHeatRecoveryMode – minimum outdoor dry-bulb temperature allowed for heat recovery operation [°C]. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- maximumOutdoorTemperatureInHeatRecoveryMode – maximum outdoor dry-bulb temperature allowed for heat recovery operation [°C]. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

[9] Tcond,in – temperature of the air entering the condenser coil [°C], Twb,o – wet-bulb temperature of the outdoor air [°C], Tdb,o – dry-bulb temperature of the outdoor air [°C], EFE – evaporative condenser effectiveness;

Automatic filling fields in EnergyPlus:

- Name – name of the VRF system, defined in the first argument of the HVACTemplateSystemVRFSpec() above;
- Zone Name for Master Thermostat Location – zone name where the master thermostat is located (if any), defined in the argument x1 of the HVACTemplateSystemVRFSpec() above.

Note: even when not setting any of the above fields to 'autosize', the "Do System Sizing Calculation" field should be set to Yes in the Simulation Control (x2 = true in section **17**). This is due to the fact that the HVAC Template System VRF object is internally converted by EnergyPlus to an Air Loop HVAC object (with the expand file), for which an autosized field is assigned, thus requiring a system sizing. Moreover, as system sizing cannot be done without zone sizing, the "Do Zone Sizing Calculation" field should also be set to Yes in the Simulation Control (x1 = true in section **17**).

<u>Zone unit</u>

The HVAC Template zone terminal unit properties are defined in the **HVACTemplateZoneVRF** table in the database, corresponding to the HVACTemplate:Zone:VRF object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- zoneCoolingSizingFactor – zone level cooling sizing ratio. The zone design cooling air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Cooling Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- ratedTotalHeatingCapacitySizingRatio – ratio of the heating coil to cooling coil size [W/W];
- coolingSupplyAirFlowRate – supply air flow rate when the terminal unit is operating in cooling mode [m3/s]. 'autosize' option is available;
- noCoolingSupplyAirFlowRate – supply air flow rate when the terminal unit's cooling coil is not operating and the previous mode was cooling [m3/s]. 'autosize' option is available, which causes the supply air flow rate to be sized to match the smaller of the Cooling and Heating flow rates;
- heatingSupplyAirFlowRate – supply air flow rate when the heating coil is operating [m3/s]. 'autosize' option is available;
- noHeatingSupplyAirFlowRate – supply air flow rate when neither cooling nor heating is required (i.e., DX coil and heater are off but the supply air fan operates). 'autosize' option is available, which causes the supply air flow rate to be sized to match the smaller of the Cooling and Heating flow rates;
- coolingOutdoorAirFlowRate – outdoor air volumetric air flow rate when the terminal unit is operating in cooling mode [m3/s]. 'autosize' option is available, which causes tis

field to be sized based on the outdoor air inputs below, unless a dedicated outdoor air system is specified for this zone and then it will be set to zero;

- heatingOutdoorAirFlowRate – outdoor air volumetric air flow rate when the terminal unit is operating in heating mode [m3/s]. 'autosize' option is available, which causes tis field to be sized based on the outdoor air inputs below, unless a dedicated outdoor air system is specified for this zone and then it will be set to zero;
- noLoadOutdoorAirFlowRate – outdoor air volumetric air flow rate when the terminal unit is not operating in cooling or heating mode [m3/s]. 'autosize' option is available, which causes tis field to be sized based on the outdoor air inputs below, unless a dedicated outdoor air system is specified for this zone and then it will be set to zero;
- outdoorAirMethod – 'Flow_Person', 'Flow_Area', 'Flow_Zone', 'Sum', 'Maximum' or 'DetailedSpecification';
- outdoorAirFlowRatePerPerson – design outdoor air flow rate per person for this zone [m^3/s]. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [$m^3/s.m^2$]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirflowRatePerZone – design outdoor air flow rate for this zone [m^3/s]. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this unit, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationZoneAirDistributionID – ID of the object which specifies the zone air distribution requirements and schedule for this unit, defined in table **DesignSpecificationZoneAirDistribution** in the database (see section **13.1.2**). Only used if outdoorAirMethod = DetailedSpecification;
- systemAvailabilityScheduleID – system availability schedule ID, defined in the Schedules table in the database (**21**). If blank, the system is always available;
- supplyFanOperatingModeScheduleID – supply fan operating mode schedule ID, defined in the Schedules table in the database (**21**). 0 - supply air fan and the heating or cooling coil cycle on and off together to meet the heating or cooling load (auto fan), ≠0 - supply fan runs continuously while the heating or cooling coil cycles to meet the load. If blank, a schedule of always zero (cycling fan) will be used;
- supplyFanPlacement – 'BlowThrough' or 'DrawThrough';
- supplyFanTotalEfficiency – total efficiency of the supply fan. Ratio of the power delivered to the air to the electrical input power at maximum flow;
- supplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- supplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed;
- coolingCoilType – 'VariableRefrigerantFlowDX' or 'None';
- coolingCoilAvailabilityScheduleID – cooling coil availability schedule ID, defined in the Schedules table in the database (**21**). If blank, the coil is always available;
- coolingCoilGrossRatedTotalCapacity – full load gross cooling capacity, including both sensible and latent capacity, in watts of the DX coil unit at rated conditions. 'autosize' option is available, which lets the automatic sizing algorithm determine the gross

cooling coil total capacity based on the maximum cooling loads during the cooling design day;

- coolingCoilGrossRatedSensibleHeatRatio – ratio of the gross sensible capacity divided by the gross total cooling capacity of the DX cooling coil at rated conditions. 'autosize' option is available, which allows the sizing algorithm to determine the gross sensible heat ratio based on the gross rated capacity and air flow rate;
- heatPumpHeatingCoilType – 'VariableRefrigerantFlowDX' or 'None';
- heatPumpHeatingCoilAvailabilityScheduleID – heating coil availability schedule ID, defined in the Schedules table in the database (**21**). If blank, the coil is always available;
- heatPumpHeatingCoilGrossRatedCapacity – full load gross heating capacity, in watts of the DX heat pump unit at rated conditions. autosize' option is available, which lets the automatic sizing algorithm determine the heat pump heating coil gorss rated capacity based on the maximum heating loads during the heating design day;
- zoneTerminalUnitOnParasiticElectricEnergyUse – parasitic electrical energy use of the zone terminal unit when either terminal unit coil is operating [W];
- zoneTerminalUnitOffParasiticElectricEnergyUse – parasitic electrical energy use of the zone terminal unit when the terminal unit coil(s) is not operating [W];
- zoneCoolingDesignSupplyAirTemperatureInputMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneCoolingDesignSupplyAirTemperature – supply air temperature for the zone cooling design air flow rate calculation and cooling coil sizing [°C]. Only used if zoneCoolingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneCoolingDesignSupplyAirTemperatureDifference – temperature difference between the cooling design supply air temperature and the zone air temperature for the zone cooling design air flow rate calculation and cooling coil sizing [°C]. Only used if zoneCoolingDesignAirTemperatureInputMethod = TemperatureDifference;
- zoneHeatingDesignSupplyAirTemperatureInputMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneHeatingDesignSupplyAirTemperature – supply air temperature for the zone heating design air flow rate calculation and heating coil sizing [°C]. Only used if zoneHeatingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneHeatingDesignSupplyAirTemperatureDifference – temperature difference between heating design supply air temperature and zone air for the zone heating design air flow rate calculation and heating coil sizing [°C]. Only used if zoneHeatingDesignAirTemperatureInputMethod = TemperatureDifference;
- baseboardHeatingType – 'None', 'HotWater' or 'Electric'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- baseboardHeatingAvailabilityScheduleID – baseboard heating availability schedule ID, defined in the Schedules table in the database (**21**). If blank, the baseboard heating is always available;
- baseboardHeatingCapacity – maximum amount of heat that the baseboard heating can deliver [W]. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template VRF System Name – name of the VRF system serving this unit, defined in section **6.11.1** or **6.11.2** and entered as the first argument in the HVACTemplateZoneVRFSpec() above;
- Template Thermostat Name – name of the thermostat assigned for the zone, defined in the first argument of the HVACTemplateZoneVRFSpec() above;
- Dedicated Outdoor Air System Name – name of the Dedicated Outdoor Air System assigned for this VRF unit (if any), defined defined in section **6.14**.

Note: even when not setting any of the above fields to 'autosize', the "Do Zone Sizing Calculation" field should be set to Yes in the Simulation Control (x1 = true in section **17**). This is due to the fact that the HVAC Template Zone Dual Duct object is internally converted by EnergyPlus to an Air Terminal Single Duct object (with the expand file), for which an autosized air flow rate field is assigned, thus requiring a zone sizing.

6.12. Constant Volume

The HVAC Template Zone Constant Volume option must be active (**HVAC_TEMPLATE_ZONE_CONSTANT_VOLUME = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

An example of this system and zone objects usage can be found in the SingleStoreyFamilyHouse_HVACT_ConstantVolume template in the SAPTool_LSP.

Prior to the zone terminal units' definition, their supply system(s) must also be defined. If the constant volume system is intended to serve multiple zone units, it must be defined in the building's HVAC template system (**6.12.1**). Otherwise, if the constant volume system is intended to serve a single zone unit, it must be defined in the zone (**6.12.2**).

6.12.1. Constant volume system supplying multiple zone units

The assignment of the supply system(s) to the building's HVAC template system is defined in the SAPTool_LSP building template, as demonstrated in section **6.1**. There, the hvacTemplateSpec's arguments should be defined as 'null' if the constant volume systems' and zones' coils (or baseboards) are not water heated/chilled; otherwise, the adequate plant loop(s) and plant heating and/or cooling equipment specifications must be properly assigned.

<u>**System**</u>

The HVAC Template System Constant Volume name must be defined as follows:

String constantVolumeSystemName = DBHVACTemplateSystemConstantVolumeType.ABC.toString() – constant volume system name, defined using the DBHVACTemplateSystemConstantVolumeType list object ('ABC', in this case). Alternatively, a string can be directly inputted here (e.g., **"ABC"**).

The specification of each constant volume system is defined in the SAPTool_LSP building template, as follows:

HVACTemplateSystemConstantVolumeSpec hvacTemplateConstantVolumeSystemSpec = new HVACTemplateSystemConstantVolumeSpec() – constant volume system specification (named hvacTemplateConstantVolumeSystemSpec in this example), defined in the table **HVACTemplateSystemConstantVolume** in the database (see section **6.12.3** below). With the following HVACTemplateSystemConstantVolumeSpec() arguments:

- **constantVolumeSystemName** – constant volume system's name, defined above;
- **x1** – ID of the cooling coil control zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if a cooling coil is assigned to the system and if the coil is zone controlled (coolingCoilSetpointControlType = ControlZone, in the table **HVACTemplateSystemConstantVolume** in the database). Otherwise, it may be **null**;
- **x2** – ID of the heating coil control zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if a heating coil is assigned to the system and if the coil is zone controlled (heatingCoilSetpointControlType = ControlZone, in the table **HVACTemplateSystemConstantVolume** in the database). Otherwise, it may be **null**;
- **x3** – ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
- **x4** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
- **x5** – ID of the night cycle control zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if the night cycle is zone controlled (nightCycleControl = CycleOnControlZone, in the table **HVACTemplateSystemConstantVolume** in the database). Otherwise, it may be **null**;
- **x6** – ID of the dehumidification control zone where the humidistat is located, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if dehumidification control is active (dehumidificationControlType = CoolReheat, in the table **HVACTemplateSystemConstantVolume** in the database). Otherwise, it may be **null**;
- **x7** – ID of the humidifier control zone for controlling humidification, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if humidification control is active (humidifierType = ElectricSteam, in the table **HVACTemplateSystemConstantVolume** in the database). **null** if nonexistent;
- **DBHVACTemplateSystemConstantVolumeType.ABC_BedroomsUnit.getID()** – ID of the constant volume system properties in the database, defined using the DBHVACTemplateSystemConstantVolumeType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The above defined HVAC Template System Constant Volume is then added to the building's HVAC template system (named hvacTemplateSpec in this example) as follows:

hvacTemplateSpec.addSystemConstantVolumeSpec(hvacTemplateConstantVolumeSystemSpec) – addition of the constant volume system (hvacTemplateConstantVolumeSystemSpec) to the building's HVAC template system.

To add more constant volume systems, one should repeat the above process, by defining new constant volume system names, their specifications (with the HVACTemplateSystemConstantVolumeSpec()), and adding them to the building's HVAC template system.

The corresponding detailed version of this template object can be defined with an Air Loop HVAC system (see section **10.1**).

__Zone units__

The specification of the zone terminal units for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneConstantVolumeSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneConstantVolume** in the database (see section **6.12.3** below), and with the following arguments:
    - **constantVolumeSystemName** – name of the constant volume system defined above;
    - **x1 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
    - **x2 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
    - **DBHVACTemplateZoneConstantVolumeType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneConstantVolumeType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
    - **db** – database unique ID.
- **null** – this terminal unit is supplied by a constant volume system that can supply multiple units and is defined outside the zone.

This zone HVAC template specification (hvacTemplateSpec_SingleBedroom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Single Bedroom, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_SingleBedroom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.SINGLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Single Bedroom, in this example);

- **db** – database unique ID.

The corresponding detailed version of this template object can be defined as presented in section **7.1.8.2** (AirTerminal Single Duct Constant Volume Reheat).

6.12.2. Constant volume system supplying a single zone unit (zone system)

If the constant volume system is intended to serve a single zone unit, it must be defined in the zone. The specification of the zone system for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneConstantVolumeSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneConstantVolume** in the database (see section **6.12.3** below), and with the following arguments:
  - **null** – since this terminal unit is supplied by a single constant volume system specific to this unit (defined in the zone). In this case, the constant volume system name is automatically assigned ("ConstantVolumeSystem" + Zone Name).
  - **x1 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
  - **x2 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **DBHVACTemplateZoneConstantVolumeType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneConstantVolumeType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
  - **db** – database unique ID.
- **new HVACTemplateSystemConstantVolumeSpec()** – specification of the zone system for this space, defined in the table **HVACTemplateSystemConstantVolume** in the database (see section **6.12.3** below), and with the following arguments:
  - **null** – constant volume system's name. As this system is specific to a zone unit (and, therefore, defined in the zone), its name is automatically assigned ("ConstantVolumeSystem" + Zone Name);
  - **null** – ID of the cooling coil control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the cooling coil control zone;
  - **null** – ID of the heating coil control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the heating coil control zone;

- **x3** – ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
- **x4** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
- **null** – ID of the night cycle control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the night cycle control zone;
- **null** – ID of the dehumidification control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the dehumidification control zone;
- **null** – ID of the humidifier control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the humidifier control zone;
- **x8** – ID of the constant volume system properties in the database, defined using the DBHVACTemplateSystemConstantVolumeType list object or directly with the proper database ID;
- **db** – database unique ID.

The zone HVAC template specification (hvacTemplateSpec_SingleBedroom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Single Bedroom, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_SingleBedroom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.SINGLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Single Bedroom, in this example);
- **db** – database unique ID.

6.12.3. System and zone unit properties

<u>**System**</u>

The HVAC Template System Constant Volume properties are defined in the **HVACTemplateSystemConstantVolume** table in the database, corresponding to the HVACTemplate:System:ConstantVolume object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – system availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the system is always available;
- supplyFanMaximumFlowRate – upper limit on system flow, even if the zone level air flow inputs sum to a greater value [m^3/s]. ‘autosize’ option is available, which sets the system maximum air-flow rate to the sum of the zone air flow rates;
- supplyFanTotalEfficiency – total efficiency of the supply fan;
- supplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;

- supplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed;
- supplyFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- supplyFanPlacement – ‘BlowThrough’ or ‘DrawThrough’;
- coolingCoilType – ‘ChilledWater’, ‘ChilledWaterDetailedFlatModel’, ‘HeatExchangerAssistedChilledWater’ or ‘None’. All the chilled water types require an HVAC Template Plant Chilled Water Loop (**6.15.1**), with one or more HVAC Template Plant Chillers (**6.16.2**) and (if present) HVAC Template Plant Towers (**6.16.3**);
- coolingCoilAvailabilityScheduleID – cooling coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- coolingCoilSetpointControlType – ‘FixedSetpoint’, ‘Scheduled’, ‘OutdoorAirTemperatureReset’, ‘Warmest’ or ‘ControlZone’;
- coolingCoilDesignSetpointTemperature – cooling supply air temperature to be used for sizing the cooling coil and zone supply air flow rates [°C]. Used if coolingCoilSetpointScheduleID is not specified;
- coolingCoilSetpointScheduleID – cooling coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Leave blank, if a constant setpoint is to be specified (coolingCoilDesignSetpointTemperature);
- coolingCoilSetpointAtOutdoorDryBulbLow – cooling coil supply air setpoint temperature when the outdoor dry-bulb temperature is at or below the low limit (coolingCoilResetOutdoorDryBulbLow) [°C]. Only used if coolingCoilType = OutdoorAirTemperatureReset;
- coolingCoilResetOutdoorDryBulbLow – low limit of outdoor dry-bulb temperature for outdoor air reset control [°C]. Only used if coolingCoilType = OutdoorAirTemperatureReset;
- coolingCoilSetpointAtOutdoorDryBulbHigh – cooling coil supply air setpoint temperature when the outdoor dry-bulb temperature is at or above the high limit (coolingCoilResetOutdoorDryBulbHigh) [°C]. Only used if coolingCoilType = OutdoorAirTemperatureReset;
- coolingCoilResetOutdoorDryBulbHigh – high limit of outdoor dry-bulb temperature for outdoor air reset control [°C]. Only used if coolingCoilType = OutdoorAirTemperatureReset;
- heatingCoilType – ‘HotWater’, ‘Electric’, ‘Gas’ or ‘None’. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- heatingCoilAvailabilityScheduleID – heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- heatingCoilSetpointControlType – ‘FixedSetpoint’, ‘Scheduled’, ‘OutdoorAirTemperatureReset’ or ‘ControlZone’;
- heatingCoilDesignSetpoint – heating supply air temperature to be used for sizing the heating coil and zone supply air flow rates [°C]. Used if heatingCoilSetpointScheduleID is not specified;
- heatingCoilSetpointScheduleID – heating coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Leave blank, if a constant setpoint is to be specified (heatingCoilDesignSetpoint);

- heatingCoilSetpointAtOutdoorDryBulbLow – heating coil supply air setpoint temperature when the outdoor dry-bulb temperature is at or below the low limit (heatingCoilResetOutdoorDryBulbLow) [°C]. Used only when heatingCoilSetpointControlType = OutdoorAirTemperatureReset;
- heatingCoilResetOutdoorDryBulbLow – low limit of outdoor dry-bulb temperature for outdoor air reset control [°C]. Only used if heatingCoilSetpointControlType = OutdoorAirTemperatureReset;
- heatingCoilSetpointAtOutdoorDryBulbHigh – heating coil supply air setpoint temperature when the outdoor dry-bulb temperature is at or above the low limit (heatingCoilResetOutdoorDryBulbHigh) [°C]. Used only when heatingCoilSetpointControlType = OutdoorAirTemperatureReset;
- heatingCoilResetOutdoorDryBulbHigh – high limit of outdoor dry-bulb temperature for outdoor air reset control [°C]. Only used if heatingCoilSetpointControlType = OutdoorAirTemperatureReset;
- heatingCoilCapacity – maximum amount of heat that the coil can deliver [W]. 'autosize' option is available;
- gasHeatingCoilEfficiency – gas burner efficiency in decimal values;
- gasHeatingCoilParasiticElectricLoad – parasitic electric load associated with the gas heating operation [W];
- preheatCoilType – 'HotWater', 'Electric', 'Gas' or 'None'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- preheatCoilAvailabilityScheduleID – preheat coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the preheat coil is always available;
- preheatCoilDesignSetpoint – preheat supply air temperature to be used for sizing the preheat coil [°C]. Used if preheatCoilSetpointScheduleID is not specified;
- preheatCoilSetpointScheduleID – preheat coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Leave blank, if a constant setpoint is to be specified (preheatCoilDesignSetpoint);
- gasPreheatCoilEfficiency – gas burner efficiency in decimal values;
- gasPreheatCoilParasiticElectricLoad – parasitic electric load associated with the gas heating operation [W];
- maximumOutdoorAirFlowRate – maximum amount of outdoor air flow into the unit when the economizer is operating [m^3/s]. 'autosize' option is available, which means that 100% of the full supply flow may be taken from outdoor air;
- minimumOutdoorAirFlowRate – minimum amount of outdoor air that can enter the unit and be distributed to the zones [m^3/s]. 'autosize' option is available;
- minimumOutdoorAirScheduleID – minimum outdoor air schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the minimum outdoor air to be the same for all hours in the entire year;
- economizerType – 'NoEconomizer', 'FixedDryBulb', 'FixedEnthalpy', 'DifferentialDryBulb', 'DifferentialEnthalpy', 'FixedDewPointAndDryBulb', 'ElectronicEnthalpy' or 'DifferentialDryBulbAndEnthalpy';
- economizerUpperTemperatureLimit – outdoor air temperature high limit for economizer operation [°C]. If the outdoor air temperature is above this limit, the outdoor air flow rate will be set to the minimum and heat recovery will be enabled if available;

- economizerLowerTemperatureLimit – outdoor air temperature low limit for economizer operation [°C]. If the outdoor air temperature is below this limit, the outdoor air flow rate will be set to the minimum and heat recovery will be enabled if available;
- economizerUpperEnthalpyLimit – outdoor air upper enthalpy limit for economizer operation [J/kg]. If the outdoor air enthalpy is above this limit, the outdoor air flow rate will be set to the minimum and heat recovery will be enabled if available;
- economizerMaximumLimitDewpointTemperature – outdoor air dewpoint limit for economizer operation [°C]. If the outdoor air dewpoint temperature is above this limit, the outdoor air flow rate will be set to the minimum. Required (even if blank [no limit]) if economizerType = FixedDewPointAndDryBulb;
- nightCycleControl – 'StayOff', 'CycleOnAny', 'CycleOnControlZone' or 'CycleOnAnyZoneFansOnly';
- heatRecoveryType – 'None', 'Sensible' or 'Enthalpy';
- sensibleHeatRecoveryEffectiveness – sensible heat recovery effectiveness;
- latentHeatRecoveryEffectiveness – latent heat recovery effectiveness. Only used if heatRecoveryType = Enthalpy;
- heatRecoveryHeatExchangerType – 'Plate' or 'Rotary';
- heatRecoveryFrostControlType – 'None', 'ExhaustAirRecirculation', 'ExhaustOnly or 'MinimumExhaustTemperature';
- dehumidificationControlType – 'None' or 'CoolReheat';
- dehumidificationRelativeHumiditySetpoint – zone humidistat setpoint for dehumidification in percent. This field is ignored if a schedule is specified in the next field;
- dehumidificationRelativeHumiditySetpointScheduleID – dehumification relative humidity setpoint schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the constant value specified in the previous field will be used;
- humidifierType – 'None' or 'ElectricSteam';
- humidifierAvailabilityScheduleID – humidifier availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, humidifier is always available;
- humidifierRatedCapacity – rated moisture output rate [m^3/s];
- humidifierRatedElectricPower – electric power input at the rated capacity moisture output [W]. 'autosize' option is available;
- humidifierRelativeHumiditySetpoint – zone humidistat setpoint for humidification in percent. This field is ignored if a schedule is specified in the next field;
- humidifierRelativeHumiditySetpointScheduleID – humidifier relative humidity setpoint schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the constant value specified in the previous field will be used;
- hasReturnFan – 'Yes' or 'No';
- returnFanTotalEfficiency – total efficiency of the return fan;
- returnFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- returnFanMotorEfficiency – shaft power of the return fan divided by the electrical power consumed;
- returnFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – name of the constant volume system, defined in the first argument of the HVACTemplateSystemConstantVolumeSpec() above;
- Cooling Coil Control Zone Name – name of the cooling coil control zone for which this object is assigned, defined in the argument x1 of the HVACTemplateSystemConstantVolumeSpec() above;
- Heating Coil Control Zone Name – name of the heating coil control zone for which this object is assigned, defined in the argument x2 of the HVACTemplateSystemConstantVolumeSpec() above;
- Supply Plenum Name – name of the zone that serves as a supply plenum for this system, defined in the argument x3 of the HVACTemplateSystemConstantVolumeSpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x4 of the HVACTemplateSystemConstantVolumeSpec() above;
- Night Cycle Control Zone Name – name of the night cycle control zone for which this object is assigned, defined in the argument x5 of the HVACTemplateSystemConstantVolumeSpec () above;
- Dehumidification Control Zone Name – zone name where the humidistat is located for controlling dehumidification (if any), defined in the argument x6 of the HVACTemplateSystemConstantVolumeSpec() above.
- Humidifier Control Zone Name – zone name where the humidistat is located for controlling humidification (if any), defined in the argument x7 of the HVACTemplateSystemConstantVolumeSpec() above.

Note: even when not setting any of the above fields to 'autosize', the "Do System Sizing Calculation" field should be set to Yes in the Simulation Control (x2 = true in section **17**). This is due to the fact that the HVAC Template System Constant Volume object is internally converted by EnergyPlus to an Air Loop HVAC object (with the expand file), for which an autosized field is assigned, thus requiring a system sizing. Moreover, as system sizing cannot be done without zone sizing, the "Do Zone Sizing Calculation" field should also be set to Yes in the Simulation Control (x1 = true in section **17**).

<u>Zone unit</u>

The HVAC Template zone terminal unit properties are defined in the **HVACTemplateZoneConstantVolume** table in the database, corresponding to the HVACTemplate:Zone:ConstantVolume object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- supplyAirMaximumFlowRate – maximum supply air flow rate into the zone [m^3/s]. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;

- zoneCoolingSizingFactor – zone level cooling sizing ratio. The zone design cooling air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Cooling Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- outdoorAirMethod – 'Flow_Person', 'Flow_Area', 'Flow_Zone', 'Sum', 'Maximum' or 'DetailedSpecification';
- outdoorAirFlowRatePerPerson – design outdoor air flow rate per person for this zone [m^3/s]. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [$m^3/s.m^2$]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirflowRatePerZone – design outdoor air flow rate for this zone [m^3/s]. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this unit, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationZoneAirDistributionID – ID of the object which specifies the zone air distribution requirements and schedule for this unit, defined in table **DesignSpecificationZoneAirDistribution** in the database (see section **13.1.2**). Only used if outdoorAirMethod = DetailedSpecification;
- reheatCoilType – 'None', 'HotWater', 'Electric' or 'Gas';
- reheatCoilAvailabilityScheduleID – reheat coil availability schedule ID, defined in the Schedules table in the database (**21**). If blank, the reheat coil is always available;
- maximumReheatAirTemperature – maximum allowable supply air temperature leaving the reheat coil during heating operation [°C]. If left blank, there is no limit, and the supply air temperature to the space may become unrealistically high during heating operation;
- baseboardHeatingType – 'None', 'HotWater' or 'Electric'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- baseboardHeatingAvailabilityScheduleID – baseboard heating availability schedule ID, defined in the Schedules table in the database (**21**). If blank, the baseboard heating is always available;
- baseboardHeatingCapacity – maximum amount of heat that the baseboard heating can deliver [W]. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- zoneCoolingDesignSupplyAirTemperatureInputMethod – 'SystemSupplyAirTemperature', 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneCoolingDesignSupplyAirTemperature – supply air temperature for the zone cooling design air flow rate calculation and cooling coil sizing [°C]. Only used if zoneCoolingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneCoolingDesignSupplyAirTemperatureDifference – temperature difference between the cooling design supply air temperature and the zone air temperature for the zone cooling design air flow rate calculation and cooling coil sizing [°C]. Only used if zoneCoolingDesignAirTemperatureInputMethod = TemperatureDifference;

- zoneHeatingDesignSupplyAirTemperatureInputMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneHeatingDesignSupplyAirTemperature – supply air temperature for the zone heating design air flow rate calculation and heating coil sizing [°C]. Only used if zoneHeatingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneHeatingDesignSupplyAirTemperatureDifference – temperature difference between heating design supply air temperature and zone air for the zone heating design air flow rate calculation and heating coil sizing [°C]. Only used if zoneHeatingDesignAirTemperatureInputMethod = TemperatureDifference;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template Constant Volume System Name – name of the constant volume system serving this unit, defined in section **6.12.1** or **6.12.2** and entered as the first argument in the HVACTemplateZoneConstantVolumeSpec() above;
- Template Thermostat Name – name of the thermostat assigned for the zone, defined in the first argument of the ZoneHVACTemplateSpec() above;
- Supply Plenum Name – name of the zone that serves as a supply plenum for this unit, defined in the argument x2 of the HVACTemplateZoneConstantVolumeSpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x1 of the HVACTemplateZoneConstantVolumeSpec() above.

Note: even when not setting any of the above fields to 'autosize', the "Do Zone Sizing Calculation" field should be set to Yes in the Simulation Control (x1 = true in section **17**). This is due to the fact that the HVAC Template Zone Constant Volume object is internally converted by EnergyPlus to an Air Terminal Single Duct object (with the expand file), for which an autosized air flow rate field is assigned, thus requiring a zone sizing.

6.13. VAV

The HVAC Template Zone Unitary System option must be active (**HVAC_TEMPLATE_ZONE_VAV = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

Prior to the zone terminal units' definition, their supply system(s) must also be defined. If the VAV system is intended to serve multiple zone units, it must be defined in the building's HVAC template system (**6.13.1**). Otherwise, if the VAV system is intended to serve a single zone unit, it must be defined in the zone (**6.13.2**).

6.13.1. VAV system supplying multiple zone units

The assignment of the supply system(s) to the building's HVAC template system is defined in the SAPTool_LSP building template, as demonstrated in section **6.1**. There, the hvacTemplateSpec's arguments should be defined as 'null' if the unitary systems' and zones' coils (or baseboards) are not water heated/chilled; otherwise, the adequate plant loop(s) and plant heating and/or cooling equipment specifications must be properly assigned.

System

There are 2 VAV supply system types that can be assigned to zone units: VAV and Packaged VAV.

a) VAV

The HVAC Template System VAV name must be defined as follows:

String vavSystemName = DBHVACTemplateSystemVAVType.ABC.toString() – VAV system name, defined using the DBHVACTemplateSystemVAVType list object ('ABC', in this case). Alternatively, a string can be directly inputted here (e.g., **"ABC"**).

The specification of each unitary is defined in the SAPTool_LSP building template, as follows:

HVACTemplateSystemVAVSpec hvacTemplateSystemVAVSpec = new HVACTemplateSystemVAVSpec() – VAV system specification (named hvacTemplateSystemVAVSpec in this example), defined in the table **HVACTemplateSystemVAV** in the database (see section **6.9.3** below). With the following HVACTemplateSystemVAVSpec() arguments:

- **vavSystemName** – VAV system's name, defined above;
- **x1** – ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
- **x2** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
- **x3** – ID of the night cycle control zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if night cycle control is zone controlled (nightCycleControl = CycleOnControlZone, in the table **HVACTemplateSystemVAV** in the database). **null** if nonexistent;
- **x4** – ID of the dehumidification control zone for controlling dehumidification, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if dehumidification control is active (humidifierType = CoolReheat, in the table **HVACTemplateSystemVAV** in the database). **null** if nonexistent;
- **x5** – ID of the humidifier control zone for controlling humidification, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if humidification control is active (humidifierType = ElectricSteam, in the table **HVACTemplateSystemVAV** in the database). **null** if nonexistent;
- **DBHVACTemplateSystemVAVType.ABC_BedroomsUnit.getID()** – ID of the VAV system properties in the database, defined using the DBHVACTemplateSystemVAVType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The above defined HVAC Template System VAV is then added to the building's HVAC template system (named hvacTemplateSpec in this example) as follows:

hvacTemplateSpec.addSystemVAVSpec(hvacTemplateSystemVAVSpec) – addition of the VAV system (hvacTemplateSystemVAVSpec) to the building's HVAC template system.

To add more VAV systems, one should repeat the above process, by defining new VAV system names, their specifications (with the HVACTemplateSystemVAVSpec()), and adding them to the building's HVAC template system.

An example of this system usage can be found in the SingleStoreyFamilyHouse_HVACT_VAV template in the SAPTool_LSP.

The corresponding detailed version of this template object can be defined with an Air Loop HVAC system (see section **10.1**).

b) Packaged VAV

The HVAC Template System Packaged VAV name must be defined as follows:

String vavSystemName= DBHVACTemplateSystemPackagedVAVType.ABC.toString() – packaged VAV system name, defined using the DBHVACTemplateSystemPackagedVAVType list object ('ABC', in this case). Alternatively, a string can be directly inputted here (e.g., **"ABC"**).

The specification of each packaged VAV system is defined in the SAPTool_LSP building template, as follows:

HVACTemplateSystemPackagedVAVSpec hvacTemplateSystemPackagedVAVSpec = new HVACTemplateSystemPackagedVAVSpec() – packaged VAV system specification (named hvacTemplateSystemPackagedVAVSpec in this example), defined in the table **HVACTemplateSystemPackagedVAV** in the database (see section **6.9.3** below). With the following HVACTemplateSystemPackagedVAVSpec() arguments:

- **vavSystemName** – packaged VAV system's name, defined above;
- **x1** – ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
- **x2** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
- **x3** – ID of the night cycle control zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if night cycle control is zone controlled (nightCycleControl = CycleOnControlZone, in the table **HVACTemplateSystemPackagedVAV** in the database). **null** if nonexistent;
- **x4** – ID of the dehumidification control zone for controlling dehumidification, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if dehumidification control is active (humidifierType = CoolReheat, in the table **HVACTemplateSystemPackagedVAV** in the database). **null** if nonexistent;
- **x5** – ID of the humidifier control zone for controlling humidification, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used if humidification control is active (humidifierType = ElectricSteam, in the table **HVACTemplateSystemPackagedVAV** in the database). **null** if nonexistent;
- **DBHVACTemplateSystemPackagedVAVType.ABC_BedroomsUnit.getID()** – ID of the packaged VAV system properties in the database, defined using the

DBHVACTemplateSystemPackagedVAVType list object (ID of ‘ABC’, in this case). Alternatively, the proper database ID can be directly inputted here;

- **db** – database unique ID.

The above defined HVAC Template System Packaged VAV is then added to the building’s HVAC template system (named hvacTemplateSpec in this example) as follows:

hvacTemplateSpec. addSystemPackagedVAVSpec(hvacTemplateSystemPackagedVAVSpec) – addition of the packaged VAV system (hvacTemplateSystemPackagedVAVSpec) to the building’s HVAC template system.

To add more packaged VAV systems, one should repeat the above process, by defining new packaged VAV system names, their specifications (with the HVACTemplateSystemPackagedVAVSpec()), and adding them to the building’s HVAC template system.

An example of this system usage can be found in the SingleStoreyFamilyHouse_HVACT_PackagedVAV template in the SAPTool_LSP.

The corresponding detailed version of this template object can be defined with an Air Loop HVAC system (see section **10.1**).

Zone units

There are 3 VAV zone types that can be assigned to zones: VAV, VAV Fan Powered, and VAV Heat and Cool:

a) VAV

The specification of the zone terminal units for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneVAVSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneVAV** in the database (see section **6.9.3** below), and with the following arguments:
  - **vavSystemName** – name of the VAV system defined above outside the zone (VAV or packaged VAV) that can supply multiple units;
  - **x1 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **x2 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;

- **DBHVACTemplateZoneVAVType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneVAVType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

- **null** – this terminal unit is supplied by a VAV system (VAV or packaged VAV – named 'vavSystemName') that can supply multiple units and is defined outside the zone.

This zone HVAC template specification (hvacTemplateSpec_SingleBedroom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Single Bedroom, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_SingleBedroom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.SINGLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Single Bedroom, in this example);
- **db** – database unique ID.

The corresponding detailed version of this template object can be defined as presented in section **7.1.8.3** (AirTerminal Single Duct VAV Reheat).

b) <u>VAV Fan Powered</u>

The specification of the zone terminal units for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneVAVFanPoweredSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneVAVFanPowered** in the database (see section **6.9.3** below), and with the following arguments:
  - **vavSystemName** – name of the VAV system defined above outside the zone (VAV or packaged VAV) that can supply multiple units;
  - **x1 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **x2 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;

- DBHVACTemplateZoneVAVFanPoweredType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneVAVFanPoweredType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
    - **db** – database unique ID.
- **null** – this terminal unit is supplied by a VAV system (VAV or packaged VAV – named 'vavSystemName') that can supply multiple units and is defined outside the zone.

This zone HVAC template specification (hvacTemplateSpec_SingleBedroom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Single Bedroom, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_SingleBedroom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.SINGLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Single Bedroom, in this example);
- **db** – database unique ID.

The corresponding detailed version of this template object can be defined as presented in section **7.1.8.7** (AirTerminal Single Duct Series PIU Reheat).

c) <u>VAV Heat and Cool</u>

The specification of the zone terminal units for each space is defined in the SAPTool_LSP building template, as follows, immediately prior to that zone specification (RoomSpec()):

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- **new HVACTemplateZoneVAVHeatAndCoolSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneVAVHeatAndCool** in the database (see section **6.9.3** below), and with the following arguments:
    - **vavSystemName** – name of the VAV system defined above outside the zone (VAV or packaged VAV) that can supply multiple units;
    - **x1 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
    - **x2 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;

    - **DBHVACTemplateZoneVAVHeatAndCoolType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneVAVHeatAndCoolType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
    - **db** – database unique ID.
- **null** – this terminal unit is supplied by a VAV system (VAV or packaged VAV – named 'vavSystemName') that can supply multiple units and is defined outside the zone.

This zone HVAC template specification (hvacTemplateSpec_SingleBedroom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Single Bedroom, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_SingleBedroom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.SINGLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Single Bedroom, in this example);
- **db** – database unique ID.

The corresponding detailed version of this template object can be defined as presented in section **7.1.8.5** (AirTerminal Single Duct VAV Heat and Cool Reheat).

6.13.2. VAV system supplying a single zone unit (zone system)

If the VAV system is intended to serve a single zone unit, it must be defined in the zone. The specification of the zone system for each space is defined in the SAPTool_LSP building template, as follows (for the 2 different supply system types), immediately prior to that zone specification (RoomSpec()):

a) <u>VAV</u>

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- 3 options:
    - **new HVACTemplateZoneVAVSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneVAV** in the database (see section **6.9.3** below), and with the following arguments:

- **null** – since this terminal unit is supplied by a single VAV system (VAV) specific to this unit (defined in the zone). In this case, the unitary system name is automatically assigned ("VAVSystem" + Zone Name).
- **x1 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
- **x2 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
- **DBHVACTemplateZoneVAVType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneVAVType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

- **new HVACTemplateZoneVAVFanPoweredSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneVAVFanPowered** in the database (see section **6.9.3** below), and with the following arguments:
  - **null** – since this terminal unit is supplied by a single VAV system (VAV) specific to this unit (defined in the zone). In this case, the unitary system name is automatically assigned ("VAVSystem" + Zone Name).
  - **x1 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **x2 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
  - **DBHVACTemplateZoneVAVFanPoweredType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneVAVFanPoweredType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
  - **db** – database unique ID.
- **new HVACTemplateZoneVAVHeatAndCoolSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneVAVHeatAndCool** in the database (see section **6.9.3** below), and with the following arguments:
  - **null** – since this terminal unit is supplied by a single VAV system (VAV) specific to this unit (defined in the zone). In this case, the unitary system name is automatically assigned ("VAVSystem" + Zone Name).
  - **x1 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **x2 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
  - **DBHVACTemplateZoneVAVHeatAndCoolType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneVAVHeatAndCoolType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
  - **db** – database unique ID.

- **new HVACTemplateSystemVAVSpec()** – specification of the zone system for this space, defined in the table **HVACTemplateSystemVAV** in the database (see section **6.9.3** below), and with the following arguments:

- **null** – VAV system’s name. As this system is specific to a zone unit (and, therefore, defined in the zone), its name is automatically assigned ("VAVSystem" + Zone Name);
- **x1** – ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
- **x2** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
- **null** – ID of the night cycle control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the night cycle control zone;
- **null** – ID of the dehumidification control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the dehumidification control zone;
- **null** – ID of the humidifier control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the humidifier control zone;
- **x6** – ID of the VAV system properties in the database, defined using the DBHVACTemplateSystemVAVType list object or directly with the proper database ID;
- **db** – database unique ID.

An example of this zone system usage can be found in the SingleStoreyFamilyHouse_HVACT_VAV template in the SAPTool_LSP.

b) <u>Packaged VAV</u>

ZoneHVACTemplateSpec hvacTemplateSpec_SingleBedroom = new ZoneHVACTemplateSpec() – zone HVAC template specification for a given space (named hvacTemplateSpec_SingleBedroom and defined for the Single Bedroom space, in this example). With the following ZoneHVACTemplateSpec() arguments:

- **new HVACTemplateThermostatSpec(x, db)** – specification of the space thermostat, defined in the ID *x* of the table **HVACTemplateThermostat** in the database db (see section **6.2**);
- 3 options:
  - **new HVACTemplateZoneVAVSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneVAV** in the database (see section **6.9.3** below), and with the following arguments:
    - **null** – since this terminal unit is supplied by a single VAV system (packaged VAV) specific to this unit (defined in the zone). In this case, the unitary system name is automatically assigned ("VAVSystem" + Zone Name).
    - **x1 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
    - **x2 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
    - **DBHVACTemplateZoneVAVType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the

DBHVACTemplateZoneVAVType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
    - **db** – database unique ID.
  - **new HVACTemplateZoneVAVFanPoweredSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneVAVFanPowered** in the database (see section **6.9.3** below), and with the following arguments:
    - **null** – since this terminal unit is supplied by a single VAV system (packaged VAV) specific to this unit (defined in the zone). In this case, the unitary system name is automatically assigned ("VAVSystem" + Zone Name).
    - **x1 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
    - **x2 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
    - **DBHVACTemplateZoneVAVFanPoweredType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneVAVFanPoweredType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
    - **db** – database unique ID.
  - **new HVACTemplateZoneVAVHeatAndCoolSpec()** – specification of the zone terminal unit for this space, defined in the table **HVACTemplateZoneVAVHeatAndCool** in the database (see section **6.9.3** below), and with the following arguments:
    - **null** – since this terminal unit is supplied by a single VAV system (packaged VAV) specific to this unit (defined in the zone). In this case, the unitary system name is automatically assigned ("VAVSystem" + Zone Name).
    - **x1 –** ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
    - **x2 –** ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
    - **DBHVACTemplateZoneVAVHeatAndCoolType.ABC.getID()** – ID of the HVAC Template terminal unit properties in the database, defined using the DBHVACTemplateZoneVAVHeatAndCoolType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
    - **db** – database unique ID.
- **new HVACTemplateSystemPackagedVAVSpec()** – specification of the zone system for this space, defined in the table **HVACTemplateSystemPackagedVAV** in the database (see section **6.9.3** below), and with the following arguments:
  - **null** – packaged VAV system's name. As this system is specific to a zone unit (and, therefore, defined in the zone), its name is automatically assigned ("VAVSystem" + Zone Name);
  - **x1** – ID of a zone that serves as supply plenum for this system (optional). **null** if no supply plenum is to be modelled;
  - **x2** – ID of a zone that serves as return plenum for this system (optional). **null** if no return plenum is to be modelled;
  - **null** – ID of the night cycle control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the night cycle control zone;

- **null** – ID of the dehumidification control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the dehumidification control zone;
- **null** – ID of the humidifier control zone. As this system is specific to a zone unit (and, therefore, defined in the zone), the zone is automatically defined as the humidifier control zone;
- **x6** – ID of the packaged VAV system properties in the database, defined using the DBHVACTemplateSystemPackagedVAVType list object or directly with the proper database ID;
- **db** – database unique ID.

An example of this zone system usage can be found in the SingleStoreyFamilyHouse_HVACT_PackagedVAV template in the SAPTool_LSP.

General

The zone HVAC template specification (hvacTemplateSpec_SingleBedroom) must then be assigned to the space, by entering it as the first argument of the ZoneSpec() object, which is defined in the RoomSpec() object for the given space (Single Bedroom, in this example). The ZoneSpec() has the following arguments:

- **hvacTemplateSpec_SingleBedroom** – the zone HVAC template specification defined above;
- **null** – used only for Zone HVAC specifications;
- **DBSpaceType.SINGLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Single Bedroom, in this example);
- **db** – database unique ID.

6.13.3. System and zone unit properties

System

There are 2 VAV supply system types that can be assigned to zone units: VAV and Packaged VAV.

a) VAV

The HVAC Template System VAV properties are defined in the **HVACTemplateSystemVAV** table in the database, corresponding to the HVACTemplate:System:VAV object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – system availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the system is always available;
- supplyFanMaximumFlowRate – upper limit on system flow, even if the zone level air flow inputs sum to a greater value [m3/s]. ‘autosize’ option is available;

- supplyFanMinimumFlowRate – minimum supply air volume m3/s]. ‘autosize’ option is available;
- supplyFanTotalEfficiency – total efficiency of the supply fan;
- supplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- supplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed;
- supplyFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- coolingCoilType – ‘ChilledWater’ or ‘ChilledWaterDetailedFlatModel’. All the chilled water types require an HVAC Template Plant Chilled Water Loop (**6.15.1**), with one or more HVAC Template Plant Chillers (**6.16.2**) and (if present) HVAC Template Plant Towers (**6.16.3**);
- coolingCoilAvailabilityScheduleID – cooling coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- coolingCoilSetpointScheduleID – cooling coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Leave blank, if a constant setpoint is to be specified (coolingCoilDesignSetpoint). Ignored if coolingCoilSetpointResetType ≠ None;
- coolingCoilDesignSetpoint – cooling supply air temperature in C to be used for sizing the cooling coil and zone supply air flow rate [°C]. Used if coolingCoilSetpointScheduleID and coolingCoilSetpointResetType are not specified;
- heatingCoilType – ‘Gas’, ‘Electric’, ‘HotWater’ or ‘None’. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- heatingCoilAvailabilityScheduleID – heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- heatingCoilSetpointScheduleID – heating coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Leave blank, if a constant setpoint is to be specified (heatingCoilDesignSetpoint). Ignored if heatingCoilSetpointResetType ≠ None;
- heatingCoilDesignSetpoint – heating supply air temperature in C to be used for sizing the heating coil and zone supply air flow rate [°C]. Used if heatingCoilSetpointScheduleID and heatingCoilSetpointResetType are not specified;
- gasHeatingCoilEfficiency – gas burner efficiency. Only used if heatingCoilType = Gas;
- gasHeatingCoilParasiticElectricLoad – parasitic electric load associated with the gas heating coil operation [W]. Only used if heatingCoilType = Gas;
- preheatCoilType – ‘None’, ‘HotWater’, ‘Electric’ or ‘Gas’. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- preheatCoilAvailabilityScheduleID – preheat coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- preheatCoilSetpointScheduleID – preheat coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Leave blank, if a constant setpoint is to be specified (preheatCoilDesignSetpoint);
- preheatCoilDesignSetpoint – preheat supply air temperature in C to be used for sizing the heating coil and zone supply air flow rate [°C]. Used if preheatCoilSetpointScheduleID is not specified;
- gasPreheatCoilEfficiency – gas burner efficiency. Only used if preheatCoilType = Gas;

- gasPreheatCoilParasiticElectricLoad – parasitic electric load associated with the gas heating operation [W]. Only used if preheatCoilType = Gas;
- maximumOutdoorAirFlowRate – maximum amount of outdoor air flow into the unit when the economizer is operating [m3/s]. 'autosize' option is available, which means that 100% of the full supply flow may be taken from outdoor air, and for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- minimumOutdoorAirFlowRate – minimum amount of outdoor air that can enter the unit and be distributed to the zones [m3/s]. 'autosize' option is available, which means that the value is calculated by the outdoor air requirements of each zone, and for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- minimumOutdoorAirControlType – 'ProportionalMinimum' or 'FixedMinimum';
- minimumOutdoorAirFlowScheduleID – minimum outdoor air schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the minimum outdoor air will be always the same;
- economizerType – 'NoEconomizer', 'FixedDryBulb', 'FixedEnthalpy', 'DifferentialDryBulb', 'DifferentialEnthalpy', 'FixedDewPointAndDryBulb', 'ElectronicEnthalpy' or 'DifferentialDryBulbAndEnthalpy';
- economizerLockout – 'NoLockout';
- economizerUpperTemperatureLimit – outdoor air temperature high limit for economizer operation [°C];
- economizerLowerTemperatureLimit – outdoor air temperature low limit for economizer operation [°C];
- economizerUpperEnthalpyLimit – outdoor air upper enthalpy limit for economizer operation [J/kg];
- economizerMaximumLimitDewpointTemperature – outdoor air dewpoint limit in Celsius for economizer operation. If blank, there is no outdoor air dewpoint limit control. Only used if economizerType = FixedDewPointAndDryBulb;
- supplyFanPlacement – 'BlowThrough' or 'DrawThrough';
- supplyFanPartLoadPowerCoefficients – 'InletVaneDampers', 'OutletDampers', 'VariableSpeedMotor', 'ASHRAE90_1$1$2004AppendixG'' or 'VariableSpeedMotorPressureReset';
- nightCycleControl – 'StayOff', 'CycleOnAny', 'CycleOnControlZone' or 'CycleOnAnyZoneFansOnly';
- heatRecoveryType – 'None', 'Sensible' or 'Enthalpy';
- sensibleHeatRecoveryEffectiveness – sensible heat recovery effectiveness;
- latentHeatRecoveryEffectiveness – latent heat recovery effectiveness. Only used if heatRecoveryType = Enthalpy;
- coolingCoilSetpointResetType – 'None', 'Warmest', 'OutdoorAirTemperatureReset' or 'WarmestTemperatureFirst';
- heatingCoilSetpointResetType – 'None' or 'OutdoorAirTemperatureReset';
- dehumificationControlType – 'None' or 'CoolReheatDesuperheater';
- dehumidificationSetpoint – zone humidistat setpoint for dehumidification in percent;
- humidifierType – 'None' or 'ElectricSteam';
- humidifierAvailabilityScheduleID – humidifier availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, humidifier is always available;

- humidifierRatedCapacity – rated moisture output rate in m3/s;
- humidifierRatedElectricPower – electric power input at the rated capacity moisture output [W]. ‘autosize’ option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- humidifierSetpoint – zone humidistat setpoint for humidification in percent;
- sizingOption – ‘NonCoincident’ or ‘Coincident’;
- hasReturnFan – ‘Yes’ or ‘No’;
- returnFanTotalEfficiency – total efficiency of the return fan;
- returnFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- returnFanMotorEfficiency – shaft power of the return fan divided by the electrical power consumed;
- returnFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- returnFanPartLoadPowerCoefficients – ‘InletVaneDampers’, ‘OutletDampers’, ‘VariableSpeedMotor’, ‘ASHRAE90_1$1$2004AppendixG’’ or ‘VariableSpeedMotorPressureReset’;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – name of the VAV system, defined in the first argument of the HVACTemplateSystemVAVSpec() above;
- Supply Plenum Name – name of the zone that serves as a supply plenum for this system, defined in the argument x1 of the HVACTemplateSystemVAVSpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x2 of the HVACTemplateSystemVAVSpec() above;
- Night Cycle Control Zone Name – zone name where the night cycle control is located (if any), defined in the argument x3 of the HVACTemplateSystemVAVSpec() above;
- Dehumidification Control Zone Name – zone name where the dehumidification control is located (if any), defined in the argument x4 of the HVACTemplateSystemVAVSpec() above;
- Humidifier Control Zone Name – zone name where the humidistat is located for controlling humidification (if any), defined in the argument x5 of the HVACTemplateSystemVAVSpec() above.

Note: even when not setting any of the above fields to ‘autosize’, the “Do System Sizing Calculation" field should be set to Yes in the Simulation Control (x2 = true in section **17**). This is due to the fact that the HVAC Template System VAV object is internally converted by EnergyPlus to an Air Loop HVAC object (with the expand file), for which an autosized field is assigned, thus requiring a system sizing. Moreover, as system sizing cannot be done without zone sizing, the “Do Zone Sizing Calculation" field should also be set to Yes in the Simulation Control (x1 = true in section **17**).

b) Packaged VAV

The HVAC Template System Packaged VAV properties are defined in the **HVACTemplateSystemPackagedVAV** table in the database, corresponding to the

HVACTemplate:System:PackagedVAV object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – system availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the system is always available;
- supplyFanMaximumFlowRate – upper limit on system flow, even if the zone level air flow inputs sum to a greater value [m3/s]. 'autosize' option is available;
- supplyFanMinimumFlowRate – minimum supply air volume m3/s]. 'autosize' option is available;
- supplyFanPlacement – 'BlowThrough' or 'DrawThrough';
- supplyFanTotalEfficiency – total efficiency of the supply fan;
- supplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- supplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed;
- supplyFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- coolingCoilType – 'TwoSpeedDX' or 'TwoSpeedHumidControlDX';
- coolingCoilAvailabilityScheduleID – cooling coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- coolingCoilSetpointScheduleID – cooling coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Leave blank, if a constant setpoint is to be specified (coolingCoilDesignSetpoint). Ignored if coolingCoilSetpointResetType ≠ None;
- coolingCoilDesignSetpoint – cooling supply air temperature in C to be used for sizing the cooling coil and zone supply air flow rate [°C]. Used if coolingCoilSetpointScheduleID and coolingCoilSetpointResetType are not specified;
- coolingCoilGrossRatedTotalCapacity – full load gross total cooling capacity, including both sensible and latent capacity, in watts of the DX coil unit at rated conditions. 'autosize' option is available, which lets the automatic sizing algorithm determine the cooling coil gross rated total capacity based on the maximum cooling loads during the cooling design day;
- coolingCoilGrossRatedSensibleHeatRatio – ratio of the gross sensible capacity divided by the gross total cooling capacity of the DX cooling coil at rated conditions. 'autosize' option is available, which allows the sizing algorithm to determine the sensible heat ratio based on the rated capacity and air flow rate;
- coolingCoilGrossRatedCOP – coefficient of performance defined as the gross cooling coil capacity in watts divided by electrical power input in watts of the DX cooling coil unit at rated conditions;
- heatingCoilType – 'Gas', 'Electric', 'HotWater' or 'None'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- heatingCoilAvailabilityScheduleID – heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- heatingCoilSetpointScheduleID – heating coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Leave blank, if a constant setpoint is to be specified (heatingCoilDesignSetpoint). Ignored if heatingCoilSetpointResetType ≠ None;

- heatingCoilDesignSetpoint – heating supply air temperature in C to be used for sizing the heating coil and zone supply air flow rate [°C]. Used if heatingCoilSetpointScheduleID and heatingCoilSetpointResetType are not specified;
- heatingCoilCapacity – maximum amount of heat that the coil can deliver in Watts. autosize' option is available, which allow the sizing algorithm to determine the proper capacity required based on the loads experienced during the heating design day;
- gasHeatingCoilEfficiency – gas burner efficiency. Only used if heatingCoilType = Gas;
- gasHeatingCoilParasiticElectricLoad – parasitic electric load associated with the gas heating coil operation [W]. Only used if heatingCoilType = Gas;
- maximumOutdoorAirFlowRate – maximum amount of outdoor air flow into the unit when the economizer is operating [m3/s]. 'autosize' option is available, which means that 100% of the full supply flow may be taken from outdoor air, and for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- minimumOutdoorAirFlowRate – minimum amount of outdoor air that can enter the unit and be distributed to the zones [m3/s]. 'autosize' option is available, which means that the value is calculated by the outdoor air requirements of each zone, and for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- minimumOutdoorAirControlType – 'ProportionalMinimum' or 'FixedMinimum';
- minimumOutdoorAirFlowScheduleID – minimum outdoor air schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, the minimum outdoor air will be always the same;
- economizerType – 'NoEconomizer', 'FixedDryBulb', 'FixedEnthalpy', 'DifferentialDryBulb', 'DifferentialEnthalpy', 'FixedDewPointAndDryBulb', 'ElectronicEnthalpy' or 'DifferentialDryBulbAndEnthalpy';
- economizerLockout – 'NoLockout', 'LockoutWithHeating' or 'LockoutWithCompressor';
- economizerMaximumLimitDryBulbTemperature – outdoor air temperature high limit for economizer operation [°C]. If blank, there is no outdoor air temperature high limit control. Required if economizerType = FixedDryBulb or FixedDewPointAndDryBulb;
- economizerMaximumLimitEnthalpy – outdoor air upper enthalpy limit for economizer operation [J/kg]. If blank or zero, there is no outdoor air enthalpy limit control;
- economizerMaximumLimitDewpointTemperature – outdoor air dewpoint limit in Celsius for economizer operation. If blank, there is no outdoor air dewpoint limit control. Only used if economizerType = FixedDewPointAndDryBulb;
- economizerMinimumLimitDryBulbTemperature – outdoor air temperature low limit for economizer operation [°C]. If blank or zero, there is no outdoor air temperature low limit control;
- supplyFanPartLoadPowerCoefficients – 'InletVaneDampers', 'OutletDampers', 'VariableSpeedMotor', 'ASHRAE90_1$1$2004AppendixG'' or 'VariableSpeedMotorPressureReset';
- nightCycleControl – 'StayOff', 'CycleOnAny', 'CycleOnControlZone' or 'CycleOnAnyZoneFansOnly';
- heatRecoveryType – 'None', 'Sensible' or 'Enthalpy';
- sensibleHeatRecoveryEffectiveness – sensible heat recovery effectiveness;
- latentHeatRecoveryEffectiveness – latent heat recovery effectiveness. Only used if heatRecoveryType = Enthalpy;

- coolingCoilSetpointResetType – 'None', 'Warmest', 'OutdoorAirTemperatureReset' or 'WarmestTemperatureFirst';
- heatingCoilSetpointResetType – 'None' or 'OutdoorAirTemperatureReset';
- dehumificationControlType – 'None' or 'CoolReheat';
- dehumidificationSetpoint – zone humidistat setpoint for dehumidification in percent;
- humidifierType – 'None' or 'ElectricSteam';
- humidifierAvailabilityScheduleID – humidifier availability schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If blank, humidifier is always available;
- humidifierRatedCapacity – rated moisture output rate in m3/s;
- humidifierRatedElectricPower – electric power input at the rated capacity moisture output [W]. 'autosize' option is available, for which the field "Do System Sizing Calculation" should be set to Yes in the Simulation Control (x2 = true in section **17**);
- humidifierSetpoint – zone humidistat setpoint for humidification in percent;
- sizingOption – 'NonCoincident' or 'Coincident';
- hasReturnFan – 'Yes' or 'No';
- returnFanTotalEfficiency – total efficiency of the return fan;
- returnFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- returnFanMotorEfficiency – shaft power of the return fan divided by the electrical power consumed;
- returnFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- returnFanPartLoadPowerCoefficients – 'InletVaneDampers', 'OutletDampers', 'VariableSpeedMotor', 'ASHRAE90_1$1$2004AppendixG'' or 'VariableSpeedMotorPressureReset';
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – name of the packaged VAV system, defined in the first argument of the HVACTemplateSystemPackagedVAVSpec() above;
- Supply Plenum Name – name of the zone that serves as a supply plenum for this system, defined in the argument x1 of the HVACTemplateSystemPackagedVAVSpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x2 of the HVACTemplateSystemPackagedVAVSpec() above;
- Night Cycle Control Zone Name – zone name where the night cycle control is located (if any), defined in the argument x3 of the HVACTemplateSystemPackagedVAVSpec() above;
- Dehumidification Control Zone Name – zone name where the dehumidification control is located (if any), defined in the argument x4 of the HVACTemplateSystemPackagedVAVSpec() above;
- Humidifier Control Zone Name – zone name where the humidistat is located for controlling humidification (if any), defined in the argument x5 of the HVACTemplateSystemPackagedVAVSpec() above.

Note: even when not setting any of the above fields to 'autosize', the "Do System Sizing Calculation" field should be set to Yes in the Simulation Control (x2 = true in section **17**). This is due to the fact that the HVAC Template System Packaged VAV object is internally converted by EnergyPlus to an Air Loop HVAC object (with the expand file), for which an autosized field is assigned, thus requiring a system sizing. Moreover, as system sizing cannot be done without zone sizing, the “Do Zone Sizing Calculation" field should also be set to Yes in the Simulation Control (x1 = true in section **17**).

Zone unit

There are 3 VAV zone types that can be assigned to zones: VAV, VAV Fan Powered, and VAV Heat and Cool.

a) VAV

The HVAC Template zone terminal unit properties are defined in the **HVACTemplateZoneVAV** table in the database, corresponding to the HVACTemplate:Zone:VAV object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- supplyAirMaximumFlowRate – maximum supply air flow rate into the zone in m3/s. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- zoneCoolingSizingFactor – zone level cooling sizing ratio. The zone design cooling air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Cooling Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- zoneMinimumAirFlowMethod – ‘Constant’, ‘FixedFlowRate’ or ‘Scheduled’;
- constantMinimumAirFlowFraction – minimum flow rate to the zone while the system is operating, specified as a fraction of the maximum air flow rate. Used if zoneMinimumAirFlowMethod = Constant;
- fixedMinimumAirFlowRate – minimum flow rate to the zone while the system is operating, specified as a fixed minimum air flow rate [m3/s]. Used if zoneMinimumAirFlowMethod = FixedFlowRate;
- minimumAirFlowFractionScheduleID – minimum air flow fraction schedule ID, defined in the Schedules table in the database (**21**). Used if zoneMinimumAirFlowMethod = Scheduled;
- outdoorAirMethod – ‘Flow_Person’, ‘Flow_Area’, ‘Flow_Zone’, ‘Sum’, ‘Maximum’ or ‘DetailedSpecification’;
- outdoorAirFlowRatePerPerson – design outdoor air flow rate per person for this zone in m3/s. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [m3/s.m2]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirflowRatePerZone – design outdoor air flow rate for this zone in m3/s. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;

- reheatCoilType – 'Gas', 'Electric', 'HotWater' or 'None'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- reheatCoilAvailabilityScheduleID – reheat coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- damperHeatingAction – 'Reverse' or 'Normal';
- maximumFlowPerZoneFloorAreaDuringReheat – this factor (m3/s.m2) is multiplied by the zone area, to determine the maximum volume flow rate (m3/s) allowed during reheat operation. 'autocalculate' option is available. If blank, the maximum flow will not be limited;
- maximumFlowFractionDuringReheat – this fraction is multiplied by the Maximum Air Flow Rate to determine the maximum volume flow rate (m3/s) allowed during reheat operation. 'autocalculate' option is available. If blank, the maximum flow will not be limited;
- maximumReheatAirTemperature – maximum allowable supply air temperature leaving the reheat coil in a VAV terminal unit during heating operation [°C]. If blank, there is no limit, and the supply air temperature to the space may become unrealistically high during heating operation;
- baseboardHeatingType – 'None', 'HotWater' or 'Electric'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- baseboardHeatingAvailabilityScheduleID – baseboard heating availability schedule ID, defined in the Schedules table in the database (**21**). If blank, the baseboard heating is always available;
- baseboardHeatingCapacity – maximum amount of heat that the baseboard heating can deliver in W. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- zoneCoolingDesignAirTemperatureInputMethod – 'SystemSupplyAirTemperature', 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneCoolingDesignAirTemperature – supply air temperature in Celsius for the zone cooling design air flow rate calculation and cooling coil sizing. Only used if zoneCoolingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneCoolingDesignAirTemperatureDifference – temperature difference between the cooling design supply air temperature and the zone air temperature in Celsius for the zone cooling design air flow rate calculation and cooling coil sizing. Only used if zoneCoolingDesignAirTemperatureInputMethod = TemperatureDifference;
- zoneHeatingDesignAirTemperatureInputMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneHeatingDesignAirTemperature – supply air temperature in Celsius for the zone heating design air flow rate calculation and heating coil sizing. Only used if zoneHeatingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneHeatingDesignAirTemperatureDifference – temperature difference between heating design supply air temperature and zone air temperature in degrees Celsius for the zone heating design air flow rate calculation and heating coil sizing. Only used if zoneHeatingDesignAirTemperatureInputMethod = TemperatureDifference;

- designSpecificationOutdoorAirForControlID – ID of the object which specifies the outdoor air requirements for control and schedule for this unit, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**);
- designSpecificationOutdoorAirForSizingID – ID of the object which specifies the outdoor air requirements for sizing and schedule for this unit, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationZoneAirDistributionID – ID of the object which specifies the zone air distribution requirements and schedule for this unit, defined in table **DesignSpecificationZoneAirDistribution** in the database (see section **13.1.2**). Only used if outdoorAirMethod = DetailedSpecification;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template VAV System Name – name of the VAV system serving this unit, defined in section **6.13.1** or **6.13.2**, entered as the first argument in the HVACTemplateZoneVAVSpec() above;
- Template Thermostat Name – name of the thermostat assigned for the zone, defined in the first argument of the HVACTemplateZoneVAVSpec() above;
- Supply Plenum Name – name of the zone that serves as a supply plenum for this unit, defined in the argument x1 of the HVACTemplateZoneVAVSpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x2 of the HVACTemplateZoneVAVSpec() above.

Note: even when not setting any of the above fields to 'autosize', the "Do Zone Sizing Calculation" field should be set to Yes in the Simulation Control (x1 = true in section **17**). This is due to the fact that the HVAC Template Zone VAV object is internally converted by EnergyPlus to an Air Terminal Single Duct Uncontrolled object (with the expand file), for which an autosized air flow rate field is assigned, thus requiring a zone sizing.

b) VAV Fan Powered

The HVAC Template zone terminal unit properties are defined in the **HVACTemplateZoneVAVFanPowered** table in the database, corresponding to the HVACTemplate:Zone:VAV:FanPowered object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- primarySupplyAirMaximumFlowRate – primary maximum supply air flow rate into the zone [m3/s]. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;

- zoneCoolingSizingFactor – zone level cooling sizing ratio. The zone design cooling air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Cooling Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- primarySupplyAirMinimumFlowFraction – fraction that the VAV box can reduce to based on the primary supply air maximum flow rate. 'autosize' option is available;
- secondarySupplyAirMaximumFlowRate – secondary maximum supply air flow rate into the zone [m3/s]. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- flowType – 'Series', 'Parallel', 'SeriesFromPlenum' or 'ParallelFromPlenum';
- parallelFanOnFlowFraction – for parallel PIUs, this field specifies the fraction of the primary air flow at which fan turns on. This field does not apply to series PIUs;
- outdoorAirMethod – 'Flow_Person', 'Flow_Area', 'Flow_Zone', 'Sum', 'Maximum' or 'DetailedSpecification';
- outdoorAirFlowRatePerPerson – design outdoor air flow rate per person for this zone in m3/s. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [m3/s.m2]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirflowRatePerZone – design outdoor air flow rate for this zone in m3/s. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;
- reheatCoilType – 'Gas', 'Electric' or 'HotWater'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- reheatCoilAvailabilityScheduleID – reheat coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- fanTotalEfficiency – total efficiency of the zone induction fan;
- fanDeltaPressure – pressure rise of the zone induction fan in Pa at full flow and standard conditions;
- fanMotorEfficiency – shaft power of the zone induction fan divided by the electrical power consumed;
- baseboardHeatingType – 'None', 'HotWater' or 'Electric'. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- baseboardHeatingAvailabilityScheduleID – baseboard heating availability schedule ID, defined in the Schedules table in the database (**21**). If blank, the baseboard heating is always available;
- baseboardHeatingCapacity – maximum amount of heat that the baseboard heating can deliver in W. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- zoneCoolingDesignAirTemperatureInputMethod – 'SystemSupplyAirTemperature', 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneCoolingDesignAirTemperature – supply air temperature in Celsius for the zone cooling design air flow rate calculation and cooling coil sizing. Only used if zoneCoolingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneCoolingDesignAirTemperatureDifference – temperature difference between the cooling design supply air temperature and the zone air temperature in Celsius for the

zone cooling design air flow rate calculation and cooling coil sizing. Only used if zoneCoolingDesignAirTemperatureInputMethod = TemperatureDifference;

- zoneHeatingDesignAirTemperatureInputMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneHeatingDesignAirTemperature – supply air temperature in Celsius for the zone heating design air flow rate calculation and heating coil sizing. Only used if zoneHeatingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneHeatingDesignAirTemperatureDifference – temperature difference between heating design supply air temperature and zone air temperature in degrees Celsius for the zone heating design air flow rate calculation and heating coil sizing. Only used if zoneHeatingDesignAirTemperatureInputMethod = TemperatureDifference;
- zonePIUFanScheduleID – zone PIU fan schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the System Availability Schedule for the HVAC Template System serving this zone will be used;
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this unit, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationZoneAirDistributionID – ID of the object which specifies the zone air distribution requirements and schedule for this unit, defined in table **DesignSpecificationZoneAirDistribution** in the database (see section **13.1.2**). Only used if outdoorAirMethod = DetailedSpecification;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template VAV System Name – name of the VAV system serving this unit, defined in section **6.13.1** or **6.13.2**, entered as the first argument in the HVACTemplateZoneVAVFanPoweredSpec() above;
- Template Thermostat Name – name of the thermostat assigned for the zone, defined in the first argument of the HVACTemplateZoneVAVFanPoweredSpec() above;
- Supply Plenum Name – name of the zone that serves as a supply plenum for this unit, defined in the argument x1 of the HVACTemplateZoneVAVFanPoweredSpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x2 of the HVACTemplateZoneVAVFanPoweredSpec() above.

Note: even when not setting any of the above fields to 'autosize', the "Do Zone Sizing Calculation" field should be set to Yes in the Simulation Control (x1 = true in section **17**). This is due to the fact that the HVAC Template Zone VAV Fan Powered object is internally converted by EnergyPlus to an Air Terminal Single Duct Uncontrolled object (with the expand file), for which an autosized air flow rate field is assigned, thus requiring a zone sizing.

c) <u>VAV Heat and Cool</u>

The HVAC Template zone terminal unit properties are defined in the **HVACTemplateZoneVAVHeatAndCool** table in the database, corresponding to the

HVACTemplate:Zone:VAV:HeatAndCool object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- supplyAirMaximumFlowRate – maximum supply air flow rate into the zone in m3/s. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- zoneCoolingSizingFactor – zone level cooling sizing ratio. The zone design cooling air flow rate and load will be multiplied by the number input in this field when supplyAirMaximumFlowRate = autosize. If blank, the Cooling Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- constantMinimumAirFlowFraction – minimum flow rate to the zone while the system is operating, specified as a fraction of the maximum air flow rate;
- outdoorAirMethod – ‘Flow_Person’, ‘Flow_Area’, ‘Flow_Zone’, ‘Sum’, ‘Maximum’ or ‘DetailedSpecification’;
- outdoorAirFlowRatePerPerson – design outdoor air flow rate per person for this zone in m3/s. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowRatePerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [m3/s.m2]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirflowRatePerZone – design outdoor air flow rate for this zone in m3/s. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;
- designSpecificationOutdoorAirForSizingID – ID of the object which specifies the outdoor air requirements for sizing and schedule for this unit, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). Only used if outdoorAirMethod = DetailedSpecification;
- designSpecificationZoneAirDistributionID – ID of the object which specifies the zone air distribution requirements and schedule for this unit, defined in table **DesignSpecificationZoneAirDistribution** in the database (see section **13.1.2**). Only used if outdoorAirMethod = DetailedSpecification;
- reheatCoilType – ‘Gas’, ‘Electric’, ‘HotWater’ or ‘None’. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);
- reheatCoilAvailabilityScheduleID – reheat coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- maximumReheatAirTemperature – maximum allowable supply air temperature leaving the reheat coil in a VAV terminal unit during heating operation [°C]. If blank, there is no limit, and the supply air temperature to the space may become unrealistically high during heating operation;
- baseboardHeatingType – ‘None’, ‘HotWater’ or ‘Electric’. HotWater requires an HVAC Template Plant Hot Water Loop to serve as the water source (**6.15.2**), with one or more HVAC Template Plant Boilers (**6.16.1**);

- baseboardHeatingAvailabilityScheduleID – baseboard heating availability schedule ID, defined in the Schedules table in the database (**21**). If blank, the baseboard heating is always available;
- baseboardHeatingCapacity – maximum amount of heat that the baseboard heating can deliver in W. 'autosize' option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- zoneCoolingDesignAirTemperatureInputMethod – 'SystemSupplyAirTemperature', 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneCoolingDesignAirTemperature – supply air temperature in Celsius for the zone cooling design air flow rate calculation and cooling coil sizing. Only used if zoneCoolingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneCoolingDesignAirTemperatureDifference – temperature difference between the cooling design supply air temperature and the zone air temperature in Celsius for the zone cooling design air flow rate calculation and cooling coil sizing. Only used if zoneCoolingDesignAirTemperatureInputMethod = TemperatureDifference;
- zoneHeatingDesignAirTemperatureInputMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneHeatingDesignAirTemperature – supply air temperature in Celsius for the zone heating design air flow rate calculation and heating coil sizing. Only used if zoneHeatingDesignAirTemperatureInputMethod = SupplyAirTemperature;
- zoneHeatingDesignAirTemperatureDifference – temperature difference between heating design supply air temperature and zone air temperature in degrees Celsius for the zone heating design air flow rate calculation and heating coil sizing. Only used if zoneHeatingDesignAirTemperatureInputMethod = TemperatureDifference;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned;
- Template VAV System Name – name of the VAV system serving this unit, defined in section **6.13.1** or **6.13.2**, entered as the first argument in the HVACTemplateZoneVAVHeatAndCoolSpec() above;
- Template Thermostat Name – name of the thermostat assigned for the zone, defined in the first argument of the HVACTemplateZoneVAVHeatAndCoolSpec() above;
- Supply Plenum Name – name of the zone that serves as a supply plenum for this unit, defined in the argument x1 of the HVACTemplateZoneVAVHeatAndCoolSpec() above;
- Return Plenum Name – name of the zone that serves as a return plenum for this system, defined in the argument x2 of the HVACTemplateZoneVAVHeatAndCoolSpec() above.

Note: even when not setting any of the above fields to 'autosize', the "Do Zone Sizing Calculation" field should be set to Yes in the Simulation Control (x1 = true in section **17**). This is due to the fact that the HVAC Template Zone VAV Heat and Cool object is internally converted by EnergyPlus to an Air Terminal Single Duct Uncontrolled object (with the expand file), for which an autosized air flow rate field is assigned, thus requiring a zone sizing.

6.14. Dedicated Outdoor Air System

If the Dedicated Outdoor Air System heating coil type is 'Hot Water', a Template Plant Hot Water Loop (**6.15.2**) and a Template Plant Boiler (**6.16.1**) must be defined (see section **6.1**). If the Dedicated Outdoor Air System cooling coil type is 'Chilled Water', 'Chilled Water Detailed Flat Model' or 'Heat Exchanger Assisted Chilled Water', a Template Plant Chilled Water Loop (**6.15.1**), and a Template Plant Chiller (**6.16.2**) must be defined (see section **6.1**).

The specification of the Dedicated Outdoor Air System is defined in the SAPTool_LSP building template, as presented below. The assignment to the building's HVAC template system is defined in the SAPTool_LSP building template, as presented in section **6.1**.

String systemDedicatedOutdoorAirName = DBHVACTemplateSystemDedicatedOutdoorType.ABC.toString() – HVAC Template Dedicated Outdoor Air System name, defined using the DBHVACTemplateSystemDedicatedOutdoorType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);

TemplateSystemDedicatedOutdoorAirSpec hvacTemplateSystemDedicatedOutdoorAirSpec = new TemplateSystemDedicatedOutdoorAirSpec() – HVAC Template Dedicated Outdoor Air System specification (named hvacTemplateSystemDedicatedOutdoorAirSpec in this example). It has the following TemplateSystemDedicatedOutdoorAirSpec() arguments:

- **systemDedicatedOutdoorAirName** – HVAC Template Dedicated Outdoor Air System name, defined above;
- **DBHVACTemplateSystemDedicatedOutdoorType.ABC.getID** – ID of the outdoor air system properties in the database, defined using the DBHVACTemplateSystemDedicatedOutdoorType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The HVAC Template Dedicated Outdoor Air System properties are defined in the **HVACTemplateSystemDedicatedOutdoorAir** table in the database, corresponding to the HVACTemplate:System:DedicatedOutdoorAir object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- systemAvailabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the system is always available;
- airOutletType – 'DirectIntoZone' (currently, there is only this option in EnergyPlus);
- supplyFanFlowRate – upper limit on system flow in m3/s, even if the zone air flow inputs sum to a greater value. 'autosize' option is available, which sets the system maximum air-flow rate to the sum of the zone air flow rates;
- supplyFanTotalEfficiency – total efficiency of the supply fan;
- supplyFanDeltaPressure – pressure rise in Pa at full flow and standard conditions;
- supplyFanMotorEfficiency – shaft power of the supply fan divided by the electrical power consumed;

- supplyFanMotorInAirStreamFraction – fraction of the motor heat that is added to the air stream;
- supplyFanPlacement – 'BlowThrough' or 'DrawThrough';
- coolingCoilType – 'None', 'ChilledWater', 'ChilledWaterDetailedFlatModel', 'TwoSpeedDX', 'TwoStageDX', 'TwoStageHumidityControlDX', 'HeatExchangerAssistedChilledWater' or 'HeatExchangerAssistedDX';
- coolingCoilAvailabilityScheduleID – cooling coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- coolingCoilSetpointControlType – 'FixedSetpoint', 'Scheduled' or 'OutdoorAirTemperatureReset';
- coolingCoilSetpointScheduleID – cooling coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Only used if coolingCoilSetpointControlType = Scheduled;
- coolingCoilDesignSetpoint – cooling supply air temperature in Celsius to be used for sizing the cooling coil and zone supply air flow rates. Only used if coolingCoilSetpointControlType = FixedSetpoint;
- coolingCoilSetpointAtOutdoorDryBulbLow – cooling coil supply air setpoint temperature in Celsius when the outdoor dry-bulb temperature is at or below the low limit (coolingCoilResetOutdoorDryBulbLow). Only used if coolingCoilSetpointControlType = OutdoorAirTemperatureReset;
- coolingCoilResetOutdoorDryBulbLow – low limit of outdoor dry-bulb temperature in Celsius for outdoor air reset control. Only used if coolingCoilSetpointControlType = OutdoorAirTemperatureReset;
- coolingCoilSetpointAtOutdoorDryBulbHigh – cooling coil supply air setpoint temperature in Celsius when the outdoor dry-bulb temperature is at or above the high limit (coolingCoilResetOutdoorDryBulbHigh). Only used if coolingCoilSetpointControlType = OutdoorAirTemperatureReset;
- coolingCoilResetOutdoorDryBulbHigh – high limit of outdoor dry-bulb temperature in Celsius for outdoor air reset control. Only used if coolingCoilSetpointControlType = OutdoorAirTemperatureReset;
- dxCoolingCoilGrossRatedTotalCapacity – full load gross total cooling capacity, including both sensible and latent capacity, in W of the DX coil unit at rated conditions. 'autosize' option is available;
- dxCoolingCoilGrossRatedSensibleHeatRatio – ratio of the gross sensible capacity divided by gross total cooling capacity of the DX cooling coil at rated conditions. 'autosize' option is available;
- dxCoolingCoilGrossRatedCOP – coefficient of performance defined as the gross cooling coil total capacity in W divided by electrical power input in watts of the DX cooling coil unit at rated conditions;
- heatingCoilType – 'None', 'HotWater', 'Electric' or 'Gas';
- heatingCoilAvailabilityScheduleID – heating coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- heatingCoilSetpointControlType – 'FixedSetpoint', 'Scheduled' or 'OutdoorAirTemperatureReset';
- heatingCoilSetpointScheduleID – heating coil setpoint schedule ID, defined in the **Schedules** table in the database (**21**). Only used if heatingCoilSetpointControlType = Scheduled;

- heatingCoilDesignSetpoint – heating supply air temperature in Celsius to be used for sizing the heating coil and zone supply air flow rates. Only used if heatingCoilSetpointControlType = FixedSetpoint;
- heatingCoilSetpointAtOutdoorDryBulbLow – heating coil supply air setpoint temperature in Celsius when the outdoor dry-bulb temperature is at or below the low limit (heatingCoilResetOutdoorDryBulbLow). Only used if heatingCoilSetpointControlType = OutdoorAirTemperatureReset;
- heatingCoilResetOutdoorDryBulbLow – low limit of outdoor dry-bulb temperature in Celsius for outdoor air reset control. Only used if heatingCoilSetpointControlType = OutdoorAirTemperatureReset;
- heatingCoilSetpointAtOutdoorDryBulbHigh – heating coil supply air setpoint temperature in Celsius when the outdoor dry-bulb temperature is at or above the high limit (heatingCoilResetOutdoorDryBulbHigh). Only used if heatingCoilSetpointControlType = OutdoorAirTemperatureReset;
- heatingCoilResetOutdoorDryBulbHigh – high limit of outdoor dry-bulb temperature in Celsius for outdoor air reset control. Only used if heatingCoilSetpointControlType = OutdoorAirTemperatureReset;
- gasHeatingCoilEfficiency – gas burner efficiency (decimal, not percent);
- gasHeatingCoilParasiticElectricLoad – parasitic electric load associated with the gas heating coil operation [W];
- heatRecoveryType – ‘None’, ‘Sensible’ or ‘Enthalpy’;
- sensibleHeatRecoveryEffectiveness – sensible heat recovery effectiveness;
- latentHeatRecoveryEffectiveness – latent heat recovery effectiveness. Only used if sensibleHeatRecoveryEffectiveness = Enthalpy;
- heatExchangerType – ‘Plate’ or ‘Rotary’;
- frostControlType – ‘None’, ‘ExhaustAirRecirculation’, ‘ExhaustOnly’ or ‘MinimumExhaustTemperature’;
- dehumidificationControlType – ‘None’, ‘CoolReheatHeatingCoil’, ‘CoolReheatDesuperheater’ or ‘Multimode’;
- dehumidificationSetpoint – supply air humidity ratio setpoint for dehumidification in kgWater/kgDryAir;
- humidifierType – ‘None’ or ‘ElectricSteam’;
- humidifierAvailabilityScheduleID – humidifier availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the humidifier is always available;
- humidifierRatedCapacity – rated moisture output rate in m3/s;
- humidifierRatedElectricPower – electric power input at the rated capacity moisture output [W]. ‘autosize’ option is available;
- humidifierSetpoint – supply air humidity ratio setpoint for humidification in kgWater/kgDryAir;
- dehumidificationSetpointScheduleID – dehumidification setpoint schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the setpoint will be constant at the dehumidificationSetpoint value;
- humidifierSetpointScheduleID – humidifier setpoint schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the setpoint will be constant at the humidifierSetpoint value.

Automatic filling fields in EnergyPlus:

- Name – systemDedicatedOutdoorAirName defined above**.**

6.15. Plant Loops

The assignment of these objects to the building's HVAC template system is defined in the SAPTool_LSP building template, as presented in section **6.1**.

6.15.1. Chilled Water Plant Loop

The specification of the Chilled Water Plant Loop is defined in the SAPTool_LSP building template, as follows:

HVACTemplatePlantChilledWaterLoopSpec hvacTemplatePlantChilledWaterLoopSpec = new HVACTemplatePlantChilledWaterLoopSpec() – HVAC Template Chilled Water Plant Loop specification (named hvacTemplatePlantChilledWaterLoopSpec in this example). With the following HVACTemplatePlantChilledWaterLoopSpec() arguments:

- **DBHVACTemplatePlantChilledWaterLoopType.ABC.toString()** – plant loop name, defined using the DBHVACTemplatePlantChilledWaterLoopType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **DBHVACTemplatePlantChilledWaterLoopType.ABC.getID** – ID of the plant loop properties in the database, defined using the DBHVACTemplatePlantChilledWaterLoopType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The HVAC Template Chilled Water Plant Loop properties are defined in the **HVACTemplatePlantChilledWaterLoop** table in the database, corresponding to the HVACTemplate:Plant: ChilledWaterLoop object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- pumpScheduleID – chilled water and condenser water pumps schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the pumps are always available;
- pumpControlType – 'Intermittent' or 'Continuous'. Applies to both chilled water and condenser loop pumps;
- chilledWaterSetpointScheduleID – chilled water setpoint schedule ID, defined in the **Schedules** table in the database (**21**). If blank, a constant setpoint is used (defined in the next field). This field is ignored if chilledWaterSetpointResetType ≠ None;
- chilledWaterDesignSetpoint – chilled water setpoint temperature to be used for sizing the chilled water loop and associated equipment [°C];
- chilledWaterPumpConfiguration – 'ConstantPrimaryNoSecondary' or 'VariablePrimaryNoSecondary' or 'ConstantPrimaryVariableSecondary';
- primaryChilledWaterPumpRatedHead – rated head of the primary chilled water pump [Pa];

- secondaryChilledWaterPumpRatedHead – rated head of the secondary chilled water pump [Pa]. Only used if chilledWaterPumpConfiguration = ConstantPrimaryVariableSecondary;
- condenserWaterTemperatureControlType – 'SpecifiedSetpoint' or 'OutdoorWetBulbTemperature';
- condenserWaterSetpointScheduleID – schedule ID of setpoint temperatures for the condenser water loop [°C], defined in the **Schedules** table in the database (**21**). Ignored if condenserWaterTemperatureControlType = OutdoorWetBulbTemperature. May be left blank if constant setpoint temperature is used for the condenser water temperature. May also be left blank if not serving any water-cooled chillers;
- condenserWaterDesignSetpoint – condenser water temperature to be used for sizing the condenser loop and associated equipment [°C]. May be left blank if not serving any water-cooled chillers. Only used when condenserWaterTemperatureControlType = SpecifiedSetpoint;
- condenserWaterPumpRatedHead – rated head of the condenser water pumps [Pa]. May be left blank if not serving any water-cooled chillers;
- chilledWaterSetpointResetType – 'None' or 'OutdoorAirTemperatureReset';
- chilledWaterSetpointAtOutdoorDryBulbLow – chilled water setpoint temperature when the outdoor dry-bulb is at or below the low limit (chilledWaterResetOutdoorDryBulbLow) [°C];
- chilledWaterResetOutdoorDryBulbLow – low limit of outdoor dry-bulb temperature for outdoor air reset control [°C];
- chilledWaterSetpointAtOutdoorDryBulbHigh – chilled water setpoint temperature when the outdoor dry-bulb is at or above the high limit (chilledWaterResetOutdoorDryBulbHigh) [°C];
- chilledWaterResetOutdoorDryBulbHigh – high limit of outdoor dry-bulb temperature for outdoor air reset control [°C];
- chilledWaterPrimaryPumpType – 'SinglePump', 'PumpPerChiller', 'TwoHeaderedPumps', 'ThreeHeaderedPumps', 'FourHeaderedPumps' or 'FiveHeaderedPumps';
- chilledWaterSecondaryPumpType – 'SinglePump', 'TwoHeaderedPumps', 'ThreeHeaderedPumps', 'FourHeaderedPumps' or 'FiveHeaderedPumps';
- condenserWaterPumpType – 'SinglePump', 'PumpPerTower', 'TwoHeaderedPumps', 'ThreeHeaderedPumps', 'FourHeaderedPumps' or 'FiveHeaderedPumps';
- hasChilledWaterSupplySideBypassPipe – '1' (Yes) or '2' (No);
- hasChilledWaterDemandSideBypassPipe – '1' (Yes) or '2' (No);
- hasCondenserWaterSupplySideBypassPipe – '1' (Yes) or '2' (No);
- hasCondenserWaterDemandSideBypassPipe – '1' (Yes) or '2' (No);
- fluidType – 'Water', 'EthyleneGlycol30', 'EthyleneGlycol40', 'EthyleneGlycol50', 'EthyleneGlycol60', 'PropyleneGlycol30', 'PropyleneGlycol40', 'PropyleneGlycol50' or 'PropyleneGlycol60';
- loopDesignDeltaTemperature – temperature difference used in sizing the loop flow rate;
- minimumOutdoorDryBulbTemperature – minimum outdoor dry bulb temperature that the chilled water loops operate [°C];
- chilledWaterLoadDistributionScheme – 'SequentialLoad', 'Optimal', 'UniformLoad', 'SequentialUniformPLR' or 'UniformPLR';

- condenserWaterLoadDistributionScheme – ‘SequentialLoad’, ‘Optimal’, ‘UniformLoad’, ‘SequentialUniformPLR’ or ‘UniformPLR’;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – “CWL” + loopName (loopName – loop name defined in the Plant Loop specification – first argument of the HVACTemplatePlantChilledWaterLoopSpec() above);
- Chiller Water Plant Operation Scheme Type – considered ‘default’, in order to not define a detailed plant equipment operation scheme;
- Chilled Water Plant Equipment Operation Schemes Name – considered null, as the previous field is set as ‘default’;
- Condenser Plant Operation Scheme Type – considered ‘default’, in order to not define a detailed plant equipment operation scheme;
- Condenser Water Plant Equipment Operation Schemes Name – considered null, as the previous field is set as ‘default’.

The corresponding detailed version of this template object can be defined as presented in section **9.1** (Plant Loop).

An example of this template object usage can be found in the SingleStoreyFamilyHouse_HVACT_Fancoil in the SAPTool_LSP.

6.15.2. Hot Water Plant Loop

The specification of the Hot Water Plant Loop is defined in the SAPTool_LSP building template, as follows:

HVACTemplatePlantHotWaterLoopSpec hvacTemplatePlantHotWaterLoopSpec = new HVACTemplatePlantHotWaterLoopSpec() – HVAC Template Hot Water Plant Loop specification (named hvacTemplatePlantHotWaterLoopSpec in this example). With the following HVACTemplatePlantHotWaterLoopSpec() arguments:

- **DBHVACTemplatePlantHotWaterLoopType.ABC.toString()** – plant loop name, defined using the DBHVACTemplatePlantHotWaterLoopType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **DBHVACTemplatePlantHotWaterLoopType.ABC.getID** – ID of the plant loop properties in the database, defined using the DBHVACTemplatePlantHotWaterLoopType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The HVAC Template Hot Water Plant Loop properties are defined in the **HVACTemplatePlantHotWaterLoop** table in the database, corresponding to the

HVACTemplate:Plant:HotWaterLoop object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- pumpScheduleID – pump schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the hot water pump is always available;
- pumpControlType – 'Intermittent' or 'Continuous';
- hotWaterSetpointScheduleID – hot water setpoint schedule ID, defined in the **Schedules** table in the database (**21**). If blank, a constant setpoint is used (defined in the next field). This field is ignored if hotWaterSetpointResetType ≠ None;
- hotWaterDesignSetpoint – hot water setpoint temperature to be used for sizing the hot water loop and associated equipment in Celsius;
- hotWaterPumpConfiguration – 'ConstantFlow' or 'VariableFlow';
- hotWaterPumpRatedHead – rated head of the hot water pump in Pa;
- hotWaterSetpointResetType – 'None' or 'OutdoorAirTemperatureReset';
- hotWaterSetpointAtOutdoorDryBulbLow – hot water setpoint temperature in Celsius when the outdoor dry-bulb is at or below the low limit (hotWaterResetOutdoorDryBulbLow);
- hotWaterResetOutdoorDryBulbLow – low limit of outdoor dry-bulb temperature in Celsius for outdoor air reset control;
- hotWaterSetpointAtOutdoorDryBulbHigh – hot water setpoint temperature in Celsius when the outdoor dry-bulb is at or above the high limit (hotWaterResetOutdoorDryBulbHigh);
- hotWaterResetOutdoorDryBulbHigh – high limit of outdoor dry-bulb temperature in Celsius for outdoor air reset control;
- hotWaterPumpType – 'SinglePump', 'PumpPerBoiler', 'TwoHeaderedPumps', 'ThreeHeaderedPumps', 'FourHeaderedPumps' or 'FiveHeaderedPumps';
- hasSupplySideBypassPipe – '1' (Yes) or '2' (No);
- hasDemandSideBypassPipe – '1' (Yes) or '2' (No);
- fluidType – 'Water', 'EthyleneGlycol30', 'EthyleneGlycol40', 'EthyleneGlycol50', 'EthyleneGlycol60', 'PropyleneGlycol30', 'PropyleneGlycol40', 'PropyleneGlycol50' or 'PropyleneGlycol60';
- loopDesignDeltaTemperature – temperature difference used in sizing the loop flow rate;
- maximumOutdoorDryBulbTemperature – maximum outdoor dry bulb temperature that the hot water loops operate in Celsius;
- loadDistributionScheme – 'SequentialLoad', 'Optimal', 'UniformLoad', 'SequentialUniformPLR' or 'UniformPLR';
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – "HWL" + loopName (loopName – loop name defined in the Plant Loop specification – first argument of the HVACTemplatePlantHotWaterLoopSpec() above);
- Hot Water Plant Operation Scheme Type – considered 'default', in order to not define a detailed plant equipment operation scheme;
- Hot Water Plant Equipment Operation Schemes Name – considered null, as the previous field is set as 'default'.

The corresponding detailed version of this template object can be defined as presented in section **9.1** (Plant Loop).

An example of this template object usage can be found in the SingleStoreyFamilyHouse_HVACT_BaseboardHeat template in the SAPTool_LSP.

6.15.3. Mixed Water Plant Loop

The specification of the Mixed Water Plant Loop is defined in the SAPTool_LSP building template, as follows:

HVACTemplatePlantMixedWaterLoopSpec hvacTemplatePlantMixedWaterLoopSpec = new HVACTemplatePlantMixedWaterLoopSpec() – HVAC Template Mixed Water Plant Loop specification (named hvacTemplatePlantMixedWaterLoopSpec in this example). With the following HVACTemplatePlantMixedWaterLoopSpec() arguments:

- **DBHVACTemplatePlantMixedWaterLoopType.ABC.toString()** – plant loop name, defined using the DBHVACTemplatePlantMixedWaterLoopType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **DBHVACTemplatePlantMixedWaterLoopType.ABC.getID** – ID of the plant loop properties in the database, defined using the DBHVACTemplatePlantMixedWaterLoopType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The HVAC Template Mixed Water Plant Loop properties are defined in the **HVACTemplatePlantMixedWaterLoop** table in the database, corresponding to the HVACTemplate:Plant:MixedWaterLoop object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- pumpScheduleID – pump schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the hot water pump is always available;
- pumpControlType – 'Intermittent' or 'Continuous';
- highTemperatureSetpointScheduleID – high temperature setpoint setpoint schedule ID, defined in the **Schedules** table in the database (**21**). If blank, a constant setpoint is used (defined in the next field);
- highTemperatureDesignSetpoint – high temperature setpoint temperature to be used for sizing the water loop and associated equipment [°C];
- lowTemperatureSetpointScheduleID – low temperature setpoint setpoint schedule ID, defined in the **Schedules** table in the database (**21**). If blank, a constant setpoint is used (defined in the next field);
- lowTemperatureDesignSetpoint – low temperature setpoint temperature to be used for sizing the water loop and associated equipment [°C];
- waterPumpConfiguration – 'ConstantFlow' or 'VariableFlow';
- waterPumpRatedHead – rated head of the hot water pump [Pa];

- waterPumpType – ‘SinglePump’, ‘PumpPerTowerOrBoiler’, ‘TwoHeaderedPumps’, ‘ThreeHeaderedPumps’, ‘FourHeaderedPumps’ or ‘FiveHeaderedPumps’;
- hasSupplySideBypassPipe – ‘1’ (Yes) or ‘2’ (No);
- hasDemandSideBypassPipe – ‘1’ (Yes) or ‘2’ (No);
- fluidType – ‘Water’, ‘EthyleneGlycol30’, ‘EthyleneGlycol40’, ‘EthyleneGlycol50’, ‘EthyleneGlycol60’, ‘PropyleneGlycol30’, ‘PropyleneGlycol40’, ‘PropyleneGlycol50’ or ‘PropyleneGlycol60’;
- loopDesignDeltaTemperature – temperature difference used in sizing the loop flow rate [°C];
- loadDistributionScheme – ‘SequentialLoad’, ‘Optimal’, ‘UniformLoad’, ‘SequentialUniformPLR’ or ‘UniformPLR’;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – “MWL” + loopName (loopName – loop name defined in the Plant Loop specification – first argument of the HVACTemplatePlantMixedWaterLoopSpec() above);
- Operation Scheme Type – considered ‘default’, in order to not define a detailed plant equipment operation scheme;
- Operation Scheme Name – considered null, as the previous field is set as ‘default’.

The corresponding detailed version of this template object can be defined as presented in section **9.1** (Plant Loop).

An example of this template object usage can be found in the SingleStoreyFamilyHouse_HVACT_WaterToAirHP template in the SAPTool_LSP.

6.16. Plant heating and cooling equipment

The assignment of these objects to the building’s HVAC template system is defined in the SAPTool_LSP building template, as presented in section **6.1**.

6.16.1. Plant Boiler

The specification of the Plant Boiler is defined in the SAPTool_LSP building template, as follows:

HVACTemplatePlantBoilerSpec hvacTemplatePlantBoilerSpec = new HVACTemplatePlantBoilerSpec() – HVAC Template Plant Boiler specification (named hvacTemplatePlantBoilerSpec in this example). With the following HVACTemplatePlantBoilerSpec() arguments:

- **DBHVACTemplatePlantBoilerType.ABC.toString()** – boiler name, defined using the DBHVACTemplatePlantBoilerType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **BoilerLoopType.XXX.toString()** – XXX = ‘HotWater’ or ‘MixedWater’;

- **DBHVACTemplatePlantBoilerType.ABC.getID** – ID of the boiler properties in the database, defined using the DBHVACTemplatePlantBoilerType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The HVAC Template Plant Boiler properties are defined in the **HVACTemplatePlantBoiler** table in the database, corresponding to the HVACTemplate:Plant:Boiler object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- boilerType – 'DistrictHotWater', 'HotWaterBoiler' or 'CondensingHotWaterBoiler';
- capacity – design heating capacity [W]. 'autosize' option is available;
- efficiency – efficiency of the boiler's burner (as a fraction between 0 and 1);
- fuelType – 'Electricity', 'NaturalGas', 'PropaneGas', 'FuelOil_1', 'FuelOil_2', 'Coal', 'Diesel', 'Gasoline', 'OtherFuel1' or 'OtherFuel2'. Not applicable if boilerType = DistrictHotWater;
- priority – priority number of the boiler, where 1 is the highest priority, 2 is just lower, 3 is lower than 2, etc.;
- sizingFactor – boiler sizing factor. Used only when the boiler design inputs are autosized;
- minimumPartLoadRatio – boiler minimum part load ratio;
- maximumPartLoadRatio – boiler maximum part load ratio;
- optimumPartLoadRatio – boiler optimum part load ratio;
- waterOutletUpperTemperatureLimit – boiler outlet temperature upper limit in Celsius;
- description – optional object description, for guidance;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – boiler name assigned in the Plant Boiler specification (first argument of the HVACTemplatePlantBoilerSpec() above);
- Template Plant Loop Type – specifies whether this boiler will serve a Hot Water Loop (**6.15.2**) or a Mixed Water Loop (**6.15.3**) (second argument of the HVACTemplatePlantBoilerSpec() above).

The corresponding detailed version of this template object can be defined as presented in section **8.5.1** (Boiler Hot Water), if boilerType = HotWaterBoiler or CondensingHotWaterBoiler or as presented in section **8.5.6** (District Heating), if boilerType = DistrictHotWater.

An example of this template object usage can be found in the SingleStoreyFamilyHouse_HVACT_BaseboardHeat template in the SAPTool_LSP.

6.16.2. Plant Chiller

The specification of the Plant Chiller is defined in the SAPTool_LSP building template, as follows:

HVACTemplatePlantChillerSpec hvacTemplatePlantChillerSpec = new HVACTemplatePlantChillerSpec() – HVAC Template Plant Chiller specification (named hvacTemplatePlantChillerSpec in this example). With the following HVACTemplatePlantChillerSpec() arguments:

- **DBHVACTemplatePlantChillerType.ABC.toString()** – chiller name, defined using the DBHVACTemplatePlantChillerType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **DBHVACTemplatePlantChillerType.ABC.getID** – ID of the chiller properties in the database, defined using the DBHVACTemplatePlantChillerType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The HVAC Template Plant Chiller properties are defined in the **HVACTemplatePlantChiller** table in the database, corresponding to the HVACTemplate:Plant:Chiller object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- chillerType – ‘DistrictChilledWater’, ‘ElectricCentrifugalChiller’, ‘ElectricScrewChiller’ or ‘ElectricReciprocatingChiller’;
- capacity – design cooling capacity [W]. ‘autosize’ option is available;
- nominalCOP – chiller’s coefficient of performance;
- condenserType – ‘AirCooled’, ‘WaterCooled’ or ‘EvaporativelyCooled’. Not applicable if chillerType = DistrictChilledWater. If condenserType = WaterCooled, at least one Plant Tower object should be defined (**6.16.3**);
- priority – priority number of the chiller, where 1 is the highest priority, 2 is just lower, 3 is lower than 2, etc.;
- sizingFactor – chiller sizing factor. Used only when the chiller design inputs are autosized;
- minimumPartLoadRatio – chiller minimum part load ratio;
- maximumPartLoadRatio – chiller maximum part load ratio;
- optimumPartLoadRatio – chiller optimum part load ratio;
- minimumUnloadingRatio – chiller minimum unloading ratio;
- leavingChilledWaterLowerTemperatureLimit – lower limit for the leaving chilled water temperature [°C]. This temperature acts as a cut off for heat transfer in the evaporator, so that the fluid doesn’t get too cold;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – chiller name assigned in the Plant Chiller specification (first argument of the HVACTemplatePlantChillerSpec() above).

The corresponding detailed version of this template object can be defined as presented in section **8.5.3** (Chiller Electric EIR), if chillerType = ElectricCentrifugalChiller, ElectricScrewChiller or ElectricReciprocatingChiller or as presented in section **8.5.7** (District Cooling), if chillerType = DistrictChilledWater.

An example of this template object usage can be found in the SingleStoreyFamilyHouse_HVACT_Fancoil template in the SAPTool_LSP.

6.16.3. Plant Tower

The specification of the Plant Tower is defined in the SAPTool_LSP building template, as follows:

HVACTemplatePlantTowerSpec hvacTemplatePlantTowerSpec = new HVACTemplatePlantTowerSpec() – HVAC Template Plant Tower specification (named hvacTemplatePlantTowerSpec in this example). With the following HVACTemplatePlantTowerSpec() arguments:

- **DBHVACTemplatePlantTowerType.ABC.toString()** – tower name, defined using the DBHVACTemplatePlantTowerType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **TowerLoopType.XXX.toString()** – XXX = ‘ChilledWater’ or ‘MixedWater’;
- **DBHVACTemplatePlantTowerType.ABC.getID** – ID of the tower properties in the database, defined using the DBHVACTemplatePlantTowerType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The HVAC Template Plant Towerproperties are defined in the **HVACTemplatePlantTower** table in the database, corresponding to the HVACTemplate:Plant:Tower object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- towerType – ‘SingleSpeed’ or ‘TwoSpeed’;
- highSpeedNominalCapacity – “nominal” heat rejection capacity of the cooling tower [W] under high-speed fan operation, with entering water at 35 °C (95 °F), leaving water at 29.4 °C (85 °F), entering air at 25.6 °C (78 °F) wetbulb and 35 °C (95 °F) drybulb temperatures. ‘autosize’ option is available. If this field is set to autosize, then the fields lowSpeedNominalCapacity and freeConvectionCapacity must also be autosized;
- highSpeedFanPower – tower fan electric consumption when at high speed [W]. ‘autosize’ option is available;
- lowSpeedNominalCapacity – “nominal” heat rejection capacity of the cooling tower in watts under low-speed fan operation, with entering water at 35 °C (95 °F), leaving water at 29.4 °C (85 °F), entering air at 25.6 °C (78 °F) wetbulb and 35 °C (95 °F) drybulb temperatures. ‘autosize’ option is available. If this field is set to autosize, then the fields highSpeedNominalCapacity and freeConvectionCapacity must also be autosized. Only used if towerType = TwoSpeed;
- lowSpeedFanPower – tower fan electric consumption when at low speed [W]. ‘autosize’ option is available. Only used if towerType = TwoSpeed;
- freeConvectionCapacity – “nominal” heat rejection capacity of the cooling tower in watts when the tower is in the “free convection” regime (water flow exists but tower fan is turned off), with entering water at 35 °C (95 °F), leaving water at 29.4 °C (85 °F), entering air at 25.6 °C (78 °F) wetbulb and 35 °C (95 °F) drybulb temperatures. ‘autosize’

option is available. If this field is set to autosize, then the fields highSpeedNominalCapacity and lowSpeedNominalCapacity must also be autosized;

- priority – priority number of the tower, where 1 is the highest priority, 2 is just lower, 3 is lower than 2, etc.;
- sizingFactor – tower sizing factor. Used only when the tower design inputs are autosized;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – tower name assigned in the Plant Tower specification (first argument of the HVACTemplatePlantTowerSpec() above);
- Template Plant Loop Type – specifies whether this tower will serve a Chilled Water Loop (**6.15.1**) or a Mixed Water Loop (**6.15.3**) (second argument of the HVACTemplatePlantTowerSpec() above).

The corresponding detailed version of this template object can be defined as presented in section **8.6.1.1** (Tower Single Speed), if towerType = SingleSpeed or as presented in section **8.6.1.2** (Tower Two Speed), if towerType = TwoSpeed.

An example of this template object usage can be found in the SingleStoreyFamilyHouse_HVACT_Fancoil template in the SAPTool_LSP.

7. ZONE HVAC

7.1. Equipment

7.1.1. Zone HVAC Ideal Loads Air System

The specification of a Zone HVAC Ideal Loads Air System is defined in the SAPTool_LSP building template for each different zone, as defined below. The Zone HVAC Ideal Loads Air System option must be active (**ZONE_HVAC_IDEAL_LOADS_AIR_SYSTEM = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and “Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**).

ZoneHVACIdealLoadsAirSystemSpec zoneHVACIdealLoadsAirSystemSpec_LivingRoom = new ZoneHVACIdealLoadsAirSystemSpec() – Zone HVAC Ideal Loads Air System specification (named zoneHVACIdealLoadsAirSystemSpec_LivingRoom in this example). With the following ZoneHVACIdealLoadsAirSystemSpec() arguments:

- **x1** – if humidificationControlType = “Humidstat" in the **ZoneHVACIdealLoadsAirSystem** table in the database (see below), the ID of the humidistat control zone in the **Zone** table (zoneControlHumidistatID in section **0**) must be assigned here (corresponding to the zone for which this zone system is defined), using the DBSpaceType list object (for example, **DBSpaceType.LIVING_ROOM.getID()** to assign the humidistat to the Living Room zone). Alternatively, the proper database ID can be directly inputted here. **null** if not defined;
- **x2** – ID of the Zone HVAC Ideal Loads Air System properties in the database for this zone, in the **ZoneHVACIdealLoadsAirSystem** table (see below);
- **db** – database unique ID.

The Zone HVAC Ideal Loads Air System properties are defined in the **ZoneHVACIdealLoadsAirSystem** table in the database, corresponding to the ZoneHVAC:IdealLoadsAirSystem object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**);
- maximumHeatingSupplyAirTemperature – maximum air temperature of the air used for heating the zone [°C];
- minimumCoolingSupplyAirTemperature – minimum air temperature of the air used for cooling the zone [°C];
- maximumHeatingSupplyAirHumidityRatio – maximum humidity ratio of the hot supply air [kgWater/kgDryAir];
- minimumCoolingSupplyAirHumidityRatio – minimum humidity ratio of the cold supply air [kgWater/kgDryAir];

- heatingLimitType – ‘LimitFlowRate’, ‘LimitCapacity’, ‘LimitFlowRateAndCapacity’ or ‘NoLimit’;
- maximumHeatingAirflowRate – maximum heating supply air flow rate in m3/s, if heatingLimitType = LimitFlowRate or LimitFlowRateAndCapacity. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- maximumSensibleHeatingCapacity – maximum allowed sensible heating capacity in W, if heatingLimitType = LimitCapacity or LimitFlowRateAndCapacity. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- coolingLimitType – ‘LimitFlowRate’, ‘LimitCapacity’, ‘LimitFlowRateAndCapacity’ or ‘NoLimit’;
- maximumCoolingAirflowRate – maximum cooling supply air flow rate in m3/s, if coolingLimitType = LimitFlowRate or LimitFlowRateAndCapacity. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- maximumTotalCoolingCapacity – maximum allowed sensible cooling capacity in W, if coolingLimitType = LimitCapacity or LimitFlowRateAndCapacity. ‘autosize’ option is available, for which the field "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**);
- heatingAvailabilityScheduleID – heating availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, heating and humidification are always available;
- coolingAvailabilityScheduleID – cooling availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, cooling and dehumidification are always available;
- humidificationControlType – ‘None’, ‘Humidistat’, ‘ConstantSensibleHeatRatio’ or ‘ConstantSupplyHumidityRatio’;
- coolingSensibleHeatRatio – Sensible Cooling divided by Total Cooling (sensible plus latent). Only used if dehumidificationControlType = ConstantSensibleHeatRatio;
- humidificationControlType – ‘None’, ‘Humidistat’ or ‘ConstantSupplyHumidityRatio’. If ‘Humidistat’ is selected, a Zone Control Humidistat is assigned to the zone, for what it should be assigned to the zone in the Zone table (section **0**) and defined in section **7.2.2**;
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this system, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**). If blank, this system will have no outdoor air, and all outdoor air control and heat recovery options will be ignored;
- demandControlledVentilationType – ‘None’, ‘OccupancySchedule’ or ‘CO2Setpoint’. For CO2Setpoint, the minimum outdoor air flow rate may be increased if necessary to maintain the level of indoor CO_2 at or below the setpoint defined in the Contaminant Controller object (**7.2.3**);
- outdoorAirEconomizerType – ‘DifferentialDryBulb’, ‘DifferentialEnthalpy’ or ‘NoEconomizer’;
- heatRecoveryType – ‘None’, ‘Sensible’ or ‘Enthalpy’;
- sensibleHeatRecoveryEffectiveness – change in supply temperature divided by the difference in entering supply and relief air temperatures;

- latentHeatRecoveryEffectiveness – change in supply humidity ratio divided by the difference in entering supply and relief air humidity ratios;
- designSpecificationZoneHVACSizingID – ID of the object which defines scalable sizing methods for sizing input fields such as Maximum Heating Air Flow Rate and Maximum Cooling Air Flow Rate in a Ideal Load Air System zone HVAC object, defined in table **DesignSpecificationZoneHVACSizing** in the database (see section **13.1.3**) (optional);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – IdealLoadsName = Zone Name + "HVAC_ILAS" (Zone Name – name of the zone for which the Zone HVAC Ideal Loads Air System is assigned);
- Zone Supply Air Node Name – IdealLoadsName + "OUTLET_NODE". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + "AIR_INLET_NODES"), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**);
- Zone Exhaust Air Node Name – IdealLoadsName + "EXHAUST_NODE". This node is automatically assigned to the zone air exhaust node list (automatically named Zone Name + "AIR_EXHAUST_NODES"), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Exhaust Node List in the Equipment Connections (see section **7.1.9**);
- System Inlet Air Node Name – optional name of the return plenum outlet node (or induced air outlet node) connected to the ideal loads object. Considered null, as no plenum objects are yet implemented;
- Outdoor Air Inlet Node Name – IdealLoadsName + "OUTDOOR_AIR_INLET_NODE". This node is only assigned if an Outdoor Air Object is assigned to the system (designSpecificationOutdoorAirID ≠ blank).

The Zone HVAC Ideal Loads Air System specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_LivingRoom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object ('ABC', in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **"ABC"**). The available options are: ABC = 'SequentialLoad', 'UniformLoad', 'UniformPLR' or 'SequentialUniformPLR';
- **new ArrayList<>()** – array list which will include the Zone HVAC Ideal Loads Air System specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;

- **DBSpaceType.LIVING_ROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Ideal Loads Air System is assigned, defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

zoneHVACSpec_LivingRoom.addSpec() – Used to add the Zone HVAC Ideal Loads Air System specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following arguments:

- **zoneHVACIdealLoadsAirSystemSpec_LivingRoom** – the Zone HVAC Ideal Loads Air System specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Ideal Loads Air System cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_LivingRoom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

As this Zone HVAC Ideal Loads Air System is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the Zone HVAC Equipment List and Equipment Connections objects in EnergyPlus, as presented in section **7.1.9**.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_ZoneIdealLoads template in the SAPTool_LSP.

7.1.2. Zone HVAC Low Temperature Radiant Variable Flow

The specification of a Zone HVAC Low Temperature Radiant Variable Flow unit is defined in the SAPTool_LSP building template for each different zone, as defined below. This object must then be assigned to a HVAC loop system – see section **9**. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**).

The Zone HVAC Low Temperature Radiant System option must be active (**ZONE_HVAC_LOW_TEMPERATURE_RADIANT_SYSTEM = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

ZoneHVACLowTemperatureRadiantVariableFlowSpec zoneHVACLowTemperatureRadiantVariableFlowSpec_LivingRoom = new ZoneHVACLowTemperatureRadiantVariableFlowSpec() – Zone HVAC Low Temperature Radiant Variable Flow specification (named zoneHVACLowTemperatureRadiantVariableFlowSpec_LivingRoom in this example). With the following ZoneHVACLowTemperatureRadiantVariableFlowSpec() arguments:

- **x** – ID of the Zone HVAC Low Temperature Radiant Variable Flow properties in the database for this zone, in the **ZoneHVACLowTemperatureRadiantVariableFlow** table (see below);
- **db** – database unique ID.

The Zone HVAC Low Temperature Radiant Variable Flow properties are defined in the **ZoneHVACLowTemperatureRadiantVariableFlow** table in the database, corresponding to the ZoneHVAC:LowTemperatureRadiant:VariableFlow object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**);
- hydronicTubingInsideDiameter – inside diameter of the tubes through which water is circulated for the system [m];
- hydronicTubingLength – total length of pipe embedded in the surface [m]. 'autosize' option is available;
- temperatureControlType – 'MeanAirTemperature', 'MeanRadiantTemperature', 'OperativeTemperature', 'OutdoorDryBulbTemperature' or 'OutdoorWetBulbTemperature';
- heatingDesignCapacityMethod – 'None', 'HeatingDesignCapacity', 'CapacityPerFloorArea' or 'FractionOfAutosizedHeatingCapacity';

- heatingDesignCapacity – design heating capacity in W, used if heatingDesignCapacityMethod = HeatingDesignCapacity. ‘autosize’ option is available. If autosized, a zone sizing run must be specified (see section **13.2.2** for details);
- heatingDesignCapacityPerFloorArea – heating capacity per unit floor area in W/m2. Used if heatingDesignCapacityMethod = CapacityPerFloorArea;
- fractionOfAutosizedHeatingDesignCapacity – heating capacity as a fraction of the autosized heating capacity. Used if heatingDesignCapacityMethod = FractionOfAutosizedHeatingCapacity;
- maximumHotWaterFlow – maximum flow rate of hot water through the radiant system in m3/s. ‘autosize’ option is available;
- heatingControlThrottlingRange – range of temperature in degrees Celsius over which the radiant system throttles from zero flow rate up to the maximum defined by the maximum hot water flow rate field described above;
- heatingControlTemperatureScheduleID – heating setpoint or control temperature schedule ID, defined in the **Schedules** table in the database (**21**);
- coolingDesignCapacityMethod – ‘None’, ‘CoolingDesignCapacity’, ‘CapacityPerFloorArea’ or ‘FractionOfAutosizedCoolingCapacity’;
- coolingDesignCapacity – design cooling capacity in W. Used if coolingDesignCapacityMethod = CoolingDesignCapacity. ‘autosize’ option is available. If autosized, a zone sizing run must be specified (see section **13.2.2** for details);
- coolingDesignCapacityPerFloorArea – cooling capacity per unit floor area in W/m2, used if coolingDesignCapacityMethod = CapacityPerFloorArea;
- fractionOfAutosizedCoolingDesignCapacity – cooling capacity as a fraction of the autosized cooling capacity. Used if coolingDesignCapacityMethod = FractionOfAutosizedCoolingCapacity;
- maximumColdWaterFlow – maximum flow rate of cold water through the radiant system in m3/s. ‘autosize’ option is available. This field is optional and not required for a heating only system;
- coolingControlThrottlingRange – range of temperature in degrees Celsius over which the radiant system throttles from zero flow rate up to the maximum defined by the maximum cold water flow rate field described above;
- coolingControlTemperatureScheduleID – cooling setpoint or control temperature schedule ID, defined in the **Schedules** table in the database (**21**);
- condensationControlType – ‘Off’ or ‘SimpleOff’;
- condensationControlDewpointOffset – difference between the calculated dew-point temperature of the space and the allowed surface temperature to which the surface can drop before the radiant system shuts down in degrees Celsius (optional). Used only if condensationControlType = SimpleOff;
- numberOfCircuits – ‘OnePerSurface’ or ‘CalculateFromCircuitLength’;
- circuitLength – length in meters of each parallel hydronic circuit in a surface, used if numberOfCircuits = CalculateFromCircuitLength;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the HVAC loop branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – ZoneLowTempRadName = “HVAC_LOW_TEMP_RAD” + Zone Name + “DEMAND”;
- Zone Name – name of the zone for which the Zone HVAC Low Temperature Radiant Variable Flow unit is assigned;
- Surface Name or Radiant Surface Group Name – name of the zone floor surface, where the Zone HVAC Low Temperature Radiant Variable Flow unit is placed*;
- Heating Water Inlet Node Name – ZoneLowTempRadName + “Hot_Water_Inlet_node”, if the HVAC Low Temperature Radiant Variable Flow unit is assigned to a heating circuit loop (CircuitType argument of PlantLoopSpec() – see section **9.1**);
- Heating Water Outlet Node Name – ZoneLowTempRadName + “Hot_Water_Outlet_node”, if the one HVAC Low Temperature Radiant Variable Flow unit is assigned to a heating circuit loop (CircuitType argument of PlantLoopSpec() – see section **9.1**);
- Cooling Water Inlet Node Name – ZoneLowTempRadName + “Cold_Water_Inlet_node”, if the HVAC Low Temperature Radiant Variable Flow unit is assigned to a cooling circuit loop (CircuitType argument of PlantLoopSpec() – see section **9.1**);
- Cooling Water Outlet Node Name – ZoneLowTempRadName + “Cold_Water_Outlet_node”, if the one HVAC Low Temperature Radiant Variable Flow unit is assigned to a cooling circuit loop (CircuitType argument of PlantLoopSpec() – see section **9.1**).

* When a Zone HVAC Low Temperature Radiant Variable Flow unit is assigned to a zone, its floor surface is automatically replaced by an internal source surface object, while maintaining the same surface layers. Its properties are defined in the **OpaqueElementRadiantLayer** table in the database, corresponding to the Construction:InternalSource object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- radiantLayerAfterConstructionLayerNumber – location of the heat source or sink in relation to the surface layers;
- dimensionsForTheCTFCalculation – detail level of the calculation: one-dimensional (‘1’) or two-dimensional (‘2’);
- tubeSpacing – defines how far apart in meters the hydronic tubing are spaced in the direction perpendicular to the main direction of heat transfer. Only used for two-dimensional solutions.

Automatic filling fields in EnergyPlus:

- Name – Zone Name + “Radiant_Surfaces” (Zone Name – name of the zone for which this object is assigned);
- Temperature Calculation Requested After Layer Number – equals to radiantLayerAfterConstructionLayerNumber;
- Outside Layer – outside layer of the zone floor surface;
- Layer X – remaining layers of the zone floor surface.

The Zone HVAC Low Temperature Radiant Variable Flow specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_LivingRoom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object ('ABC', in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **"ABC"**). The available options are: ABC = 'SequentialLoad', 'UniformLoad', 'UniformPLR' or 'SequentialUniformPLR';
- **new ArrayList<>()** – array list which will include the Zone HVAC Low Temperature Radiant Variable Flow specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.LIVING_ROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Low Temperature Radiant Variable Flow is assigned, defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

zoneHVACSpec_LivingRoom.addSpec() – Used to add the Zone HVAC Low Temperature Radiant Variable Flow specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following arguments:

- **zoneHVACLowTemperatureRadiantVariableFlowSpec_LivingRoom** – the Zone HVAC Low Temperature Radiant Variable Flow specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Low Temperature Radiant Variable Flow cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_LivingRoom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

As this Zone HVAC Low Temperature Radiant Variable Flow is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the Zone HVAC Equipment List and Equipment Connections objects in EnergyPlus, as presented in section **7.1.9**.

The Low Temperature Radiant Variable Flow unit must be assigned to a hot water loop demand side brach (see section **9.3**) in order to feed the unit.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_RadiantFloor template in the SAPTool_LSP.

7.1.3. Zone HVAC Baseboard

7.1.3.1. Convective Water

The specification of a Zone HVAC Baseboard Convective Water unit is defined in the SAPTool_LSP building template for each different zone, as defined below. This object must then be assigned to a HVAC loop system – see section **9**. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**).

The Zone HVAC Baseboard Convective Water System option must be active (**ZONE_HVAC_BASEBOARD_CONVECTIVE_WATER_SYSTEM = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

ZoneHVACBaseboardConvectiveWaterSpec zoneHVACBaseboardConvectiveWaterSpec_DoubleBedroom = new ZoneHVACBaseboardConvectiveWaterSpec() – Zone HVAC Baseboard Convective Water specification (named zoneHVACBaseboardConvectiveWaterSpec_DoubleBedroom in this example). With the following ZoneHVACBaseboardConvectiveWaterSpec() arguments:

- **x** – ID of the Zone HVAC Baseboard Convective Water properties in the database for this zone, in the **ZoneHVACBaseboardConvectiveWater** table (see below);
- **db** – database unique ID.

The Zone HVAC Baseboard Convective Water properties are defined in the **ZoneHVACBaseboardConvectiveWater** table in the database, corresponding to the ZoneHVAC:Baseboard:Convective:Water object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the equipment is always available;
- heatingDesignCapacityMethod – 'HeatingDesignCapacity', 'CapacityPerFloorArea' or 'FractionOfAutosizedHeatingCapacity';
- heatingDesignCapacity – hot water baseboard heater design heating capacity in W. Used if heatingDesignCapacityMethod = HeatingDesignCapacity. 'autosize' option is available. If autosized, a zone sizing run must be specified (see section **13.2.2** for details);
- heatingDesignCapacityPerFloorArea – heating capacity per unit floor area in W/m2. Used if heatingDesignCapacityMethod = CapacityPerFloorArea;
- fractionOfAutosizedHeatingDesignCapacity – heating capacity as a fraction of the autosized heating capacity. Used if heatingDesignCapacityMethod = FractionOfAutosizedHeatingCapacity;
- uFactorTimesAreaValue – overall heat transfer coefficient for the baseboard heater in watts per degree Celsius at design conditions. 'autosize' option is available;
- maximumWaterFlowRate – maximum hot water volumetric flow rate in m3/s. 'autosize' option is available;
- convergenceTolerance – control tolerance for the unit heating output;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the HVAC loop branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – ZoneBasebConvWatName = Zone Name + "HVAC_BASEBOARD_CONV_WAT" + "DEMAND";
- Inlet Node Name – ZoneBasebConvWatName + "Inlet_node";
- Outlet Node Name – ZoneBasebConvWatName + "Outlet_node".

The Zone HVAC Baseboard Convective Water specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_DoubleBedroom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object ('ABC', in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **"ABC"**). The available options are: ABC = 'SequentialLoad', 'UniformLoad', 'UniformPLR' or 'SequentialUniformPLR';

- **new ArrayList<>()** – array list which will include the Zone HVAC Baseboard Convective Water specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Baseboard Convective Water is assigned, defined using the DBSpaceType list object (Double Bedroom, in this example);
- **db** – database unique ID.

zoneHVACSpec_DoubleBedroom.addSpec() – Used to add the Zone HVAC Baseboard Convective Water specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following arguments:

- **zoneHVACBaseboardConvectiveWaterSpec_DoubleBedroom** – the Zone HVAC Baseboard Convective Water specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Baseboard Convective Water cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object (“SCH1”, in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object (“SCH2”, in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_DoubleBedroom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Double bedroom, in this example);

- **db** – database unique ID.

As this Zone HVAC Baseboard Convective Water is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the ZoneHVAC:EquipmentList and ZoneHVAC:EquipmentConnections objects in EnergyPlus, as presented in section **7.1.9**.

The Baseboard Convective Water unit must be assigned to a hot water loop demand side brach (see section **9.3**) in order to feed the unit.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_BaseboardConvWater template in the SAPTool_LSP.

7.1.3.2. Convective Electric

The specification of a Zone HVAC Baseboard Convective Electric unit is defined in the SAPTool_LSP building template for each different zone, as defined below. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**).

The Zone HVAC Baseboard Convective Electric System option must be active (**ZONE_HVAC_BASEBOARD_CONVECTIVE_ELECTRIC_SYSTEM = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

ZoneHVACBaseboardConvectiveElectricSpec zoneHVACBaseboardConvectiveElectricSpec_DoubleBedroom = new ZoneHVACBaseboardConvectiveElectricSpec() – Zone HVAC Baseboard Convective Electric specification (named zoneHVACBaseboardConvectiveElectricSpec_DoubleBedroom in this example). With the following ZoneHVACBaseboardConvectiveElectricSpec() arguments:

- **x** – ID of the Zone HVAC Baseboard Convective Electric properties in the database for this zone, in the **ZoneHVACBaseboardConvectiveElectric** table (see below);
- **db** – database unique ID.

The Zone HVAC Baseboard Convective Electric properties are defined in the **ZoneHVACBaseboardConvectiveElectric** table in the database, corresponding to the ZoneHVAC:Baseboard:Convective:Electric object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the equipment is always available;
- heatingDesignCapacityMethod – 'HeatingDesignCapacity', 'CapacityPerFloorArea' or 'FractionOfAutosizedHeatingCapacity';

- heatingDesignCapacity – convective electric baseboard nominal heating capacity in W. Used if heatingDesignCapacityMethod = HeatingDesignCapacity. 'autosize' option is available. If autosized, a zone sizing run must be specified (see section **13.2.2** for details);
- heatingDesignCapacityPerFloorArea – heating capacity per unit floor area in W/m2. Used if heatingDesignCapacityMethod = CapacityPerFloorArea;
- fractionOfAutosizedHeatingDesignCapacity – heating capacity as a fraction of the autosized heating capacity. Used if heatingDesignCapacityMethod = FractionOfAutosizedHeatingCapacity;
- efficiency – overall electrical efficiency of the electric baseboard;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – ZoneBasebConvElectName = Zone Name + "HVAC_BASEBOARD_CONV_ELECT" (Zone Name – name of the zone for which the Zone HVAC Baseboard Convective Electric unit is assigned).

The Zone HVAC Baseboard Convective Electric specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_DoubleBedroom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object ('ABC', in this example), in the Zone HVAC Equipment List (see section **7.1.9**) , in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **"ABC"**). The available options are: ABC = 'SequentialLoad', 'UniformLoad', 'UniformPLR' or 'SequentialUniformPLR';
- **new ArrayList<>()** – array list which will include the Zone HVAC Baseboard Convective Electric specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Baseboard Convective Electric is assigned, defined using the DBSpaceType list object (Double Bedroom, in this example);
- **db** – database unique ID.

zoneHVACSpec_DoubleBedroom.addSpec() – Used to add the Zone HVAC Baseboard Convective Electric specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following arguments:

- **zoneHVACBaseboardConvectiveElectricSpec_DoubleBedroom** – the Zone HVAC Baseboard Convective Electric specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Baseboard Convective Electric cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_DoubleBedroom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Double bedroom, in this example);
- **db** – database unique ID.

As this Zone HVAC Baseboard Convective Electric is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the ZoneHVAC:EquipmentList and ZoneHVAC:EquipmentConnections objects in EnergyPlus, as presented in section **7.1.9**.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_BaseboardConvElectric template in the SAPTool_LSP.

7.1.4. Zone HVAC Four Pipe Fancoil

The specification of a Zone HVAC Four Pipe Fan Coil unit is defined in the SAPTool_LSP building template for each different zone, as defined below. This object must then be assigned to a HVAC loop system – see section **9**. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and “Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**).

The Zone HVAC Four Pipe Fan Coil System option must be active (**ZONE_HVAC_FOUR_PIPE_FANCOIL = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

ZoneHVACFourPipeFancoilSpec zoneHVACFourPipeFancoilSpec_DoubleBedroom = new ZoneHVACFourPipeFancoilSpec() – Zone HVAC Four Pipe Fan Coil specification (named zoneHVACFourPipeFancoilSpec_DoubleBedroom in this example). With the following ZoneHVACFourPipeFancoilSpec() arguments:

- **x1** – has (“true”) or not (“false”) an Outdoor Air Mixer. An OA mixer should not be present only if the fan coil unit is connected to central dedicated outdoor air through an Air Terminal Single Duct Mixer object (not yet implemented);
- **x2** – name of the supply air fan specification assigned to this fan coil unit. The valid supply air fan types currently available are: Fan On-Off (**8.8.2**), Fan Constant Volume (**8.8.3**), and Fan Variable Volume (**8.8.4**);
- **x3** – name of the cooling coil specification assigned to this fan coil unit. The valid coil types currently available are: Coil Cooling Water (**8.9.1.9**) and Coil Cooling Water Detailed Geometry (**8.9.1.10**). The coil is automatically assigned to a plant loop for cold water source when the fan coil unit is assigned to a loop equipment brach (see section **9.3**);
- **x4** – name of the heating coil specification assigned to this fan coil unit. The valid coil types currently available are: Coil Heating Water (**8.9.2.10**) and Coil Heating Electric (**8.9.2.6**). The coil is automatically assigned to a plant loop for hot water source when the fan coil unit is assigned to a loop equipment brach (see section **9.3**);
- **x5** – ID of the Zone HVAC Four Pipe Fan Coil properties in the database for this zone, in the **ZoneHVACFourPipeFanCoil** table (see below);
- **db** – database unique ID.

An availability manager, if defined, must be assigned to the fan coil unit as follows:

zoneHVACFourPipeFancoilSpec_DoubleBedroom.addAvailabilityManager(ams) – assigns the ams availability manager to the fan coil zoneHVACFourPipeFancoilSpec_DoubleBedroom. Currently, there is only one availability manager type implemented that can be used by a fan coil unit: Scheduled (**15.1**).

The Zone HVAC Four Pipe Fan Coil properties are defined in the **ZoneHVACFourPipeFanCoil** table in the database, corresponding to the ZoneHVAC:FourPipeFanCoil object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the equipment is always available;

- capacityControlMethod – ‘ConstantFanVariableFlow’, ‘CyclingFan’, ‘VariableFanVariableFlow’, ‘VariableFanConstantFlow’, ‘MultiSpeedFan’ or ‘ASHRAE90VariableFan’;
- maximumSupplyAirFlowRate – maximum volumetric airflow rate through the fan coil unit [m^3/s]. This is also the design, rated airflow rate of the unit. ‘autosize’ option is available;
- lowSpeedSupplyAirFlowRatio – ratio of the low speed flow rate to the maximum supply air flow rate. This value should be less than the mediumSpeedSupplyAirFlowRatio. If left blank, the default value is 0.33. Leave this field blank if the capacityControlMethod is not ‘CyclingFan’ or ‘ASHRAE90VariableFan’. The suggested value is 0.5 when using the ‘ASHRAE90VariableFan’ capacity control method;
- mediumSpeedSupplyAirFlowRatio – ratio of the medium speed flow rate to the maximum supply air flow rate. Its value should be greater than the lowSpeedSupplyAirFlowRatio but less than 1. If blank, the default value is 0.66. Leave this field blank if the capacityControlMethod selected is not ‘CyclingFan’ or ‘MultiSpeedFan’;
- maximumOutdoorAirFlowRate – outdoor air volumetric flow rate, if the fan coil unit uses outdoor air [m^3/sec]. This flow rate should be less than or equal to the maximumSupplyAirFlowRate. A value of zero specifies no outdoor air. This field is set to zero flow when the FanCoil is connected to an Air Terminal Single Duct Mixer object (not yet implemented). ‘autosize’ option is available;
- outdoorAirScheduleID – schedule ID of the values (0.0 to 1.0) that are used as multipliers to alter the outdoor air flow rate, defined in the **Schedules** table in the database (**21**). If blank, the values will default to 1.0;
- maximumColdWaterFlowRate – maximum cold water volumetric flow rate through the fan coil unit’s cooling coil [m^3/s]. ‘autosize’ option is available;
- minimumColdWaterFlowRate – minimum cold water volumetric flow rate through the fan coil unit’s cooling coil [m^3/s];
- coolingConvergenceTolerance – convergence tolerance for the control of the unit cooling output. The unit is controlled by matching the unit output to the zone demand. For units with water coils, the model must be numerically inverted to obtain a specified output. The cooling convergence tolerance is the error tolerance used to terminate the numerical inversion procedure;
- maximumHotWaterFlowRate – maximum hot water volumetric flow rate [m^3/sec] through the fan coil unit’s heating coil. This field is not used with an electric heating coil. ‘autosize’ option is available;
- minimumHotWaterFlowRate – maximum hot water volumetric flow rate [m^3/sec] through the fan coil unit’s heating coil. This field is not used with an electric heating coil;
- heatingConvergenceTolerance – convergence tolerance for the control of the unit heating output. The unit is controlled by matching the unit output to the zone demand. For units with water coils, the model must be numerically inverted to obtain a specified output. The heating convergence tolerance is the error tolerance used to terminate the numerical inversion procedure;
- designSpecificationZoneHVACSizingID – ID of the object which defines scalable sizing methods for sizing input fields such as Maximum Air Flow Rate in this Four Pipe FanCoil zone HVAC object, defined in table **DesignSpecificationZoneHVACSizing** in the database (see section **13.1.3**) (optional);

- supplyFanOperatingScheduleID – fan operation control schedule ID, defined in the **Schedules** table in the database (**21**). Values of 0 denote cycling fan operation (fan cycles with heating or cooling coil) and values greater than 0 denote constant fan operation (fan runs continually regardless of coil operation). If blank, the fan operating mode defaults to cycling fan operation. This input field is only used if capacityControlMethod = 'MultiSpeedFan';
- minimumSupplyAirTemperatureInCoolingMode – minimum supply air temperature in cooling mode [°C] (optional). Only used when capacityControlMethod = 'ASHRAE90VariableFan'. 'autosize' option is available. When the fan coil capacity is greater than the zone load, the fan speed will modulate down to the minimum fan speed, based on the lowSpeedSupplyAirFlowRatio, and the water flow rate will also be reduced to maintain the zone thermostat set point temperature. When the zone load is one-half the fan coil capacity, the fan will operate at the minimum speed. When these fields are not entered, a zone sizing simulation must be performed. Both the cooling and heating supply air temperature must be entered or blank in unison. Values must be greater than 0 or this field is autosizable. A value of 0 (in both fields) will disregard these fields;
- maximumSupplyAirTemperatureInHeatingMode – maximum supply air temperature in heating mode [°C] (optional). Only used when capacityControlMethod = 'ASHRAE90VariableFan'. 'autosize' option is available. When the fan coil capacity is greater than the zone load, the fan speed will modulate down to the minimum fan speed, based on the lowSpeedSupplyAirFlowRatio, and the water flow rate will also be reduced to maintain the zone thermostat set point temperature. When the zone load is one-half the fan coil capacity, the fan will operate at the minimum speed. When these fields are not entered, a zone sizing simulation must be performed. Both the cooling and heating supply air temperature must be entered or blank in unison. Values must be greater than 0 or this field is autosizable. A value of 0 (in both fields) will disregard these fields;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – fanCoilName = Zone Name + "HVAC_FOUR_PIPE_FANCOIL" + "DEMAND" (Zone Name – name of the zone for which the Zone HVAC Four Pipe Fan Coil is assigned);
- Air Inlet Node Name – fanCoilName + "Inlet_node". This node is automatically assigned to the zone air exhaust node list (automatically named Zone Name + "AIR_EXHAUST_NODES"), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Exhaust Node List in the Equipment Connections (see section **7.1.9**);
- Air Outlet Node Name – fanCoilName + "Outlet_Node". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + "AIR_INLET_NODES"), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**);
- Outdoor Air Mixer Object Type – outdoor air mixer type assigned to this unit, if the argument x1 of the ZoneHVACFourPipeFancoilSpec() above is 'true'. Currently, the only object type available in EnergyPlus is the Outdoor Air Mixer (see section **10.5.2**);

- Outdoor Air Mixer Name – fanCoilName + “Mixer”;
- Supply Air Fan Object Type – supply fan type assigned in the argument x2 of the ZoneHVACFourPipeFancoilSpec() above;
- Supply Air Fan Name – fanCoilName + “Supply_Fan”;
- Cooling Coil Object Type – cooling coil type assigned in the argument x3 of the ZoneHVACFourPipeFancoilSpec() above;
- Cooling Coil Name – fanCoilName + “Cooling_Coil”;
- Heating Coil Object Type – heating coil type assigned in the argument x4 of the ZoneHVACFourPipeFancoilSpec() above;
- Heating Coil Name – fanCoilName + “Heating_Coil”;
- Availability Manager List Name – name of the availability manager list defined above (fancoilName + "AM_List").

The Zone HVAC Four Pipe Fan Coil specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_DoubleBedroom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object (‘ABC’, in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **“ABC”**). The available options are: ABC = ‘SequentialLoad’, ‘UniformLoad’, ‘UniformPLR’ or ‘SequentialUniformPLR’;
- **new ArrayList<>()** – array list which will include the Zone HVAC Four Pipe Fan Coil specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Four Pipe Fan Coil is assigned, defined using the DBSpaceType list object (Double Bedroom, in this example);
- **db** – database unique ID.

zoneHVACSpec_DoubleBedroom.addSpec() – Used to add the Zone HVAC Four Pipe Fan Coil specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following arguments:

- **zoneHVACFourPipeFancoilSpec_DoubleBedroom** – the Zone HVAC Four Pipe Fan Coil specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Four Pipe Fan Coil cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section

7.1.9), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;

- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_DoubleBedroom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Double bedroom, in this example);
- **db** – database unique ID.

As this Zone HVAC Four Pipe Fan Coil is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the ZoneHVAC:EquipmentList and ZoneHVAC:EquipmentConnections objects in EnergyPlus, as presented in section **7.1.9**.

The fan coil unit must be assigned to a water loop demand side brach (see section **9.3**) for each water coil present in the unit, in order to feed the coil(s).

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_Fancoils_DOAS_HotColdCndWaterLoops template in the SAPTool_LSP.

7.1.5. Zone HVAC Packaged Terminal

7.1.5.1. Air Conditioner

The specification of a Zone HVAC Packaged Terminal Air Conditioner unit is defined in the SAPTool_LSP building template for each different zone, as defined below. If this object's heating coil is water or steam type, the object must then be assigned to a HVAC loop system – see section **9**. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**).

The Zone HVAC Packaged Terminal Air Conditioner System option must be active (**ZONE_HVAC_PACKAGED_TERMINAL_AIR_CONDITIONER = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

ZoneHVACPackagedTerminalAirConditionerSpec zonePTAC_DoubleBedroom = new ZoneHVACPackagedTerminalAirConditionerSpec() – Zone HVAC Packaged Terminal Air Conditioner specification (named zonePTAC_DoubleBedroom in this example). With the following ZoneHVACPackagedTerminalAirConditionerSpec() arguments:

- **x1** – has ("true") or not ("false") an Outdoor Air Mixer. An OA mixer should <u>not</u> be present if the PTAC unit is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- **FanPlacementType.XX.toString()** – fan placement type, defined using the FanPlacementType list object. XX = 'BlowThrough' or 'DrawThrough';
- **x2** – name of the supply air fan specification assigned to this PTAC unit. The valid supply air fan types currently available are: Fan On-Off (**8.8.2**) and Fan Constant Volume (**8.8.3**);
- **x3** – name of the heating coil specification assigned to this PTAC unit. The valid coil types currently available are: Coil Heating Fuel (**8.9.2.8**), Coil Heating Electric (**8.9.2.6**), Coil Heating Water (**8.9.2.10**) and Coil Heating Steam (**8.9.2.11**). The coil is automatically assigned to a plant loop for hot water or steam source when the PTAC unit is assigned to a loop equipment brach (see section **9.3**);
- **x4** – name of the cooling coil specification assigned to this PTAC unit. The valid coil types currently available are: Coil Cooling DX Single Speed (**8.9.1.1**) and Coil Cooling DX Variable Speed (**8.9.1.4**);
- **x5** – ID of the Zone HVAC Packaged Terminal Air Conditioner properties in the database for this zone, in the **ZoneHVACPackagedTerminalAirConditioner** table (see below);
- **db** – database unique ID.

An availability manager, if defined, must be assigned to the PTAC unit as follows:

zonePTAC_DoubleBedroom.addAvailabilityManager(ams) – assigns the ams availability manager to the PTAC unit zonePTAC_DoubleBedroom. Currently, there is only one availability manager type implemented that can be used by a PTAC unit: Scheduled (**15.1**).

The Zone HVAC Packaged Terminal Air Conditioner properties are defined in the **ZoneHVACPackagedTerminalAirConditioner** table in the database, corresponding to the ZoneHVAC:PackagedTerminalAirConditioner object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the equipment is always available;
- coolingSupplyAirFlowRate – supply air flow rate leaving the air conditioner when the DX cooling coil is operating [m3/s]. 'autosize' option is available;

- heatingSupplyAirFlowRate – supply air flow rate leaving the air conditioner when the heating coil is operating [m3/s]. ‘autosize’ option is available;
- noLoadSupplyAirFlowRate – supply air flow rate leaving the air when neither cooling nor heating is required (i.e., DX coil and heater are off but the supply air fan operates) [m3/s]. This field is only used when the air conditioner’s supply air fan operating mode schedule specifies continuous fan operation. ‘autosize’ option is available;
- coolingOutdoorAirFlowRate – outdoor air flow rate through the air conditioner when the DX cooling coil is operating [m3/s]. ‘autosize’ option is available. This field is set to zero flow when the PTAC is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- heatingOutdoorAirFlowRate – outdoor air flow rate through the air conditioner when the heating coil is operating [m3/s]. ‘autosize’ option is available. This field is set to zero flow when the PTAC is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- noLoadOutdoorAirFlowRate – outdoor air flow rate through the air conditioner when neither cooling nor heating is required (i.e., cooling and heating coils are off but the supply air fan operates) [m3/s]. ‘autosize’ option is available. This field is set to zero flow when the PTAC is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- supplyAirFanOperatingModeScheduleID – supply air fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). 0 – the supply air fan and the heating or cooling coil cycle on and off together to meet the heating or cooling load (auto fan). ≠ 0 – supply fan runs continuously while the heating or cooling coil cycles to meet the load;
- designSpecificationZoneHVACSizingID – ID of the object which defines scalable sizing methods for sizing input fields such as Maximum Air Flow Rate in this PTAC zone HVAC object, defined in table **DesignSpecificationZoneHVACSizing** in the database (see section **13.1.3**) (optional);
- capacityControlMethod – ‘None’ or ‘SingleZoneVAV’;
- minimumSupplyAirTemperatureInCoolingMode – minimum air temperature limit for reduced fan speed in cooling mode, if capacityControlMethod = SingleZoneVAV. ‘autosize’ option is available;
- maximumSupplyAirTemperatureInHeatingMode – maximum air temperature limit for reduced fan speed in heating mode, if capacityControlMethod = SingleZoneVAV. ‘autosize’ option is available;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – packTermACName = Zone Name + “HVAC_PACK_TERM_AC" + “DEMAND” (Zone Name – name of the zone for which the Zone HVAC Packaged Terminal Air Conditioner is assigned);
- Air Inlet Node Name – packTermACName + “Inlet_node”. This node is automatically assigned to the zone air exhaust node list (automatically named Zone Name + “AIR_EXHAUST_NODES”), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Exhaust Node List in the Equipment Connections (see section **7.1.9**);

- Air Outlet Node Name – packTermACName + "Outlet_Node". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + “AIR_INLET_NODES”), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**);
- Outdoor Air Mixer Object Type – outdoor air mixer type assigned to this unit, if the argument x1 of the ZoneHVACPackagedTerminalAirConditionerSpec() above is ‘true’. Currently, the only object type available in EnergyPlus is the Outdoor Air Mixer (see section **10.5.2**);
- Outdoor Air Mixer Name – packTermACName + “Mixer”;
- Supply Air Fan Object Type – supply fan type assigned in the argument x2 of the ZoneHVACPackagedTerminalAirConditionerSpec() above;
- Supply Air Fan Name – packTermACName + “Supply_Fan”;
- Heating Coil Object Type – heating coil type assigned in the argument x3 of the ZoneHVACPackagedTerminalAirConditionerSpec() above;
- Heating Coil Name – packTermACName + “Heating_Coil”;
- Cooling Coil Object Type – cooling coil type assigned in the argument x4 of the ZoneHVACPackagedTerminalAirConditionerSpec() above;
- Cooling Coil Name – packTermACName + “Cooling_Coil”;
- Fan Placement – supply fan placement assigned in the second argument of the ZoneHVACPackagedTerminalAirConditionerSpec() above;
- Availability Manager List Name – name of the availability manager list defined above (packTermACName + "AM_List").

The Zone HVAC Packaged Terminal Air Conditioner specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_DoubleBedroom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object (‘ABC’, in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **“ABC”**). The available options are: ABC = ‘SequentialLoad’, ‘UniformLoad’, ‘UniformPLR’ or ‘SequentialUniformPLR’;
- **new ArrayList<>()** – array list which will include the Zone HVAC Packaged Terminal Air Conditioner specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Packaged Terminal Air Conditioner is assigned, defined using the DBSpaceType list object (Double Bedroom, in this example);
- **db** – database unique ID.

zoneHVACSpec_DoubleBedroom.addSpec() – Used to add the Zone HVAC Packaged Terminal Air Conditioner specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following arguments:

- **zonePTAC_DoubleBedroom** – the Zone HVAC Packaged Terminal Air Conditioner specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Packaged Terminal Air Conditioner cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object (“SCH1”, in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object (“SCH2”, in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_DoubleBedroom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Double bedroom, in this example);
- **db** – database unique ID.

As this Zone HVAC Packaged Terminal Air Conditioner is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the ZoneHVAC:EquipmentList and ZoneHVAC:EquipmentConnections objects in EnergyPlus, as presented in section **7.1.9**.

If the PTAC unit’s heating coil is water or steam type, the unit must be assigned to a water loop demand side brach (see section **9.3**), in order to feed the coil.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_PTAC_DOAS template in the SAPTool_LSP.

7.1.5.2. Heat Pump

The specification of a Zone HVAC Packaged Terminal Heat Pump unit is defined in the SAPTool_LSP building template for each different zone, as defined below. If this object's supplemental heating coil is water or steam type, the object must then be assigned to a HVAC loop system – see section **9**. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**).

The Zone HVAC Packaged Terminal Air Conditioner System option must be active (**ZONE_HVAC_PACKAGED_TERMINAL_HEAT_PUMP = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

ZoneHVACPackagedTerminalHeatPumpSpec zonePTHP_DoubleBedroom = new ZoneHVACPackagedTerminalHeatPumpSpec() – Zone HVAC Packaged Terminal Heat Pump specification (named zonePTHP_DoubleBedroom in this example). With the following ZoneHVACPackagedTerminalHeatPumpSpec() arguments:

- **x1** – has ("true") or not ("false") an Outdoor Air Mixer. An OA mixer should <u>not</u> be present if the PTHP unit is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- **FanPlacementType.XX.toString()** – fan placement type, defined using the FanPlacementType list object. XX = 'BlowThrough' or 'DrawThrough';
- **x2** – name of the supply air fan specification assigned to this PTHP unit. The valid supply air fan types currently available are: Fan On-Off (**8.8.2**) and Fan Constant Volume (**8.8.3**);
- **x3** – name of the heating coil specification assigned to this PTHP unit. The valid coil types currently available are: Coil Heating DX Single Speed (**8.9.2.1**) and Coil Heating DX Variable Speed (**8.9.2.3**);
- **x4** – name of the cooling coil specification assigned to this PTHP unit. The valid coil types currently available are: Coil Cooling DX Single Speed (**8.9.1.1**) and Coil Cooling DX Variable Speed (**8.9.1.4**);
- **x5** – name of the supplemental heating coil specification assigned to this PTHP unit. The valid coil types available are: Coil Heating Fuel (**8.9.2.8**), Coil Heating Electric (**8.9.2.6**), Coil Heating Water (**8.9.2.10**) and Coil Heating Steam (**8.9.2.11**). The coil is automatically assigned to a plant loop for hot water or steam source when the PTHP unit is assigned to a loop equipment brach (see section **9.3**);
- **x6** – ID of the Zone HVAC Packaged Terminal Heat Pump properties in the database for this zone, in the **ZoneHVACPackagedTerminalHeatPump** table (see below);
- **db** – database unique ID.

An availability manager, if defined, must be assigned to the PTHP unit as follows:

zonePTHP_DoubleBedroom.addAvailabilityManager(ams) – assigns the ams availability manager to the PTHP unit zonePTHP_DoubleBedroom. Currently, there is only one availability manager type implemented that can be used by a PTHP unit: Scheduled (**15.1**).

The Zone HVAC Packaged Terminal Heat Pump properties are defined in the **ZoneHVACPackagedTerminalHeatPump** table in the database, corresponding to the ZoneHVAC:PackagedTerminalHeatPump object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the equipment is always available;
- coolingSupplyAirFlowRate – supply air flow rate leaving the air conditioner when the DX cooling coil is operating [m3/s]. 'autosize' option is available;
- heatingSupplyAirFlowRate – supply air flow rate leaving the air conditioner when the DX heating coil and/or supplemental heater are operating [m3/s]. 'autosize' option is available;
- noLoadSupplyAirFlowRate – supply air flow rate leaving the air when neither cooling nor heating is required (i.e., DX coils and supplemental heater are off but the supply air fan operates) [m3/s]. This field is only used when the air conditioner's supply air fan operating mode schedule specifies continuous fan operation. 'autosize' option is available;
- coolingOutdoorAirFlowRate – outdoor air flow rate through the air conditioner when the DX cooling coil is operating [m3/s]. 'autosize' option is available. This field is set to zero flow when the PTHP is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- heatingOutdoorAirFlowRate – outdoor air flow rate through the air conditioner when the DX heating coil and/or supplemental heater are operating [m3/s]. 'autosize' option is available. This field is set to zero flow when the PTHP is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- noLoadOutdoorAirFlowRate – outdoor air flow rate through the air conditioner when neither cooling nor heating is required (i.e., DX coils and supplemental heater are off but the supply air fan operates) [m3/s]. 'autosize' option is available. This field is set to zero flow when the PTHP is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- heatingConvergenceTolerance – convergence tolerance for the unit's heating output;
- coolingConvergenceTolerance – convergence tolerance for the unit's cooling output;
- maximumSupplyAirTemperatureFromSupplementalHeater – maximum supply air temperature exiting the heat pump supplemental heater coil [°C]. 'autosize' option is available;
- maximumOutdoorDryBulbTemperatureForSupplementalHeaterOperation – maximum outdoor dry-bulb temperature for PTHP supplemental heater operation [°C]. The maximum value must be less than or equal to 21°C;
- supplyAirFanOperatingModeScheduleID – supply air fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). 0 – the supply air fan and the heating or cooling coil cycle on and off together to meet the heating or cooling load (auto fan).

≠ 0 – supply fan runs continuously while the heating or cooling coil cycles to meet the load;

- designSpecificationZoneHVACSizingID – ID of the object which defines scalable sizing methods for sizing input fields such as Maximum Air Flow Rate in this PTHP zone HVAC object, defined in table **DesignSpecificationZoneHVACSizing** in the database (see section **13.1.3**) (optional);
- capacityControlMethod – 'None' or 'SingleZoneVAV';
- minimumSupplyAirTemperatureInCoolingMode – minimum air temperature limit for reduced fan speed in cooling mode, if capacityControlMethod = SingleZoneVAV. 'autosize' option is available;
- maximumSupplyAirTemperatureInHeatingMode – maximum air temperature limit for reduced fan speed in heating mode, if capacityControlMethod = SingleZoneVAV. 'autosize' option is available;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – packTermHPName = Zone Name + "HVAC_PACK_TERM_HP" + "DEMAND" (Zone Name – name of the zone for which the Zone HVAC Packaged Terminal Heat Pump is assigned);
- Air Inlet Node Name – packTermHPName + "Inlet_node". This node is automatically assigned to the zone air exhaust node list (automatically named Zone Name + "AIR_EXHAUST_NODES"), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Exhaust Node List in the Equipment Connections (see section **7.1.9**);
- Air Outlet Node Name – packTermHPName + "Outlet_Node". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + "AIR_INLET_NODES"), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**);
- Outdoor Air Mixer Object Type – outdoor air mixer type assigned to this unit, if the argument x1 of the ZoneHVACPackagedTerminalHeatPumpSpec() above is 'true'. Currently, the only object type available in EnergyPlus is the Outdoor Air Mixer (see section **10.5.2**);
- Outdoor Air Mixer Name – packTermHPName + "Mixer";
- Supply Air Fan Object Type – supply fan type assigned in the argument x2 of the ZoneHVACPackagedTerminalHeatPumpSpec() above;
- Supply Air Fan Name – packTermHPName + "Supply_Fan";
- Heating Coil Object Type – heating coil type assigned in the argument x3 of the ZoneHVACPackagedTerminalHeatPumpSpec() above;
- Heating Coil Name – packTermHPName + "Heating_Coil";
- Cooling Coil Object Type – cooling coil type assigned in the argument x4 of the ZoneHVACPackagedTerminalHeatPumpSpec() above;
- Cooling Coil Name – packTermHPName + "Cooling_Coil";
- Supplemental Heating Coil Object Type – supplemental heating coil type assigned in the argument x5 of the ZoneHVACPackagedTerminalHeatPumpSpec() above;
- Supplemental Heating Coil Name – packTermHPName + "Supplemental_Heating_Coil";

- Fan Placement – supply fan placement assigned in the second argument of the ZoneHVACPackagedTerminalHeatPumpSpec() above;
- Availability Manager List Name – name of the availability manager list defined above (packTermHPName + "AM_List").

The Zone HVAC Packaged Terminal Heat Pump specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_DoubleBedroom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object ('ABC', in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **"ABC"**). The available options are: ABC = 'SequentialLoad', 'UniformLoad', 'UniformPLR' or 'SequentialUniformPLR';
- **new ArrayList<>()** – array list which will include the Zone HVAC Packaged Terminal Heat Pump specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Packaged Terminal Heat Pump is assigned, defined using the DBSpaceType list object (Double Bedroom, in this example);
- **db** – database unique ID.

zoneHVACSpec_DoubleBedroom.addSpec() – Used to add the Zone HVAC Packaged Terminal Heat Pump specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following arguments:

- **zonePTHP_DoubleBedroom** – the Zone HVAC Packaged Terminal Heat Pump specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Packaged Terminal Heat Pump cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;

- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_DoubleBedroom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Double bedroom, in this example);
- **db** – database unique ID.

As this Zone HVAC Packaged Terminal Heat Pump is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the ZoneHVAC:EquipmentList and ZoneHVAC:EquipmentConnections objects in EnergyPlus, as presented in section **7.1.9**.

If the PTHP unit's supplemental heating coil is water or steam type, the unit must be assigned to a water loop demand side brach (see section **9.3**), in order to feed the coil.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_PTHP template in the SAPTool_LSP.

7.1.6. Zone HVAC Water-to-Air Heat Pump

The specification of a Zone HVAC Water-to-Air Heat Pump unit is defined in the SAPTool_LSP building template for each different zone, as defined below. This object must then be assigned to a HVAC loop system – see section **9** –, and if its supplemental heating coil is water or steam type, the object must also be assigned to an additional HVAC loop system. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**).

The Zone HVAC Water-to-Air Heat Pump System option must be active (**ZONE_HVAC_WATER_TO_AIR_HEAT_PUMP = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

ZoneHVACWaterToAirHeatPumpSpec zoneWAHP_DoubleBedroom = new ZoneHVACWaterToAirHeatPumpSpec() – Zone HVAC Water-to-Air Heat Pump specification (named zoneWAHP_DoubleBedroom in this example). With the following ZoneHVACWaterToAirHeatPumpSpec() arguments:

- **x1** – has ("true") or not ("false") an Outdoor Air Mixer. An OA mixer should not be present if the heat pump unit is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- **FanPlacementType.XX.toString()** – fan placement type, defined using the FanPlacementType list object. XX = 'BlowThrough' or 'DrawThrough';
- **x2** – name of the supply air fan specification assigned to this heat pump unit. The valid supply air fan types currently available is Fan On-Off (**8.8.2**);
- **x3** – name of the heating coil specification assigned to this heat pump unit. The valid coil types currently available are: Coil Heating Water-to-Air Heat Pump Equation Fit (**8.9.2.12**) and Coil Heating Water-to-Air Heat Pump Variable Speed Equation Fit (**8.9.2.14**). The coil is automatically assigned to a plant water loop when the heat pump unit is assigned to a loop equipment brach (see section **9.3**);
- **x4** – name of the cooling coil specification assigned to this heat pump unit. The valid coil types currently available are: Coil Cooling Water-to-Air Heat Pump Equation Fit (**8.9.1.11**) and Coil Cooling Water-to-Air Heat Pump Variable Speed Equation Fit (**8.9.1.12**). The coil is automatically assigned to a plant water loop when the heat pump unit is assigned to a loop equipment brach (see section **9.3**);
- **x5** – name of the supplemental heating coil specification assigned to this heat pump unit. The valid coil types available are: Coil Heating Fuel (**8.9.2.8**), Coil Heating Electric (**8.9.2.6**), Coil Heating Water (**8.9.2.10**) and Coil Heating Steam (**8.9.2.11**). The coil is automatically assigned to a plant loop for hot water or steam source when the heat pump unit is assigned to a loop equipment brach (see section **9.3**);
- **x6** – ID of the Zone HVAC Water-to-Air Heat Pump properties in the database for this zone, in the **ZoneHVACWaterToAirHeatPump** table (see below);
- **db** – database unique ID.

An availability manager, if defined, must be assigned to the heat pump unit as follows:

zoneWAHP_DoubleBedroom.addAvailabilityManager(ams) – assigns the ams availability manager to the heat pump unit zoneWAHP_DoubleBedroom. Currently, there is only one availability manager type implemented that can be used by a water-to-air heat pump unit: Scheduled (**15.1**).

The Zone HVAC Water-to-Air Heat Pump properties are defined in the **ZoneHVACWaterToAirHeatPump** table in the database, corresponding to the ZoneHVAC:WaterToAirHeatPump object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the equipment is always available;
- coolingSupplyAirFlowRate – supply air flow rate leaving the air conditioner when the DX cooling coil is operating [m3/s]. 'autosize' option is available;

- heatingSupplyAirFlowRate – supply air flow rate leaving the air conditioner when the DX heating coil and/or supplemental heater are operating [m3/s]. 'autosize' option is available;
- noLoadSupplyAirFlowRate – supply air flow rate leaving the air when neither cooling nor heating is required (i.e., DX coils and supplemental heater are off but the supply air fan operates) [m3/s]. This field is only used when the air conditioner's supply air fan operating mode schedule specifies continuous fan operation. 'autosize' option is available;
- coolingOutdoorAirFlowRate – outdoor air flow rate through the air conditioner when the DX cooling coil is operating [m3/s]. 'autosize' option is available. This field is set to zero flow when the heat pump is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- heatingOutdoorAirFlowRate – outdoor air flow rate through the air conditioner when the DX heating coil and/or supplemental heater are operating [m3/s]. 'autosize' option is available. This field is set to zero flow when the heat pump is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- noLoadOutdoorAirFlowRate – outdoor air flow rate through the air conditioner when neither cooling nor heating is required (i.e., DX coils and supplemental heater are off but the supply air fan operates) [m3/s]. 'autosize' option is available. This field is set to zero flow when the heat pump is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- maximumCyclingRate – maximum on-off cycling rate for the compressor, which occurs at 50% run time fraction [cycles/h];
- heatPumpTimeConstant – time constant for the cooling coil's capacity to reach steady state after startup [s];
- fractionOfOnCyclePowerUse – fraction of on-cycle power use to adjust the part load fraction based on the off-cycle power consumption due to crankcase heaters, controls, fans, etc.;
- heatPumpFanDelayTime – time delay in seconds for the heat pump supply air fan to shut off after compressor cycle off [s];
- maximumSupplyAirTemperatureFromSupplementalHeater – maximum allowed supply air temperature exiting the heat pump supplemental heating coil [°C];
- maximumOutdoorDryBulbTemperatureForSupplementalHeaterOperation – maximum outdoor dry-bulb temperature above which the heat pump supplemental heating coil is disabled [°C]. The maximum value must be less than or equal to 21°C;
- supplyAirFanOperatingModeScheduleID – supply air fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). 0 – the supply air fan and the heating or cooling coil cycle on and off together to meet the heating or cooling load (auto fan). ≠ 0 – supply fan runs continuously while the heating or cooling coil cycles to meet the load;
- heatPumpCoilWaterFlowMode – 'Cycling', 'Constant' or 'ConstantOnDemand';
- designSpecificationZoneHVACSizingID – ID of the object which defines scalable sizing methods for sizing input fields such as Maximum Air Flow Rate in this heat pump zone HVAC object, defined in table **DesignSpecificationZoneHVACSizing** in the database (see section **13.1.3**) (optional);
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – waterToAirHPName = Zone Name + “HVAC_WATER_AIR_HP" + “DEMAND” (Zone Name – name of the zone for which the Zone HVAC Water-to-Air Heat Pump is assigned);
- Air Inlet Node Name – waterToAirHPName + “Inlet_node”. This node is automatically assigned to the zone air exhaust node list (automatically named Zone Name + “AIR_EXHAUST_NODES”), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Exhaust Node List in the Equipment Connections (see section **7.1.9**);
- Air Outlet Node Name – waterToAirHPName + "Outlet_Node". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + “AIR_INLET_NODES”), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**);
- Outdoor Air Mixer Object Type – outdoor air mixer type assigned to this unit, if the argument x1 of the ZoneHVACWaterToAirHeatPumpSpec() above is ‘true’. Currently, the only object type available in EnergyPlus is the Outdoor Air Mixer (see section **10.5.2**);
- Outdoor Air Mixer Name – waterToAirHPName + “Mixer”;
- Supply Air Fan Object Type – supply fan type assigned in the argument x2 of the ZoneHVACWaterToAirHeatPumpSpec() above;
- Supply Air Fan Name – waterToAirHPName + “Supply_Fan”;
- Heating Coil Object Type – heating coil type assigned in the argument x3 of the ZoneHVACWaterToAirHeatPumpSpec() above;
- Heating Coil Name – waterToAirHPName + “Heating_Coil”;
- Cooling Coil Object Type – cooling coil type assigned in the argument x4 of the ZoneHVACWaterToAirHeatPumpSpec() above;
- Cooling Coil Name – waterToAirHPName + “Cooling_Coil”;
- Supplemental Heating Coil Object Type – supplemental heating coil type assigned in the argument x5 of the ZoneHVACWaterToAirHeatPumpSpec() above;
- Supplemental Heating Coil Name – waterToAirHPName + “Supplemental_Heating_Coil”;
- Outdoor Dry-Bulb Temperature Sensor Node Name – waterToAirHPName + "OA_Stream_Node"*;
- Fan Placement – supply fan placement assigned in the second argument of the ZoneHVACWaterToAirHeatPumpSpec() above;
- Availability Manager List Name – name of the availability manager list defined above (waterToAirHPName + "AM_List").

*An OutdoorAir:Node object is automatically created in EnergyPlus and its fields automatically filled:

- Name – waterToAirHPName + "OA_Stream_Node";
- Height Above Ground – null.

The Zone HVAC Water-to-Air Heat Pump specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_DoubleBedroom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object ('ABC', in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **"ABC"**). The available options are: ABC = 'SequentialLoad', 'UniformLoad', 'UniformPLR' or 'SequentialUniformPLR';
- **new ArrayList<>()** – array list which will include the Zone HVAC Water-to-Air Heat Pump specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Water-to-Air Heat Pump is assigned, defined using the DBSpaceType list object (Double Bedroom, in this example);
- **db** – database unique ID.

zoneHVACSpec_DoubleBedroom.addSpec() – Used to add the Zone HVAC Water-to-Air Heat Pump specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following arguments:

- **zoneWAHP_DoubleBedroom** – the Zone HVAC Water-to-Air Heat Pump specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Water-to-Air Heat Pump cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_DoubleBedroom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Double bedroom, in this example);
- **db** – database unique ID.

As this Zone HVAC Water-to-Air Heat Pump is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the ZoneHVAC:EquipmentList and ZoneHVAC:EquipmentConnections objects in EnergyPlus, as presented in section **7.1.9**.

The heat pump unit must be assigned to a plant loop demand side brach (see section **9.3**), in order to feed its heating and cooling coils. In addition, if its supplemental heating coil is water or steam type, the unit must also be assigned to a hot water loop demand side brach (see section **9.3**), in order to feed the coil.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_WaterToAir_HeatPump template in the SAPTool_LSP.

7.1.7. Zone HVAC Terminal Unit Variable Refrigerant Flow

The specification of a Zone HVAC Terminal Unit Variable Refrigerant Flow is defined in the SAPTool_LSP building template for each different zone, as defined below. This object must then be assigned to an Air Conditioner Variable Refrigerant Flow system – see section **11**. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**).

The Zone HVAC Terminal Unit Variable Refrigerant Flow system option must be active (**ZONE_HVAC_TERMINAL_UNIT_VRF = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

ZoneHVACTerminalUnitVariableRefrigerantFlowSpec zoneVRF_DoubleBedroom = new ZoneHVACTerminalUnitVariableRefrigerantFlowSpec() – Zone HVAC Terminal Unit Variable Refrigerant Flow specification (named zoneVRF_DoubleBedroom in this example). With the following ZoneHVACTerminalUnitVariableRefrigerantFlowSpec() arguments:

- **x1** – name of the Air Conditioner VRF (defined in section **11**) for which this Zone HVAC Terminal Unit VRF is assigned;
- **x2** – has ("true") or not ("false") an Outdoor Air Mixer. An OA mixer should <u>not</u> be present if the heat pump unit is connected to an Air Terminal Single Duct Mixer object (not yet implemented);

- **FanPlacementType.XX.toString()** – fan placement type, defined using the FanPlacementType list object. XX = 'BlowThrough' or 'DrawThrough';
- **x3** – name of the supply air fan specification assigned to this VRF unit. The valid supply air fan types available are: Fan On-Off (**8.8.2**), Fan Constant Volume (**8.8.3**) and Fan Variable Volume (**8.8.4**). Fan On-Off or Fan Constant Volume must be used if the air conditioner system assigned in argument **x1** is Air Conditioner VRF (**11**). Fan Variable Volume must be used if the air conditioner system assigned in argument **x1** is Air Conditioner VRF Fluid Temperature Control or Air Conditioner VRF Fluid Temperature Control HR (both not yet implemented).
- **x4** – name of the cooling coil specification assigned to this VRF unit (optional; **null** if not present). The valid coil types available are: Coil Cooling DX Variable Refrigerant Flow (**8.9.1.6**) and Coil Cooling DX Variable Refrigerant Flow Fluid Temperature Control (**8.9.1.7**). Coil Cooling DX Variable Refrigerant Flow must be used if if the air conditioner system assigned in argument **x1** is Air Conditioner VRF (**11**). Coil Cooling DX Variable Refrigerant Flow Fluid Temperature Control must be used if the air conditioner system assigned in argument **x1** is Air Conditioner VRF Fluid Temperature Control or Air Conditioner VRF Fluid Temperature Control HR (both not yet implemented);
- **x5** – name of the heating coil specification assigned to this VRF unit (optional; **null** if not present). The valid coil types available are: Coil Heating DX Variable Refrigerant Flow (**8.9.2.4**) and Coil Heating DX Variable Refrigerant Flow Fluid Temperature Control (**8.9.2.5**). Coil Heating DX Variable Refrigerant Flow must be used if if the air conditioner system assigned in argument **x1** is Air Conditioner VRF (**11**). Coil Heating DX Variable Refrigerant Flow Fluid Temperature Control must be used if the air conditioner system assigned in argument **x1** is Air Conditioner VRF Fluid Temperature Control or Air Conditioner VRF Fluid Temperature Control HR (both not yet implemented);
- **x6** – name of the supplemental heating coil specification assigned to this VRF unit (optional; **null** if not present). The valid coil types available are: Coil Heating Fuel (**8.9.2.8**), Coil Heating Electric (**8.9.2.6**), Coil Heating Water (**8.9.2.10**), and Coil Heating Steam (**8.9.2.11**). The coil is automatically assigned to a plant loop for hot water or steam source when the VRF unit is assigned to a loop equipment brach (see section **9.3**);
- **x7** – ID of the Zone HVAC Terminal Unit Variable Refrigerant Flow properties in the database for this zone, in the **ZoneHVACTerminalUnitVariableRefrigerantFlow** table (see below);
- **db** – database unique ID.

An availability manager, if defined, must be assigned to the VRF unit as follows:

zoneVRF_DoubleBedroom.addAvailabilityManager(ams) – assigns the ams availability manager to the VRF unit zoneVRF_DoubleBedroom. Currently, there is only one availability manager type implemented that can be used by a VRF terminal unit: Scheduled (**15.1**).

The Zone HVAC Terminal Unit Variable Refrigerant Flow properties are defined in the **ZoneHVACTerminalUnitVariableRefrigerantFlow** table in the database, corresponding to the ZoneHVAC:TerminalUnit:VariableRefrigerantFlow object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the equipment is always available;
- coolingSupplyAirFlowRate – terminal unit's operating volumetric air flow rate when operating in cooling mode [m3/s]. 'autosize' option is available;
- noCoolingSupplyAirFlowRate – terminal unit's operating volumetric air flow rate when the terminal unit's cooling coil is not operating and the previous mode was cooling [m3/s]. 'autosize' option is available;
- heatingSupplyAirFlowRate – terminal unit's operating volumetric air flow rate when operating in heating mode [m3/s]. 'autosize' option is available;
- noHeatingSupplyAirFlowRate – terminal unit's operating volumetric air flow rate when the terminal unit's heating coil is not operating and the previous mode was heating [m3/s]. 'autosize' option is available;
- coolingOutdoorAirFlowRate – outdoor air volumetric air flow rate when the terminal unit is operating in cooling mode [m3/s]. 'autosize' option is available. This field is set to zero flow when the VRF unit is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- heatingOutdoorAirFlowRate – outdoor air volumetric air flow rate when the terminal unit is operating in heating mode [m3/s]. 'autosize' option is available. This field is set to zero flow when the VRF unit is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- noLoadOutdoorAirFlowRate – outdoor air volumetric air flow rate when the terminal unit is not operating in cooling or heating mode [m3/s]. 'autosize' option is available. This field is set to zero flow when the VRF unit is connected to an Air Terminal Single Duct Mixer object (not yet implemented);
- supplyAirFanOperatingModeScheduleID – supply air fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). 0 – cycling fan/cycling coil operation. ≠ 0 – constant fan/cycling coil operation;
- zoneTerminalUnitOnParasiticElectricEnergyUse – parasitic electrical energy use of the zone terminal unit when either terminal unit coil is operating [W];
- zoneTerminalUnitOffParasiticElectricEnergyUse – parasitic electrical energy use of the zone terminal unit when the terminal unit coil(s) is not operating [W];
- ratedTotalHeatingCapacitySizingRatio – ratio of the heating coil to cooling coil size when autosizing is used;
- designSpecificationZoneHVACSizingID – ID of the object which defines scalable sizing methods for sizing input fields such as Cooling Supply Air Flow Rate in this VRF unit zone HVAC object, defined in table **DesignSpecificationZoneHVACSizing** in the database (see section **13.1.3**) (optional);
- maximumSupplyAirTemperatureFromSupplementalHeater – maximum supply air temperature leaving the VRF terminal unit supplemental heater coil [°C]. 'autosize' option is available (default);
- maximumOutdoorDryBulbTemperatureForSupplementalHeaterOperation – maximum outdoor dry-bulb temperature for this VRF terminal unit supplemental heating coil operation [°C].The maximum value must be less than or equal to 21 °C (default value);
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Zone Terminal Unit Name – terminalVRFName = Zone Name + “HVAC_TERM_UNIT_VRF" (Zone Name – name of the zone for which the Zone HVAC VRF unit is assigned);
- Terminal Unit Air Inlet Node Name – terminalVRFName + “Inlet_node”. This node is automatically assigned to the zone air exhaust node list (automatically named Zone Name + “AIR_EXHAUST_NODES”), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Exhaust Node List in the Equipment Connections (see section **7.1.9**);
- Terminal Unit Air Outlet Node Name – terminalVRFName + "Outlet_Node". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + “AIR_INLET_NODES”), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**);
- Supply Air Fan Placement – supply air fan placement assigned in the third argument of the ZoneHVACTerminalUnitVariableRefrigerantFlowSpec() above;
- Supply Air Fan Object Type – supply air fan type assigned in the argument x3 of the ZoneHVACTerminalUnitVariableRefrigerantFlowSpec() above;
- Supply Air Fan Name – terminalVRFName + “Supply_Fan”;
- Outdoor Air Mixer Object Type – outdoor air mixer type assigned to this unit, if the argument x2 of the ZoneHVACTerminalUnitVariableRefrigerantFlowSpec() above is ‘true’. Currently, the only object type available in EnergyPlus is the Outdoor Air Mixer (see section **10.5.2**);
- Outdoor Air Mixer Object Name – terminalVRFName + “Mixer”;
- DX Cooling Coil Object Type – cooling coil type assigned in the argument x4 of the ZoneHVACTerminalUnitVariableRefrigerantFlowSpec() above;
- DX Cooling Coil Object Name – terminalVRFName + “Cooling_Coil”;
- DX Heating Coil Object Type – heating coil type assigned in the argument x5 of the ZoneHVACTerminalUnitVariableRefrigerantFlowSpec() above;
- DX Heating Coil Object Name – terminalVRFName + “Heating_Coil”;
- Supplemental Heating Coil Object Type – supplemental heating coil type assigned in the argument x6 of the ZoneHVACTerminalUnitVariableRefrigerantFlowSpec() above;
- Supplemental Heating Coil Object Name – terminalVRFName + “Supplemental_Heating_Coil”;
- Availability Manager List Name – name of the availability manager list defined above (terminalVRFName + "AM_List").

The Zone HVAC Terminal Unit Variable Refrigerant Flow specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_DoubleBedroom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object (‘ABC’, in this example), in the Zone HVAC Equipment List (see section **7.1.9**).

Alternatively, a string can be directly inputted here (e.g., **"ABC"**). The available options are: ABC = 'SequentialLoad', 'UniformLoad', 'UniformPLR' or 'SequentialUniformPLR';

- **new ArrayList<>()** – array list which will include the Zone HVAC Terminal Unit Variable Refrigerant Flow specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.DOUBLE_BEDROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Terminal Unit Variable Refrigerant Flow is assigned, defined using the DBSpaceType list object (Double Bedroom, in this example);
- **db** – database unique ID.

zoneHVACSpec_DoubleBedroom.addSpec() – Used to add the Zone HVAC Terminal Unit Variable Refrigerant Flow specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_DoubleBedroom in this example). With the following arguments:

- **zoneVRF_DoubleBedroom** – the Zone HVAC Terminal Unit Variable Refrigerant Flow specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Terminal Unit Variable Refrigerant Flow cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_DoubleBedroom** – the Zone HVAC system specification defined previously;

- **DBSpaceType.DOUBLE_BEDROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Double bedroom, in this example);
- **db** – database unique ID.

As this Zone HVAC Terminal Unit Variable Refrigerant Flow is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the ZoneHVAC:EquipmentList and ZoneHVAC:EquipmentConnections objects in EnergyPlus, as presented in section **7.1.9**.

If the VRF unit's supplemental heating coil is water or steam type, the unit must be assigned to a water loop demand side brach (see section **9.3**), in order to feed the coil.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_VRF_MixedWaterLoop template in the SAPTool_LSP.

7.1.8. Zone HVAC Air Terminal Single Duct

7.1.8.1. Uncontrolled

The specification of a Zone HVAC Air Terminal Single Duct Uncontrolled is defined in the SAPTool_LSP building template for each different zone, as defined below. The Zone HVAC Air Terminal Single Duct Uncontrolled option must be active (**ZONE_HVAC_AIR_TERMINAL_SINGLE_DUCT_UNCONTROLLED = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and "Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**). An Air Loop HVAC must be defined, in order to assign the air terminal to (**10**).

ZoneHVACAirTerminalSingleDuctUncontrolledSpec airTerminalSingleDuctUncontrolled_LivingRoom = new ZoneHVACAirTerminalSingleDuctUncontrolledSpec() – Zone HVAC Air Terminal Single Duct Uncontrolled specification (named airTerminalSingleDuctUncontrolled_LivingRoom in this example). With the following ZoneHVACAirTerminalSingleDuctUncontrolledSpec() arguments:

- **x1** – name of the Air Loop HVAC (defined in section **10.1**) for which this Zone HVAC Air Terminal Single Duct Uncontrolled is assigned;
- **x2** – ID of the Zone HVAC Air Terminal Single Duct Uncontrolled properties in the database for this zone, in the **ZoneHVACAirTerminalSingleDuctUncontrolled** table (see below);
- **db** – database unique ID.

The Zone HVAC Air Terminal Single Duct Uncontrolled properties are defined in the **ZoneHVACAirTerminalSingleDuctUncontrolled** table in the database, corresponding to the AirTerminal:SingleDuct:Uncontrolled object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the unit is always available;
- maximumAirFlowRate – design maximum volume flow rate [m^3/s]. 'autosize' option is available;
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this system, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**) (optional). If blank, the terminal unit will not be controlled for outdoor air flow;
- perPersonVentilationRateMode – 'CurrentOccupancy' or 'DesignOccupancy';
- designSpecificationAirTerminalSizingID – ID of the object which specifies sizing adjustments to be made for this terminal unit, defined in table **DesignSpecificationAirTerminalSizing** in the database (see section **13.1.4**) (optional). If blank, no adjustments are made;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName = Zone Name + "HVAC_Air_Terminal_SD_Uncontrolled" (Zone Name – name of the zone for which the Zone HVAC Air Terminal Single Duct Uncontrolled is assigned);
- Zone Supply Air Node Name – airTerminalName + "OUTLET_NODE". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + "AIR_INLET_NODES"), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**).

The Zone HVAC Air Terminal Single Duct Uncontrolled specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_LivingRoom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object ('ABC', in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **"ABC"**). The available options are: ABC = 'SequentialLoad', 'UniformLoad', 'UniformPLR' or 'SequentialUniformPLR';
- **new ArrayList<>()** – array list which will include the Zone HVAC Air Terminal Single Duct Uncontrolled specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;

- **DBSpaceType.LIVING_ROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Air Terminal Single Duct Uncontrolled is assigned, defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

zoneHVACSpec_LivingRoom.addSpec() – Used to add the Zone HVAC Air Terminal Single Duct Uncontrolled specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following arguments:

- **airTerminalSingleDuctUncontrolled_LivingRoom** – the Zone HVAC Air Terminal Single Duct Uncontrolled specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Air Terminal Single Duct Uncontrolled cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_LivingRoom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

As this Zone HVAC Air Terminal Single Duct Uncontrolled is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the Zone HVAC Equipment List and Equipment Connections objects in EnergyPlus, as presented in section **7.1.9**.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_UnitarySystem_HotWaterLoop template in the SAPTool_LSP.

7.1.8.2. Constant Volume Reheat

The specification of a Zone HVAC Air Terminal Single Duct Constant Volume Reheat is defined in the SAPTool_LSP building template for each different zone, as defined below. The Zone HVAC Air Terminal Single Duct Constant Volume Reheat option must be active (**ZONE_HVAC_AIR_TERMINAL_SINGLE_DUCT_CONSTANT_VOLUME_REHEAT = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and “Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**). An Air Loop HVAC must be defined, in order to assign the air terminal to (**10**).

ZoneHVACAirTerminalSingleDuctConstantVolumeReheatSpec airTerminalSingleDuctConstantVolumeReheat_LivingRoom = new ZoneHVACAirTerminalSingleDuctConstantVolumeReheatSpec() – Zone HVAC Air Terminal Single Duct Constant Volume Reheat specification (named airTerminalSingleDuctConstantVolumeReheat_LivingRoom in this example). With the following ZoneHVACAirTerminalSingleDuctConstantVolumeReheatSpec() arguments:

- **x1** – name of the Air Loop HVAC (defined in section **10.1**) for which this Zone HVAC Air Terminal Single Duct Constant Volume Reheat is assigned;
- **x2** – name of the reheat coil specification assigned to this air terminal. The valid reheat component objects currently available are: Coil Heating Water (**8.9.2.10**), Coil Heating Steam (**8.9.2.11**), Coil Heating Electric (**8.9.2.6**), and Coil Heating Fuel (**8.9.2.8**). If the coil is a water or steam coil, it must be assigned to a plant loop for heat source (see section Reheat coil connection to a plant loop below);
- **x3** – ID of the Zone HVAC Air Terminal Single Duct Constant Volume Reheat properties in the database for this zone, in the **ZoneHVACAirTerminalSingleDuctConstantVolumeReheat** table (see below);
- **db** – database unique ID.

The Zone HVAC Air Terminal Single Duct Constant Volume Reheat properties are defined in the **ZoneHVACAirTerminalSingleDuctConstantVolumeReheat** table in the database, corresponding to the AirTerminal:SingleDuct:ConstantVolume:Reheat object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the unit is always available;
- maximumAirFlowRate – design maximum volume flow rate [m^3/s]. ‘autosize’ option is available;
- maximumHotWaterOrStreamFlowRate – maximum design hot water or steam volumetric flow for the hot water or steam heating coil [m^3/s]. This field is zero for gas and electric coils. ‘autosize’ option is available;

- minimumHotWaterOrStreamFlowRate – minimum design hot water or steam volumetric flow rate for the hot water or steam heating coil, normally set to be a shut off valve that is set to zero [m^3/s]. This field is zero for gas and electric coils;
- convergenceTolerance – termination criteria for the hot water mass flow rate iterative solution;
- maximumReheatAirTemperature – maximum supply air temperature leaving the reheat coil in a VAV terminal unit during heating operation [°C];
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName = Zone Name + "HVAC_Air_Terminal_SD_CV_Reheat" (Zone Name – name of the zone for which the Zone HVAC Air Terminal Single Duct Constant Volume Reheat is assigned);
- Air Outlet Node Name – airTerminalName + "OUTLET_NODE". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + "AIR_INLET_NODES"), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**);
- Air Inlet Node Name – airTerminalName + "Inlet_node";
- Reheat Coil Object Type – type of reheat coil assigned to this unit (in the argument x2 of the ZoneHVACAirTerminalSingleDuctConstantVolumeReheatSpec() above);
- Reheat Coil Name – airTerminalName + "Reheat_Coil".

The following fields in the **ZoneHVACAirTerminalSingleDuctConstantVolumeReheat** table are used to define the Air Distribution Unit containing this Air Terminal unit, corresponding to the ZoneHVAC:AirDistributionUnit object in EnergyPlus:

- nominalUpstreamLeakageFraction – leakage upstream of the terminal unit as a fraction of the design flow rate through the unit. It is the leakage fraction at the design flow rate (optional);
- constantDownstreamLeakageFraction – leakage downstream of the terminal unit as a fraction of the current flow rate through the terminal unit (optional);
- designSpecificationAirTerminalSizingID – ID of the object which specifies sizing adjustments to be made for this terminal unit, defined in table **DesignSpecificationAirTerminalSizing** in the database (see section **13.1.4**) (optional). If blank, no adjustments are made.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName + "Air_Distribution_Unit";
- Distribution Unit Outlet Node Name – Air Outlet Node Name of the Air Terminal unit;
- Air Terminal Object Type – AirTerminal:SingleDuct:ConstantVolume:Reheat;
- Air Terminal Name – airTerminalName.

The Zone HVAC Air Terminal Single Duct Constant Volume Reheat specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_LivingRoom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object ('ABC', in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **"ABC"**). The available options are: ABC = 'SequentialLoad', 'UniformLoad', 'UniformPLR' or 'SequentialUniformPLR';
- **new ArrayList<>()** – array list which will include the Zone HVAC Air Terminal Single Duct Constant Volume Reheat specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.LIVING_ROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Air Terminal Single Duct Constant Volume Reheat is assigned, defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

zoneHVACSpec_LivingRoom.addSpec() – Used to add the Zone HVAC Air Terminal Single Duct Constant Volume Reheat specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following arguments:

- **airTerminalSingleDuctConstantVolumeReheat_LivingRoom** – the Zone HVAC Air Terminal Single Duct Constant Volume Reheat specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Air Terminal Single Duct Constant Volume Reheat cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies

if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_LivingRoom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

As this Zone HVAC Air Terminal Single Duct Constant Volume Reheat is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the Zone HVAC Equipment List and Equipment Connections objects in EnergyPlus, as presented in section **7.1.9**.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_ConstVol_Reheat_Chiller_HeatRecov_WaterHeater template in the SAPTool_LSP.

<u>Reheat coil connection to a plant loop</u>

If the reheat coil is a water or steam coil, it must be assigned to a plant loop for heat source (hot water loop or steam loop, depending on the coil type). This is defined in the SAPTool_LSP building template, as follows:

AirLoopSystemAndElementType airLoopSystemAndElementType = new AirLoopSystemAndElementType() – air loop system and element type specification (named airLoopSystemAndElementType in this example). With the following AirLoopSystemAndElementType() arguments:

- **x1** – name of the Air Loop HVAC specification to which the air terminal containing the reheat coil is assigned (**10.1**);
- **AirLoopSystemAndElementType.AirLoopHVACSystemType.XX** – system type, defined with the AirLoopHVACSystemType list object. In this case, XX = **AIR_TERMINAL_SINGLE_DUCT_CONSTANT_VOLUME_REHEAT**;
- **x2** – air terminal zone ID, which corresponds to the order for which the zone is added to the spaceSpec list in the building template;
- **AirLoopSystemAndElementType.ElementType.XX** – element type for which the plant loop is assigned, defined with the ElementType list object: XX = **COOLING_COIL**, **HEATING_COIL**, **SUPPLEMENTAL_HEATING_COIL**, **REHEAT_COIL** or **HEAT_RECOVERY**. In this case = **REHEAT_COIL**.

The air loop system and element type specification name (airLoopSystemAndElementType, in this example) must then be assigned to the proper loop branch, as shown in section **9.3**. A branch object is automatically assigned to the element type together with its pressure drop curve, if defined (see section **9.3** for details).

Notice that for each element type assignment to a plant loop, a different air loop system and element type specification must be defined.

7.1.8.3. VAV Reheat

The specification of a Zone HVAC Air Terminal Single Duct VAV Reheat is defined in the SAPTool_LSP building template for each different zone, as defined below. The Zone HVAC Air Terminal Single Duct VAV Reheat option must be active (**ZONE_HVAC_AIR_TERMINAL_SINGLE_DUCT_VAV_REHEAT = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and “Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**). An Air Loop HVAC must be defined, in order to assign the air terminal to (**10**).

ZoneHVACAirTerminalSingleDuctVAVReheatSpec airTerminalSingleDuctVAVReheat_LivingRoom = new ZoneHVACAirTerminalSingleDuctVAVReheatSpec() – Zone HVAC Air Terminal Single Duct VAV Reheat specification (named airTerminalSingleDuctVAVReheat_LivingRoom in this example). With the following ZoneHVACAirTerminalSingleDuctVAVReheatSpec() arguments:

- **x1** – name of the Air Loop HVAC (defined in section **10.1**) for which this Zone HVAC Air Terminal Single Duct VAV Reheat is assigned;
- **x2** – name of the reheat coil specification assigned to this air terminal. The valid reheat component objects currently available are: Coil Heating Water (**8.9.2.10**), Coil Heating Steam (**8.9.2.11**), Coil Heating Electric (**8.9.2.6**), and Coil Heating Fuel (**8.9.2.8**). If the coil is a water or steam coil, it must be assigned to a plant loop for heat source (see section Reheat coil connection to a plant loop below);
- **x3** – ID of the Zone HVAC Air Terminal Single Duct VAV Reheat properties in the database for this zone, in the **ZoneHVACAirTerminalSingleDuctVAVReheat** table (see below);
- **db** – database unique ID.

The Zone HVAC Air Terminal Single Duct VAV Reheat properties are defined in the **ZoneHVACAirTerminalSingleDuctVAVReheat** table in the database, corresponding to the AirTerminal:SingleDuct:VAV:Reheat object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the unit is always available;
- maximumAirFlowRate – design maximum volume flow rate [m^3/s]. ‘autosize’ option is available;
- zoneMinimumAirFlowInputMethod – ‘Constant’, ‘FixedFlowRate’ or ‘Scheduled’;

- constantMinimumAirFlowFraction – minimum flow rate to the zone while the system is operating, specified as a fraction of the maximum air flow rate. Used if zoneMinimumAirFlowInputMethod = Constant. ‘autosize’ option is available;
- fixedMinimumAirFlowRate – minimum flow rate to the zone while the system is operating, specified as a fixed minimum air flow rate [m^3/s]. Used if zoneMinimumAirFlowInputMethod = FixedFlowRate. ‘autosize’ option is available;
- minimumAirFlowFractionScheduleID – schedule that determines the value of the minimum air flow fraction, defined in the **Schedules** table in the database (**21**). Used if zoneMinimumAirFlowInputMethod = Scheduled;
- maximumHotWaterOrSteamFlowRate – maximum design hot water or steam volumetric flow for the hot water or steam heating coil [m^3/s]. This field is zero for gas and electric coils. ‘autosize’ option is available;
- minimumHotWaterOrSteamFlowRate – minimum design hot water or steam volumetric flow rate for the hot water or steam heating coil, normally set to be a shut off valve that is set to zero [m^3/s]. This field is zero for gas and electric coils;
- convergenceTolerance – termination criteria for the hot water mass flow rate iterative solution;
- damperHeatingAction – ‘Normal’, ‘ReverseWithLimits’ or ‘Reverse’;
- maximumFlowPerZoneFloorAreaDuringReheat – this factor is multiplied by the zone area, to determine the maximum volume flow rate allowed during reheat operation. Used only if Reheat Coil Object Type = Coil:Heating:Water and damperHeatingAction = ReverseWithLimits. ‘autosize’ option is available. If autosize is selected or the field is blank, the value is filled from the similar inputs in Sizing Zone (**13.2.2**). If there is no sizing calculation the value is set to 0.002032 $m^3/(s.m^2)$. If this field and the following field are entered, the greater of the two inputs is used;
- maximumFlowFractionDuringReheat – this fraction is multiplied by the Maximum Air Flow Rate to determine the maximum volume flow rate allowed during reheat operation. Used only if Reheat Coil Object Type = Coil:Heating:Water and damperHeatingAction = ReverseWithLimits. ‘autosize’ option is available. If autosize is selected or the field is blank, the value is set to 0.002032 $m^3/(s.m^2)$ multiplied by the zone floor area divided by the maximumAirFlowRate. If this field and the previous field are entered, the greater of the two inputs is used
- maximumReheatAirTemperature – maximum supply air temperature leaving the reheat coil in a VAV terminal unit during heating operation [°C];
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this system, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**) (optional). If blank, the terminal unit will not be controlled for outdoor air flow;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName = Zone Name + “HVAC_Air_Terminal_SD_VAV_Reheat" (Zone Name – name of the zone for which the Zone HVAC Air Terminal Single Duct VAV Reheat is assigned);
- Damper Air Outlet Node Name – inlet node name of the reheat coil assigned to this air terminal unit;

- Air Inlet Node Name – airTerminalName + “Inlet_node”;
- Reheat Coil Object Type – type of reheat coil assigned to this unit (in the argument x2 of the ZoneHVACAirTerminalSingleDuctVAVReheatSpec() above);
- Reheat Coil Name – airTerminalName + “Reheat_Coil”;
- Air Outlet Node Name – airTerminalName + "OUTLET_NODE". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + “AIR_INLET_NODES”), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**).

The following fields in the **ZoneHVACAirTerminalSingleDuctVAVReheat** table are used to define the Air Distribution Unit containing this Air Terminal unit, corresponding to the ZoneHVAC:AirDistributionUnit object in EnergyPlus:

- nominalUpstreamLeakageFraction – leakage upstream of the terminal unit as a fraction of the design flow rate through the unit. It is the leakage fraction at the design flow rate (optional);
- constantDownstreamLeakageFraction – leakage downstream of the terminal unit as a fraction of the current flow rate through the terminal unit (optional);
- designSpecificationAirTerminalSizingID – ID of the object which specifies sizing adjustments to be made for this terminal unit, defined in table **DesignSpecificationAirTerminalSizing** in the database (see section **13.1.4**) (optional). If blank, no adjustments are made.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName + “Air_Distribution_Unit”;
- Distribution Unit Outlet Node Name – Air Outlet Node Name of the Air Terminal unit;
- Air Terminal Object Type – AirTerminal:SingleDuct:VAV:Reheat;
- Air Terminal Name – airTerminalName.

The Zone HVAC Air Terminal Single Duct VAV Reheat specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_LivingRoom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object (‘ABC’, in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **“ABC”**). The available options are: ABC = ‘SequentialLoad’, ‘UniformLoad’, ‘UniformPLR’ or ‘SequentialUniformPLR’;
- **new ArrayList<>()** – array list which will include the Zone HVAC Air Terminal Single Duct VAV Reheat specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;

- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.LIVING_ROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Air Terminal Single Duct VAV Reheat is assigned, defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

zoneHVACSpec_LivingRoom.addSpec() – Used to add the Zone HVAC Air Terminal Single Duct VAV Reheat specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following arguments:

- **airTerminalSingleDuctVAVReheat_LivingRoom** – the Zone HVAC Air Terminal Single Duct VAV Reheat specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Air Terminal Single Duct VAV Reheat cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_LivingRoom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

As this Zone HVAC Air Terminal Single Duct VAV Reheat is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the Zone HVAC Equipment List and Equipment Connections objects in EnergyPlus, as presented in section **7.1.9**.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_VAV_Reheat_HotColdWaterLoops template in the SAPTool_LSP.

Reheat coil connection to a plant loop

If the reheat coil is a water or steam coil, it must be assigned to a plant loop for heat source (hot water loop or steam loop, depending on the coil type). This is defined in the SAPTool_LSP building template, as follows:

AirLoopSystemAndElementType airLoopSystemAndElementType = new AirLoopSystemAndElementType() – air loop system and element type specification (named airLoopSystemAndElementType in this example). With the following AirLoopSystemAndElementType() arguments:

- **x1** – name of the Air Loop HVAC specification to which the air terminal containing the reheat coil is assigned (**10.1**);
- **AirLoopSystemAndElementType.AirLoopHVACSystemType.XX** – system type, defined with the AirLoopHVACSystemType list object. In this case, XX = **AIR_TERMINAL_SINGLE_DUCT_VAV_REHEAT**;
- **x2** – air terminal zone ID, which corresponds to the order for which the zone is added to the spaceSpec list in the building template;
- **AirLoopSystemAndElementType.ElementType.XX** – element type for which the plant loop is assigned, defined with the ElementType list object: XX = **COOLING_COIL**, **HEATING_COIL**, **SUPPLEMENTAL_HEATING_COIL**, **REHEAT_COIL** or **HEAT_RECOVERY**. In this case = **REHEAT_COIL**.

The air loop system and element type specification name (airLoopSystemAndElementType, in this example) must then be assigned to the proper loop branch, as shown in section **9.3**. A branch object is automatically assigned to the element type together with its pressure drop curve, if defined (see section **9.3** for details).

Notice that for each element type assignment to a plant loop, a different air loop system and element type specification must be defined.

7.1.8.4. VAV No Reheat

The specification of a Zone HVAC Air Terminal Single Duct VAV No Reheat is defined in the SAPTool_LSP building template for each different zone, as defined below. The Zone HVAC Air Terminal Single Duct VAV No Reheat option must be active (**ZONE_HVAC_AIR_TERMINAL_SINGLE_DUCT_VAV_NO_REHEAT = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and

“Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**). An Air Loop HVAC must be defined, in order to assign the air terminal to (**10**).

ZoneHVACAirTerminalSingleDuctVAVNoReheatSpec airTerminalSingleDuctVAVNoReheat_LivingRoom = new ZoneHVACAirTerminalSingleDuctVAVNoReheatSpec() – Zone HVAC Air Terminal Single Duct VAV No Reheat specification (named airTerminalSingleDuctVAVNoReheat_LivingRoom in this example). With the following ZoneHVACAirTerminalSingleDuctVAVNoReheatSpec() arguments:

- **x1** – name of the Air Loop HVAC (defined in section **10.1**) for which this Zone HVAC Air Terminal Single Duct VAV No Reheat is assigned;
- **x2** – ID of the Zone HVAC Air Terminal Single Duct VAV No Reheat properties in the database for this zone, in the **ZoneHVACAirTerminalSingleDuctVAVNoReheat** table (see below);
- **db** – database unique ID.

The Zone HVAC Air Terminal Single Duct VAV No Reheat properties are defined in the **ZoneHVACAirTerminalSingleDuctVAVNoReheat** table in the database, corresponding to the AirTerminal:SingleDuct:VAV:NoReheat object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the unit is always available;
- maximumAirFlowRate – design maximum volume flow rate [m^3/s]. ‘autosize’ option is available;
- zoneMinimumAirFlowInputMethod – ‘Constant’, ‘FixedFlowRate’ or ‘Scheduled’;
- constantMinimumAirFlowFraction – minimum flow rate to the zone while the system is operating, specified as a fraction of the maximum air flow rate. Used if zoneMinimumAirFlowInputMethod = Constant. ‘autosize’ option is available;
- fixedMinimumAirFlowRate – minimum flow rate to the zone while the system is operating, specified as a fixed minimum air flow rate [m^3/s]. Used if zoneMinimumAirFlowInputMethod = FixedFlowRate. ‘autosize’ option is available;
- minimumAirFlowFractionScheduleID – schedule that determines the value of the minimum air flow fraction, defined in the **Schedules** table in the database (**21**). Used if zoneMinimumAirFlowInputMethod = Scheduled;
- designSpecificationOutdoorAirID – ID of the object which specifies the outdoor air requirements and schedule for this system, defined in table **DesignSpecificationOutdoorAir** in the database (see section **13.1.1**) (optional). If blank, the terminal unit will not be controlled for outdoor air flow;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName = Zone Name + “HVAC_Air_Terminal_SD_VAV_No_Reheat" (Zone Name – name of the zone for which the Zone HVAC Air Terminal Single Duct VAV No Reheat is assigned);

- Air Inlet Node Name – airTerminalName + “Inlet_node”;
- Air Outlet Node Name – airTerminalName + "OUTLET_NODE". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + “AIR_INLET_NODES”), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**).

The following fields in the **ZoneHVACAirTerminalSingleDuctVAVNoReheat** table are used to define the Air Distribution Unit containing this Air Terminal unit, corresponding to the ZoneHVAC:AirDistributionUnit object in EnergyPlus:

- nominalUpstreamLeakageFraction – leakage upstream of the terminal unit as a fraction of the design flow rate through the unit. It is the leakage fraction at the design flow rate (optional);
- constantDownstreamLeakageFraction – leakage downstream of the terminal unit as a fraction of the current flow rate through the terminal unit (optional);
- designSpecificationAirTerminalSizingID – ID of the object which specifies sizing adjustments to be made for this terminal unit, defined in table **DesignSpecificationAirTerminalSizing** in the database (see section **13.1.4**) (optional). If blank, no adjustments are made.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName + “Air_Distribution_Unit”;
- Distribution Unit Outlet Node Name – Air Outlet Node Name of the Air Terminal unit;
- Air Terminal Object Type – AirTerminal:SingleDuct:VAV:NoReheat;
- Air Terminal Name – airTerminalName.

The Zone HVAC Air Terminal Single Duct VAV No Reheat specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_LivingRoom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object (‘ABC’, in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **“ABC”**). The available options are: ABC = ‘SequentialLoad’, ‘UniformLoad’, ‘UniformPLR’ or ‘SequentialUniformPLR’;
- **new ArrayList<>()** – array list which will include the Zone HVAC Air Terminal Single Duct VAV No Reheat specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;

- **DBSpaceType.LIVING_ROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Air Terminal Single Duct VAV No Reheat is assigned, defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

zoneHVACSpec_LivingRoom.addSpec() – Used to add the Zone HVAC Air Terminal Single Duct VAV No Reheat specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following arguments:

- **airTerminalSingleDuctVAVNoReheat_LivingRoom** – the Zone HVAC Air Terminal Single Duct VAV No Reheat specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Air Terminal Single Duct VAV No Reheat cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_LivingRoom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

As this Zone HVAC Air Terminal Single Duct VAV No Reheat is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the Zone HVAC Equipment List and Equipment Connections objects in EnergyPlus, as presented in section **7.1.9**.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_Fancoils_DOAS_HotColdCndWaterLoops template in the SAPTool_LSP.

7.1.8.5. VAV Heat and Cool Reheat

The specification of a Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat is defined in the SAPTool_LSP building template for each different zone, as defined below. The Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat option must be active (**ZONE_HVAC_AIR_TERMINAL_SINGLE_DUCT_VAV_HEAT_AND_COOL_REHEAT = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and “Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**). An Air Loop HVAC must be defined, in order to assign the air terminal to (**10**).

ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolReheatSpec airTerminalSingleDuctVAVHeatCoolReheat_LivingRoom = new ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolReheatSpec() – Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat specification (named airTerminalSingleDuctVAVHeatCoolReheat_LivingRoom in this example). With the following ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolReheatSpec() arguments:

- **x1** – name of the Air Loop HVAC (defined in section **10.1**) for which this Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat is assigned;
- **x2** – name of the reheat coil specification assigned to this air terminal. The valid reheat component objects currently available are: Coil Heating Water (**8.9.2.10**), Coil Heating Steam (**8.9.2.11**), Coil Heating Electric (**8.9.2.6**), and Coil Heating Fuel (**8.9.2.8**). If the coil is a water or steam coil, it must be assigned to a plant loop for heat source (see section Reheat coil connection to a plant loop below);
- **x3** – ID of the Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat properties in the database for this zone, in the **ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolReheat** table (see below);
- **db** – database unique ID.

The Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat properties are defined in the **ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolReheat** table in the database, corresponding to the AirTerminal:SingleDuct:VAV:HeatAndCool:Reheat object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the unit is always available;
- maximumAirFlowRate – design maximum volume flow rate [m^3/s]. ‘autosize’ option is available;
- zoneMinimumAirFlowFraction – minimum air volumetric flow rate to the zone while the system is operating, specified as a fraction of the maximum air flow rate;

- maximumHotWaterOrSteamFlowRate – maximum design hot water or steam volumetric flow for the hot water or steam heating coil [m^3/s]. This field is zero for gas and electric coils. 'autosize' option is available;
- minimumHotWaterOrSteamFlowRate – minimum design hot water or steam volumetric flow rate for the hot water or steam heating coil, normally set to be a shut off valve that is set to zero [m^3/s]. This field is zero for gas and electric coils;
- convergenceTolerance – termination criteria for the hot water mass flow rate iterative solution;
- maximumReheatAirTemperature – maximum supply air temperature leaving the reheat coil in a VAV terminal unit during heating operation [°C];
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName = Zone Name + "HVAC_Air_Terminal_SD_VAV_HeatCool_Reheat" (Zone Name – name of the zone for which the Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat is assigned);
- Damper Air Outlet Node Name – inlet node name of the reheat coil assigned to this air terminal unit;
- Air Inlet Node Name – airTerminalName + "Inlet_node";
- Reheat Coil Object Type – type of reheat coil assigned to this unit (in the argument x2 of the ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolReheatSpec() above);
- Reheat Coil Name – airTerminalName + "Reheat_Coil";
- Air Outlet Node Name – airTerminalName + "OUTLET_NODE". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + "AIR_INLET_NODES"), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**).

The following fields in the **ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolReheat** table are used to define the Air Distribution Unit containing this Air Terminal unit, corresponding to the ZoneHVAC:AirDistributionUnit object in EnergyPlus:

- nominalUpstreamLeakageFraction – leakage upstream of the terminal unit as a fraction of the design flow rate through the unit. It is the leakage fraction at the design flow rate (optional);
- constantDownstreamLeakageFraction – leakage downstream of the terminal unit as a fraction of the current flow rate through the terminal unit (optional);
- designSpecificationAirTerminalSizingID – ID of the object which specifies sizing adjustments to be made for this terminal unit, defined in table **DesignSpecificationAirTerminalSizing** in the database (see section **13.1.4**) (optional). If blank, no adjustments are made.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName + "Air_Distribution_Unit";
- Distribution Unit Outlet Node Name – Air Outlet Node Name of the Air Terminal unit;

- Air Terminal Object Type – AirTerminal:SingleDuct:VAV:HeatAndCool:Reheat;
- Air Terminal Name – airTerminalName.

The Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_LivingRoom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object ('ABC', in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **"ABC"**). The available options are: ABC = 'SequentialLoad', 'UniformLoad', 'UniformPLR' or 'SequentialUniformPLR';
- **new ArrayList<>()** – array list which will include the Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.LIVING_ROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat is assigned, defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

zoneHVACSpec_LivingRoom.addSpec() – Used to add the Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following arguments:

- **airTerminalSingleDuctVAVHeatCoolReheat_LivingRoom** – the Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;

- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_LivingRoom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

As this Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the Zone HVAC Equipment List and Equipment Connections objects in EnergyPlus, as presented in section **7.1.9**.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_VAVHeatCool_VAVSeriesPIU_ReheatWaterLoop template in the SAPTool_LSP.

<u>**Reheat coil connection to a plant loop**</u>

If the reheat coil is a water or steam coil, it must be assigned to a plant loop for heat source (hot water loop or steam loop, depending on the coil type). This is defined in the SAPTool_LSP building template, as follows:

AirLoopSystemAndElementType airLoopSystemAndElementType = new AirLoopSystemAndElementType() – air loop system and element type specification (named airLoopSystemAndElementType in this example). With the following AirLoopSystemAndElementType() arguments:

- **x1** – name of the Air Loop HVAC specification to which the air terminal containing the reheat coil is assigned (**10.1**);
- **AirLoopSystemAndElementType.AirLoopHVACSystemType.XX** – system type, defined with the AirLoopHVACSystemType list object. In this case, XX = **AIR_TERMINAL_SINGLE_DUCT_VAV_HEAT_AND_COOL_REHEAT**;
- **x2** – air terminal zone ID, which corresponds to the order for which the zone is added to the spaceSpec list in the building template;
- **AirLoopSystemAndElementType.ElementType.XX** – element type for which the plant loop is assigned, defined with the ElementType list object: XX = **COOLING_COIL**,

HEATING_COIL, **SUPPLEMENTAL_HEATING_COIL**, **REHEAT_COIL** or **HEAT_RECOVERY**. In this case = **REHEAT_COIL**.

The air loop system and element type specification name (airLoopSystemAndElementType, in this example) must then be assigned to the proper loop branch, as shown in section **9.3**. A branch object is automatically assigned to the element type together with its pressure drop curve, if defined (see section **9.3** for details).

Notice that for each element type assignment to a plant loop, a different air loop system and element type specification must be defined.

7.1.8.6. VAV Heat and Cool No Reheat

The specification of a Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat is defined in the SAPTool_LSP building template for each different zone, as defined below. The Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat option must be active (**ZONE_HVAC_AIR_TERMINAL_SINGLE_DUCT_VAV_HEAT_AND_COOL_NO_REHEAT = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and “Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**). An Air Loop HVAC must be defined, in order to assign the air terminal to (**10**).

ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolNoReheatSpec airTerminalSingleDuctVAVHeatCoolNoReheat_LivingRoom = new ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolNoReheatSpec() – Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat specification (named airTerminalSingleDuctVAVHeatCoolNoReheat_LivingRoom in this example). With the following ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolNoReheatSpec() arguments:

- **x1** – name of the Air Loop HVAC (defined in section **10.1**) for which this Zone HVAC Air Terminal Single Duct VAV No Reheat is assigned;
- **x2** – ID of the Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat properties in the database for this zone, in the **ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolNoReheat** table (see below);
- **db** – database unique ID.

The Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat properties are defined in the **ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolNoReheat** table in the database, corresponding to the AirTerminal:SingleDuct:VAV:HeatAndCool:NoReheat object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the unit is always available;
- maximumAirFlowRate – design maximum volume flow rate [m^3/s]. ‘autosize’ option is available;

- zoneMinimumAirFlowFraction – minimum air volume flow rate to the zone while the system is operating, specified as a fraction of the maximum air flow rate;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName = Zone Name + "HVAC_Air_Terminal_SD_VAV_HeatCool_No_Reheat" (Zone Name – name of the zone for which the Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat is assigned);
- Air Inlet Node Name – airTerminalName + "Inlet_node";
- Air Outlet Node Name – airTerminalName + "OUTLET_NODE". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + "AIR_INLET_NODES"), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**).

The following fields in the **ZoneHVACAirTerminalSingleDuctVAVHeatAndCoolNoReheat** table are used to define the Air Distribution Unit containing this Air Terminal unit, corresponding to the ZoneHVAC:AirDistributionUnit object in EnergyPlus:

- nominalUpstreamLeakageFraction – leakage upstream of the terminal unit as a fraction of the design flow rate through the unit. It is the leakage fraction at the design flow rate (optional);
- constantDownstreamLeakageFraction – leakage downstream of the terminal unit as a fraction of the current flow rate through the terminal unit (optional);
- designSpecificationAirTerminalSizingID – ID of the object which specifies sizing adjustments to be made for this terminal unit, defined in table **DesignSpecificationAirTerminalSizing** in the database (see section **13.1.4**) (optional). If blank, no adjustments are made.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName + "Air_Distribution_Unit";
- Distribution Unit Outlet Node Name – Air Outlet Node Name of the Air Terminal unit;
- Air Terminal Object Type – AirTerminal:SingleDuct:VAV:HeatAndCool:NoReheat;
- Air Terminal Name – airTerminalName.

The Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_LivingRoom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object

(‘ABC’, in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **“ABC”**). The available options are: ABC = ‘SequentialLoad’, ‘UniformLoad’, ‘UniformPLR’ or ‘SequentialUniformPLR’;

- **new ArrayList<>()** – array list which will include the Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.LIVING_ROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat is assigned, defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

zoneHVACSpec_LivingRoom.addSpec() – Used to add the Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following arguments:

- **airTerminalSingleDuctVAVHeatCoolNoReheat_LivingRoom** – the Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object (“SCH1”, in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object (“SCH2”, in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_LivingRoom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

As this Zone HVAC Air Terminal Single Duct VAV Heat and Cool No Reheat is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the Zone HVAC Equipment List and Equipment Connections objects in EnergyPlus, as presented in section **7.1.9**.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_VAVHeatCool_VAVSeriesPIU_ReheatWaterLoop template in the SAPTool_LSP.

7.1.8.7. Series PIU Reheat

The specification of a Zone HVAC Air Terminal Single Duct Series PIU Reheat is defined in the SAPTool_LSP building template for each different zone, as defined below. The Zone HVAC Air Terminal Single Duct Series PIU Reheat option must be active (**ZONE_HVAC_AIR_TERMINAL_SINGLE_DUCT_SERIESPIU_REHEAT = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables. A Zone Control Thermostat (**7.2.1**) must also be defined for each zone. If zone autosized fields are used for zone design air flow calculation, a Sizing Zone (**13.2.2**) must be defined and “Do Zone Sizing Calculation" should be set to Yes in the Simulation Control (x1 = true in section **17**). An Air Loop HVAC must be defined, in order to assign the air terminal to (**10**).

ZoneHVACAirTerminalSingleDuctSeriesPIUReheatSpec airTerminalSingleDuctSPIUReheat_LivingRoom = new ZoneHVACAirTerminalSingleDuctSeriesPIUReheatSpec() – Zone HVAC Air Terminal Single Duct Series PIU Reheat specification (named airTerminalSingleDuctSPIUReheat_LivingRoom in this example). With the following ZoneHVACAirTerminalSingleDuctSeriesPIUReheatSpec() arguments:

- **x1** – name of the Air Loop HVAC (defined in section **10.1**) for which this Zone HVAC Air Terminal Single Duct VAV Heat and Cool Reheat is assigned;
- **x2** – name of the fan specification assigned to this air terminal. The only valid fan component objects currently available is Fan Constant Volume (**8.8.3**);
- **x3** – name of the reheat coil specification assigned to this air terminal. The valid reheat component objects currently available are: Coil Heating Water (**8.9.2.10**), Coil Heating Steam (**8.9.2.11**), Coil Heating Electric (**8.9.2.6**), and Coil Heating Fuel (**8.9.2.8**). If the coil is a water or steam coil, it must be assigned to a plant loop for heat source (see section <u>Reheat coil connection to a plant loop</u> below);
- **x3** – ID of the Zone HVAC Air Terminal Single Duct Series PIU Reheat properties in the database for this zone, in the **ZoneHVACAirTerminalSingleDuctSeriesPIUReheat** table (see below);
- **db** – database unique ID.

The Zone HVAC Air Terminal Single Duct Series PIU Reheat properties are defined in the **ZoneHVACAirTerminalSingleDuctSeriesPIUReheat** table in the database, corresponding to the AirTerminal:SingleDuct:SeriesPIU:Reheat object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the unit is always available;
- maximumAirFlowRate – design maximum volume flow rate [m^3/s]. 'autosize' option is available;
- maximumPrimaryAirFlowRate – maximum volumetric air flow rate of primary air through the unit [m^3/s]. This is the primary air flow rate at full cooling load when the primary air damper is fully open. 'autosize' option is available;
- minimumPrimaryAirFlowFraction – minimum volumetric air flow rate of primary air through the unit expressed as a fraction of the maximum volumetric air flow rate of primary air. 'autosize' option is available;
- maximumHotWaterOrSteamFlowRate – maximum design hot water or steam volumetric flow for the hot water or steam heating coil [m^3/s]. This field is zero for gas and electric coils. 'autosize' option is available;
- minimumHotWaterOrSteamFlowRate – minimum design hot water or steam volumetric flow rate for the hot water or steam heating coil, normally set to be a shut off valve that is set to zero [m^3/s]. This field is zero for gas and electric coils;
- convergenceTolerance – termination criteria for the hot water mass flow rate iterative solution;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName = Zone Name + "HVAC_Air_Terminal_SD_SeriesPIU_Reheat" (Zone Name – name of the zone for which the Zone HVAC Air Terminal Single Duct Series PIU Reheat is assigned);
- Supply Air Inlet Node Name – airTerminalName + "Inlet_node";
- Secondary Air Inlet Node Name – airTerminalName + "SECONDARY_INLET_NODE"". This node is automatically assigned to the zone exhaust node list (automatically named Zone Name + "AIR_EXHAUST_NODES"), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Exhaust Node List in the Equipment Connections (see section **7.1.9**);
- Outlet Node Name – airTerminalName + "OUTLET_NODE". This node is automatically assigned to the zone inlet node list (automatically named Zone Name + "AIR_INLET_NODES"), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Inlet Node List in the Equipment Connections (see section **7.1.9**);
- Reheat Coil Air Inlet Node Name – name of the outlet node of the fan assigned to this terminal unit (in the argument x2 of the ZoneHVACAirTerminalSingleDuctSeriesPIUReheatSpec() above);
- Zone Mixer Name – zoneMixerName = airTerminalName + "Mixer"*;

- Fan Name – airTerminalName + "Fan";
- Reheat Coil Object Type – type of reheat coil assigned to this unit (in the argument x3 of the ZoneHVACAirTerminalSingleDuctSeriesPIUReheatSpec() above);
- Reheat Coil Name – airTerminalName + "Reheat_Coil".

*A zone mixer is automatically defined, corresponding to the AirLoopHVAC:ZoneMixer object in EnergyPlus, where all fields are automatically filled, as follows:

- Name – zoneMixerName;
- Outlet Node Name – name of the inlet node of the fan assigned to this terminal unit (in the argument x2 of the ZoneHVACAirTerminalSingleDuctSeriesPIUReheatSpec() above);
- Inlet 1 Node Name – Supply Air Inlet Node Name defined above;
- Inlet 2 Node Name – Secondary Air Inlet Node Name defined above.

The following fields in the **ZoneHVACAirTerminalSingleDuctSeriesPIUReheat** table are used to define the Air Distribution Unit containing this Air Terminal unit, corresponding to the ZoneHVAC:AirDistributionUnit object in EnergyPlus:

- nominalUpstreamLeakageFraction – leakage upstream of the terminal unit as a fraction of the design flow rate through the unit. It is the leakage fraction at the design flow rate (optional);
- constantDownstreamLeakageFraction – leakage downstream of the terminal unit as a fraction of the current flow rate through the terminal unit (optional);
- designSpecificationAirTerminalSizingID – ID of the object which specifies sizing adjustments to be made for this terminal unit, defined in table **DesignSpecificationAirTerminalSizing** in the database (see section **13.1.4**) (optional). If blank, no adjustments are made.

Automatic filling fields in EnergyPlus:

- Name – airTerminalName + "Air_Distribution_Unit";
- Distribution Unit Outlet Node Name – Air Outlet Node Name of the Air Terminal unit;
- Air Terminal Object Type – AirTerminal:SingleDuct:SeriesPIU:Reheat;
- Air Terminal Name – airTerminalName.

The Zone HVAC Air Terminal Single Duct Series PIU Reheat specified above must then be added to the Zone HVAC systems specifications, as follows:

ZoneHVACSpec zoneHVACSpec_LivingRoom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object ('ABC', in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **"ABC"**). The available options are: ABC = 'SequentialLoad', 'UniformLoad', 'UniformPLR' or 'SequentialUniformPLR';

- **new ArrayList<>()** – array list which will include the Zone HVAC Air Terminal Single Duct Series PIU Reheat specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction;
- **x1** – used only for Fan Zone Exhaust cooling and heating or no-load sequences;
- **x2** – used only for Fan Zone Exhaust sequential cooling fraction schedule;
- **x3** – used only for Fan Zone Exhaust sequential heating fraction schedule;
- **DBSpaceType.LIVING_ROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Zone HVAC Air Terminal Single Duct Series PIU Reheat is assigned, defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

zoneHVACSpec_LivingRoom.addSpec() – Used to add the Zone HVAC Air Terminal Single Duct Series PIU Reheat specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following arguments:

- **airTerminalSingleDuctSPIUReheat_LivingRoom** – the Zone HVAC Air Terminal Single Duct Series PIU Reheat specification defined previously;
- **new Integer[]{a,b}** – a defines the Zone HVAC Air Terminal Single Duct Series PIU Reheat cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH1", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0.

Finally, the Zone HVAC systems specified above must be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_LivingRoom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

As this Zone HVAC Air Terminal Single Duct Series PIU Reheat is a Zone HVAC object, it must be assigned to an equipment list, for which its connections must be defined. This is done automatically by filling the Zone HVAC Equipment List and Equipment Connections objects in EnergyPlus, as presented in section **7.1.9**.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_VAVHeatCool_VAVSeriesPIU_ReheatWaterLoop template in the SAPTool_LSP.

Reheat coil connection to a plant loop

If the reheat coil is a water or steam coil, it must be assigned to a plant loop for heat source (hot water loop or steam loop, depending on the coil type). This is defined in the SAPTool_LSP building template, as follows:

AirLoopSystemAndElementType airLoopSystemAndElementType = new AirLoopSystemAndElementType() – air loop system and element type specification (named airLoopSystemAndElementType in this example). With the following AirLoopSystemAndElementType() arguments:

- **x1** – name of the Air Loop HVAC specification to which the air terminal containing the reheat coil is assigned (**10.1**);
- **AirLoopSystemAndElementType.AirLoopHVACSystemType.XX** – system type, defined with the AirLoopHVACSystemType list object. In this case, XX = **AIR_TERMINAL_SINGLE_DUCT_SERIES_PIU_REHEAT**;
- **x2** – air terminal zone ID, which corresponds to the order for which the zone is added to the spaceSpec list in the building template;
- **AirLoopSystemAndElementType.ElementType.XX** – element type for which the plant loop is assigned, defined with the ElementType list object: XX = **COOLING_COIL**, **HEATING_COIL**, **SUPPLEMENTAL_HEATING_COIL**, **REHEAT_COIL** or **HEAT_RECOVERY**. In this case = **REHEAT_COIL**.

The air loop system and element type specification name (airLoopSystemAndElementType, in this example) must then be assigned to the proper loop branch, as shown in section **9.3**. A branch object is automatically assigned to the element type together with its pressure drop curve, if defined (see section **9.3** for details).

Notice that for each element type assignment to a plant loop, a different air loop system and element type specification must be defined.

7.1.9. Equipment Connections

The following two objects are automatically defined for a zone whenever a Zone HVAC object is assigned to it:

ZoneHVAC:EquipmentList

- Name – equipmentListName = Zone Name + "EQP_LIST" (Zone Name – name of the zone for which the equipment list is assigned);
- Load Distribution Scheme – algorithm used to allocate the current zone load across the zone equipment;
- Zone Equipment X Object Type – component X type;
- Zone Equipment X Name – component X name;
- Zone Equipment X Cooling Sequence – zone equipment simulation order when the zone thermostat requests cooling, defined for component X;
- Equipment X Heating or No-Load Sequence – zone equipment simulation when the zone thermostat requests heating or no load, defined for component X;
- Zone Equipment X Sequential Cooling Fraction Schedule – schedule that specifies the fraction of the remaining cooling load that component X will attempt to serve;
- Equipment X Sequential Heating Fraction Schedule – schedule that specifies the fraction of the remaining heating load that component X will attempt to serve.

ZoneHVAC:EquipmentConnections

- Zone Name – name of the zone for which the equipment list is assigned;
- Zone Conditioning Equipment List Name – equipment list name (equipmentListName defined above in the Zone HVAC Equipment List object);
- Zone Air Inlet Node List Name – list of the zone air inlet nodes, which is automatically assigned depending on the equipment (if necessary);
- Zone Air Exhaust Node List Name – list of the zone air exhaust nodes, which is automatically assigned depending on the equipment (if necessary);
- Zone Air Node Name – Zone Name + "AIR_NODE";
- Zone Return Node Name – Zone Name + "RETURN_NODE";
- Zone Return Air Flow Rate Fraction Schedule Name – not yet implemented;
- Zone Return Air Flow Rate Basis Node Name – not yet implemented;

Note: It is not possible to simultaneously assign a Zone HVAC Equipment and a Zone HVAC Template (**5**) to the same zone. This is due to the fact that a Zone HVAC Template is internally converted by EnergyPlus to a Zone HVAC Equipment for the simulation (with the expand file), thus automatically defining a new Equipment Connections object in the zone, in addition to the Equipment Connections object already defined for the Zone HVAC Equipment (described above); when only one Equipment Connections object is allowed per zone.

7.2. Zone Controls

7.2.1. Thermostat

This object is used to control a zone to a specified temperature.

A Zone Control Thermostat object is only active if required by a specific Zone HVAC object, which is automatically verified, and must be assigned to the zone in the 'zoneControlThermostatID' column of the **Zone** table in the database (**0**). Its setpoint type schedule and setpoint type(s) are defined in the **ZoneControlThermostat** table in the database, which corresponds to the ZoneControl:Thermostat object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- thermostatSetpointTypeScheduleID – thermostat setpoint type schedule ID, defined in the **Schedules** table in the database (**21**). 0 - Uncontrolled, 1 - Single Heating Setpoint, 2 - Single Cooling Setpoint, 3 - Single Heating Cooling Setpoint, 4 - Dual Setpoint with Deadband (Heating and Cooling). Each non-zero control type which is used in this schedule must appear in the following field which lists the specific thermostat control objects to be used for this zone;
- thermostatSetpointTypeIDs – IDs of the thermostat setpoint types assigned for this object (up to four IDs can be specified), which are defined in the **ThermostatSetpointType** table in the database (see below);
- temperatureDifferenceBetweenCutoutAndSetpoint – temperature difference between cutout temperature and setpoint (optional);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "CTRL_TS" + Zone Name;
- Zone Name – name of the zone for which this object is assigned;
- Control X Object Type – thermostat setpoint type X assigned to this object;
- Control X Name – name of the thermostat setpoint X assigned to this object.

The following fields are present in the **ThermostatSetpointType** table in the database:

- id – object ID;
- type – thermostat setpoint specification type in the corresponding Type table. There are four Thermostat Setpoint Types available: 'SingleHeating' (**ThermostatSetpointSingleHeating** table in the database – **7.2.1.1**), 'SingleCooling' (**ThermostatSetpointSingleCooling** table in the database – **7.2.1.2**), 'SingleHeatingOrCooling' (**ThermostatSetpointSingleHeatingOrCooling** table in the database – **7.2.1.3**), and 'DualSetpoint' (**ThermostatSetpointDualSetpoint** – **7.2.1.4**);
- thermostatSetpointID – thermostat setpoint type ID in the corresponding table.

7.2.1.1. Single Heating

The following fields are present in the **ThermostatSetpointSingleHeating** table in the database, corresponding to the ThermostatSetpoint:SingleHeating object in EnergyPlus:

- id – object ID;
- setpointTemperatureScheduleID – setpoint temperature schedule ID, defined in the **Schedules** table in the database (**21**).

Automatic filling fields in EnergyPlus:

- Name – "TS_SingleHeating" + Zone Name (Zone Name – name of the zone for which this thermostat setpoint is assigned).

7.2.1.2. Single Cooling

The following fields are present in the **ThermostatSetpointSingleCooling** table in the database, corresponding to the ThermostatSetpoint:SingleCooling object in EnergyPlus:

- id – object ID;
- setpointTemperatureScheduleID – setpoint temperature schedule ID, defined in the **Schedules** table in the database (**21**).

Automatic filling fields in EnergyPlus:

- Name – “TS_SingleCooling” + Zone Name (Zone Name – name of the zone for which this thermostat setpoint is assigned).

7.2.1.3. Single Heating or Cooling

The following fields are present in the **ThermostatSetpointSingleHeatingOrCooling** table in the database, corresponding to the ThermostatSetpoint:SingleHeatingOrCooling object in EnergyPlus:

- id – object ID;
- setpointTemperatureScheduleID – setpoint temperature schedule ID, defined in the **Schedules** table in the database (**21**).

Automatic filling fields in EnergyPlus:

- Name – “TS_SingleHeatingOrCooling” + Zone Name (Zone Name – name of the zone for which this thermostat setpoint is assigned).

7.2.1.4. Dual Setpoint

The following fields are present in the **ThermostatSetpointDualSetpoint** table in the database, corresponding to the ThermostatSetpoint:DualSetpoint object in EnergyPlus:

- id – object ID;
- heatingSetpointTemperatureScheduleID – heating setpoint temperature schedule ID, defined in the **Schedules** table in the database (**21**);
- coolingSetpointTemperatureScheduleID – cooling setpoint temperature schedule ID, defined in the **Schedules** table in the database (**21**).

Automatic filling fields in EnergyPlus:

- Name – “TS_DualSetpoint” + Zone Name (Zone Name – name of the zone for which this thermostat setpoint is assigned).

7.2.2. Humidistat

This object is used to control a zone to a single relative humidity setpoint schedule or to dual humidity setpoint schedules (humidifying/dehumidifying setpoints with deadband).

A Zone Control Humidistat object is only active if required by a specific HVAC equipment/system, which is automatically verified, and must be assigned to the zone in the 'zoneControlHumidistatID' column of the **Zone** table in the database (**0**). Its setpoint schedules are defined in the **ZoneControlHumidistat** table in the database, which corresponds to the ZoneControl:Humidistat object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- humidifyingRelativeHumiditySetpointScheduleID – humidifying relative humidity setpoint schedule ID, defined in the **Schedules** table in the database (**21**);
- dehumidifyingRelativeHumiditySetpointScheduleID – dehumidifying relative humidity setpoint schedule ID (optional), defined in the **Schedules** table in the database (**21**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "CTRL_HS" + Zone Name;
- Zone Name – name of the zone for which this object is assigned.

7.2.3. Contaminant Controller

This object is used to control a zone to a specified indoor level of contaminants, and to specify minimum or maximum CO_2 concentration schedule name for a zone.

A Zone Control Contaminant Controller object is only active if contaminant concentration simulation (CO_2 and/or generic contaminant) is active in the Zone Air Contaminant Balance object (**3**), and must be assigned to the zone in the 'zoneControlContaminantControllerID' column of the **Zone** table in the database (**0**). Its schedules are defined in the **ZoneControlContaminantController** table in the database, which corresponds to the ZoneControl:ContaminantController object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- carbonDioxideControlAvailabilityScheduleID – carbon dioxide control availability schedule ID, defined in the **Schedules** table in the database (**21**);
- carbonDioxideSetpointScheduleID – carbon dioxide setpoint schedule ID, defined in the **Schedules** table in the database (**21**);
- minimumCarbonDioxideConcentrationScheduleID – minimum carbon dioxide concentration schedule ID, defined in the **Schedules** table in the database (**21**);
- maximumCarbonDioxideConcentrationScheduleID – maximum carbon dioxide concentration schedule ID, defined in the **Schedules** table in the database (**21**);
- genericContaminantControlAvailabilityScheduleID – generic contaminant control availability schedule ID, defined in the **Schedules** table in the database (**21**). This field is only used if the generic contaminant concentration simulation is active in the Zone Air Contaminant Balance object (**3**);
- genericContaminantSetpointScheduleID – generic contaminant setpoint schedule ID, defined in the **Schedules** table in the database (**21**). This field is only used if the generic

contaminant concentration simulation is active in the Zone Air Contaminant Balance object (**3**);

- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – “CTRL_CONTAM” + Zone Name;
- Zone Name – name of the zone for which this object is assigned.

8. HVAC EQUIPMENT

8.1. Pipes

8.1.1. Adiabatic

The specification of a Pipe Adiabatic is defined in the SAPTool_LSP building template, as follows:

PipeAdiabaticSpec pipeAdiabaticSpec = new PipeAdiabaticSpec() – Pipe Adiabatic specification (named pipeAdiabaticSpec in this example). With the following PipeAdiabaticSpec() arguments:

- **DBPipeAdiabaticType.ABC.toString()** – pipe name, defined using the DBPipeAdiabaticType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **DBPipeAdiabaticType.ABC.getID** – ID of the Pipe Adiabatic properties in the database, defined using the DBPipeAdiabaticType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Pipe Adiabatic properties are defined in the **PipeAdiabatic** table in the database, corresponding to the Pipe:Adiabatic object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – pipeName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the pipe is assigned;
  - loopSide – loop side for which the pipe is assigned (‘PLANT’, ‘DEMAND’ or ‘CONDENSER’);
  - equipmentID – pipe position on the branch equipment list;
  - name – defined in the first argument of the PipeAdiabaticSpec() above;
- Inlet Node Name – pipeName + “Inlet_node”;
- Outlet Node Name – pipeName + “Outlet_node”.

8.1.2. Adiabatic Steam

This pipe type is required for steam plant loops (fluidType = Steam in section **9.1**). The specification of a Pipe Adiabatic Steam is defined in the SAPTool_LSP building template, as follows:

PipeAdiabaticSteamSpec pipeAdiabaticSteamSpec = new PipeAdiabaticSteamSpec() – Pipe Adiabatic Steam specification (named pipeAdiabaticSteamSpec in this example). With the following PipeAdiabaticSteamSpec() arguments:

- **DBPipeAdiabaticSteamType.ABC.toString()** – pipe name, defined using the DBPipeAdiabaticSteamType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **DBPipeAdiabaticSteamType.ABC.getID** – ID of the Pipe Adiabatic properties in the database, defined using the DBPipeAdiabaticType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Pipe Adiabatic Steam properties are defined in the **PipeAdiabaticSteam** table in the database, corresponding to the Pipe:Adiabatic:Steam object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – pipeName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the pipe is assigned;
  - loopSide – loop side for which the pipe is assigned ('PLANT' or 'DEMAND');
  - equipmentID – pipe position on the branch equipment list;
  - name – defined in the first argument of the PipeAdiabaticSteamSpec() above;
- Inlet Node Name – pipeName + "Inlet_node";
- Outlet Node Name – pipeName + "Outlet_node".

8.1.3. Indoor

The specification of a Pipe Indoor is defined in the SAPTool_LSP building template, as follows:

PipeIndoorSpec pipeIndoorSpec = new PipeIndoorSpec() – Pipe Indoor specification (named pipeIndoorSpec in this example). With the following PipeIndoorSpec() arguments:

- **DBPipeIndoorType.ABC.toString()** – pipe name, defined using the DBPipeIndoorType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **x** – ID of the zone for which the pipe is assigned, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Only used when environmentType = Zone, in the PipeIndoor table in the database (see below). Otherwise, this argument may be **null**, if no zone assignment;

- **DBPipeIndoorType.ABC.getID** – ID of the Pipe Indoor properties in the database, defined using the DBPipeIndoorType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Pipe Indoor properties are defined in the **PipeIndoor** table in the database, corresponding to the Pipe:Indoor object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- opaqueElementID – pipe construction element ID, defined in the **OpaqueElement** table in the database;
- environmentType – 'Zone' or 'Schedule';
- ambientTemperatureScheduleID – ambient temperature schedule ID, defined in the **Schedules** table in the database (**21**). Only used if environmentType = Schedule;
- ambientAirVelocityScheduleID – ambient air velocity schedule ID, defined in the **Schedules** table in the database (**21**). Only used if environmentType = Schedule;
- pipeInsideDiameter – inside diameter of the pipe [m];
- pipeLength – length of the pipe [m];
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – pipeName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the pipe is assigned;
  - loopSide – loop side for which the pipe is assigned ('PLANT', 'DEMAND' or 'CONDENSER');
  - equipmentID – pipe position on the branch equipment list;
  - name – defined in the first argument of the PipeIndoorSpec() above;
- Construction Name – construction object that gives a layer-by-layer description of the pipe wall and its insulation (opaqueElementID), defined in the **OpaqueElement** table in the database;
- Fluid Inlet Node Name – pipeName + "Inlet_node";
- Fluid Outlet Node Name – pipeName + "Outlet_node";
- Ambient Temperature Zone Name – zone for which the pipe is assigned (if any), defined in argument x of the PipeIndoorSpec() above.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_Fancoils_DOAS_HotColdCndWaterLoops template in the SAPTool_LSP.

8.1.4. Outdoor

The specification of a Pipe Outdoor is defined in the SAPTool_LSP building template, as follows:

PipeOutdoorSpec pipeOutdoorSpec = new PipeOutdoorSpec() – Pipe Outdoor specification (named pipeOutdoorSpec in this example). With the following PipeOutdoorSpec() arguments:

- **DBPipeOutdoorType.ABC.toString()** – pipe name, defined using the DBPipeOutdoorType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **DBPipeOutdoorType.ABC.getID** – ID of the Pipe Outdoor properties in the database, defined using the DBPipeOutdoorType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Pipe Outdoor properties are defined in the **PipeOutdoor** table in the database, corresponding to the Pipe:Outdoor object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- opaqueElementID – pipe construction element ID, defined in the **OpaqueElement** table in the database;
- pipeInsideDiameter – inside diameter of the pipe [m];
- pipeLength – length of the pipe [m];
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – pipeName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the pipe is assigned;
  - loopSide – loop side for which the pipe is assigned ('PLANT', 'DEMAND' or 'CONDENSER');
  - equipmentID – pipe position on the branch equipment list;
  - name – defined in the first argument of the PipeOutdoorSpec() above;
- Construction Name – construction object that gives a layer-by-layer description of the pipe wall and its insulation (opaqueElementID), defined in the **OpaqueElement** table in the database;
- Fluid Inlet Node Name – pipeName + "Inlet_node";
- Fluid Outlet Node Name – pipeName + "Outlet_node".

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_Fancoils_DOAS_HotColdCndWaterLoops template in the SAPTool_LSP.

8.1.5. Underground

The specification of a Pipe Underground is defined in the SAPTool_LSP building template, as follows:

PipeUndergroundSpec pipeUndergroundSpec = new PipeUndergroundSpec() – Pipe Underground specification (named pipeUndergroundSpec in this example). With the following PipeUndergroundSpec() arguments:

- **DBPipeUndergroundType.ABC.toString()** – pipe name, defined using the DBPipeUndergroundType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **DBPipeUndergroundType.ABC.getID** – ID of the Pipe Underground properties in the database, defined using the DBPipeUndergroundType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Pipe Underground properties are defined in the **PipeUnderground** table in the database, corresponding to the Pipe:Underground object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- opaqueElementID – pipe construction element ID, defined in the **OpaqueElement** table in the database;
- sunExposure – ‘SunExposed’ or ‘NoSun’;
- pipeInsideDiameter – inside diameter of the pipe [m];
- pipeLength – length of the pipe [m];
- soilMaterialID – soil material element ID, defined in the **Material** table in the database;
- soilThickness – soil material thickness [m];
- undisturbedGroundTemperatureModelType – ‘FiniteDifference’, ‘KusudaAchenbach’ or ‘Xing’. Currently, ‘FiniteDifference’ results in a fatal error in EnergyPlus (v. 9.0.1);
- undisturbedGroundTemperatureModelID – ID of the undisturbed ground temperature model type (selected in the previous field) in the database: table **SiteGroundTemperatureUndisturbedFiniteDifference** (section **22.2.1.1**), table **SiteGroundTemperatureUndisturbedKusudaAchenbach**, (section **22.2.1.2**) or table **SiteGroundTemperatureUndisturbedXing** (section **22.2.1.3**);
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – pipeName = loopName&ID + loopSide + equipmentID + name:
    - loopName&ID – loop name and ID for which the pipe is assigned;
    - loopSide – loop side for which the pipe is assigned (‘PLANT’, ‘DEMAND’ or ‘CONDENSER’);
    - equipmentID – pipe position on the branch equipment list;

- ▪ name – defined in the first argument of the PipeUndergroundSpec() above;
- Construction Name – construction object that gives a layer-by-layer description of the pipe wall and its insulation (opaqueElementID), defined in the **OpaqueElement** table in the database;
- Fluid Inlet Node Name – pipeName + “Inlet_node”;
- Fluid Outlet Node Name – pipeName + “Outlet_node”;
- Soil Material Name – materialName + materialThickness (materialName – defined in the **Material** table in the database; materialThickness – defined in the soilThickness field);
- Name of Undisturbed Ground Temperature Object – "SGT_Undist" + pipeName.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVAC_Fancoils_DOAS_HotColdCndWaterLoops template in the SAPTool_LSP.

8.2. Pumps

8.2.1. Constant Speed

The specification of a Pump Constant Speed is defined in the SAPTool_LSP building template, as follows:

PumpConstantSpeedSpec pumpConstantSpeedSpec = new PumpConstantSpeedSpec() – Pump Constant Speed specification (named pumpConstantSpeedSpec in this example). With the following PumpConstantSpeedSpec() arguments:

- **DBPumpConstantSpeedType.ABC.toString()** – pump name, defined using the DBPumpConstantSpeedType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **x** – ID of the zone for which the pump is assigned, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if no zone assignment;
- **DBPumpConstantSpeedType.ABC.getID** – ID of the Pump Constant Speed properties in the database, defined using the DBPumpConstantSpeedType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Pump Constant Speed properties are defined in the **PumpConstantSpeed** table in the database, corresponding to the Pump:ConstantSpeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- designFlowRate – design volume flow rate in m3/s. ‘autosize’ option is available;
- designPumpHead – design head pressure in Pa;
- designPowerConsumption – rated power consumption in W. ‘autosize’ option is available;

- motorEfficiency – pump's efficiency;
- fractionOfMotorInefficienciesToFluidStream – fraction of power loss to the fluid;
- pumpControlType – 'Continuous' or 'Intermittent';
- pumpFlowRateScheduleID – pump flow rate schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- pumpCurveID – pump curve ID, defined in the **PerformanceCurve** table in the database (**22**). Only used if pressureSimulationType = LoopFlowCorrection, in the Plant Loop specification (**9.1**);
- impellerDiameter – impeller diameter. Only used if pressureSimulationType = LoopFlowCorrection, in the Plant Loop specification (**9.1**);
- rotationalSpeed – rotational speed. Only used if pressureSimulationType = LoopFlowCorrection, in the Plant Loop specification (**9.1**);
- skinLossRadiativeFraction – pump thermal losses to the zone. Only used if the pump is assigned to a zone;
- designPowerSizingMethod – 'PowerPerFlowPerPressure' or 'PowerPerFlow'. Only used if designPowerConsumption = autosize;
- designElectricPowerPerUnitFlowRate – design electrical power per unit flow rate. Only used if designPowerConsumption = autosize and designPowerSizingMethod = PowerPerFlow;
- designShaftPowerPerUnitFlowRatePerUnitHead – design electrical power per unit flow rate per unit head. Only used if designPowerConsumption = autosize and designPowerSizingMethod = PowerPerFlowPerPressure;
- endUseSubcategory – pump end-use subcategory;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – pumpConstSpeedName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the pump is assigned;
  - loopSide – loop side for which the pump is assigned ('PLANT', 'DEMAND' or 'CONDENSER');
  - equipmentID – pump position on the branch equipment list;
  - name – defined in the first argument of the PumpConstantSpeedSpec() above;
- Inlet Node Name – pumpConstSpeedName + "Inlet_node";
- Outlet Node Name – pumpConstSpeedName + "Outlet_node";
- Zone Name – zone for which the pump is assigned (if any), defined in argument x of the PumpConstantSpeedSpec() above.

8.2.2. Variable Speed

The specification of a Pump Variable Speed is defined in the SAPTool_LSP building template, as follows:

PumpVariableSpeedSpec pumpVariableSpeedSpec = new PumpVariableSpeedSpec() – Pump Variable Speed specification (named pumpVariableSpeedSpec in this example). With the following PumpVariableSpeedSpec() arguments:

- **DBPumpVariableSpeedType.ABC.toString()** – pump name, defined using the DBPumpVariableSpeedType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **x** – ID of the zone for which the pump is assigned, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if no zone assignment;
- **DBPumpVariableSpeedType.ABC.getID** – ID of the Pump Variable Speed properties in the database, defined using the DBPumpVariableSpeedType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Pump Variable Speed properties are defined in the **PumpVariableSpeed** table in the database, corresponding to the Pump:VariableSpeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- designMaximumFlowRate – design maximum volume flow rate in m3/s. 'autosize' option is available;
- designPumpHead – design head pressure in Pa;
- designPowerConsumption – rated power consumption in W. 'autosize' option is available;
- motorEfficiency – pump's efficiency;
- fractionOfMotorInefficienciesToFluidStream – fraction of power loss to the fluid;
- coefficient1OfThePartLoadPerformanceCurve – coefficient C1 in the part load ratio curve[10];
- coefficient2OfThePartLoadPerformanceCurve – coefficient C2 in the part load ratio curve;
- coefficient3OfThePartLoadPerformanceCurve – coefficient C3 in the part load ratio curve;
- coefficient4OfThePartLoadPerformanceCurve – coefficient C4 in the part load ratio curve;
- designMinimumFlowRate – minimum volume flow rate while operating in variable flow capacity rate in m3/s. 'autosize' option is available;
- pumpControlType – 'Continuous' or 'Intermittent';
- pumpFlowRateScheduleID – pump flow rate schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- pumpCurveID – pump curve ID, defined in the **PerformanceCurve** table in the database (**22**). Only used if pressureSimulationType = LoopFlowCorrection, in the Plant Loop specification (**9.1**);

[10] Fraction Full Load Power = C1 + C2*PLR + C3*PLR**2 + C4*PLR**3 (PLR – Part Load Ratio)

- impellerDiameter – impeller diameter. Only used if pressureSimulationType = LoopFlowCorrection, in the Plant Loop specification (**9.1**);
- vfdControlType – 'PressureSetPointControl' or 'ManualControl' (optional);
- pumpRPMScheduleID – pump RPM schedule ID, defined in the **Schedules** table in the database (**21**). Only used if vdfControlType = ManualControl;
- minimumPressureScheduleID – minimum pressure schedule ID, defined in the **Schedules** table in the database (**21**). Only used if vdfControlType = PressureSetPointControl;
- maximumPressureScheduleID – maximum pressure schedule ID, defined in the **Schedules** table in the database (**21**). Only used if vdfControlType = PressureSetPointControl;
- minimumRPMScheduleID – minimum RPM schedule ID, defined in the **Schedules** table in the database (**21**). Only used if vdfControlType = PressureSetPointControl;
- maximumRPMScheduleID – maximum RPM schedule ID, defined in the **Schedules** table in the database (**21**). Only used if vdfControlType = PressureSetPointControl;
- skinLossRadiativeFraction – pump thermal losses to the zone. Only used if the pump is assigned to a zone;
- designPowerSizingMethod – 'PowerPerFlowPerPressure' or 'PowerPerFlow'. Only used if designPowerConsumption = autosize;
- designElectricPowerPerUnitFlowRate – design electrical power per unit flow rate. Only used if designPowerConsumption = autosize and designPowerSizingMethod = PowerPerFlow;
- designShaftPowerPerUnitFlowRatePerUnitHead – design shaft power per unit flow rate per unit head. Only used if designPowerConsumption = autosize and designPowerSizingMethod = PowerPerFlowPerPressure;
- designMinimumFlowRateFraction – design minimum flow rate fraction. Used only if designMinimumFlowRate = autosize;
- endUseSubcategory – pump end-use subcategory;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – pumpVarSpeedName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the pump is assigned;
  - loopSide – loop side for which the pump is assigned ('PLANT', 'DEMAND' or 'CONDENSER');
  - equipmentID – pump position on the branch equipment list;
  - name – defined in the first argument of the PumpVariableSpeedSpec() above;
- Inlet Node Name – pumpVarSpeedName + "Inlet_node";
- Outlet Node Name – pumpVarSpeedName + "Outlet_node";
- Zone Name – zone for which the pump is assigned (if any), defined in argument x of the PumpVariableSpeedSpec() above.

8.2.3. Variable Speed Condensate

This pump type is required for steam plant loops (fluidType = Steam in section **9.1**). The specification of a Pump Variable Speed Condensate is defined in the SAPTool_LSP building template, as follows:

PumpVariableSpeedCondensateSpec pumpVariableSpeedCondensateSpec = new PumpVariableSpeedCondensateSpec() – Pump Variable Speed Condensate specification (named pumpVariableSpeedCondensateSpec in this example). With the following PumpVariableSpeedCondensateSpec() arguments:

- **DBPumpVariableSpeedCondensateType.ABC.toString()** – pump name, defined using the DBPumpVariableSpeedType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **x** – ID of the zone for which the pump is assigned, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if no zone assignment;
- **DBPumpVariableSpeedType.ABC.getID** – ID of the Pump Variable Speed Condensate properties in the database, defined using the DBPumpVariableSpeedCondensateType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Pump Variable Speed Condensate properties are defined in the **PumpVariableSpeedCondensate** table in the database, corresponding to the Pump:VariableSpeed:Condensate object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- designSteamVolumeFlowRate – pump's design volume flow rate in m3/s. 'autosize' option is available;
- designPumpHead – design head pressure in Pa;
- designPowerConsumption – rated power consumption in W. 'autosize' option is available;
- motorEfficiency – pump's efficiency;
- fractionOfMotorInefficienciesToFluidStream – fraction of power loss to the fluid;
- coefficient1OfThePartLoadPerformanceCurve – coefficient C1 in the part load ratio curve[11];
- coefficient2OfThePartLoadPerformanceCurve – coefficient C2 in the part load ratio curve;
- coefficient3OfThePartLoadPerformanceCurve – coefficient C3 in the part load ratio curve;
- coefficient4OfThePartLoadPerformanceCurve – coefficient C4 in the part load ratio curve;
- pumpFlowRateScheduleID – pump flow rate schedule ID, defined in the **Schedules** table in the database (**21**) (optional);

[11] Fraction Full Load Power = C1 + C2*PLR + C3*PLR**2 + C4*PLR**3 (PLR – Part Load Ratio)

- skinLossRadiativeFraction – pump thermal losses to the zone (optional). Only used if the pump is assigned to a zone;
- designPowerSizingMethod – ‘PowerPerFlowPerPressure’ or ‘PowerPerFlow’ (optional);
- designElectricPowerPerUnitFlowRate – design electrical power per unit flow rate (optional). Only used if designPowerSizingMethod = PowerPerFlow;
- designShaftPowerPerUnitFlowRatePerUnitHead – design shaft power per unit flow rate per unit head (optional). Only used if designPowerSizingMethod = PowerPerFlowPerPressure;
- endUseSubcategory – pump end-use subcategory;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – pumpVarSpeedCondName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the pump is assigned;
  - loopSide – loop side for which the pump is assigned (‘PLANT’, ‘DEMAND’ or ‘CONDENSER’);
  - equipmentID – pump position on the branch equipment list;
  - name – defined in the first argument of the PumpVariableSpeedCondensateSpec() above;
- Inlet Node Name – pumpVarSpeedCondName + “Inlet_node”;
- Outlet Node Name – pumpVarSpeedCondName + “Outlet_node”;
- Zone Name – zone for which the pump is assigned (if any), defined in argument x of the PumpVariableSpeedCondensateSpec() above.

8.3. Tempering Valve

The specification of a Tempering Valve is defined in the SAPTool_LSP building template, as follows:

TemperingValveSpec temperingValveSpec = new TemperingValveSpec() – Tempering Valve specification (named temperingValveSpec in this example). With the following TemperingValveSpec() arguments:

- **DBTemperingValveType.ABC.toString()** – tempering valve name, defined using the DBTemperingValveType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **DBTemperingValveType.ABC.getID** – ID of the Tempering Valve properties in the database, defined using the DBTemperingValveType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Tempering Valve properties are defined in the **TemperingValve** table in the database, corresponding to the TemperingValve object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- setpointManagerType – defines the Setpoint Manager type for the Temperature Setpoint Node (automatically defined node). 'ScheduledSingleSetpoint', 'ScheduledDualSetpoint' or 'OutdoorAirReset' (see section **14** for details);
- setpointManagerID – ID of the Setpoint Manager assigned to Temperature Setpoint Node, which is defined in the **setpointManagerSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **setpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**);
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – valveName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the valve is assigned;
  - loopSide – loop side for which the valve is assigned ('PLANT', 'DEMAND' or 'CONDENSER');
  - equipmentID – valve position on the branch equipment list;
  - name – defined in the first argument of the TemperingValveSpec() above;
- Inlet Node Name – valveName + "Inlet_node";
- Outlet Node Name – valveName + "Outlet_node";
- Stream 2 Source Node Name – outlet node of the second to last equipment present in the loop side branch for which this tempering valve is assigned*;
- Temperature Setpoint Node Name – outlet node of the last equipment present in the loop side branch for which this tempering valve is assigned*. This is the node assigned to the setpoint manager (**14**);
- Pump Outlet Node Name – outlet node of the pump present in the loop for which this tempering valve is assigned.

* Note: currently, the loop side branch for which this tempering valve is assigned only admits 4 equipment, in the following order: inlet equipment (e.g., pipe, pump), stream 1 equipment (tempering valve), stream 2 equipment (e.g., water heater), outlet equipment (e.g., pipe).

8.4. Solar Collectors

8.4.1. Flat Plate Water

The specification of a Solar Collector Flat Plate Water is defined in the SAPTool_LSP building template, as follows:

SolarCollectorFlatPlateWaterSpec solarCollectorSpec = new SolarCollectorFlatPlateWaterSpec() – Solar Collector Flat Plate Water specification (named solarCollectorSpec in this example). With the following SolarCollectorFlatPlateWaterSpec() arguments:

- **DBSolarCollectorFlatPlateType.ABC.toString()** – solar collector name, defined using the DBSolarCollectorFlatPlateType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **ModulePlacementType.ROOF** – solar collector module location, defined using the ModulePlacementType list object (currently, only a **roof** surface is available);
- **x1** – solar collector module tilt angle (double type input);
- **x2** – solar collector module azimuth angle (double type input);
- **PVModuleOrientationType.XX.toString()** – solar collector module orientation, defined using the PVModuleOrientationType list object. XX = 'Vertical' or 'Horizontal';
- **DBSolarCollectorFlatPlateType.ABC.getID** – ID of the Solar Collector Flat Plate Water properties in the database, defined using the DBSolarCollectorFlatPlateType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Solar Collector Flat Plate Water properties are defined in the **SolarCollectorFlatPlateWater** table in the database, corresponding to the SolarCollector:FlatPlate:Water and SolarCollectorPerformance:FlatPlate objects in EnergyPlus. The following fields are present in the table:

- id – object ID;
- brandAndModelName – brand and model name;
- width – solar collector width [m];
- height – solar collector height [m];
- maximumFlowRate – maximum flow rate allowed through the collector [m3/s];
- testFluid – currently only 'Water' is allowed in EnergyPlus;
- testFlowRate – volumetric flow rate during testing [m3/s];
- testCorrelationType – 'Inlet', 'Outlet' or 'Average';
- coefficient1OfEnergyEquation – first coefficient of efficiency equation for energy conversion [dimensionless];
- coefficient2OfEnergyEquation – second coefficient of efficiency equation for energy conversion [W/m2.K];
- coefficient3OfEnergyEquation – third coefficient of efficiency equation for energy conversion [W/m2.K] (optional). If blank or set to zero, a first-order linear correlation is used;
- coefficient2OfIncidentAngleModifier – second coefficient of the incident angle modifier equation;
- coefficient3OfIncidentAngleModifier – third coefficient of the incident angle modifier equation (optional). If blank or set to zero, a first-order linear correlation is used;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus for the SolarCollector:FlatPlate:Water object:

- Name – collectorName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the collector is assigned;
  - loopSide – loop side for which the collector is assigned ('PLANT' or 'DEMAND');
  - equipmentID – collector position on the branch equipment list;
  - name – defined in the first argument of the SolarCollectorFlatPlateWaterSpec() above;
- SolarCollectorPerformance Name – solarCollectorPerformanceName = collectorName + brandAndModelName;
- Surface Name – name of the surface where the solar collector is placed*;
- Inlet Node Name – collectorName + "Inlet_node";
- Outlet Node Name – collectorName + "Outlet_node".

Automatic filling fields in EnergyPlus for the SolarCollectorPerformance:FlatPlate object:

- Name – solarCollectorPerformanceName;
- Gross Area – width * height.

* For each solar collector added, a shading surface is automatically created in order to place it. This surface acts as a shading element to the building surface for which it is assigned with the ModulePlacementType object (see above). It corresponds to a Shading:Building object in EnergyPlus, where all fields are automatically filled:

- Name – "MODULE" + collectorName;
- Azimuth Angle – argument x2 in the SolarCollectorFlatPlateWaterSpec() above;
- Tilt Angle – argument x1 in the SolarCollectorFlatPlateWaterSpec() above;
- Starting X Coordinate – related to the *width* value defined in the **SolarCollectorFlatPlateWater** table in the database;
- Starting Y Coordinate – related to the *height* value defined in the **SolarCollectorFlatPlateWater** table in the database;
- Starting Z Coordinate – related to the building height;
- Length – *width* or *height* defined in the **SolarCollectorFlatPlateWater** table in the database, depending on the module orientation (PVModuleOrientationType);
- Height – *height* or *width* defined in the **SolarCollectorFlatPlateWater** table in the database, depending on the module orientation (PVModuleOrientationType).

8.5. Heating and Cooling

8.5.1. Boiler Hot Water

The specification of a Boiler Hot Water is defined in the SAPTool_LSP building template, as follows:

BoilerHotWaterSpec boilerHotWaterSpec = new BoilerHotWaterSpec() – Boiler Hot Water specification (named boilerHotWaterSpec in this example). With the following BoilerHotWaterSpec() arguments:

- **DBBoilerType.ABC.toString()** – boiler name, defined using the DBBoilerType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **DBBoilerType.ABC.getID** – ID of the Boiler Hot Water properties in the database, defined using the DBBoilerType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Boiler Hot Water properties are defined in the **BoilerHotWater** table in the database, corresponding to the Boiler:HotWater object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – optional object description, for guidance;
- fuelType – 'Electricity', 'NaturalGas', 'PropaneGas', 'FuelOil_1', 'FuelOil_2', 'Coal', 'Diesel', 'Gasoline', 'OtherFuel1' or 'OtherFuel2';
- nominalCapacity – nominal operating capacity [W]. 'autosize' option is available, for which a Plant Sizing object must be defined (see section **13.2.4**);
- nominalThermalEfficiency – heating efficiency of the boiler's burner;
- efficiencyCurveTemperatureEvaluation – 'EnteringBoiler' or 'LeavingBoiler'. Only used if type of curve is one that uses temperature as an independent variable;
- normalizedBoilerEfficiencyCurveID – normalized boiler efficiency curve ID (curve name which describes the normalized heating efficiency of the boiler's burner), defined in the **PerformanceCurve** table in the database (**22**);
- designWaterFlowRate – maximum design water volumetric flow rate in m3/s. 'autosize' option is available;
- minimumPartLoadRatio – minimum part load ratio;
- maximumPartLoadRatio – maximum part load ratio;
- optimumPartLoadRatio – optimum part load ratio;
- waterOutletUpperTemperatureLimit – outlet temperature upper limit in Celsius;
- boilerFlowMode – 'NotModulated', 'ConstantFlow' or 'LeavingSetpointModulated';
- setpointManagerType – defines the Setpoint Manager type for the Temperature Setpoint Node (automatically defined as the boiler outlet node). 'ScheduledSingleSetpoint', 'ScheduledDualSetpoint' or 'OutdoorAirReset' (see section **14** for details). Only used if boilerFlowMode = LeavingSetpointModulated;
- setpointManagerID – ID of the Setpoint Manager assigned to Temperature Setpoint Node, which is defined in the **setpointManagerSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **setpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**). Only used if boilerFlowMode = LeavingSetpointModulated;
- parasiticElectricLoad – parasitic electric power consumed by a forced draft fan or other electrical device associated with the boiler [W];
- sizingFactor – sizing factor;

- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – boilerHotWaterName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the boiler is assigned;
  - loopSide – branch side for which the boiler is assigned (‘PLANT’ or ‘DEMAND’);
  - equipmentID – boiler position on the branch equipment list;
  - name – defined in the first argument of the BoilerHotWaterSpec() above;
- Inlet Node Name – boilerHotWaterName + “Inlet_node”;
- Outlet Node Name – boilerHotWaterName + “Outlet_node”.

8.5.2. Boiler Steam

This boiler type is required for steam plant loops (fluidType = Steam in section **9.1**). The specification of a Boiler Steam is defined in the SAPTool_LSP building template, as follows:

BoilerSteamSpec boilerSteamSpec = new BoilerSteamSpec() – Boiler Steam specification (named boilerSteamSpec in this example). With the following BoilerSteamSpec() arguments:

- **DBBoilerSteamType.ABC.toString()** – boiler steam name, defined using the DBBoilerSteamType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **DBBoilerSteamType.ABC.getID** – ID of the Boiler Steam properties in the database, defined using the DBBoilerSteamType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Boiler Steam properties are defined in the **BoilerSteam** table in the database, corresponding to the Boiler:Steam object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – optional object description, for guidance;
- fuelType – ‘Electricity’, ‘NaturalGas’, ‘PropaneGas’, ‘FuelOil_1’, ‘FuelOil_2’, ‘Coal’, ‘Diesel’, ‘Gasoline’, ‘OtherFuel1’ or ‘OtherFuel2’;
- maximumOperatingPressure – maximum value of pressure up to which the boiler would operate or the maximum design pressure [Pa];
- theoreticalEfficiency – heating efficiency of the boiler’s burner;
- designOutletSteamTemperature – maximum value of steam temperature the boiler can provide, in Celsius;
- nominalCapacity – nominal operating capacity [W];
- minimumPartLoadRatio – minimum part load ratio;
- maximumPartLoadRatio – maximum part load ratio;
- optimumPartLoadRatio – optimum part load ratio;
- coefficient1 – fuel use / Part Load Ratio coefficient 1;

- coefficient2 – fuel use / Part Load Ratio coefficient 2;
- coefficient3 – fuel use / Part Load Ratio coefficient 3;
- sizingFactor – sizing factor;
- endUseSubcategory – boiler end-use subcategory;
- setpointManagerType – defines the Setpoint Manager type for the Temperature Setpoint Node (automatically defined as the boiler outlet node). 'ScheduledSingleSetpoint', 'ScheduledDualSetpoint' or 'OutdoorAirReset' (see section **14** for details);
- setpointManagerID – ID of the Setpoint Manager assigned to Temperature Setpoint Node, which is defined in the **setpointManagerSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **setpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**);
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – boilerSteamName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the boiler is assigned;
  - loopSide – loop side for which the boiler is assigned ('PLANT' or 'DEMAND');
  - equipmentID – boiler position on the branch equipment list;
  - name – defined in the first argument of the BoilerSteamSpec() above;
- Inlet Node Name – boilerSteamName + "Inlet_node";
- Outlet Node Name – boilerSteamName + "Outlet_node".

8.5.3. Chiller Electric EIR

The specification of a Chiller Electric EIR is defined in the SAPTool_LSP building template, as follows:

ChillerElectricEIRSpec chillerSpec = new ChillerElectricEIRSpec() – Chiller Electric EIR specification (named chillerSpec in this example). With the following ChillerElectricEIRSpec() arguments:

- **DBChillerElectricEIRType.ABC.toString()** – chiller name, defined using the DBChillerElectricEIRType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **CondenserType.XX.toString()** – type of condenser will be modeled with this chiller, defined using the CondenserType list object. The available options are: XX = 'AirCooled', 'EvaporativelyCooled' or 'WaterCooled'. 'AirCooled' and 'EvaporativelyCooled' do not require a Condenser Loop to be specified, whereas the 'WaterCooled' option requires the full specification of the Condenser Loop and its associated equipment;

- **DBChillerElectricEIRType.ABC.getID** – ID of the Chiller Electric EIR properties in the database, defined using the DBChillerElectricEIRType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Chiller Electric EIR properties are defined in the **ChillerElectricEIR** table in the database, corresponding to the Chiller:Electric:EIR object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- referenceCapacity – reference cooling capacity of the chiller [W] at the reference temperatures and water flow rates defined below. 'autosize' option is available;
- referenceCOP – chiller's coefficient of performance at the reference temperatures and water flow rates defined below. Should not include energy use due to pumps or cooling tower fans. Should include evap-cooled or air-cooled condenser fans except when condenserFanPowerRatio is used and is greater than 0;
- referenceLeavingChilledWaterTemperature – chiller's reference leaving chilled water temperature [°C];
- referenceEnteringCondenserFluidTemperature – chiller's reference entering condenser fluid temperature [°C]. For water-cooled chillers this is the water temperature entering the condenser (e.g., leaving the cooling tower). For air- or evap-cooled condensers this is the entering outdoor air dry-bulb or wet-bulb temperature, respectively;
- referenceChilledWaterFlowRate – for a variable flow chiller this is the maximum water flow rate and for a constant flow chiller this is the operating water flow rate through the chiller's evaporator [m^3/s]. 'autosize' option is available;
- referenceCondenserFluidFlowRate – chiller's operating condenser fluid flow rate [m^3/s]. 'autosize' option is available. This field is also used to enter the air flow rate if condenserType = 'AirCooled' or 'EvaporativelyCooled' and Heat Recovery is specified. If 'AirCooled' or 'EvaporativelyCooled' and this field is autosized, the air flow rate is set to 0.000114 m^3/s/W multiplied by the referenceCapacity. For air- and evaporatively-cooled condensers, this flow rate is used to set condenser outlet air node conditions and used for evaporatively-cooled condensers to calculate water use rate;
- coolingCapacityFunctionOfTemperatureCurveID – performance curve ID (biquadratic) that parameterizes the variation of the cooling capacity as a function of the leaving chilled water temperature and the entering condenser fluid temperature, defined in the **PerformanceCurve** table in the database (**22**);
- electricInputToCoolingOutputRatioFunctionOfTemperatureCurveID – performance curve ID (biquadratic) that parameterizes the variation of the energy input to cooling output ratio (EIR) as a function of the leaving chilled water temperature and the entering condenser fluid temperature, defined in the **PerformanceCurve** table in the database (**22**);
- electricInputToCoolingOutputRatioFunctionOfPartLoadRatioCurveID – performance curve ID (quadratic) that parameterizes the variation of the energy input ratio (EIR) as a function of the part-load ratio (EIRfTPLR), defined in the **PerformanceCurve** table in the database (**22**);

- minimumPartLoadRatio – chiller's minimum part-load ratio (0-1). Below this part-load ratio, the compressor cycles on and off to meet the cooling load. The minimumPartLoadRatio must be less than or equal to the maximumPartLoadRatio;
- maximumPartLoadRatio – chiller's maximum part-load ratio (0-1, but may exceed 1). Below this part-load ratio, the compressor cycles on and off to meet the cooling load. The maximumPartLoadRatio must be greater than the minimumPartLoadRatio;
- optimumPartLoadRatio – chiller's optimum part-load ratio. This is the part-load ratio at which the chiller performs at its maximum COP. The optimumPartLoadRatio must be greater than or equal to the minimumPartLoadRatio, and less than or equal to the maximumPartLoadRatio;
- minimumUnloadingRatio – chiller's minimum unloading ratio (0-1). The minimum unloading ratio is where the chiller capacity can no longer be reduced by unloading and must be false loaded to meet smaller cooling loads. A typical false loading strategy is hot-gas bypass. The minimumUnloadingRatio must be greater than or equal to the minimumPartLoadRatio, and less than or equal to the maximumPartLoadRatio;
- condenserFanPowerRatio – ratio of the condenser fan power to the reference chiller cooling capacity [W/W]. Associated with air-cooled or evaporatively-cooled condensers. If this input is greater than 0, the condenser fan power is modeled seperatly from compressor power;
- fractionOfCompressorElectricConsumptionRejectedByCondenser – fraction of compressor electrical energy consumption that must be rejected by the condenser (0-1). Enter a value of 1.0 when modeling hermetic chillers. For open chillers, enter the compressor motor efficiency;
- leavingChilledWaterLowerTemperatureLimit – lower limit for the leaving chilled water temperature [°C];
- chillerFlowMode – 'NotModulated', 'ConstantFlow' or 'LeavingSetpointModulated';
- setpointManagerType – defines the Setpoint Manager type for the Temperature Setpoint Node (automatically defined as the chiller outlet node). 'ScheduledSingleSetpoint', 'ScheduledDualSetpoint' or 'OutdoorAirReset' (see section **14** for details). Only used if chillerFlowMode = LeavingSetpointModulated;
- setpointManagerID – ID of the Setpoint Manager assigned to Temperature Setpoint Node, which is defined in the **setpointManagerSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **setpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**). Only used if chillerFlowMode = LeavingSetpointModulated;
- designHeatRecoveryWaterFlowRate – design heat recovery water flow rate if the heat recovery option is being simulated [m^3/s]. 'autosized' option is available. When autosizing, the flow rate is simply the product of the referenceCondenserFluidFlowRate and the condenserHeatRecoveryRelativeCapacityFraction. If this value is greater than 0.0 (or Autosize), a heat recovery loop must be specified and attached to the chiller. Heat recovery is only available with Condenser Type = WaterCooled (second argument in the ChillerElectricEIRSpec() above);
- sizingFactor – sizing factor. The sizing factor is used when the component design inputs (referenceCapacity, referenceChilledWaterFlowRate and referenceCondenserFluidFlowRate) are autosized: the autosizing calculations are performed as usual and the results are multiplied by the sizing factor;

- basinHeaterCapacity – capacity of the chiller's electric basin heater [W/K]. Only used if Condenser Type = EvaporativelyCooled (second argument in the ChillerElectricEIRSpec() above). The basin heater electric power is equal to basinHeaterCapacity multiplied by the difference between the basinHeaterSetpointTemperature and the outdoor dry-bulb temperature. The basin heater only operates when the chiller is off, regardless of the basin heater schedule described below. The basin heater capacity must be greater than or equal to zero, with a default value of zero if this field is left blank;
- basinHeaterSetpointTemperature – set point temperature for the basin heater [°C] (≥ 2 °C; 2 °C is the default value if this field is left blank). Only used if Condenser Type = EvaporativelyCooled (second argument in the ChillerElectricEIRSpec() above). The basin heater is active when the outdoor air dry-bulb temperature falls below this setpoint temperature, as long as the chiller is off;
- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the basin heater is available to operate throughout the simulation. Regardless of this schedule, the basin heater may only operate when the chiller is off;
- condenserHeatRecoveryRelativeCapacityFraction – fraction of total rejected heat that can be recovered at full load (0-1) (optional). This fraction will be applied to the full heat rejection when operating at nominal capacity and nominal COP to model a capacity limit for the heat rejection. If blank, the capacity fraction is set to 1.0;
- heatRecoveryInletHighTemperatureLimitScheduleID – ID of a schedule of temperature values describing the upper limits for the return fluid temperatures entering the chiller at the heat recovery inlet node, defined in the **Schedules** table in the database (**21**) (optional). If blank, the basin heater is available to operate throughout the simulation. Regardless of this schedule, the basin heater may only operate when the chiller is off;
- endUseSubcategory – user-defined end-use subcategory (optional);
- pressureDropCurveID – chiller side pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- pressureDropCurveCondenserID – condenser side pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- pressureDropCurveHeatRecoveryID – heat recovery side pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – if the chiller is assigned to a single loop (chilled water loop): chillerName = loopName&ID + loopSide + equipmentID + name:
    - loopName&ID – loop name and ID for which the chiller is assigned;
    - loopSide – branch side for which the chiller is assigned ('PLANT', 'DEMAND' or 'CONDENSER');
    - equipmentID – chiller position on the branch equipment list;
    - name – defined in the first argument of the ChillerElectricEIRSpec() above;

If the chiller is assigned to two loops (chilled water and condenser loops): chillerName = “TWO_LOOPS” + name;

If the chiller is assigned to three loops (chilled water, condenser and heat recovery loops): chillerName = “THREE_LOOPS” + name;

- Chilled Water Inlet Node Name – chillerName + “Chiller_Inlet_node”;
- Chilled Water Outlet Node Name – chillerName + “Chiller_Outlet_Node”;
- Condenser Inlet Node Name – chillerName + “Condenser_Inlet_node”. If Condenser Type = AirCooled or EvaporativelyCooled, a OutdoorAir:Node object is automatically created in EnergyPlus and its fields automatically filled with the Condenser Inlet Node Name;
- Condenser Outlet Node Name – chillerName + “Condenser_Outlet_node” (defined only if the chiller is assigned to a condenser loop);
- Condenser Type – defined in the second argument of the ChillerElectricEIRSpec() above;
- Heat Recovery Inlet Node Name – chillerName + “HeatRecovery_Inlet_node” (defined only if the chiller is assigned to a heat recovery loop);
- Heat Recovery Outlet Node Name – chillerName + “HeatRecovery_Outlet_node” (defined only if the chiller is assigned to a heat recovery loop);
- Heat Recovery Leaving Temperature Setpoint Node Name – not yet implemented.

Assignment to plant and condenser loops

A chiller electric EIR is specified using the ChillerElectricEIRSpec() object (as presented above), and then linked to its loop side(s) using the ChillerElectricEIRSideSpec object:

ChillerElectricEIRSideSpec chillerElectricEIRSideSpec new ChillerElectricEIRSideSpec() – specification of the linkage between the chiller electric EIR and its loop sides (chilled water, condenser and heat recovery) (named chillerElectricEIRSideSpec in this example). With the following ChillerElectricEIRSideSpec() arguments:

- **NumberOfLoopSidesType.XX** – number of sides/loops assigned to the chiller. XX = ‘OneSide’ (chilled water side), ’TwoSides’ (chilled water and condenser sides) or ‘ThreeSides’ (chilled water, condenser and heat recovery sides);
- **ChillerSideType.XX** – chiller side for which the current loop is assigned. XX = ‘Chiller’, ‘Condenser’ or ‘HeatRecovery’;
- **ChillerElectricEIRSpec** – chiller electric EIR specification object (previously defined) assigned to this chiller.

A ChillerElectricEIRSideSpec() object must be defined for each loop that the chiller is assigned to (i.e., with the same chiller electric EIR specification – third argument of ChillerElectricEIRSideSpec()). For ChillerSideType.Chiller and ChillerSideType.HeatRecovery, the ChillerElectricEIRSideSpec object names (e.g., chillerElectricEIRSide1Spec, chillerElectricEIRSide2Spec) must then be assigned to the proper <u>plant</u> loop branch, as described in section **9.3**. For ChillerSideType.Condenser, the ChillerElectricEIRSideSpec name must then be assigned to the proper <u>condenser</u> loop branch, as described in section **9.3**.

8.5.4. Chiller Electric

The specification of a Chiller Electric is defined in the SAPTool_LSP building template, as follows:

ChillerElectricSpec chillerSpec = new ChillerElectricSpec() – Chiller Electric specification (named chillerSpec in this example). With the following ChillerElectricSpec() arguments:

- **DBChillerElectricType.ABC.toString()** – chiller name, defined using the DBChillerElectricType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **CondenserType.XX.toString()** – type of condenser will be modeled with this chiller, defined using the CondenserType list object. The available options are: XX = ‘AirCooled’, ‘EvaporativelyCooled’ or ‘WaterCooled’. ‘AirCooled’ and ‘EvaporativelyCooled’ do not require a Condenser Loop to be specified, whereas the ‘WaterCooled’ option requires the full specification of the Condenser Loop and its associated equipment;
- **DBChillerElectricType.ABC.getID** – ID of the Chiller Electric properties in the database, defined using the DBChillerElectricType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Chiller Electric properties are defined in the **ChillerElectric** table in the database, corresponding to the Chiller:Electric object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- nominalCapacity – nominal cooling capability of the chiller [W]. ‘autosize’ option is available;
- nominalCOP – chiller’s coefficient of performance. For a water-cooled chiller, this number does not include energy use due to condenser pumps and/or fans. For an air-cooled or evap-cooled chiller, this number includes condenser fan power;
- minimumPartLoadRatio – chiller’s minimum part-load ratio (0-1). The minimum part load is not the load where the machine shuts off, but where the amount of power remains constant to produce smaller loads than this fraction;
- maximumPartLoadRatio – chiller’s maximum part-load ratio (0-1.1);
- optimumPartLoadRatio – chiller’s optimum part-load ratio. This is the part-load ratio at which the chiller performs at its maximum COP;
- designCondenserInletTemperature – electric chiller’s condenser inlet design temperature [°C];
- temperatureRiseCoefficient – electric chiller’s temperature rise coefficient which is defined as the ratio of the required change in condenser water temperature to a given change in chilled water temperature, which maintains the capacity at the nominal value: (TCEreq-TCErat)/(TELreq-TELrat), where:
  - TCEreq – required entering condenser air or water temperature to maintain rated capacity;
  - TCErat – rated entering condenser air or water temperature at rated capacity;
  - TELreq – required leaving evaporator water outlet temperature to maintain rated capacity;
  - TELrat – rated leaving evaporator water outlet temperature at rated capacity;

- designChilledWaterOutletTemperature – electric chiller's evaporator outlet design temperature [°C];
- designChilledWaterFlowRate – for variable volume chiller this is the maximum flow and for constant flow chiller this is the design flow rate [m^3/s]. 'autosize' option is available;
- designCondenserFluidFlowRate – electric chiller's design condenser water flow rate [m^3/s]. 'autosize' option is available. This field is also used to enter the air flow rate if the Condenser Type = 'AirCooled' or 'EvaporativelyCooled' and Heat Recovery is specified;
- coefficient1OfCapacityRatioCurve – first coefficient for the capacity ratio curve;
- coefficient2OfCapacityRatioCurve – second coefficient for the capacity ratio curve;
- coefficient3OfCapacityRatioCurve – third coefficient for the capacity ratio curve;
- coefficient1OfPowerRatioCurve – first coefficient for the power ratio curve;
- coefficient2OfPowerRatioCurve – second coefficient for the power ratio curve;
- coefficient3OfPowerRatioCurve – third coefficient for the power ratio curve;
- coefficient1OfFullLoadRatioCurve – first coefficient for the full load ratio curve;
- coefficient2OfFullLoadRatioCurve – second coefficient for the full load ratio curve;
- coefficient3OfFullLoadRatioCurve – third coefficient for the full load ratio curve;
- chilledWaterOutletTemperatureLowerLimit – lower limit for the evaporator outlet temperature [°C]. This temperature acts as a cut off for heat transfer in the evaporator, so that the fluid doesn't get too cold;
- chillerFlowMode – 'NotModulated', 'ConstantFlow' or 'LeavingSetpointModulated';
- setpointManagerType – defines the Setpoint Manager type for the Temperature Setpoint Node (automatically defined as the chiller outlet node). 'ScheduledSingleSetpoint', 'ScheduledDualSetpoint' or 'OutdoorAirReset' (see section **14** for details). Only used if chillerFlowMode = LeavingSetpointModulated;
- setpointManagerID – ID of the Setpoint Manager assigned to Temperature Setpoint Node, which is defined in the **setpointManagerSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **setpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**). Only used if chillerFlowMode = LeavingSetpointModulated;
- designHeatRecoveryWaterFlowRate – design heat recovery water flow rate if the heat recovery option is being simulated [m^3/s]. 'autosized' option is available. When autosizing, the flow rate is simply the product of the referenceCondenserFluidFlowRate and the condenserHeatRecoveryRelativeCapacityFraction. If this value is greater than 0.0, a heat recovery loop must be specified and attached to the chiller. Heat recovery is only available with Condenser Type = WaterCooled (second argument in the ChillerElectricTSpec() above);
- sizingFactor – sizing factor. The sizing factor is used when the component design inputs (nominalCapacity, designChilledWaterFlowRate and designCondenserFluidFlowRate) are autosized: the autosizing calculations are performed as usual and the results are multiplied by the sizing factor;
- basinHeaterCapacity – capacity of the chiller's electric basin heater [W/K]. Only used if Condenser Type = EvaporativelyCooled (second argument in the ChillerElectricSpec() above). The basin heater electric power is equal to basinHeaterCapacity multiplied by the difference between the basinHeaterSetpointTemperature and the outdoor dry-bulb temperature. The basin heater only operates when the chiller is off, regardless of the

basin heater schedule described below. The basin heater capacity must be greater than or equal to zero, with a default value of zero if this field is left blank;

- basinHeaterSetpointTemperature – set point temperature for the basin heater [°C] (≥ 2 °C; 2 °C is the default value if this field is left blank). Only used if Condenser Type = EvaporativelyCooled (second argument in the ChillerElectricSpec() above). The basin heater is active when the outdoor air dry-bulb temperature falls below this setpoint temperature, as long as the chiller is off;
- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the basin heater is available to operate throughout the simulation. Regardless of this schedule, the basin heater may only operate when the chiller is off;
- condenserHeatRecoveryRelativeCapacityFraction – fraction of total rejected heat that can be recovered at full load (0-1) (optional). This fraction will be applied to the full heat rejection when operating at nominal capacity and nominal COP to model a capacity limit for the heat rejection. If blank, the capacity fraction is set to 1.0;
  heatRecoveryInletHighTemperatureLimitScheduleID – ID of a schedule of temperature values describing the upper limits for the return fluid temperatures entering the chiller at the heat recovery inlet node, defined in the **Schedules** table in the database (**21**) (optional). If blank, the basin heater is available to operate throughout the simulation. Regardless of this schedule, the basin heater may only operate when the chiller is off;
- endUseSubcategory – user-defined end-use subcategory (optional);
- pressureDropCurveID – chiller side pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- pressureDropCurveCondenserID – condenser side pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- pressureDropCurveHeatRecoveryID – heat recovery side pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – if the chiller is assigned to a single loop (chilled water loop): chillerName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the chiller is assigned;
  - loopSide – branch side for which the chiller is assigned (‘PLANT’, ‘DEMAND’ or ‘CONDENSER’);
  - equipmentID – chiller position on the branch equipment list;
  - name – defined in the first argument of the ChillerElectricSpec() above;

  If the chiller is assigned to two loops (chilled water and condenser loops): chillerName = “TWO_LOOPS” + name;

  If the chiller is assigned to three loops (chilled water, condenser and heat recovery loops): chillerName = “THREE_LOOPS” + name;
- Condenser Type – defined in the second argument of the ChillerElectricSpec() above;

- Chilled Water Inlet Node Name – chillerName + “Chiller_Inlet_node”;
- Chilled Water Outlet Node Name – chillerName + “Chiller_Outlet_Node”;
- Condenser Inlet Node Name – chillerName + “Condenser_Inlet_node”. If Condenser Type = AirCooled or EvaporativelyCooled, a OutdoorAir:Node object is automatically created in EnergyPlus and its fields automatically filled with the Condenser Inlet Node Name;
- Condenser Outlet Node Name – chillerName + “Condenser_Outlet_node” (defined only if the chiller is assigned to a condenser loop);
- Heat Recovery Inlet Node Name – chillerName + “HeatRecovery_Inlet_node” (defined only if the chiller is assigned to a heat recovery loop);
- Heat Recovery Outlet Node Name – chillerName + “HeatRecovery_Outlet_node” (defined only if the chiller is assigned to a heat recovery loop);
- Heat Recovery Leaving Temperature Setpoint Node Name – not yet implemented.

Assignment to plant and condenser loops

A chiller electric is specified using the ChillerElectricSpec() object (as presented above), and then linked to its loop side(s) using the ChillerElectricSideSpec object:

ChillerElectricSideSpec chillerElectricSideSpec new ChillerElectricSideSpec() – specification of the linkage between the chiller electric and its loop sides (chilled water, condenser and heat recovery) (named chillerElectricSideSpec in this example). With the following ChillerElectricSideSpec() arguments:

- **NumberOfLoopSidesType.XX** – number of sides/loops assigned to the chiller. XX = ‘OneSide’ (chilled water side), ’TwoSides’ (chilled water and condenser sides) or ‘ThreeSides’ (chilled water, condenser and heat recovery sides);
- **ChillerSideType.XX** – chiller side for which the current loop is assigned. XX = ‘Chiller’, ‘Condenser’ or ‘HeatRecovery’;
- **ChillerElectricEIRSpec** – chiller electric EIR specification object (previously defined) assigned to this chiller.

A ChillerElectricSideSpec() object must be defined for each loop that the chiller is assigned to (i.e., with the same chiller electric specification – third argument of ChillerElectricSideSpec()). For ChillerSideType.Chiller and ChillerSideType.HeatRecovery, the ChillerElectricSideSpec object names (e.g., chillerElectricSide1Spec, chillerElectricSide2Spec) must then be assigned to the proper plant loop branch, as described in section **9.3**. For ChillerSideType.Condenser, the ChillerElectricSideSpec name must then be assigned to the proper condenser loop branch, as described in section **9.3**.

8.5.5. Chiller Constant COP

The specification of a Chiller Constant COP is defined in the SAPTool_LSP building template, as follows:

ChillerConstantCOPSpec chillerSpec = new ChillerConstantCOPSpec() – Chiller Constant COP specification (named chillerSpec in this example). With the following ChillerConstantCOPSpec() arguments:

- **DBChillerConstantCOPType.ABC.toString()** – chiller name, defined using the DBChillerConstantCOPType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **CondenserType.XX.toString()** – type of condenser will be modeled with this chiller, defined using the CondenserType list object. The available options are: XX = ‘AirCooled’, ‘EvaporativelyCooled’ or ‘WaterCooled’. ‘AirCooled’ and ‘EvaporativelyCooled’ do not require a Condenser Loop to be specified, whereas the ‘WaterCooled’ option requires the full specification of the Condenser Loop and its associated equipment;
- **DBChillerConstantCOPType.ABC.getID** – ID of the Chiller Constant COP properties in the database, defined using the DBChillerConstantCOPType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Chiller Constant COP properties are defined in the **ChillerConstantCOP** table in the database, corresponding to the Chiller:ConstantCOP object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- nominalCapacity – nominal cooling capability of the chiller [W]. ‘autosize’ option is available;
- nominalCOP – chiller’s coefficient of performance;
- designChilledWaterFlowRate – for variable volume chiller this is the maximum flow and for constant flow chiller this is the design flow rate [m^3/s]. ‘autosize’ option is available;
- designCondenserFluidFlowRate – electric chiller’s design condenser water flow rate [m^3/s]. ‘autosize’ option is available. This field is not used if the Condenser Type = ‘AirCooled’ or ‘EvaporativelyCooled’;
- chillerFlowMode – ‘NotModulated’, ‘ConstantFlow’ or ‘LeavingSetpointModulated’;
- setpointManagerType – defines the Setpoint Manager type for the Temperature Setpoint Node (automatically defined as the chiller outlet node). ‘ScheduledSingleSetpoint’, ‘ScheduledDualSetpoint’ or ‘OutdoorAirReset’ (see section **14** for details). Only used if chillerFlowMode = LeavingSetpointModulated;
- setpointManagerID – ID of the Setpoint Manager assigned to Temperature Setpoint Node, which is defined in the **setpointManagerSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **setpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**). Only used if chillerFlowMode = LeavingSetpointModulated;
- sizingFactor – sizing factor. The sizing factor is used when the component design inputs (nominalCapacity, designChilledWaterFlowRate and designCondenserFluidFlowRate) are autosized: the autosizing calculations are performed as usual and the results are multiplied by the sizing factor;
- basinHeaterCapacity – capacity of the chiller’s electric basin heater [W/K]. Only used if Condenser Type = EvaporativelyCooled (second argument in the ChillerConstantCOPSpec() above). The basin heater electric power is equal to

basinHeaterCapacity multiplied by the difference between the basinHeaterSetpointTemperature and the outdoor dry-bulb temperature. The basin heater only operates when the chiller is off, regardless of the basin heater schedule described below. The basin heater capacity must be greater than or equal to zero, with a default value of zero if this field is left blank;

- basinHeaterSetpointTemperature – set point temperature for the basin heater [°C] (≥ 2 °C; 2 °C is the default value if this field is left blank). Only used if Condenser Type = EvaporativelyCooled (second argument in the ChillerConstantCOPSpec() above). The basin heater is active when the outdoor air dry-bulb temperature falls below this setpoint temperature, as long as the chiller is off;
- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the basin heater is available to operate throughout the simulation. Regardless of this schedule, the basin heater may only operate when the chiller is off;
- pressureDropCurveID – chiller side pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- pressureDropCurveCondenserID – condenser side pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – if the chiller is assigned to a single loop (chilled water loop): chillerName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the chiller is assigned;
  - loopSide – branch side for which the chiller is assigned (‘PLANT’, ‘DEMAND’ or ‘CONDENSER’);
  - equipmentID – chiller position on the branch equipment list;
  - name – defined in the first argument of the ChillerElectricSpec() above;

  If the chiller is assigned to two loops (chilled water and condenser loops): chillerName = “TWO_LOOPS” + name;
- Condenser Type – defined in the second argument of the ChillerElectricSpec() above;
- Chilled Water Inlet Node Name – chillerName + “Chiller_Inlet_node”;
- Chilled Water Outlet Node Name – chillerName + “Chiller_Outlet_Node”;
- Condenser Inlet Node Name – chillerName + “Condenser_Inlet_node”. If Condenser Type = AirCooled or EvaporativelyCooled, a OutdoorAir:Node object is automatically created in EnergyPlus and its fields automatically filled with the Condenser Inlet Node Name;
- Condenser Outlet Node Name – chillerName + “Condenser_Outlet_node” (defined only if the chiller is assigned to a condenser loop).

Assignment to plant and condenser loops

A chiller electric is specified using the ChillerConstantCOPSpec() object (as presented above), and then linked to its loop side(s) using the ChillerConstantCOPSideSpec object:

ChillerConstantCOPSideSpec chillerConstantCOPSideSpec new ChillerConstantCOPSideSpec() – specification of the linkage between the chiller constant COP and its loop sides (chilled water and condenser) (named chillerConstantCOPSideSpec in this example). With the following ChillerConstantCOPSideSpec() arguments:

- **NumberOfLoopSidesType.XX** – number of sides/loops assigned to the chiller. XX = 'OneSide' (chilled water side) or 'TwoSides' (chilled water and condenser sides);
- **ChillerSideType.XX** – chiller side for which the current loop is assigned. XX = 'Chiller' or 'Condenser';
- **ChillerElectricEIRSpec** – chiller constant COP specification object (previously defined) assigned to this chiller.

A ChillerConstantCOPSideSpec() object must be defined for each loop that the chiller is assigned to (i.e., with the same chiller constant COP specification – third argument of ChillerConstantCOPSideSpec()). For ChillerSideType.Chiller, the ChillerElectricSideSpec object names (e.g., chillerElectricSide1Spec, chillerElectricSide2Spec) must then be assigned to the proper <u>plant</u> loop branch, as described in section **9.3**. For ChillerSideType.Condenser, the ChillerConstantCOPSideSpec name must then be assigned to the proper <u>condenser</u> loop branch, as described in section **9.3**.

8.5.6. District Heating

The specification of a District Heating system is defined in the SAPTool_LSP building template, as follows:

DistrictHeatingSpec districtHeatingSpec = new DistrictHeatingSpec() – District Heating specification (named districtHeatingSpec in this example). With the following DistrictHeatingSpec() arguments:

- **DBDistrictHeatingType.ABC.toString()** – district heating name, defined using the DBDistrictHeatingType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **DBDistrictHeatingType.ABC.getID** – ID of the District Heating properties in the database, defined using the DBDistrictHeatingType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The District Heating properties are defined in the **DistrictHeating** table in the database, corresponding to the DistrictHeating object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- nominalCapacity – nominal demand that the district heating will meet [W]. 'autosize' option is available;
- capacityFractionScheduleID – capacity fraction schedule ID, defined in the **Schedules** table in the database (**21**). If blank, = 1;

- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – districtHeatingName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the district heating is assigned;
  - loopSide – loop side for which the district heating is assigned (‘PLANT’ or ‘DEMAND’);
  - equipmentID – district heating position on the branch equipment list;
  - name – defined in the first argument of the DistrictHeatingSpec() above;
- Inlet Node Name – districtHeatingName + “Inlet_node”;
- Outlet Node Name – districtHeatingName + “Outlet_node”.

8.5.7. District Cooling

The specification of a District Cooling system is defined in the SAPTool_LSP building template, as follows:

DistrictCoolingSpec districtCoolingSpec = new DistrictCoolingSpec() – District Cooling specification (named districtCoolingSpec in this example). With the following DistrictCoolingSpec() arguments:

- **DBDistrictCoolingType.ABC.toString()** – district cooling name, defined using the DBDistrictCoolingType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **DBDistrictCoolingType.ABC.getID** – ID of the District Cooling properties in the database, defined using the DBDistrictCoolingType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The District Cooling properties are defined in the **DistrictCooling** table in the database, corresponding to the DistrictCooling object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- nominalCapacity – nominal demand that the district cooling will meet [W]. ‘autosize’ option is available;
- capacityFractionScheduleID – capacity fraction schedule ID, defined in the **Schedules** table in the database (**21**). If blank, = 1;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – districtCoolingName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the district cooling is assigned;
  - loopSide – loop side for which the district cooling is assigned (‘PLANT’ or ‘DEMAND’);
  - equipmentID – district cooling position on the branch equipment list;
  - name – defined in the first argument of the DistrictCoolingSpec() above;
- Inlet Node Name – districtCoolingName + “Inlet_node”;
- Outlet Node Name – districtCoolingName + “Outlet_node”.

8.6. Condenser Equipment and Heat Exchangers

8.6.1. Cooling Towers

8.6.1.1. Tower Single Speed

The specification of a Cooling Tower Single Speed is defined in the SAPTool_LSP building template, as follows:

CoolingTowerSingleSpeedSpec coolingTowerSingleSpeedSpec = new CoolingTowerSingleSpeedSpec() – Cooling Tower Single Speed specification (named coolingTowerSingleSpeedSpec in this example). With the following CoolingTowerSingleSpeedSpec() arguments:

- **DBCoolingTowerSingleSpeedType.ABC.toString()** – tower name, defined using the DBCoolingTowerSingleSpeedType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **x1** – name of the supply water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **DBCoolingTowerSingleSpeedType.ABC.getID** – ID of the Cooling Tower Single Speed properties in the database, defined using the DBCoolingTowerSingleSpeedType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Cooling Tower Single Speed properties are defined in the **CoolingTowerSingleSpeed** table in the database, corresponding to the CoolingTower:SingleSpeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- designWaterFlowRate – design water flow rate through the tower [m^3/s]. ‘autosize’ option is available. This value is the flow rate of the condenser loop water being cooled by the tower. If performanceInputMethod = ‘UFactorTimesAreaAndDesignWaterFlowRate’, a water flow rate greater than zero must be defined or the field can be autosized. If autosized, a Plant Sizing object must be defined (see section **13.2.4**) and the design water flow rate is derived from the design load to be rejected by the condenser loop and the design loop delta T. If performanceInputMethod = ‘NominalCapacity’, this field must be left blank since the

model automatically assumes a water flow rate of 5.382E-8 m^3/s per Watt of tower capacity specified in the field nominalCapacity;

- designAirFlowRate – design air flow rate induced by the tower fan [m^3/s] (> 0). 'autosize' option is available;
- designFanPower – fan power [W] at the design air flow rate specified in the previous field (> 0). 'autosize' option is available;
- designUFactorTimesAreaValue – heat transfer coefficient-area product (UA) [W/K] corresponding to the design air and water flow rates specified above. If performanceInputMethod = 'UFactorTimesAreaAndDesignWaterFlowRate', a UA value greater than 0 but less than or equal to 300000 must be defined or the field can be autosized. If autosized, a Plant Sizing object must be defined (see section **13.2.4**) and the design tower UA value is derived from the design load to be rejected by the condenser loop and the design loop delta T , assuming a tower water inlet temperature of 35 °C and tower inlet air at 35 °C drybulb/25.6 °C wetbulb. If performanceInputMethod = 'NominalCapacity', this field must be left blank since the model automatically calculates the tower UA based on the tower capacity specified in the field nominalCapacity;
- freeConvectionAirFlowRate – air flow rate when the tower is in the "free convection" regime (water flow exists but tower fan is turned off) [m^3/s]. This value must be less than the value specified in designAirFlowRate. This field may be autocalculated, in which case it is set to a fraction of the designAirFlowRate determined in the following input field. If the user does not wish to model "free convection" and performanceInputMethod = 'UFactorTimesAreaAndDesignWaterFlowRate', this field should be set to 0.0. If the user specifies the freeConvectionUFactorTimesAreaValue or freeConvectionCapacity as a value greater than zero, then the free convection air flow rate must be specified greater than 0.0;
- freeConvectionAirFlowRateSizingFactor – sizing factor to use when calculating the free convection regime air flow rate;
- freeConvectionUFactorTimesAreaValue – heat transfer coefficient-area product when the tower is in the "free convection" regime (water flow exists but tower fan is turned off) [W/K]. This value must be less than the value specified designUFactorTimesAreaValue. 'autocalculate' option is available, in which case it is set to a fraction of the designUFactorTimesAreaValue determined in the following input field. If the user does not wish to model "free convection" and performanceInputMethod = 'UFactorTimesAreaAndDesignWaterFlowRate', then this field should be set to 0.0. If performanceInputMethod = 'NominalCapacity', then this field must be left blank since the model automatically calculates the tower UA based on the tower capacity specified in freeConvectionCapacity;
- freeConvectionUFactorTimesAreaValueSizingFactor – sizing factor to use when calculating the free convection regime U-Factor times area value;
- performanceInputMethod – 'UFactorTimesAreaAndDesignWaterFlowRate' or 'NominalCapacity';
- heatRejectionCapacityAndNominalCapacitySizingRatio – ratio of actual tower heat rejection to nominal capacity, defined at entering water at 35 °C, leaving water at 29.4 °C, entering air at 25.6 °C wetbulb and 35 °C drybulb temperatures;

- nominalCapacity – “nominal” heat rejection capacity of the cooling tower [W], with entering water at 35 °C, leaving water at 29.4 °C, entering air at 25.6 °C wetbulb and 35 °C drybulb temperatures;
- freeConvectionCapacity – “nominal” heat rejection capacity of the cooling tower in watts when the tower is in the “free convection” regime (water flow exists but tower fan is turned off), with entering water at 35 °C, leaving water at 29.4 °C, entering air at 25.6 °C wetbulb and 35 °C drybulb temperatures. The value specified for this field must be less than the value specified in nominalCapacity. If the user does not wish to model “free convection”, then this field should be set to 0.0. If the user specifies a value greater than zero, then freeConvectionAirFlowRate must contain a value greater than zero. This field can be automatically calculated using the sizing factor in the following field (autocalculate);
- freeConvectionNominalCapacitySizingFactor – sizing factor to use when calculating the freeConvectionCapacity;
- designInletAirDryBulbTemperature – design inlet air dry-bulb temperature [°C] (≥ 20);
- designInletAirWetBulbTemperature – inlet air wet-bulb temperature at design condition [°C] (≥ 20; if blank, equals to 25.6 °C). This design temperature should correspond with the design values for range temperature, approach temperature, water flow rate, and air flow rate specified in the following fields;
- designApproachTemperature – tower approach temperature at design conditions [ΔT] (> 0; if blank, equals to 3.9 °C). ‘autosize’ option is available. The approach temperature is the outlet water temperature minus the inlet air wet-bulb temperature. The design approach temperature should correspond with the design values for inlet air wet-bulb temperature, range temperature, water flow rate, and air flow rate specified for this tower;
- designRangeTemperature – range temperature at design conditions [ΔT] (> 0; if blank, equals to 5.6 °C). ‘autosize’ option is available. The range temperature is defined as the inlet water temperature minus the outlet water temperature. The design range temperature should correspond with the design values for inlet air wet-bulb temperature, approach temperature, water flow rate, and air flow rate specified for this tower;
- basinHeaterCapacity – capacity of the tower’s electric basin heater [W/K]. The basin heater electric power is equal to basinHeaterCapacity multiplied by the difference between the basinHeaterSetpointTemperature and the outdoor dry-bulb temperature. The basin heater only operates when the tower fan is off and water is not flowing through the tower, regardless of the basin heater schedule described below. The basin heater capacity must be greater than or equal to zero, with a default value of zero if this field is left blank;
- basinHeaterSetpointTemperature – set point temperature for the basin heater [°C] (≥ 2 °C; 2 °C is the default value if this field is left blank). The basin heater is active when the outdoor air dry-bulb temperature falls below this setpoint temperature, as long as the tower fan is off and water is not flowing through the tower;
- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**). The basin heater operates when scheduled on and the outdoor air dry-bulb temperature is below the set point temperature described in the previous field. If blank, the basin heater is available to operate throughout the

simulation. Regardless of this schedule, the basin heater may only operate when the cooling tower fan is off and water is not flowing through the tower;

- evaporationLossMode – 'SaturatedExit' or 'LossFactor';
- evaporationLossFactor – rate of water evaporated from the cooling tower and lost to the outside air [percent/K]. Only used if evaporationLossMode = 'LossFactor';
- driftLossPercent – rate of water lost to the exiting air as entrained droplets [%]. The drift loss is a percent of the condenser water flow;
- blowdownCalculationMode – 'ConcentrationRatio' or 'ScheduledRate';
- blowdownConcentrationRatio – used to dynamically adjust the rate of blowdown in the cooling tower as a function of the rate of evaporation (≥ 2). Blowdown is water intentionally drained from the tower in order to offset the build up of solids in the water that would otherwise occur because of evaporation;
- blowdownMakeupWaterUsageScheduleID – schedule ID used to define the amount of water [m^3/s] flushed from the basin on a periodic basis to purge the tower of mineral scale build-up and other contaminants, defined in the **Schedules** table in the database (**21**). Only used if blowdownCalculationMode = 'ScheduledRate';
- capacityControl – 'FanCycling' or 'FluidBypass';
- numberOfCells – number of cells in the multi-cell cooling tower. If not entered, the program will assume it is a single-cell cooling tower;
- cellControl – 'MinimalCell' or 'MaximalCell';
- cellMinimumWaterFlowRateFraction – allowable smallest fraction of the design water flow rate. If blank, the default value is 0.33;
- cellMaximumWaterFlowRateFraction – allowable largest fraction of the design water flow rate. If blank, the default value is 2.5;
- sizingFactor – sizing factor (optional). Used when the component design inputs (designWaterFlowRate, designAirFlowRate, designFanPower, freeConvectionAirFlowRate, and freeConvectionUFactorTimesAreaValue) are autosized: the autosizing calculations are performed as usual and the results are multiplied by the sizingFactor. designUFactorTimesAreaValue is not multiplied by the Sizing Factor. Instead the design tower load is multiplied by the sizingFactor and the design UA then calculated as usual. The freeConvectionUFactorTimesAreaValue is set to 10% of the new design Tower UA;
- endUseSubcategory – user-defined end-use subcategory (optional);
- setpointManagerType – defines the Setpoint Manager type for the Temperature Setpoint Node (automatically defined as the tower outlet node). 'ScheduledSingleSetpoint', 'ScheduledDualSetpoint' or 'OutdoorAirReset' (see section **14** for details);
- setpointManagerID – ID of the Setpoint Manager assigned to Temperature Setpoint Node, which is defined in the **setpointManagerSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **setpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**);
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – towerName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the tower is assigned;
  - loopSide – branch side for which the tower is assigned ('CONDENSER' or 'DEMAND');
  - equipmentID – tower position on the branch equipment list;
  - name – defined in the first argument of the CoolingTowerSingleSpeedSpec() above;
- Water Inlet Node Name – towerName + "Inlet_node";
- Water Outlet Node Name – towerName + "Outlet_node";
- Supply Water Storage Tank Name – supply water storage tank name defined in argument x1 of the CoolingTowerSingleSpeedSpec() above;
- Outdoor Air Inlet Node Name – towerName + "OA_Inlet_node". A OutdoorAir:Node object is automatically created in EnergyPlus and its fields automatically filled with the Outdoor Air Inlet Node Name.

8.6.1.2. Tower Two Speed

The specification of a Cooling Tower Two Speed is defined in the SAPTool_LSP building template, as follows:

CoolingTowerTwoSpeedSpec coolingTowerTwoSpeedSpec = new CoolingTowerTwoSpeedSpec() – Cooling Tower Two Speed specification (named coolingTowerTwoSpeedSpec in this example). With the following CoolingTowerTwoSpeedSpec() arguments:

- **DBCoolingTowerTwoSpeedType.ABC.toString()** – tower name, defined using the DBCoolingTowerTwoSpeedType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **x1** – name of the supply water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **DBCoolingTowerTwoSpeedType.ABC.getID** – ID of the Cooling Tower Two Speed properties in the database, defined using the DBCoolingTowerTwoSpeedType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Cooling Tower Two Speed properties are defined in the **CoolingTowerTwoSpeed** table in the database, corresponding to the CoolingTower:TwoSpeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- designWaterFlowRate – design water flow rate through the tower [m^3/s]. 'autosize' option is available. This value is the flow rate of the condenser loop water being cooled by the tower. If performanceInputMethod = 'UFactorTimesAreaAndDesignWaterFlowRate', a water flow rate greater than zero must be defined or the field can be autosized. If autosized, a Plant Sizing object must be defined (see section **13.2.4**) and the design water flow rate is derived from the design

load to be rejected by the condenser loop and the design loop delta T. If performanceInputMethod = ‘NominalCapacity’, this field must be left blank since the model automatically assumes a water flow rate of 5.382E-8 m^3/s per Watt of tower capacity specified in the field nominalCapacity;

- highFanSpeedAirFlowRate – tower air flow rate at high fan speed [m^3/s] (> 0). ‘autosize’ option is available;
- highFanSpeedFanPower – fan power [W] at the high-speed air flow rate specified in the previous field (> 0). ‘autosize’ option is available;
- highFanSpeedUFactorTimesAreaValue – heat transfer coefficient-area product (UA) [W/K] corresponding to the high-speed air flow rate and design water flow rate specified above. If performanceInputMethod = ‘UFactorTimesAreaAndDesignWaterFlowRate’, a UA value greater than 0 but less than or equal to 300000 must be defined or the field can be autosized. If autosized, a Plant Sizing object must be defined (see section **13.2.4**) and the design tower UA value at high fan speed is derived from the design load to be rejected by the condenser loop and the design loop delta T , assuming a tower water inlet temperature of 35 °C and tower inlet air at 35 °C drybulb/25.6 °C wetbulb. If performanceInputMethod = ‘NominalCapacity’, this field must be left blank since the model automatically calculates the tower UA based on the tower capacity specified in the field highSpeedNominalCapacity;
- lowFanSpeedAirFlowRate – tower air flow rate at low fan speed [m^3/s] (> 0, < highFanSpeedAirFlowRate, and > freeConvectionAirFlowRate). ‘autocalculate’ option is available, in which case it is set to a fraction of the highFanSpeedAirFlowRate;
- lowFanSpeedAirFlowRateSizingFactor – sizing factor to use when calculating the low fan speed air flow rate;
- lowFanSpeedFanPower – fan power [W] at the low-speed air flow rate specified in the previous field. This value must be specified greater than zero or the field may be autocalculated, in which case it is set to a fraction of highFanSpeedFanPower;
- lowFanSpeedFanPowerSizingFactor – sizing factor to use when calculating the low speed fan power;
- lowFanSpeedUFactorTimesAreaValue – heat transfer coefficient-area product (UA) [W/K] corresponding to the low-speed air flow rate and design water flow rate specified above. If performanceInputMethod = ‘UFactorTimesAreaAndDesignWaterFlowRate’, this value must be greater than zero but less than or equal to 300000, less than the value specified in highFanSpeedUFactorTimesAreaValue, and greater than the value specified in freeConvectionUFactorTimesAreaValue. This field may be autocalculated, in which case it is set to a fraction of the highFanSpeedUFactorTimesAreaValue. If performanceInputMethod = ‘NominalCapacity’, this field must be left blank since the model automatically calculates the tower UA based on the tower capacity specified in the field lowSpeedNominalCapacity;
- lowFanSpeedUFactorTimesAreaSizingFactor – sizing factor to use when calculating the low speed heat transfer coefficient-area product (UA);
- freeConvectionAirFlowRate – air flow rate when the tower is in the “free convection” regime (water flow exists but tower fan is turned off) [m^3/s]. This value must be less than the value specified in lowFanSpeedAirFlowRate. This field may be autocalculated, in which case it is set to a fraction of the highFanSpeedAirFlowRate. If the user does not wish to model “free convection” and performanceInputMethod = ‘UFactorTimesAreaAndDesignWaterFlowRate’, this field should be set to 0.0. If the user

specifies the freeConvectionUFactorTimesAreaValue or freeConvectionCapacity as a value greater than zero, then the free convection air flow rate must be specified greater than 0.0;

- freeConvectionAirFlowRateSizingFactor – sizing factor to use when calculating the free convection regime air flow rate;
- freeConvectionUFactorTimesAreaValue – heat transfer coefficient-area product when the tower is in the "free convection" regime (water flow exists but tower fan is turned off) [W/K]. This value must be less than the value specified lowFanSpeedUFactorTimesAreaValue. 'autocalculate' option is available, in which case it is set to a fraction of the highFanSpeedUFactorTimesAreaValue. If the user does not wish to model "free convection" and performanceInputMethod = 'UFactorTimesAreaAndDesignWaterFlowRate', then this field should be set to 0.0. If performanceInputMethod = 'NominalCapacity', then this field must be left blank since the model automatically calculates the tower UA based on the tower capacity specified in freeConvectionCapacity;
- freeConvectionUFactorTimesAreaValueSizingFactor – sizing factor to use when calculating the free convection regime U-Factor times area value;
- performanceInputMethod – 'UFactorTimesAreaAndDesignWaterFlowRate' or 'NominalCapacity';
- heatRejectionCapacityAndNominalCapacitySizingRatio – ratio of actual tower heat rejection to nominal capacity, defined at entering water at 35 °C, leaving water at 29.4 °C, entering air at 25.6 °C wetbulb and 35 °C drybulb temperatures;
- highSpeedNominalCapacity – "nominal" heat rejection capacity of the cooling tower under high-speed fan operation [W], with entering water at 35 °C, leaving water at 29.4 °C, entering air at 25.6 °C wetbulb and 35 °C drybulb temperatures;
- lowSpeedNominalCapacity – "nominal" heat rejection capacity of the cooling tower under low-speed fan operation [W], with entering water at 35 °C, leaving water at 29.4 °C, entering air at 25.6 °C wetbulb and 35 °C drybulb temperatures;
- lowSpeedNominalCapacitySizingFactor – sizing factor to use when calculating the lowSpeedNominalCapacity;
- freeConvectionCapacity – "nominal" heat rejection capacity of the cooling tower in watts when the tower is in the "free convection" regime (water flow exists but tower fan is turned off), with entering water at 35 °C, leaving water at 29.4 °C, entering air at 25.6 °C wetbulb and 35 °C drybulb temperatures. The value specified for this field must be less than the value specified in lowSpeedNominalCapacity. If the user does not wish to model "free convection", then this field should be set to 0.0. If the user specifies a value greater than zero, then freeConvectionAirFlowRate must contain a value greater than zero. This field may be autocalculated, in which case it is set to a fraction of the highSpeedNominalCapacity;
- freeConvectionNominalCapacitySizingFactor – sizing factor to use when calculating the freeConvectionCapacity;
- designInletAirDryBulbTemperature – design inlet air dry-bulb temperature [°C] (≥ 20);
- designInletAirWetBulbTemperature – inlet air wet-bulb temperature at design condition [°C] (≥ 20; if blank, equals to 25.6 °C). This design temperature should correspond with the design values for range temperature, approach temperature, water flow rate, and air flow rate specified in the following fields;

- designApproachTemperature – tower approach temperature at design conditions [ΔT] (> 0; if blank, equals to 3.9 °C). 'autosize' option is available. The approach temperature is the outlet water temperature minus the inlet air wet-bulb temperature. The design approach temperature should correspond with the design values for inlet air wet-bulb temperature, range temperature, water flow rate, and air flow rate specified for this tower;
- designRangeTemperature – range temperature at design conditions [ΔT] (> 0; if blank, equals to 5.6 °C). 'autosize' option is available. The range temperature is defined as the inlet water temperature minus the outlet water temperature. The design range temperature should correspond with the design values for inlet air wet-bulb temperature, approach temperature, water flow rate, and air flow rate specified for this tower;
- basinHeaterCapacity – capacity of the tower's electric basin heater [W/K]. The basin heater electric power is equal to basinHeaterCapacity multiplied by the difference between the basinHeaterSetpointTemperature and the outdoor dry-bulb temperature. The basin heater only operates when the tower fan is off and water is not flowing through the tower, regardless of the basin heater schedule described below. The basin heater capacity must be greater than or equal to zero, with a default value of zero if this field is left blank;
- basinHeaterSetpointTemperature – set point temperature for the basin heater [°C] (≥ 2 °C; 2 °C is the default value if this field is left blank). The basin heater is active when the outdoor air dry-bulb temperature falls below this setpoint temperature, as long as the tower fan is off and water is not flowing through the tower;
- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**). The basin heater operates when scheduled on and the outdoor air dry-bulb temperature is below the set point temperature described in the previous field. If blank, the basin heater is available to operate throughout the simulation. Regardless of this schedule, the basin heater may only operate when the cooling tower fan is off and water is not flowing through the tower;
- evaporationLossMode – 'SaturatedExit' or 'LossFactor';
- evaporationLossFactor – rate of water evaporated from the cooling tower and lost to the outside air [percent/K]. Only used if evaporationLossMode = 'LossFactor';
- driftLossPercent – rate of water lost to the exiting air as entrained droplets [%]. The drift loss is a percent of the condenser water flow;
- blowdownCalculationMode – 'ConcentrationRatio' or 'ScheduledRate';
- blowdownConcentrationRatio – used to dynamically adjust the rate of blowdown in the cooling tower as a function of the rate of evaporation (≥ 2). Blowdown is water intentionally drained from the tower in order to offset the build up of solids in the water that would otherwise occur because of evaporation;
- blowdownMakeupWaterUsageScheduleID – schedule ID used to define the amount of water [m^3/s] flushed from the basin on a periodic basis to purge the tower of mineral scale build-up and other contaminants, defined in the **Schedules** table in the database (**21**). Only used if blowdownCalculationMode = 'ScheduledRate';
- numberOfCells – number of cells in the multi-cell cooling tower. If not entered, the program will assume it is a single-cell cooling tower;
- cellControl – 'MinimalCell' or 'MaximalCell';

- cellMinimumWaterFlowRateFraction – allowable smallest fraction of the design water flow rate. If blank, the default value is 0.33;
- cellMaximumWaterFlowRateFraction – allowable largest fraction of the design water flow rate. If blank, the default value is 2.5;
- sizingFactor – sizing factor (optional). Used when the component design inputs (designWaterFlowRate, highFanSpeedAirFlowRate, highFanSpeedFanPower, lowFanSpeedAirFlowRate, lowFanSpeedFanPower, lowFanSpeedUFactorTimesAreaValue, freeConvectionAirFlowRate, and freeConvectionUFactorTimesAreaValue) are autosized: the autosizing calculations are performed as usual and the results are multiplied by the sizingFactor. highFanSpeedUFactorTimesAreaValue is not multiplied by the Sizing Factor. Instead the design tower load is multiplied by the sizingFactor and the design UA then calculated as usual. lowFanSpeedUFactorTimesAreaValue is set to a fraction of the full load design UA determined by lowFanSpeedUFactorTimesAreaValueSizingFactor. freeConvectionUFactorTimesAreaValue is set to a fraction of the design Tower UA determined by the field freeConvectionUFactorTimesAreaValueSizingFactor.
- endUseSubcategory – user-defined end-use subcategory (optional);
- setpointManagerType – defines the Setpoint Manager type for the Temperature Setpoint Node (automatically defined as the tower outlet node). 'ScheduledSingleSetpoint', 'ScheduledDualSetpoint' or 'OutdoorAirReset' (see section **14** for details);
- setpointManagerID – ID of the Setpoint Manager assigned to Temperature Setpoint Node, which is defined in the **setpointManagerSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **setpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**);
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – towerName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the tower is assigned;
  - loopSide – branch side for which the tower is assigned ('CONDENSER' or 'DEMAND');
  - equipmentID – tower position on the branch equipment list;
  - name – defined in the first argument of the CoolingTowerTwoSpeedSpec() above;
- Water Inlet Node Name – towerName + "Inlet_node";
- Water Outlet Node Name – towerName + "Outlet_node";
- Supply Water Storage Tank Name – supply water storage tank name defined in argument x1 of the CoolingTowerTwoSpeedSpec() above;
- Outdoor Air Inlet Node Name – towerName + "OA_Inlet_node". A OutdoorAir:Node object is automatically created in EnergyPlus and its fields automatically filled with the Outdoor Air Inlet Node Name.

8.6.1.3. Tower Variable Speed

The specification of a Cooling Tower Variable Speed is defined in the SAPTool_LSP building template, as follows:

CoolingTowerVariableSpeedSpec coolingTowerVariableSpeedSpec = new CoolingTowerVariableSpeedSpec() – Cooling Tower Variable Speed specification (named coolingTowerVariableSpeedSpec in this example). With the following CoolingTowerVariableSpeedSpec() arguments:

- **DBCoolingTowerVariableSpeedType.ABC.toString()** – tower name, defined using the DBCoolingTowerVariableSpeedType list object (‘ABC’, in this example). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **x1** – name of the supply water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **DBCoolingTowerVariableSpeedType.ABC.getID** – ID of the Cooling Tower Variable Speed properties in the database, defined using the DBCoolingTowerVariableSpeedType list object (ID of ‘ABC’, in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Cooling Tower Variable Speed properties are defined in the **CoolingTowerVariableSpeed** table in the database, corresponding to the CoolingTower:VariableSpeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- modelType – ‘YorkCalc’, ‘CoolToolsCrossFlow’, ‘YorkCalcUserDefined’ or ‘CoolToolsUserDefined’;
- userDefinedCoolingTowerPerformanceID – user-defined performance model type ID, defined in the corresponding table in the database: if modelType = ‘YorkCalcUserDefined’, **CoolingTowerPerformanceYorkCalc** table in the database (**8.6.1.3.1**); and if modelType = ‘CoolToolsUserDefined’, **CoolingTowerPerformanceCoolTools** table in the database (**8.6.1.3.2**);
- designInletAirWetBulbTemperature – inlet air wet-bulb temperature at design condition [°C] (≥ 20; if blank, equals to 25.6 °C). This design temperature should correspond with the design values for range temperature, approach temperature, water flow rate, and air flow rate specified in the following fields;
- designApproachTemperature – tower approach temperature at design conditions [ΔT] (> 0; if blank, equals to 3.9 °C). ‘autosize’ option is available. The approach temperature is the outlet water temperature minus the inlet air wet-bulb temperature. The design approach temperature should correspond with the design values for inlet air wet-bulb temperature, range temperature, water flow rate, and air flow rate specified for this tower;
- designRangeTemperature – range temperature at design conditions [ΔT] (> 0; if blank, equals to 5.6 °C). ‘autosize’ option is available. The range temperature is defined as the inlet water temperature minus the outlet water temperature. The design range temperature should correspond with the design values for inlet air wet-bulb

temperature, approach temperature, water flow rate, and air flow rate specified for this tower;

- designWaterFlowRate – design water flow rate through the tower [m^3/s]. 'autosize' option is available. If modelType = 'CoolToolsCrossFlow' or 'CoolToolsUserDefined', the value entered should be within ±25% of the tower's rated water mass flow rate as specified by the manufacturer. This value is the flow rate of the condenser loop water being cooled by the tower. A Plant Sizing object must be defined (see section **13.2.4**) if the field is autosized and the design water flow rate is then derived from the design load to be rejected by the condenser loop and the design loop delta T. The design water flow rate should correspond with the design values specified for the inlet air wet-bulb temperature, approach temperature, range temperature, and air flow rate. When this field is not autosized, the condenser loop flow rate specified in other objects should be within ±25% of the tower's rated water flow rate (different range is permissible if modelType = 'User Defined');
- designAirFlowRate – design air flow rate induced by the tower fan [m^3/s] (> 0). 'autosize' option is available. Autosizing of this field does not require a Plant Sizing;
- designFanPower – fan power [W] at the design (maximum) air flow rate through the tower (> 0). 'autosize' option is available. If autosized, a Plant Sizing object must be defined (see section **13.2.4**);
- fanPowerRatioFunctionOfAirFlowRatioCurveID – performance curve ID (cubic) for fan power ratio (fan power/design fan power) as a function of air flow rate ratio (air flow rate/design air flow rate), defined in the **PerformanceCurve** table in the database (**22**). If blank, a theoretical fan curve is assumed where fan power ratio is directly proportional to the air flow rate ratio cubed;
- minimumAirFlowRateRatio – minimum air flow rate ratio (0.2-0.5). If blank, a default value of 0.2 is assigned;
- fractionOfTowerCapacityInFreeConvectionRegime – fraction of tower capacity available in the free convection regime (i.e., when the tower fan is off but water continues to flow through the tower) (0.0-0.2). If blank, a default value of 0.125 is assigned;
- basinHeaterCapacity – capacity of the tower's electric basin heater [W/K]. The basin heater electric power is equal to basinHeaterCapacity multiplied by the difference between the basinHeaterSetpointTemperature and the outdoor dry-bulb temperature. The basin heater only operates when the tower fan is off and water is not flowing through the tower, regardless of the basin heater schedule described below. The basin heater capacity must be greater than or equal to zero, with a default value of zero if this field is left blank;
- basinHeaterSetpointTemperature – set point temperature for the basin heater [°C] (≥ 2 °C; 2 °C is the default value if this field is left blank). The basin heater is active when the outdoor air dry-bulb temperature falls below this setpoint temperature, as long as the tower fan is off and water is not flowing through the tower;
- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**). The basin heater operates when scheduled on and the outdoor air dry-bulb temperature is below the set point temperature described in the previous field. If blank, the basin heater is available to operate throughout the simulation. Regardless of this schedule, the basin heater may only operate when the cooling tower fan is off and water is not flowing through the tower;
- evaporationLossMode – 'SaturatedExit' or 'LossFactor';

- evaporationLossFactor – rate of water evaporated from the cooling tower and lost to the outside air [percent/K]. Only used if evaporationLossMode = 'LossFactor';
- driftLossPercent – rate of water lost to the exiting air as entrained droplets [%]. The drift loss is a percent of the condenser water flow;
- blowdownCalculationMode – 'ConcentrationRatio' or 'ScheduledRate';
- blowdownConcentrationRatio – used to dynamically adjust the rate of blowdown in the cooling tower as a function of the rate of evaporation (≥ 2). Blowdown is water intentionally drained from the tower in order to offset the build up of solids in the water that would otherwise occur because of evaporation;
- blowdownMakeupWaterUsageScheduleID – schedule ID used to define the amount of water [m^3/s] flushed from the basin on a periodic basis to purge the tower of mineral scale build-up and other contaminants, defined in the **Schedules** table in the database (**21**). Only used if blowdownCalculationMode = 'ScheduledRate';
- numberOfCells – number of cells in the multi-cell cooling tower. If not entered, the program will assume it is a single-cell cooling tower;
- cellControl – 'MinimalCell' or 'MaximalCell';
- cellMinimumWaterFlowRateFraction – allowable smallest fraction of the design water flow rate. If blank, the default value is 0.33;
- cellMaximumWaterFlowRateFraction – allowable largest fraction of the design water flow rate. If blank, the default value is 2.5;
- sizingFactor – sizing factor (optional). Used when the component design inputs (designWaterFlowRate, designAirFlowRate, and designFanPower) are autosized: the autosizing calculations are performed as usual and the results are multiplied by the sizingFactor;
- endUseSubcategory – user-defined end-use subcategory (optional);
- setpointManagerType – defines the Setpoint Manager type for the Temperature Setpoint Node (automatically defined as the tower outlet node). 'ScheduledSingleSetpoint', 'ScheduledDualSetpoint' or 'OutdoorAirReset' (see section **14** for details);
- setpointManagerID – ID of the Setpoint Manager assigned to Temperature Setpoint Node, which is defined in the **setpointManagerSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **setpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**);
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – towerName = loopName&ID + loopSide + equipmentID + name:
  - loopName&ID – loop name and ID for which the tower is assigned;
  - loopSide – branch side for which the tower is assigned ('CONDENSER' or 'DEMAND');
  - equipmentID – tower position on the branch equipment list;
  - name – defined in the first argument of the CoolingTowerVariableSpeedSpec() above;

- Water Inlet Node Name – towerName + “Inlet_node”;
- Water Outlet Node Name – towerName + “Outlet_node”;
- Model Coefficient Name – name of the coefficient model defined in userDefinedCoolingTowerPerformanceID;
- Fan Power Ratio Function of Air Flow Rate Ratio Curve Name – name of the curve defined in fanPowerRatioFunctionOfAirFlowRatioCurveID;
- Supply Water Storage Tank Name – supply water storage tank name defined in argument x1 of the CoolingTowerVariableSpeedSpec() above;
- Outdoor Air Inlet Node Name – towerName + “OA_Inlet_node”. A OutdoorAir:Node object is automatically created in EnergyPlus and its fields automatically filled with the Outdoor Air Inlet Node Name.

8.6.1.3.1. Performance York Calc

The Performance York Calc model properties are defined in the **CoolingTowerPerformanceYorkCalc** table in the database, corresponding to the CoolingTowerPerformance:YorkCalc object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- minimumInletAirWetBulbTemperature – minimum inlet air wet-bulb temperature to be used by the model (approach temperature correlation) [°C];
- maximumInletAirWetBulbTemperature – maximum inlet air wet-bulb temperature to be used by the model (approach temperature correlation) [°C];
- minimumRangeTemperature – minimum range temperature (inlet water temperature minus outlet water temperature) to be used by the empirical model [ΔT];
- maximumRangeTemperature – maximum range temperature (inlet water temperature minus outlet water temperature) to be used by the empirical model [ΔT];
- minimumApproachTemperature – minimum approach temperature (outlet water temperature minus inlet air wet-bulb temperature) to be used by the empirical model [ΔT];
- maximumApproachTemperature – maximum approach temperature (outlet water temperature minus inlet air wet-bulb temperature) to be used by the empirical model [ΔT];
- minimumWaterFlowRateRatio – minimum water flow rate ratio (ratio of actual water flow rate to rated water flow rate) to be used by the empirical model;
- maximumWaterFlowRateRatio – maximum water flow rate ratio (ratio of actual water flow rate to rated water flow rate) to be used by the empirical model;
- maximumLiquidToGasRatio – maximum liquid-to-gas ratio (ratio of actual water flow rate ratio [capped to be within the minimum/maximum water flow rate ratio defined above as necessary] to actual air flow rate ratio) to be used by the empirical model;
- coefficient1-27 – coefficients to be used by the YorkCalc approach temperature correlation.

Automatic filling fields in EnergyPlus:

- Name – towerName + “Performance_York_Calc”.

8.6.1.3.2. Performance Cool Tools

The Performance Cool Tools model properties are defined in the **CoolingTowerPerformanceCoolTools** table in the database, corresponding to the CoolingTowerPerformance:CoolTools object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- minimumInletAirWetBulbTemperature – minimum inlet air wet-bulb temperature to be used by the model (approach temperature correlation) [°C];
- maximumInletAirWetBulbTemperature – maximum inlet air wet-bulb temperature to be used by the model (approach temperature correlation) [°C];
- minimumRangeTemperature – minimum range temperature (inlet water temperature minus outlet water temperature) to be used by the empirical model [ΔT];
- maximumRangeTemperature – maximum range temperature (inlet water temperature minus outlet water temperature) to be used by the empirical model [ΔT];
- minimumApproachTemperature – minimum approach temperature (outlet water temperature minus inlet air wet-bulb temperature) to be used by the empirical model [ΔT];
- maximumApproachTemperature – maximum approach temperature (outlet water temperature minus inlet air wet-bulb temperature) to be used by the empirical model [ΔT];
- minimumWaterFlowRateRatio – minimum water flow rate ratio (ratio of actual water flow rate to rated water flow rate) to be used by the empirical model;
- maximumWaterFlowRateRatio – maximum water flow rate ratio (ratio of actual water flow rate to rated water flow rate) to be used by the empirical model;
- coefficient1-35 – coefficients to be used by the CoolTools approach temperature correlation.

Automatic filling fields in EnergyPlus:

- Name – towerName + "Performance_Cool_Tools".

8.6.2. Heat Exchanger

8.6.2.1. Fluid-to-Fluid

The specification of a Heat Exchanger Fluid-to-Fluid is defined in the SAPTool_LSP building template, as follows:

HeatExchangerFluidToFluidSpec heatExchangerFluidToFluidSpec = new HeatExchangerFluidToFluidSpec() – Heat Exchanger Fluid-to-Fluid specification (named heatExchangerFluidToFluidSpec in this example). With the following HeatExchangerFluidToFluidSpec() arguments:

- **DBHeatExchangerFluidToFluidType.ABC.toString()** – heat exchanger name, defined using the DBHeatExchangerFluidToFluidType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);

- **DBHeatExchangerFluidToFluidType.ABC.getID** – ID of the Heat Exchanger Fluid-to-Fluid properties in the database, defined using the DBHeatExchangerFluidToFluidType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Heat Exchanger Fluid-to-Fluid properties are defined in the **HeatExchangerFluidToFluid** table in the database, corresponding to the HeatExchanger:FluidToFluid object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- availabilityScheduleID – heat exchanger availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the heat exchanger always available;
- loopDemandSideDesignFlowRate – design flow rate of the hydronic fluid passing through the heat exchanger on the Loop Demand Side [m^3/s]. 'autosize' option is available, for which this design flow rate is set to equal the design flow rate for the Loop Supply Side;
- loopSupplySideDesignFlowRate – design flow rate of the fluid passing through the heat exchanger on the Loop Supply Side [m^3/s]. 'autosize' option is available, for which this design flow rate is set equal to the overall design flow rate of the loop that is connected;
- heatExchangerModelType – 'Ideal', 'CrossFlowBothUnMixed', 'CrossFlowBothMixed', 'CrossFlowSupplyMixedDemandUnMixed', 'CrossFlowSupplyUnMixedDemandMixed', 'ParallelFlow' or 'CounterFlow';
- heatExchangerUFactorTimesAreaValue – overall U-Factor Times Area (UA) for use in the calculation of the heat exchanger effectiveness using the appropriate D-NTU correlation [W/K]. 'autosize' option is available. If heatExchangerModelType = Ideal, this field is set to 1.0;
- controlType – 'UncontrolledOn', 'OperationSchemeModulated', 'OperationSchemeOnOff', 'HeatingSetpointModulated', 'HeatingSetpointOnOff', 'CoolingSetpointModulated', 'CoolingSetpointOnOff', 'DualDeadbandSetpointModulated', 'DualDeadbandSetpointOnOff', 'CoolingDifferentialOnOff' or 'CoolingSetpointOnOffWithComponentOverride'[12];
- setpointLocationInLoopSupplySide – 'Inlet' (Loop Supply Side Inlet Node) or 'Outlet' (Loop Supply Side Outlet Node). Only used when the previous field is set to one of the "Setpoint" control types;
- setpointManagerType – defines the Setpoint Manager type for the Temperature Setpoint Node. 'ScheduledSingleSetpoint' or 'ScheduledDualSetpoint' (see section **14** for details). Only used when the controlType field is set to one of the "Setpoint" control types. 'ScheduledDualSetpoint' must be defined if controlType = DualDeadbandSetpointModulated or DualDeadbandSetpointOnOff. Otherwise, 'ScheduledSingleSetpoint' must be used;

[12] CoolingSetpointOnOffWithComponentOverride is only valid for situations where the heat exchanger operation is integrated with the operation of a specific chiller. Typically, the heat exchanger and chiller are in parallel on separate branches. When conditions are favorable for the heat exchanger to provide cooling to the Loop Supply Side, the heat exchanger is run and the integrated chiller is turned off. When conditions are not favorable, the heat exchanger is competely off and the chiller is allowed to run as usual.

- setpointManagerID – ID of the Setpoint Manager assigned to Temperature Setpoint Node, which is defined in the **setpointManagerSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint or in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint (**14**);
- minimumTemperatureDifferenceToActivateHeatExchanger – temperature tolerance used in control decision [°C]. Not used when controlType = UncontrolledOn, OperationSchemeModulated or OperationSchemeOnOff;
- heatTransferMeteringEndUseType – 'LoopToLoop', 'FreeCooling', 'HeatRecovery', 'HeatRejection', 'HeatRecoveryForCooling' or 'HeatRecoveryForHeating';
- componentOverrideCoolingControlTemperatureMode – 'Loop', 'WetBulbTemperature' or 'DryBulbTemperature'. Only used if controlType = CoolingSetpointOnOffWithComponentOverride;
- sizingFactor – sizing factor (optional) that modifies sizing results by multiplying them by the factor entered here. This factor is applied to the Loop Supply Side Design Flow rate and in turn affects the heat exchanger UA and the Loop Demand Side Flow rate which are derived from that flow rate;
- operationMinimumTemperatureLimit – lower limit on inlet temperatures, below which the heat exchanger will not operate [°C] (optional);
- operationMaximumTemperatureLimit – upper limit on inlet temperatures, above which the heat exchanger will not operate [°C] (optional);
- pressureDropCurveDemandSideID – demand side pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the demand side branch object automatically created for this equipment – see section **9.3**;
- pressureDropCurveSupplySideID – supply side pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the supply side branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – defined in the first argument of the HeatExchangerFluidToFluidSpec() above (hxName);
- Loop Demand Side Inlet Node Name – hxName + "Demand_Side_Inlet_node";
- Loop Demand Side Outlet Node Name – hxName + "Demand_Side_Outlet_node";
- Loop Supply Side Inlet Node Name – hxName + "Supply _Side_Inlet_node";
- Loop Supply Side Outlet Node Name – hxName + "Supply_Side_Outlet_node";
- Heat Exchanger Setpoint Node Name – Loop Supply Side Inlet Node Name, if setpointLocationInLoopSupplySide = Inlet, Loop Supply Side Outlet Node Name, if setpointLocationInLoopSupplySide = Outlet. Only used when the controlType field is set to one of the "Setpoint" control types;
- Component Override Loop Supply Side Inlet Node Name – chilled water inlet node name of a chiller located in the same loop side of this heat exchanger. Only used if controlType = CoolingSetpointOnOffWithComponentOverride
- Component Override Loop Demand Side Inlet Node Name – condenser (water) inlet node name of a chiller located in the same loop side of this heat exchanger (the chiller

must be water-cooled). Only used if controlType = CoolingSetpointOnOffWithComponentOverride.

Assignment to plant and condenser loops

A Heat Exchanger Loop To Loop is specified using the HeatExchangerFluidToFluidSpec() object (as presented above), and then linked to its loop sides using the HeatExchangerFluidToFluidSideSpec object:

HeatExchangerFluidToFluidSideSpec heatExchangerFluidToFluidSideSpec new HeatExchangerFluidToFluidSideSpec() – specification of the linkage between the Heat Exchanger Loop To Loop and its loop sides (demand and supply) (named heatExchangerFluidToFluidSideSpec in this example). With the following HeatExchangerFluidToFluidSideSpec() arguments:

- **HeatExchangerSideType.XX** – heat exchanger side for which the current loop is assigned. XX = 'Demand' or 'Supply';
- **HeatExchangerFluidToFluidSpec** – Heat Exchanger Loop To Loop specification object (previously defined) assigned to this heat exchanger.

A HeatExchangerFluidToFluidSideSpec() object must be defined for each loop that the heat exhcanger is assigned to (i.e., with the same Heat Exchanger Loop To Loop specification – second argument of HeatExchangerFluidToFluidSideSpec()). The HeatExchangerFluidToFluidSideSpec object name (e.g., heatExchangerFluidToFluidSideSpec) must then be assigned to the proper plant or condenser loop branch, as described in section **9.3**.

8.7. Water Heaters and Thermal Storage

8.7.1. Water Heater Mixed

The specification of a Water Heater Mixed is defined in the SAPTool_LSP building template, as presented below. This is valid for a water heater in a plant loop (**8.7.1.1**) or a stand-alone water heater (**8.7.1.2**), i.e., a water heater not assigned to any loop.

WaterHeaterMixedSpec storageTankSpec = new WaterHeaterMixedSpec() – Water Heater Mixed specification (named storageTankSpec in this example). With the following WaterHeaterMixedSpec() arguments:

- **DBWaterHeaterMixedType.ABC.toString()** – water heater name, defined using the DBWaterHeaterMixedType list object ('ABC', in this example). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **x1** – ID of the zone for which the water heater is assigned, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if no zone assignment;
- **DBWaterHeaterMixedType.ABC.getID** – ID of the Water Heater Mixed properties in the database, defined using the DBWaterHeaterMixedType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;

- **db** – database unique ID.

The Water Heater Mixed properties are defined in the **WaterHeaterMixed** table in the database, corresponding to the WaterHeater:Mixed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- tankVolume – volume of the storage tank [m3];
- setpointTemperatureScheduleID – setpoint temperature schedule ID, defined in the **Schedules** table in the database (**21**);
- deadbandTemperatureDifference – delta temperature difference [Δ°C] between the setpoint and the "cut-in" temperature at which the heater will turn on;
- maximumTemperatureLimit – temperature [°C] at which the tank water becomes dangerously hot and is vented through boiling or an automatic safety. Note: The maximum temperature must be greater than the setpoint temperature at all times;
- heaterControlType – 'Cycle' or 'Modulate';
- heaterMaximumCapacity – maximum heat rate that can be supplied to the water [W]. Can be null if a heater is not present;
- heaterMinimumCapacity – minimum heat rate that can be supplied to the water [W]. Only used if heaterControlType = Modulate;
- heaterIgnitionMinimumFlowRate – not yet available in EnergyPlus;
- heaterIgnitionDelay – not yet available in EnergyPlus;
- heaterFuelType – 'Electricity', 'NaturalGas', 'PropaneGas', 'FuelOil_1', 'FuelOil_2', 'Coal', 'Diesel', 'Gasoline', 'Steam', 'OtherFuel1', 'OtherFuel2' or 'DistrictHeating';
- heaterThermalEfficiency – thermal conversion efficiency from fuel energy to heat energy for the heater element or burner;
- partLoadCurveID – part load curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional);
- offCycleParasiticFuelConsumptionRate – off-Cycle Parasitic Fuel Consumption Rate [W];
- offCycleParasiticFuelType – 'Electricity', 'NaturalGas', 'PropaneGas', 'FuelOil_1', 'FuelOil_2', 'Coal', 'Diesel', 'Gasoline', 'Steam', 'OtherFuel1', 'OtherFuel2' or 'DistrictHeating';
- offCycleParasiticHeatFractionToTank – fraction of off-cycle parasitic fuel energy that is converted to heat energy that ends up in the tank water;
- onCycleParasiticFuelConsumptionRate – on-Cycle Parasitic Fuel Consumption Rate [W];
- onCycleParasiticFuelType – 'Electricity', 'NaturalGas', 'PropaneGas', 'FuelOil_1', 'FuelOil_2', 'Coal', 'Diesel', 'Gasoline', 'Steam', 'OtherFuel1', 'OtherFuel2' or 'DistrictHeating';
- onCycleParasiticHeatFractionToTank – fraction of on-cycle parasitic fuel energy that is converted to heat energy that ends up in the tank water;
- ambientTemperatureScheduleID – ambient temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- offCycleLossCoefficientToAmbientTemperature – loss coefficient to the ambient air temperature [W/K];

- offCycleLossFractionToZone – fraction of the off-cycle losses to the zone heat balance as an internal gain. Only used if the water heater is assigned to a zone;
- onCycleLossCoefficientToAmbientTemperature – loss coefficient to the ambient air temperature [W/K];
- onCycleLossFractionToZone – fraction of the on-cycle losses to the zone heat balance as an internal gain. Only used if the water heater is assigned to a zone;
- peakUseFlowRate – peak flow rate of domestic hot water usage [m3/s] . Only used if for a stand-alone water heater, i.e., without plant loop connections;
- useFlowRateFractionScheduleID – use flow rate schedule ID, defined in the **Schedules** table in the database (**21**). It specifies the current fraction of Peak Volumetric Use Flow Rate. Only used for a stand-alone water heater, i.e., without plant loop connections;
- coldWaterSupplyTemperatureScheduleID – cold water supply temperature schedule ID, defined in the **Schedules** table in the database (**21**). If blank, water temperatures are calculated by the Site:WaterMainsTemperature object – see section **22.1**. Only used for a stand-alone water heater, i.e., without plant loop connections;
- useSideEffectiveness – heat transfer effectiveness between the use side water and the tank water;
- sourceSideEffectiveness – heat transfer effectiveness between the source side water and the tank water;
- useSideDesignFlowRate – design flow rate through the Use Side (if connected to a loop) of the water heater [m3]. ‘autosize’ option is available;
- sourceSideDesignFlowRate – design flow rate through the Source Side (if connected to a loop) of the water heater [m3]. ‘autosize’ option is available;
- indirectWaterHeatingRecoveryTime – indirect water heating recovery time [h];
- sourceSideFlowControlMode – ‘IndirectHeatPrimarySetpoint’, ‘IndirectHeatAlternateSetpoint’, ‘StorageTank’ or blank (optional);
- indirectAlternateSetpointTemperatureScheduleID – indirect alternate setpoint temperature schedule ID, defined in the **Schedules** table in the database (**21**) (optional). Only if sourceSideFlowControlMode = IndirectHeatAlternateSetpoint;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve is related to the branch object automatically created for this equipment – see section **9.3**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – waterHeaterName = loopName&ID + loopSide + equipmentID + name + zoneWaterHeaterID:
  - loopName&ID – loop name and ID for which the water heater is assigned, if assigned to a single loop (Water Heater Use Side only); or “Source&UseLoops”, if assigned to two loops (Water Heater Source Side and Use Side). For a stand-alone water heater, the loopName&ID is not added;
  - loopSide – loop side for which the water heater is assigned (= PLANT, as a water heater is always a plant side equipment). For a stand-alone water heater, the loopSide is not added;
  - equipmentID – water heater position on the branch equipment list, if the water heater is assigned to a single loop. If the water heater is assigned to two loops, the

equipmentID is not added, as this ID can be different for both loops. For a stand-alone water heater, the equipmentID is not added;
    - name – defined in the first argument of the WaterHeaterMixedSpec() above;
    - zoneWaterHeaterID – ID of the water heater in the zone. Only used if a stand-alone water heater is assigned to a zone;
- Ambient Temperature Indicator – 'Schedule', if the ambientTemperatureScheduleID field is not empty (in the **WaterHeaterMixed** table in the database). Otherwise, 'Outdoors', if the water heater is not assigned to a zone or 'Zone', if it is assigned to a zone;
- Ambient Temperature Zone Name – name of the zone for which the water heater is assigned, if Ambient Temperature Indicator = Zone. Defined in argument x1 of the WaterHeaterMixedSpec() above;
- Ambient Temperature Outdoor Air Node Name – waterHeaterName + "Outdoor_Air_Node"*. Defined and used only if Ambient Temperature Indicator = Outdoors;
- Use Side Inlet Node Name – waterHeaterName + "Use_Inlet_node". Only defined if the water heater Use Side is assigned to a loop;
- Use Side Outlet Node Name – waterHeaterName + "Use_Outlet_node". Only defined if the water heater Use Side is assigned to a loop;
- Source Side Inlet Node Name – waterHeaterName + "Source_Inlet_node". Only defined if the water heater Source Side is assigned to a loop;
- Source Side Outlet Node Name – waterHeaterName + "Source_Outlet_node". Only defined if the water heater Source Side is assigned to a loop.

*Every time this node is defined, a OutdoorAir:Node object is automatically created in EnergyPlus and its fields automatically filled:

- Name – waterHeaterName + "Outdoor_Air_Node";
- Height Above Ground – null.

8.7.1.1. Plant loop

A water heater in a loop is specified using the WaterHeaterMixedSpec() object (as presented in the beginning of section **8.7.1**), and then linked to its loop sides using the WaterHeaterMixedSideSpec object:

WaterHeaterMixedSideSpec waterHeaterMixedSideSpec new WaterHeaterMixedSideSpec() – specification of the linkage between the water heater and one of its loop sides (use or source) (named waterHeaterMixedSideSpec in this example). With the following WaterHeaterMixedSideSpec() arguments:

- **NumberOfLoopSidesType.XX** – number of sides/loops assigned to the water heater. XX = 'OneSide' or 'TwoSides';
- **WaterHeaterSideType.XX** – water heater side for which the current loop is assigned. XX = 'SOURCE' or 'USE';
- **storageTankSpec** – water heater specification object (previously defined) assigned to this water heater.

If the water heater is only assigned to one loop (NumberOfLoopSidesType.OneSide), the WaterHeaterSideType option must forcibly be ‘Use’. Otherwise, if the water heater is assigned to two loops (NumberOfLoopSidesType.TwoSides), two WaterHeaterMixedSideSpec() objects must be defined, where the WaterHeaterSideType option is ‘Source’ for the source loop object and ‘Use’ for the use loop object; both with the same specification object (storageTankSpec, in this example).

The WaterHeaterMixedSideSpec name (waterHeaterMixedSideSpec, in this example) must then be assigned to the proper loop branch, as described in section **9.3**.

8.7.1.2. Stand-alone

The stand-alone water heater is specified using the WaterHeaterMixedSpec() object (as presented in the beginning of section **8.7.1**), and then simply assigned to the HVAC detailed systems specifications. The HVAC detailed systems specifications must be defined in the SAPTool_LSP building template, as follows:

HVACSpec hVACSpec = new HVACSpec()

The hVACSpec must then be assigned to the layout specifications object (LayoutSpecs(), in its second to last argument), in the end of the SAPTool_LSP building template.

The WaterHeaterMixedSpec() object is assigned to the HVAC detailed systems specifications (named hVACSpec in this example) as follows:

hVACSpec.addWaterHeaterMixedSpec(waterHeaterMixedStandAloneSpec) – assignment of the stand-alone water heater specification (named waterHeaterMixedStandAloneSpec in this example) to the hVACSpec object.

8.8. Fans

8.8.1. Zone Exhaust

This component is defined in the **FanZoneExhaust** table in the database, corresponding to the Fan:ZoneExhaust object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – fan availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the fan is always available;
- fanTotalEfficiency – overall efficiency of the fan, i.e., the ratio of the power delivered to the fluid to the electrical input power;
- pressureRise – The pressure rise in Pascals at full flow and standard (sea level) conditions (20 °C and 101325 Pa);
- maximumFlowRate – The full load air volumetric flow rate [m^3/sec] at standard temperature and pressure (dry air at 20 °C dry bulb);
- endUseSubcategory – user-defined end-use subcategory;
- flowFractionScheduleID – flow fraction schedule ID, defined in the **Schedules** table in the database (**21**) (optional);

- systemAvailabilityManagerCouplingMode – ‘Coupled’ (default, if blank) or ‘Decoupled’;
- minimumZoneTemperatureLimitScheduleID – minimum zone temperature limit Schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If it is not used then there will be no temperature-related control over the operation of the exhaust fan;
- balancedExhaustFractionScheduleID – balanced exhaust fraction schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If it is not used, then all the exhaust air flow is assumed to be unbalanced by any simple airflows, such as infiltration, ventilation or zone mixing.

Automatic filling fields in EnergyPlus:

- Name – fanName = “EXHAUST_FAN” + Zone Name (Zone Name – name of the zone for which this object is assigned);
- Air Inlet Node Name – fanName + “INLET_NODE”. This node is automatically assigned to the zone air exhaust node list (automatically named Zone Name + “AIR_EXHAUST_NODES”), with the EnergyPlus object NodeList. This node list is then assigned to the Zone Air Exhaust Node List in the Equipment Connections (see section **7.1.9**);
- Air Outlet Node Name – fanName + “OUTLET_NODE”.

If there are other zone HVAC equipment assigned to the same zone, the exhaust fan cooling and heating or no-load sequences must be defined in the Zone HVAC systems specifications in the SAPTool_LSP building template, as follows:

ZoneHVACSpec zoneHVACSpec_LivingRoom = new ZoneHVACSpec() – Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example). With the following ZoneHVACSpec() arguments:

- **DBLoadDistributionScheme.ABC.toString()** – load distribution scheme of the different equipment defined for this zone, using the DBLoadDistributionSchemeType list object (‘ABC’, in this example), in the Zone HVAC Equipment List (see section **7.1.9**). Alternatively, a string can be directly inputted here (e.g., **“ABC”**). The available options are: ABC = ‘SequentialLoad’, ‘UniformLoad’, ‘UniformPLR’ or ‘SequentialUniformPLR’;
- **new ArrayList<>()** – used to defined the Zone HVAC systems specification (see section **7.1**);
- **new Integer[]{a,b}** – a defines the Fan Zone Exhaust cooling sequence and b defines the heating or no-load sequence in the Zone HVAC Equipment List (see section **7.1.9**), for the case when more than one zone equipment is assigned to the zone. Otherwise (if only one zone equipment is assigned to the zone), this field can be left blank (**null**), and both a and b will be automatically set as 1;
- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – schedule that specifies the fraction of the remaining cooling load this equipment will attempt to serve, in the Zone HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object (“SCH1”, in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;
- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – schedule that specifies the fraction of the remaining heating load this equipment will attempt to serve, in the Zone

HVAC Equipment List (see section **7.1.9**). Specified using the schedule ID in the database db, defined with the DBScheduleType list object ("SCH2", in this example). Only applies if the load distribution scheme is SequentialLoad. This field can be left blank (**null**), which indicates a constant schedule of 1.0;

- **DBSpaceType.LIVING_ROOM.getID()** – ID of the zone (in the Zone table in the database – section **0**) for which the Fan Zone Exhaust is assigned, defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

The Zone HVAC systems specified above must then be added to the zone specifications (ZoneSpec()), with the following arguments:

- **x** – used only for HVAC Template specifications;
- **zoneHVACSpec_LivingRoom** – the Zone HVAC system specification defined previously;
- **DBSpaceType.LIVING_ROOM.getID()** – zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living room, in this example);
- **db** – database unique ID.

This component is treated as a Zone HVAC object, therefore it must be assigned to an equipment list, for which its connections must be defined. This is done by automatically filling the Zone HVAC Equipment List and Equipment Connections objects in EnergyPlus, as presented in section **7.1.9**.

8.8.2. On-Off

The specification of a Fan On-Off is defined in the SAPTool_LSP building template, as follows:

FanOnOffSpec bedroomsSupplyFanSpec = new FanOnOffSpec() – Fan On-Off specification (named bedroomsSupplyFanSpec in this example). With the following FanOnOffSpec() arguments:

- **x1** – ID of the Fan On-Off properties in the **FanOnOff** table of the database;
- **db** – database unique ID.

The Fan On-Off is specified using the FanOnOffSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (bedroomsSupplyFanSpec, in this example) to the system specification.

This component is defined in the **FanOnOff** table in the database, corresponding to the Fan:OnOff object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – fan availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the fan is always available;
- fanTotalEfficiency – overall efficiency of the fan, i.e., the ratio of the power delivered to the fluid to the electrical input power;

- pressureRise – The pressure rise in Pascals at full flow and standard (sea level) conditions (20 °C and 101325 Pa);
- maximumFlowRate – The full load air volumetric flow rate [m^3/sec] at standard temperature and pressure (dry air at 20 °C dry bulb);
- motorEfficiency – shaft power divided by the electrical power consumed;
- motorInAirstreamFraction – fraction of the motor heat that is added to the air stream;
- fanPowerRatioFunctionOfSpeedRatioCurveID – exponent performance curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). Represents the ratio of actual fan power to rated fan power when a change in fan speed occurs. Only for multi-speed fan motors;
- fanEfficiencyRatioFunctionOfSpeedRatioCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). Represents the ratio of actual fan total efficiency to rated fan total efficiency when a change in fan speed occurs. Only for multi-speed fan motors;
- endUseSubcategory – user-defined end-use subcategory.

Automatic filling fields in EnergyPlus:

- Name – fanName = System name + Fan type (System name – system name for which the fan is assigned to; Fan type – type of fan in the specific system);
- Air Inlet Node Name – name of the HVAC system node which supplies the inlet air conditions to the fan (normally, the outlet node of the equipment upstream of the fan or the inlet node of the unit for which the fan is assigned to, if the fan is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the fan sends its outlet air (normally, fanName + "Outlet_node").

8.8.3. Constant Volume

The specification of a Fan Constant Volume is defined in the SAPTool_LSP building template, as follows:

FanConstantVolumeSpec bedroomsSupplyFanSpec = new FanConstantVolumeSpec() – Fan Constant Volume specification (named bedroomsSupplyFanSpec in this example). With the following FanConstantVolumeSpec() arguments:

- **x1** – ID of the Fan Constant Volume properties in the **FanConstantVolume** table of the database;
- **db** – database unique ID.

The Fan Constant Volume is specified using the FanConstantVolumeSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (bedroomsSupplyFanSpec, in this example) to the system specification.

This component is defined in the **FanConstantVolume** table in the database, corresponding to the Fan:ConstantVolume object in EnergyPlus. The following fields are present in the table:

- id – object ID;

- availabilityScheduleID – fan availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the fan is always available;
- fanTotalEfficiency – overall efficiency of the fan, i.e., the ratio of the power delivered to the fluid to the electrical input power;
- pressureRise – The pressure rise in Pascals at full flow and standard (sea level) conditions (20 °C and 101325 Pa);
- maximumFlowRate – The full load air volumetric flow rate [m^3/sec] at standard temperature and pressure (dry air at 20 °C dry bulb);
- motorEfficiency – shaft power divided by the electrical power consumed;
- motorInAirstreamFraction – fraction of the motor heat that is added to the air stream;
- endUseSubcategory – user-defined end-use subcategory.

Automatic filling fields in EnergyPlus:

- Name – fanName = System name + Fan type (System name – system name for which the fan is assigned to; Fan type – type of fan in the specific system);
- Air Inlet Node Name – name of the HVAC system node which supplies the inlet air conditions to the fan (normally, the outlet node of the equipment upstream of the fan or the inlet node of the system for which the fan is assigned to, if the fan is the first equipment in the system);
- Air Outlet Node Name – name of the HVAC system node to which the fan sends its outlet air (normally, fanName + "Outlet_node").

8.8.4. Variable Volume

The specification of a Fan Variable Volume is defined in the SAPTool_LSP building template, as follows:

FanVariableVolumeSpec bedroomsSupplyFanSpec = new FanVariableVolumeSpec() – Fan Variable Volume specification (named bedroomsSupplyFanSpec in this example). With the following FanVariableVolumeSpec() arguments:

- **x1** – ID of the Fan Variable Volume properties in the **FanVariableVolume** table of the database;
- **db** – database unique ID.

The Fan Variable Volume is specified using the FanVariableVolumeSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (bedroomsSupplyFanSpec, in this example) to the system specification.

This component is defined in the **FanVariableVolume** table in the database, corresponding to the Fan:VariableVolume object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – fan availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the fan is always available;
- fanTotalEfficiency – overall efficiency of the fan, i.e., the ratio of the power delivered to the fluid to the electrical input power;

- pressureRise – The pressure rise in Pascals at full flow and standard (sea level) conditions (20 °C and 101325 Pa);
- maximumFlowRate – The full load air volumetric flow rate [m^3/sec] at standard temperature and pressure (dry air at 20 °C dry bulb);
- fanPowerMinimumFlowRateInputMethod – 'Fraction' or 'FixedFlowRate';
- fanPowerMinimumFlowFraction – minimum air volumetric flow rate for fan power, specified as a fraction of maximum system air flow rate
- fanPowerMinimumAirFlowRate – minimum air volumetric flow rate for fan power, specified as a constant minimum air flow rate [m^3/sec];
- motorEfficiency – shaft power divided by the electrical power consumed;
- motorInAirstreamFraction – fraction of the motor heat that is added to the air stream;
- fanPowerCoefficient1 – constant coefficient (C1) in a fourth order polynomial curve giving the fraction of full load power (PLF) as a function of flow fraction (FF)[13];
- fanPowerCoefficient2 – linear coefficient (C2) in a fourth order polynomial curve giving the fraction of full load power (PLF) as a function of flow fraction (FF);
- fanPowerCoefficient3 – quadratic coefficient (C3) in a fourth order polynomial curve giving the fraction of full load power (PLF) as a function of flow fraction (FF);
- fanPowerCoefficient4 – cubic coefficient (C4) in a fourth order polynomial curve giving the fraction of full load power (PLF) as a function of flow fraction (FF);
- fanPowerCoefficient5 – coefficient C5 in a fourth order polynomial curve giving the fraction of full load power (PLF) as a function of flow fraction (FF);
- endUseSubcategory – user-defined end-use subcategory.

Automatic filling fields in EnergyPlus:

- Name – fanName = System name + Fan type (System name – system name for which the fan is assigned to; Fan type – type of fan in the specific system);
- Air Inlet Node Name – name of the HVAC system node which supplies the inlet air conditions to the fan (normally, the outlet node of the equipment upstream of the fan or the inlet node of the system for which the fan is assigned to, if the fan is the first equipment in the system);
- Air Outlet Node Name – name of the HVAC system node to which the fan sends its outlet air (normally, fanName + "Outlet_node").

8.9. Coils

8.9.1. Cooling

8.9.1.1. DX Single Speed

The specification of a Cooling Coil DX Single Speed is defined in the SAPTool_LSP building template, as follows:

[13] Fraction Full Load Power = PLF = C1 + C2*FF + C3*FF**2 + C4*FF**3 + C5*FF**4, FF = air mass flow rate divided by the maximum air mass flow rate

CoilCoolingDXSingleSpeedSpec coolingCoilSpec = new CoilCoolingDXSingleSpeedSpec() – Cooling Coil DX Single Speed specification (named coolingCoilSpec in this example). With the following CoilCoolingDXSingleSpeedSpec() arguments:

- **x1** – name of the supply water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **x2** – name of the condensate collection water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **x3** – ID of a conditioned or unconditioned zone where the secondary coil (condenser) is to be placed (optional), which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if not defined;
- **x4** – ID of the Cooling Coil DX Single Speed properties in the **CoilCoolingDXSingleSpeed** table of the database;
- **db** – database unique ID.

The Cooling Coil DX Single Speed is specified using the CoilCoolingDXSingleSpeedSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (coolingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilCoolingDXSingleSpeed** table in the database, corresponding to the Coil:Cooling:DX:SingleSpeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- grossRatedTotalCoolingCapacity – total cooling capacity (sensible plus latent) in watts of the DX coil unit at rated conditions (air entering the cooling coil at 26.7 °C drybulb/19.4 °C wetbulb, air entering the outdoor condenser coil at 35 °C drybulb/23.9 °C wetbulb, and a cooling coil air flow rate defined by field rated air flow rate below), not accounting for the effect of supply air fan heat. 'autosize' option is available;
- grossRatedSensibleHeatRatio – sensible heat ratio (SHR = gross sensible cooling capacity divided by gross total cooling capacity) of the DX cooling coil at rated conditions, not accounting for the effect of supply air fan heat. 'autosize' option is available;
- grossRatedCoolingCOP – ratio of the gross total cooling capacity in watts to electrical power input in watts of the DX cooling coil unit at rated conditions, not accounting for the effect of supply air fan heat or the supply fan electrical energy input;
- ratedAirFlowRate – air volume flow rate across the DX cooling coil at rated conditions [m^3/s]. Should be between 0.00004027 m^3/s and 0.00006041 m^3/s per watt of gross rated total cooling capacity. 'autosize' option is available;
- ratedEvaporatorFanPowerPerVolumeFlowRate – electric power for the evaporator (cooling coil) fan per air volume flow rate through the coil at the rated conditions [W/(m^3/s)];
- totalCoolingCapacityFunctionOfTemperatureCurveID – performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity as a function of the wet-bulb temperature of the air entering the cooling coil, and the dry-bulb temperature of the air entering the

air-cooled condenser coil (wet-bulb temperature if modeling an evaporative-cooled condenser). Typically, a biquadratic but any curve or table with two independent variables can be used;

- totalCoolingCapacityFunctionOfFlowFractionCurveID – performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate (i.e., fraction of full load flow). Typically, a quadratic curve;
- energyInputRatioFunctionOfTemperatureCurveID – performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the wet-bulb temperature of the air entering the cooling coil, and the dry-bulb temperature of the air entering the air-cooled condenser coil (wet-bulb temperature if modeling an evaporative-cooled condenser). Typically, a biquadratic but any curve or table with two independent variables can be used;
- energyInputRatioFunctionOfFlowFractionCurveID – performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate (i.e., fraction of full load flow). Typically, a quadratic or cubic but any curve or table with one independent variables can be used;
- partLoadFractionCorrelationCurveID – performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of electrical power input to the DX unit as a function of the part load ratio (PLR, sensible cooling load/steady-state sensible cooling capacity). Typically, a quadratic or cubic but any curve or table with one independent variables can be used;
- minimumOutdoorDryBulbTemperatureForCompressorOperation – minimum outdoor air dry-bulb temperature where the cooling coil compressor turns off [°C];
- nominalTimeForCondensateRemovalToBegin – nominal time after startup for condensate to begin leaving the coil's condensate drain line at the coil's rated airflow and temperature conditions, starting with a dry coil [s];
- ratioOfInitialMoistureEvaporationRateAndSteadyStateLatentCapacity – ratio of the initial moisture evaporation rate from the cooling coil (when the compressor first turns off, in Watts) and the coil's steady-state latent capacity (Watts) at rated airflow and temperature conditions;
- maximumCyclingRate – maximum on-off cycling rate for the compressor, which occurs at 50% run time fraction [cycles/h];
- latentCapacityTimeConstant – time constant for the cooling coil's latent capacity to reach steady state after startup [s];
- condenserType – 'AirCooled' or 'EvaporativelyCooled';
- evaporativeCondenserEffectiveness – effectiveness of the evaporative condenser, which is used to determine the temperature of the air entering the outdoor condenser coil. Only used if condenserType = EvaporativelyCooled;
- evaporativeCondenserAirFlowRate – air volume flow rate entering the evaporative condenser [m^3/s]. Only used if condenserType = EvaporativelyCooled. 'autosize' option is available;

- evaporativeCondenserPumpRatedPowerConsumption – rated power of the evaporative condenser water pump [W]. Only used if condenserType = EvaporativelyCooled. 'autosize' option is available;
- crankcaseHeaterCapacity – crankcase heater capacity [W];
- maximumOutdoorDryBulbTemperatureForCrankcaseHeaterOperation – outdoor air dry-bulb temperature above which the compressor s crankcase heater is disabled [°C];
- basinHeaterCapacity – capacity of the DX coil s electric evaporative cooler basin heater [W/K]. Only used if condenserType = EvaporativelyCooled;
- basinHeaterSetpointTemperature – set point temperature for the basin heater described in the previous field [°C]. Only used if condenserType = EvaporativelyCooled;
- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the basin heater is always available. Only used if condenserType = EvaporativelyCooled;
- sensibleHeatRatioFunctionOfTemperatureCurveID – biquadratic normalized curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This curve parameterizes the variation of the sensible heat ratio (SHR) as a function of DX cooling coil entering air wet-bulb and dry-bulb temperatures;
- sensibleHeatRatioFunctionOfFlowFractionCurveID – quadratic or cubic normalized curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This curve parameterizes the variation of the sensible heat ratio (SHR) as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate (i.e., fraction of full load flow);
- reportASHRAEStandard127PerformanceRatings – 'Yes' or 'No';
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node");
- Condenser Air Inlet Node Name – considered null for the outdoor air temperature entering the condenser to be taken directly from the weather data;
- Supply Water Storage Tank Name – name of the supply water storage tank, assigned in the argument x1 of the CoilCoolingDXSingleSpeedSpec() above;
- Condensate Collection Water Storage Tank Name – name of the condensate collection water storage tank, assigned in the argument x2 of the CoilCoolingDXSingleSpeedSpec() above;
- Zone Name for Condenser Placement – name of a conditioned or unconditioned zone where the secondary coil (condenser) is to be placed, assigned in the argument x3 of the CoilCoolingDXSingleSpeedSpec() above.

The following fields in the **CoilCoolingDXSingleSpeed** table are used if the coil is directly assigned to an air loop (**10.1**) or an outdoor air system (**10.5**), for which the coil is contained in a cooling coil system that provides the controls needed to operate the coil. This corresponds to the CoilSystem:Cooling:DX object in EnergyPlus, which is automatically defined:

- coilSystemRunOnSensibleLoad – ‘Yes’ or ‘No’;
- coilSystemRunOnLatentLoad – ‘Yes’ or ‘No’;
- coilSystemUseOutdoorAirDXCoolingCoil – ‘Yes’ or ‘No’;
- coilSystemOutdoorAirDXCoolingCoilLeavingMinimumAirTemperature – DX cooling coil leaving supply air minimum temperature specified for frost control [°C];

Automatic filling fields in EnergyPlus:

- Name – coilName + “DX_System”;
- Availability Schedule Name – the same schedule defined above for the coil in the availabilityScheduleID field;
- DX Cooling Coil System Inlet Node Name – coil’s Air Inlet Node Name;
- DX Cooling Coil System Outlet Node Name – coil’s Air Outlet Node Name;
- DX Cooling Coil System Sensor Node Name – coil’s Air Outlet Node Name;
- Cooling Coil Object Type – Coil:Cooling:DX:SingleSpeed;
- Cooling Coil Name – coilName;
- Dehumidification Control Type – defined as ‘None’, as it is not valid for this coil type.

8.9.1.2. DX Two Speed

The specification of a Cooling Coil DX Two Speed is defined in the SAPTool_LSP building template, as follows:

CoilCoolingDXTwoSpeedSpec coolingCoilSpec = new CoilCoolingDXTwoSpeedSpec() – Cooling Coil DX Two Speed specification (named coolingCoilSpec in this example). With the following CoilCoolingDXTwoSpeedSpec() arguments:

- **x1** – name of the supply water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **x2** – name of the condensate collection water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **x3** – ID of a conditioned or unconditioned zone where the secondary coil (condenser) is to be placed (optional), which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if not defined;
- **x4** – ID of the Cooling Coil DX Two Speed properties in the **CoilCoolingDXTwoSpeed** table of the database;
- **db** – database unique ID.

The Cooling Coil DX Two Speed is specified using the CoilCoolingDXTwoSpeedSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (coolingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilCoolingDXTwoSpeed** table in the database, corresponding to the Coil:Cooling:DX:TwoSpeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- highSpeedGrossRatedTotalCoolingCapacity – total cooling capacity (sensible plus latent) in watts of the DX coil unit for high speed compressor and high speed fan at rated conditions (air entering the cooling coil at 26.7 °C drybulb/19.4 °C wetbulb, air entering the outdoor condenser coil at 35 °C drybulb/23.9 °C wetbulb, and a cooling coil air flow rate defined by field rated air flow rate below), not accounting for the effect of supply air fan heat. 'autosize' option is available;
- highSpeedRatedSensibleHeatRatio – sensible heat ratio (SHR = gross sensible cooling capacity divided by gross total cooling capacity) of the DX cooling coil for high speed compressor and high speed fan at rated conditions, not accounting for the effect of supply air fan heat. 'autosize' option is available;
- highSpeedGrossRatedCoolingCOP – ratio of the gross total cooling capacity in watts to electrical power input in watts of the DX cooling coil unit for high speed compressor and high speed fan at rated conditions, not accounting for the effect of supply air fan heat or the supply fan electrical energy input;
- highSpeedRatedAirFlowRate – high speed air volume flow rate across the DX cooling coil at rated conditions [m^3/s]. Should be between 0.00004027 m^3/s and 0.00006041 m^3/s per watt of gross rated total cooling capacity. 'autosize' option is available;
- unitInternalStaticAirPressure – pressure drop for the unit containing the coil [Pa] (optional);
- totalCoolingCapacityFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity as a function of the wet-bulb temperature of the air entering the cooling coil, and the dry-bulb temperature of the air entering the air-cooled condenser coil (wet-bulb temperature if modeling an evaporative-cooled condenser), for high speed compressor and high speed fan;
- totalCoolingCapacityFunctionOfFlowFractionCurveID – quadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate (i.e., fraction of full load flow), for high speed compressor and high speed fan;
- energyInputRatioFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the wet-bulb temperature of the air entering the cooling coil, and the dry-bulb temperature of the air entering the air-cooled condenser coil (wet-bulb temperature if modeling an evaporative-cooled condenser), for high speed compressor and high speed fan;
- energyInputRatioFunctionOfFlowFractionCurveID – quadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate (i.e., fraction of full load flow), for high speed compressor and high speed fan;
- partLoadFractionCorrelationCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the

variation of electrical power input to the DX unit as a function of the part load ratio (PLR, sensible cooling load/steady-state sensible cooling capacity);

- lowSpeedGrossRatedTotalCoolingCapacity – total cooling capacity (sensible plus latent) in watts of the DX coil unit for low speed compressor and low speed fan at rated conditions (air entering the cooling coil at 26.7 °C drybulb/19.4 °C wetbulb, air entering the outdoor condenser coil at 35 °C drybulb/23.9 °C wetbulb, and a cooling coil air flow rate defined by field rated air flow rate below), not accounting for the effect of supply air fan heat. 'autosize' option is available;
- lowSpeedRatedSensibleHeatRatio – sensible heat ratio (SHR = gross sensible cooling capacity divided by gross total cooling capacity) of the DX cooling coil for low speed compressor and low speed fan at rated conditions, not accounting for the effect of supply air fan heat. 'autosize' option is available;
- lowSpeedGrossRatedCoolingCOP – ratio of the gross total cooling capacity in watts to electrical power input in watts of the DX cooling coil unit for low speed compressor and low speed fan at rated conditions, not accounting for the effect of supply air fan heat or the supply fan electrical energy input;
- lowSpeedRatedAirFlowRate – low speed air volume flow rate across the DX cooling coil at rated conditions [m^3/s]. Should be between 0.00004027 m^3/s and 0.00006041 m^3/s per watt of gross rated total cooling capacity. 'autosize' option is available;
- lowSpeedTotalCoolingCapacityFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity as a function of the wet-bulb temperature of the air entering the cooling coil, and the dry-bulb temperature of the air entering the air-cooled condenser coil (wet-bulb temperature if modeling an evaporative-cooled condenser), for low speed compressor and low speed fan;
- lowSpeedEnergyInputRatioFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the wet-bulb temperature of the air entering the cooling coil, and the dry-bulb temperature of the air entering the air-cooled condenser coil (wet-bulb temperature if modeling an evaporative-cooled condenser), for low speed compressor and low speed fan;
- condenserType – 'AirCooled' or 'EvaporativelyCooled';
- minimumOutdoorDryBulbTemperatureForCompressorOperation – minimum outdoor air dry-bulb temperature where the cooling coil compressor turns off [°C];
- highSpeedEvaporativeCondenserEffectiveness – effectiveness of the evaporative condenser at high compressor/fan speed, which is used to determine the temperature of the air entering the outdoor condenser coil. Only used if condenserType = EvaporativelyCooled;
- highSpeedEvaporativeCondenserAirFlowRate – air volume flow rate entering the evaporative condenser at high compressor/fan speed [m3/s]. Only used if condenserType = EvaporativelyCooled. 'autosize' option is available;
- highSpeedEvaporativeCondenserPumpRatedPowerConsumption – rated power of the evaporative condenser water pump at high compressor/fan speed [W]. Only used if condenserType = EvaporativelyCooled. 'autosize' option is available;
- lowSpeedEvaporativeCondenserEffectiveness – effectiveness of the evaporative condenser at low compressor/fan speed, which is used to determine the temperature

of the air entering the outdoor condenser coil. Only used if condenserType = EvaporativelyCooled;

- lowSpeedEvaporativeCondenserAirFlowRate – air volume flow rate entering the evaporative condenser at low compressor/fan speed [m3/s]. Only used if condenserType = EvaporativelyCooled. 'autosize' option is available;
- lowSpeedEvaporativeCondenserPumpRatedPowerConsumption – rated power of the evaporative condenser water pump at low compressor/fan speed [W]. Only used if condenserType = EvaporativelyCooled. 'autosize' option is available;
- basinHeaterCapacity – capacity of the DX coil s electric evaporative cooler basin heater [W/K]. Only used if condenserType = EvaporativelyCooled;
- basinHeaterSetpointTemperature – set point temperature for the basin heater described in the previous field [°C]. Only used if condenserType = EvaporativelyCooled;
- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the basin heater is always available. Only used if condenserType = EvaporativelyCooled;
- sensibleHeatRatioFunctionOfTemperatureCurveID – biquadratic normalized curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This curve parameterizes the variation of the sensible heat ratio (SHR) as a function of DX cooling coil entering air wet-bulb and dry-bulb temperatures;
- sensibleHeatRatioFunctionOfFlowFractionCurveID – quadratic or cubic normalized curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This curve parameterizes the variation of the sensible heat ratio (SHR) as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate (i.e., fraction of full load flow);
- lowSpeedSensibleHeatRatioFunctionOfFlowTemperatureCurveID – biquadratic normalized curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This curve parameterizes the variation of the sensible heat ratio (SHR) as a function of DX cooling coil entering air wet-bulb and dry-bulb temperatures;
- lowSpeedSensibleHeatRatioFunctionOfFlowFlowFractionCurveID – quadratic or cubic normalized curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This curve parameterizes the variation of the sensible heat ratio (SHR) as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate (i.e., fraction of full load flow);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node");
- Condenser Air Inlet Node Name – considered null for the outdoor air temperature entering the condenser to be taken directly from the weather data;
- Supply Water Storage Tank Name – name of the supply water storage tank, assigned in the argument x1 of the CoilCoolingDXTwoSpeedSpec() above;

- Condensate Collection Water Storage Tank Name – name of the condensate collection water storage tank, assigned in the argument x2 of the CoilCoolingDXTwoSpeedSpec() above;
- Zone Name for Condenser Placement – name of a conditioned or unconditioned zone where the secondary coil (condenser) is to be placed, assigned in the argument x3 of the CoilCoolingDXTwoSpeedSpec() above.

The following fields in the **CoilCoolingDXTwoSpeed** table are used if the coil is directly assigned to an air loop (**10.1**) or an outdoor air system (**10.5**), for which the coil is contained in a cooling coil system that provides the controls needed to operate the coil. This corresponds to the CoilSystem:Cooling:DX object in EnergyPlus, which is automatically defined:

- coilSystemRunOnSensibleLoad – 'Yes' or 'No';
- coilSystemRunOnLatentLoad – 'Yes' or 'No';
- coilSystemUseOutdoorAirDXCoolingCoil – 'Yes' or 'No';
- coilSystemOutdoorAirDXCoolingCoilLeavingMinimumAirTemperature – DX cooling coil leaving supply air minimum temperature specified for frost control [°C];

Automatic filling fields in EnergyPlus:

- Name – coilName + "DX_System";
- Availability Schedule Name – the same schedule defined above for the coil in the availabilityScheduleID field;
- DX Cooling Coil System Inlet Node Name – coil's Air Inlet Node Name;
- DX Cooling Coil System Outlet Node Name – coil's Air Outlet Node Name;
- DX Cooling Coil System Sensor Node Name – coil's Air Outlet Node Name;
- Cooling Coil Object Type – Coil:Cooling:DX:TwoSpeed;
- Cooling Coil Name – coilName;
- Dehumidification Control Type – defined as 'None', as it is not valid for this coil type.

8.9.1.3. DX Multi Speed

The specification of a Cooling Coil DX Multi Speed is defined in the SAPTool_LSP building template, as follows:

CoilCoolingDXMultiSpeedSpec coolingCoilSpec = new CoilCoolingDXMultiSpeedSpec() – Cooling Coil DX Multi Speed specification (named coolingCoilSpec in this example). With the following CoilCoolingDXMultiSpeedSpec() arguments:

- **x1** – name of the supply water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **x2** – name of the condensate collection water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **x3** – ID of a conditioned or unconditioned zone where the secondary coil (condenser) is to be placed (optional), which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if not defined;
- **x4** – ID of the Cooling Coil DX Multi Speed properties in the **CoilCoolingDXMultiSpeed** table of the database;

- **db** – database unique ID.

The Cooling Coil DX Multi Speed is specified using the CoilCoolingDXMultiSpeedSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (coolingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilCoolingDXMultiSpeed** table in the database, corresponding to the Coil:Cooling:DX:MultiSpeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- condenserType – 'AirCooled' or 'EvaporativelyCooled';
- applyPartLoadFractionToSpeedsGreaterThan1 – 'Yes' or 'No';
- applyLatentDegradationToSpeedsGreaterThan1 – 'Yes' or 'No';
- crankcaseHeaterCapacity – crankcase heater capacity [W];
- maximumOutdoorDryBulbTemperatureForCrankcaseHeaterOperation – outdoor air dry-bulb temperature above which the compressor s crankcase heater is disabled [°C];
- basinHeaterCapacity – capacity of the DX coil s electric evaporative cooler basin heater [W/K]. Only used if condenserType = EvaporativelyCooled;
- basinHeaterSetpointTemperature – set point temperature for the basin heater described in the previous field [°C]. Only used if condenserType = EvaporativelyCooled;
- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the basin heater is always available. Only used if condenserType = EvaporativelyCooled;
- fuelType – 'Electricity', 'NaturalGas', 'Propane', 'Diesel', 'Gasoline', 'FuelOil_1', 'FuelOil_2', 'OtherFuel1' or 'OtherFuel2';
- numberOfSpeeds – 2 to 4;
- speed<x>GrossRatedTotalCoolingCapacity – total cooling capacity (sensible plus latent) in watts of the DX coil unit for Speed <x> operation at rated conditions (air entering the cooling coil at 26.7 °C drybulb/19.4 °C wetbulb, air entering the outdoor condenser coil at 35 °C drybulb/23.9 °C wetbulb, and a cooling coil air flow rate defined by field Rated Air Flow Rate, Speed <x> below), not accounting for the effect of the supply air fan heat. 'autosize' option is available;
- speed<x>GrossRatedSensibleHeatRatio – sensible heat ratio (SHR = gross sensible capacity divided by gross total cooling capacity) of the DX cooling coil for Speed <x> operation at rated conditions, not accounting for the effect of the supply air fan heat. 'autosize' option is available;
- speed<x>GrossRatedCoolingCOP – ratio of the gross total cooling capacity in watts to electrical power input in watts of the DX cooling coil unit for Speed <x> operation at rated conditions, not accounting for the effect of supply air fan heat or the supply fan electrical energy input;
- speed<x>RatedAirFlowRate – volumetric air volume flow rate across the DX cooling coil at rated conditions for Speed <x> [m^3/s]. Should be between 0.00004027 m^3/s and

0.00006041 m^3/s per watt of gross rated total cooling capacity. ‘autosize’ option is available;

- speed<x>RatedEvaporatorFanPowerPerVolumeFlowRate – electric power for the evaporator (cooling coil) fan per air volume flow rate through the coil at the rated conditions for Speed <x> [$W/(m^3/s)$];
- speed<x>TotalCoolingCapacityFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity for Speed <x> as a function of the wet-bulb temperature of the air entering the cooling coil, and the dry-bulb temperature of the air entering the air-cooled condenser coil (wet-bulb temperature if modeling an evaporative-cooled condenser);
- speed<x>TotalCoolingCapacityFunctionOfFlowFractionCurveID – quadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity for Speed <x> as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate for Speed <x> (i.e., fraction of full load flow);
- speed<x>EnergyInputRatioFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) for Speed <x> as a function of the wet-bulb temperature of the air entering the cooling coil, and the dry-bulb temperature of the air entering the air-cooled condenser coil (wet-bulb temperature if modeling an evaporative-cooled condenser);
- speed<x>EnergyInputRatioFunctionOfFlowFractionCurveID – quadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) for Speed <x> as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate for Speed <x> (i.e., fraction of full load flow);
- speed<x>PartLoadFractionCorrelationCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of electrical power input to the DX unit as a function of the part load ratio (PLR, sensible cooling load/steady-state sensible cooling capacity for Speed <x>);
- speed<x>NominalTimeForCondensateRemovalToBegin – nominal time after startup for condensate to begin leaving the coil’s condensate drain line at the coil’s rated airflow and temperature conditions, starting with a dry coil, for Speed <x> [s];
- speed<x>RatioOfInitialMoistureEvaporationRateAndSteadyStateLatentCapacity – ratio of the initial moisture evaporation rate from the cooling coil (when the compressor first turns off, in Watts) and the coil’s steady-state latent capacity (Watts) for Speed <x> at rated airflow and temperature conditions;
- speed<x>MaximumCyclingRate – maximum on-off cycling rate for the compressor, which occurs at 50% run time fraction, for Speed <x> [cycles/h];
- speed<x>LatentCapacityTimeConstant – time constant for the cooling coil’s latent capacity to reach steady state after startup for Speed <x> [s];
- speed<x>RatedWasteHeatFractionOfPowerInput – fraction of energy input to the cooling coil that is available as recoverable waste heat at full load and rated conditions for Speed <x>;

- speed<x>WasteHeatFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the waste heat recovery as a function of outdoor dry-bulb temperature and the entering coil dry-bulb temperature at Speed <x>;
- speed<x>EvaporativeCondenserEffectiveness – effectiveness of the evaporative condenser at Speed <x>, which is used to determine the temperature of the air entering the outdoor condenser coil. Only used if condenserType = EvaporativelyCooled;
- speed<x>EvaporativeCondenserAirFlowRate – air volume flow rate entering the evaporative condenser at Speed <x> [m^3/s]. Only used if condenserType = EvaporativelyCooled;
- speed<x>RatedEvaporativeCondenserPumpPowerConsumption – rated power of the evaporative condenser water pump in Watts at Speed <x>. Only used if condenserType = EvaporativelyCooled;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node");
- Condenser Air Inlet Node Name – considered null for the outdoor air temperature entering the condenser to be taken directly from the weather data;
- Supply Water Storage Tank Name – name of the supply water storage tank, assigned in the argument x1 of the CoilCoolingDXMultiSpeedSpec() above;
- Condensate Collection Water Storage Tank Name – name of the condensate collection water storage tank, assigned in the argument x2 of the CoilCoolingDXMultiSpeedSpec() above;
- Zone Name for Condenser Placement – name of a conditioned or unconditioned zone where the secondary coil (condenser) is to be placed, assigned in the argument x3 of the CoilCoolingDXMultiSpeedSpec() above.

8.9.1.4. DX Variable Speed

The specification of a Cooling Coil DX Variable Speed is defined in the SAPTool_LSP building template, as follows:

CoilCoolingDXVariableSpeedSpec coolingCoilSpec = new CoilCoolingDXVariableSpeedSpec() – Cooling Coil DX Variable Speed specification (named coolingCoilSpec in this example). With the following CoilCoolingDXVariableSpeedSpec() arguments:

- **x1** – name of the supply water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **x2** – name of the condensate collection water storage tank specification (if any), defined in section **5.3**. **null** if not present;

- **x3** – ID of the Cooling Coil DX Variable Speed properties in the **CoilCoolingDXVariableSpeed** table of the database;
- **db** – database unique ID.

The Cooling Coil DX Variable Speed is specified using the CoilCoolingDXVariableSpeedSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (coolingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilCoolingDXVariableSpeed** table in the database, corresponding to the Coil:Cooling:DX:VariableSpeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- numberOfSpeeds – 1 to 10;
- nominalSpeedLevel – nominal speed level, at which the rated capacity and rated air rate are correlated;
- grossRatedTotalCoolingCapacityAtSelectedNominalSpeedLevel – total cooling capacity at the nominal speed level, not accounting for the effect of supply fan heat [W]. 'autosize' option is available;
- ratedAirFlowRateAtSelectedNominalSpeedLevel – rated volumetric air flow rate on the load side of the DX unit, corresponding to the nominal speed level [m^3/s]. 'autosize' option is available;
- nominalTimeForCondensateToBeginLeavingTheCoil – nominal time after startup for condensate to begin leaving the coil's condensate drain line at the coil's rated airflow and temperature conditions, starting with a dry coil [s];
- initialMoistureEvaporationRateDividedBySteadyStateACLatentCapacity – ratio of the initial moisture evaporation rate from the cooling coil (when the compressor first turns off, in Watts) and the coil's steady-state latent capacity (Watts) at rated airflow and temperature conditions;
- energyPartLoadFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of electrical power input to the unit as a function of the part load ratio (PLR, sensible or latent load/steady-state sensible or latent cooling capacity for Speed 1), in the case that the unit operates under the lowest speed, i.e. on/off;
- condenserType – 'AirCooled' or 'EvaporativelyCooled';
- evaporativeCondenserPumpRatedPowerConsumption – rated power of the evaporative condenser water pump [W]. Only used if condenserType = EvaporativelyCooled;
- crankcaseHeaterCapacity – crankcase heater capacity [W];
- maximumOutdoorDryBulbTemperatureForCrankcaseHeaterOperation – outdoor air dry-bulb temperature above which the compressor s crankcase heater is disabled [°C];
- basinHeaterCapacity – capacity of the DX coil s electric evaporative cooler basin heater [W/K]. Only used if condenserType = EvaporativelyCooled;
- basinHeaterSetpointTemperature – set point temperature for the basin heater described in the previous field [°C]. Only used if condenserType = EvaporativelyCooled;

- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the basin heater is always available. Only used if condenserType = EvaporativelyCooled;
- speed<x>ReferenceUnitGrossRatedTotalCoolingCapacity – total cooling capacity in watts of the air-to-air cooling coil unit for Speed <x> operation;
- speed<x>ReferenceUnitGrossRatedSensibleHeatRatio – sensible heat transfer ratio (SHR = gross sensible cooling capacity divided by gross total cooling capacity) of the cooling coil unit at rated conditions for Speed <x> operation;
- speed<x>ReferenceUnitGrossRatedCoolingCOP – coefficient of performance (COP = the gross total cooling capacity in watts divided by electrical power input in watts) of the cooling coil unit at rated conditions for Speed <x> operation, not accounting for the supply air fan;
- speed<x>ReferenceUnitRatedAirFlowRate – volumetric air flow rate across the cooling coil at rated conditions for Speed <x> operation [m^3/s];
- speed<x>ReferenceUnitRatedCondenserAirFlowRate – condenser volumetric air flow rate across the condenser coil at rated conditions for Speed <x> operation [m^3/s]. Only used if condenserType = EvaporativelyCooled;
- speed<x>ReferenceUnitRatedPadEffectivenessOfEvapPrecooling – effectiveness of condenser evaporative precooling pad at rated condition;
- speed<x>TotalCoolingCapacityFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity for Speed <x> as a function of the wet-bulb temperature of the air entering the cooling coil, and the dry-bulb temperature of the air entering the air-cooled condenser coil (wet-bulb temperature if modeling an evaporative-cooled condenser);
- speed<x>TotalCoolingCapacityFunctionOfAirFlowFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity for Speed <x> as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate for Speed <x> (i.e., fraction of full load flow at Speed <x>);
- speed<x>EnergyInputRatioFunctionOfTemperatureCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) for Speed <x> as a function of the both the indoor air wet-bulb and condenser entering air temperature;
- speed<x>EnergyInputRatioFunctionOfAirFlowFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) for Speed <x> as a function of the ratio of actual air flow rate across the cooling coil to the design air flow rate for Speed <x> (i.e., fraction of full load flow, at Speed <x>);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);

- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + “Outlet_node”);
- Condenser Air Inlet Node Name – considered null for the outdoor air temperature entering the condenser to be taken directly from the weather data;
- Supply Water Storage Tank Name – name of the supply water storage tank, assigned in the argument x1 of the CoilCoolingDXVariableSpeedSpec() above;
- Condensate Collection Water Storage Tank Name – name of the condensate collection water storage tank, assigned in the argument x2 of the CoilCoolingDXVariableSpeedSpec() above.

The following fields in the **CoilCoolingDXVariableSpeed** table are used if the coil is directly assigned to an air loop (**10.1**) or an outdoor air system (**10.5**), for which the coil is contained in a cooling coil system that provides the controls needed to operate the coil. This corresponds to the CoilSystem:Cooling:DX object in EnergyPlus, which is automatically defined:

- coilSystemAvailabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- coilSystemRunOnSensibleLoad – ‘Yes’ or ‘No’;
- coilSystemRunOnLatentLoad – ‘Yes’ or ‘No’;
- coilSystemUseOutdoorAirDXCoolingCoil – ‘Yes’ or ‘No’;
- coilSystemOutdoorAirDXCoolingCoilLeavingMinimumAirTemperature – DX cooling coil leaving supply air minimum temperature specified for frost control [°C];

Automatic filling fields in EnergyPlus:

- Name – coilName + “DX_System”;
- DX Cooling Coil System Inlet Node Name – coil’s Air Inlet Node Name;
- DX Cooling Coil System Outlet Node Name – coil’s Air Outlet Node Name;
- DX Cooling Coil System Sensor Node Name – coil’s Air Outlet Node Name;
- Cooling Coil Object Type – Coil:Cooling:DX:VariableSpeed;
- Cooling Coil Name – coilName;
- Dehumidification Control Type – defined as ‘None’, as it is not valid for this coil type.

8.9.1.5. DX Two Stage with Humidity Control Mode

The specification of a Cooling Coil DX Two Stage with Humidity Control Mode is defined in the SAPTool_LSP building template, as follows:

CoilCoolingDXTwoStageWithHumidityControlMode Spec coolingCoilSpec = new CoilCoolingDXTwoStageWithHumidityControlMode Spec() – Cooling Coil DX Two Stage with Humidity Control specification (named coolingCoilSpec in this example). With the following CoilCoolingDXTwoStageWithHumidityControlMode() arguments:

- **x1** – name of the supply water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **x2** – name of the condensate collection water storage tank specification (if any), defined in section **5.3**. **null** if not present;

- **x3** – ID of the Cooling Coil DX Two Stage With Humidity Control properties in the **CoilCoolingDXTwoStageWithHumidityControlMode** table of the database;
- **db** – database unique ID.

The Cooling Coil DX Two Stage with Humidity Control Mode is specified using the CoilCoolingDXTwoStageWithHumidityControlMode() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (coolingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilCoolingDXTwoStageWithHumidityControlMode** table in the database, corresponding to the Coil:Cooling:DX:TwoStageWithHumidityControlMode object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- crankcaseHeaterCapacity – crankcase heater capacity [W];
- maximumOutdoorDryBulbTemperatureForCrankcaseHeaterOperation – outdoor air dry-bulb temperature above which the compressor s crankcase heater is disabled [°C];
- numberOfCapacityStages – 1 or 2;
- numberOfEnhancedDehumidificationModes – 0 or 1;
- normalModeStage1CoilPerformanceDXCoolingID – coil performance object ID, defined in the **CoilPerformanceDXCooling** table in the database (**8.9.1.8**);
- normalModeStage1and2CoilPerformanceDXCoolingID – coil performance object ID, defined in the **CoilPerformanceDXCooling** table in the database (**8.9.1.8**) (optional);
- dehumidificationMode1Stage1CoilPerformanceDXCoolingID – coil performance object ID, defined in the **CoilPerformanceDXCooling** table in the database (**8.9.1.8**) (optional);
- dehumidificationMode1Stage1and2CoilPerformanceDXCoolingID – coil performance object ID, defined in the **CoilPerformanceDXCooling** table in the database (**8.9.1.8**) (optional);
- minimumOutdoorDryBulbTemperatureForCompressorOperation – minimum outdoor air dry-bulb temperature where the cooling coil compressor turns off [°C];
- basinHeaterCapacity – capacity of the DX coil s electric evaporative cooler basin heater [W/K]. Only used if condenserType = EvaporativelyCooled;
- basinHeaterSetpointTemperature – set point temperature for the basin heater described in the previous field [°C]. Only used if condenserType = EvaporativelyCooled;
- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the basin heater is always available. Only used if condenserType = EvaporativelyCooled;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);

- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + “Outlet_node”);
- Supply Water Storage Tank Name – name of the supply water storage tank, assigned in the argument x1 of the CoilCoolingDXTwoStageWithHumidityControlMode() above;
- Condensate Collection Water Storage Tank Name – name of the condensate collection water storage tank, assigned in the argument x2 of the CoilCoolingDXTwoStageWithHumidityControlMode() above.

The following fields in the **CoilCoolingDXTwoStageWithHumidityControlMode** table are used if the coil is directly assigned to an air loop (**10.1**) or an outdoor air system (**10.5**), for which the coil is contained in a cooling coil system that provides the controls needed to operate the coil. This corresponds to the CoilSystem:Cooling:DX object in EnergyPlus, which is automatically defined:

- coilSystemDehumidificationControlType – ‘None’, ‘Multimode’ or ‘CoolReheat’;
- coilSystemRunOnSensibleLoad – ‘Yes’ or ‘No’;
- coilSystemRunOnLatentLoad – ‘Yes’ or ‘No’;
- coilSystemUseOutdoorAirDXCoolingCoil – ‘Yes’ or ‘No’;
- coilSystemOutdoorAirDXCoolingCoilLeavingMinimumAirTemperature – DX cooling coil leaving supply air minimum temperature specified for frost control [°C];

Automatic filling fields in EnergyPlus:

- Name – coilName + “DX_System”;
- Availability Schedule Name – the same schedule defined above for the coil in the availabilityScheduleID field;
- DX Cooling Coil System Inlet Node Name – coil’s Air Inlet Node Name;
- DX Cooling Coil System Outlet Node Name – coil’s Air Outlet Node Name;
- DX Cooling Coil System Sensor Node Name – coil’s Air Outlet Node Name;
- Cooling Coil Object Type – Coil:Cooling:DX:TwoStageWithHumidityControlMode;
- Cooling Coil Name – coilName.

8.9.1.6. DX Variable Refrigerant Flow

The specification of a Cooling Coil DX Variable Refrigerant Flow is defined in the SAPTool_LSP building template, as follows:

CoilCoolingDXVariableRefrigerantFlowSpec coolingCoilSpec = new CoilCoolingDXVariableRefrigerantFlowSpec() – Cooling Coil DX Variable Refrigerant Flow specification (named coolingCoilSpec in this example). With the following CoilCoolingDXVariableRefrigerantFlowSpec() arguments:

- **x1** – name of the condensate collection water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **x2** – ID of the Cooling Coil DX Variable Refrigerant Flow properties in the **CoilCoolingDXVariableRefrigerantFlow** table of the database;

- **db** – database unique ID.

The Cooling Coil DX Variable Refrigerant Flow is specified using the CoilCoolingDXVariableRefrigerantFlowSpec() object and must then be assigned to the specific system (e.g., a Zone HVAC Terminal Unit Variable Refrigerant Flow (**7.1.7**)), by assigning the specification name (coolingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilCoolingDXVariableRefrigerantFlow** table in the database, corresponding to the Coil:Cooling:DX:VariableRefrigerantFlow object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- grossRatedTotalCoolingCapacity – gross rated total cooling capacity of the DX cooling coil at a rating point of 19.44 °C indoor wet-bulb temperature and 35 °C outdoor dry-bulb temperature [W]. ‘autosize’ option is available;
- grossRatedSensibleHeatRatio – gross sensible heat ratio (sensible capacity divided by total cooling capacity) of the DX cooling coil at rated conditions. ‘autosize’ option is available;
- ratedAirFlowRate – air volume flow rate across the DX cooling coil at rated conditions [m3/s]. The rated air volume flow rate should be between 0.00004027 m3/s and 0.00006041 m3/s per watt of rated total cooling capacity (300 to 450 cfm/ton);
- coolingCapacityRatioModifierFunctionOfTemperatureCurveID – linear, quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the cooling capacity ratio modifier as a function of indoor wet-bulb temperature or indoor wet-bulb and outdoor dry-bulb temperatures. The curve is normalized to 1 at 19.44 °C indoor wet-bulb temperature and if a biquadratic curve is used also at 35 °C outdoor dry-bulb temperature;
- coolingCapacityModifierFunctionOfFlowFractionCurveID – linear, quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of total cooling capacity as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate (i.e., fraction of full load flow);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Coil Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Coil Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Coil Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + “Outlet_node”);

- Condensate Collection Water Storage Tank Name – name of the condensate collection water storage tank, assigned in the argument x1 of the CoilCoolingDXVariableRefrigerantFlowSpec () above.

8.9.1.7. DX Variable Refrigerant Flow Fluid Temperature Control

The specification of a Cooling Coil DX Variable Refrigerant Flow Fluid Temperature Control is defined in the SAPTool_LSP building template, as follows:

CoilCoolingDXVariableRefrigerantFlowFluidTemperatureControlSpec coolingCoilSpec = new CoilCoolingDXVariableRefrigerantFlowFluidTemperatureControlSpec() – Cooling Coil DX Variable Refrigerant Flow Fluid Temperature Control specification (named coolingCoilSpec in this example). With the following CoilCoolingDXVariableRefrigerantFlowFluidTemperatureControlSpec() arguments:

- **x1** – name of the condensate collection water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **x2** – ID of the Cooling Coil DX Variable Refrigerant Flow Fluid Temperature Control properties in the **CoilCoolingDXVariableRefrigerantFlowFluidTemperatureControl** table of the database;
- **db** – database unique ID.

The Cooling Coil DX Variable Refrigerant Flow Fluid Temperature Control is specified using the CoilCoolingDXVariableRefrigerantFlowFluidTemperatureControlSpec() object and must then be assigned to the specific system (e.g., a Zone HVAC Terminal Unit Variable Refrigerant Flow (**7.1.7**)), by assigning the specification name (coolingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilCoolingDXVariableRefrigerantFlowFluidTemperatureControl** table in the database, corresponding to the Coil:Cooling:DX:VariableRefrigerantFlow:FluidTemperatureControl object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- ratedTotalCoolingCapacity – gross rated total cooling capacity of the DX cooling coil [W]. 'autosize' option is available;
- ratedSensibleHeatRatio – gross sensible heat ratio (sensible capacity divided by total cooling capacity) of the DX cooling coil at rated conditions. 'autosize' option is available;
- indoorUnitReferenceSuperheating – defines the reference superheating degrees of the indoor unit [°C];
- indoorUnitEvaporatingTemperatureFunctionOfSuperheatingCurveID – quadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of indoor unit evaporating temperature as a function of superheating degrees;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Coil Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Coil Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Coil Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node");
- Condensate Collection Water Storage Tank Name – name of the condensate collection water storage tank, assigned in the argument x1 of the CoilCoolingDXVariableRefrigerantFlowFluidTemperatureControlSpec() above.

8.9.1.8. Performance DX

This performance mode is defined in the **CoilPerformanceDXCooling** table in the database, corresponding to the CoilPerformance:DX:Cooling object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- grossRatedTotalCoolingCapacity – total cooling capacity (sensible plus latent) in watts of the DX coil unit at rated conditions (air entering the cooling coil at 26.7 °C drybulb/19.4 °C wetbulb, air entering the outdoor condenser coil at 35 °C drybulb/23.9 °C wetbulb, and a cooling coil air flow rate defined by field rated air flow rate below), not accounting for the effect of supply air fan heat. 'autosize' option is available;
- grossRatedSensibleHeatRatio – sensible heat ratio (SHR = gross sensible cooling capacity divided by gross total cooling capacity) of the DX cooling coil at rated conditions, not accounting for the effect of supply air fan heat. 'autosize' option is available;
- grossRatedCoolingCOP – ratio of the gross total cooling capacity in watts to electrical power input in watts of the DX cooling coil unit at rated conditions, not accounting for the effect of supply air fan heat or the supply fan electrical energy input;
- ratedAirFlowRate – air volume flow rate across the DX cooling coil at rated conditions [m^3/s]. 'autosize' option is available;
- fractionOfAirFlowBypassedAroundCoil – fraction of the Rated Air Volume Flow Rate which bypasses the active cooling coil for this performance mode. The remaining portion of the flow should be between 0.00004027 m^3/s and 0.00006041 m^3/s per watt of gross rated total cooling capacity for this performance mode;
- totalCoolingCapacityFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity as a function of the wet-bulb temperature of the air entering the cooling coil, and the dry-bulb temperature of the air entering the air-cooled condenser coil (wet-bulb temperature if modeling an evaporative-cooled condenser);
- totalCoolingCapacityFunctionOfFlowFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity as a function of the ratio

of actual air flow rate across the cooling coil to the rated air flow rate (i.e., fraction of full load flow);

- energyInputRatioFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the wet-bulb temperature of the air entering the cooling coil, and the dry-bulb temperature of the air entering the air-cooled condenser coil (wet-bulb temperature if modeling an evaporative-cooled condenser);
- energyInputRatioFunctionOfFlowFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate (i.e., fraction of full load flow);
- partLoadFractionCorrelationCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of electrical power input to the DX unit as a function of the part load ratio (PLR, sensible cooling load/steady-state sensible cooling capacity);
- nominalTimeForCondensateRemovalToBegin – nominal time after startup for condensate to begin leaving the coil's condensate drain line at the coil's rated airflow and temperature conditions, starting with a dry coil [s];
- ratioOfInitialMoistureEvaporationRateAndSteadyStateLatentCapacity – ratio of the initial moisture evaporation rate from the cooling coil (when the compressor first turns off, in Watts) and the coil's steady-state latent capacity (Watts) at rated airflow and temperature conditions;
- maximumCyclingRate – maximum on-off cycling rate for the compressor, which occurs at 50% run time fraction [cycles/h];
- latentCapacityTimeConstant – time constant for the cooling coil's latent capacity to reach steady state after startup [s];
- condenserType – 'AirCooled' or 'EvaporativelyCooled';
- evaporativeCondenserEffectiveness – effectiveness of the evaporative condenser, which is used to determine the temperature of the air entering the outdoor condenser coil. Only used if condenserType = EvaporativelyCooled;
- evaporativeCondenserAirFlowRate – air volume flow rate entering the evaporative condenser [m^3/s]. Only used if condenserType = EvaporativelyCooled. 'autosize' option is available;
- evaporativeCondenserPumpRatedPowerConsumption – rated power of the evaporative condenser water pump [W]. Only used if condenserType = EvaporativelyCooled. 'autosize' option is available;
- sensibleHeatRatioFunctionOfTemperatureCurveID – biquadratic normalized curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This curve parameterizes the variation of the sensible heat ratio (SHR) as a function of DX cooling coil entering air wet-bulb and dry-bulb temperatures;
- sensibleHeatRatioFunctionOfFlowFractionCurveID – quadratic or cubic normalized curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This curve parameterizes the variation of the sensible heat ratio (SHR) as a function of the ratio of actual air flow rate across the cooling coil to the rated air flow rate (i.e., fraction of full load flow);

- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – Coil name + Performance type (Coil name – coil name for which this performance mode is assigned to; Performance type – type of performance mode: normal mode stage 1, normal mode stage 1+2, dehumidification mode stage 1 or dehumidification mode stage 1+2);
- Condenser Air Inlet Node Name – considered null for the outdoor air temperature entering the condenser to be taken directly from the weather data.

8.9.1.9. Water

The specification of a Cooling Coil Water is defined in the SAPTool_LSP building template, as follows:

CoilCoolingWaterSpec coolingCoilSpec = new CoilCoolingWaterSpec() – Cooling Coil Water specification (named coolingCoilSpec in this example). With the following CoilCoolingWaterSpec() arguments:

- **x1** – name of the condensate collection water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **x2** – ID of the Cooling Coil Water properties in the **CoilCoolingWater** table of the database;
- **db** – database unique ID.

The Cooling Coil Water is specified using the CoilCoolingWaterSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**), directly to an Air Loop (**10.2**) or and Air Loop Outdoor Air System (**10.5.1**)), by assigning the specification name (coolingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilCoolingWater** table in the database, corresponding to the Coil:Cooling:Water object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- designWaterFlowRate – maximum possible water volume flow rate through the coil [m^3/s]. ‘autosize’ option is available;
- designAirFlowRate – maximum possible air volume flow rate through the coil [m^3/s]. ‘autosize’ option is available;
- designInletWaterTemperature – inlet water temperature for the design flow [°C]. ‘autosize’ option is available;
- designInletAirTemperature – inlet air temperature for the design flow [°C]. ‘autosize’ option is available;
- designOutletAirTemperature – outlet air temperature for the design flow [°C]. ‘autosize’ option is available;

- designInletAirHumidityRatio – highest value of humidity ratio possible for the Design inlet air stream [kg_{Water}/kg_{DryAir}]. 'autosize' option is available;
- designOutletAirHumidityRatio – value of humidity ratio for the Design outlet air stream [kg_{Water}/kg_{DryAir}]. 'autosize' option is available;
- typeOfAnalysis – 'SimpleAnalysis' or 'DetailedAnalysis';
- heatExchangerConfiguration – 'CounterFlow' or 'CrossFlow';
- designWaterTemperatureDifference – used for sizing the Design Water Flow Rate (optional). If blank, the Loop Design Temperature Difference value specified in Sizing Plant (**13.2.4**) is used for sizing the Design Water Flow Rate;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve defines the pressure drop across the coil in the cold water loop (see section **9.3**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Water Inlet Node Name – coilName + "Cold_Water_Inlet_node" (for connection to a cold water loop);
- Water Outlet Node Name – coilName + "Cold_Water_Outlet_node" (for connection to a cold water loop);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node");
- Condensate Collection Water Storage Tank Name – name of the condensate collection water storage tank, assigned in the argument x1 of the CoilCoolingWaterSpec() above

The following fields in the **CoilCoolingWater** table are used if the coil is directly assigned to an air loop (**10.1**) or an outdoor air system (**10.5**), for which a water coil controller is required, corresponding to the Controller:WaterCoil object in EnergyPlus:

- controlVariable – 'Temperature', 'HumidityRatio' or 'TemperatureAndHumidityRatio';
- controllerActuatorVariable – 'Flow';
- controllerConvergenceTolerance – maximum difference between the actual temperature at the setpoint node and the setpoint temperature [°C];
- controllerMaximumActuatedFlow – maximum water flow through the coil [m^3/s]. 'autosize' option is available;
- controllerMinimumActuatedFlow – minimum design water flow for the water coil, normally a shut off valve that is set to zero [m^3/s];
- controllerSetpointManagerType – defines the Setpoint Manager type for the controller Sensor Node (automatically defined as the coil's air outlet node). 'ScheduledSingleSetpoint', 'ScheduledDualSetpoint' or 'OutdoorAirReset' (see section **14** for details);
- controllerSetpointManagerID – ID of the Setpoint Manager assigned to the controller Sensor Node, which is defined in the **setpointManagerSingleSetpoint** table, if

setpointManagerType = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **setpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**).

Automatic filling fields in EnergyPlus:

- Name – coilName + "Controller";
- Action – chilled water coils are defined as 'Reverse' and hot water coils are defined as 'Normal';
- Sensor Node Name – coil's Air Outlet Node Name;
- Actuator Node Name – coil's Water Inlet Node Name.

This controller is then assigned to the air loop system controller list (**10.1**) or the outdoor air system controller list (**10.5.3**), using the object AirLoopHVAC:ControllerList in EnergyPlus, where all the fields are automatically filled:

- Name – systemName + "Controller_List" (systemName – name of the system for which this list is assigned);
- Controller <x> Object Type – Controller:WaterCoil;
- Controller <x> Name – name of the controller assigned to the list.

8.9.1.10. Water Detailed Geometry

The specification of a Cooling Coil Water Detailed Geometry is defined in the SAPTool_LSP building template, as follows:

CoilCoolingWaterDetailedGeometrySpec coolingCoilSpec = new CoilCoolingWaterDetailedGeometrSpec() – Cooling Coil Water Detailed Geometry specification (named coolingCoilSpec in this example). With the following CoilCoolingWaterDetailedGeometrySpec() arguments:

- **x1** – name of the condensate collection water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **x2** – ID of the Cooling Coil Water properties in the **CoilCoolingDetailedGeometryWater** table of the database;
- **db** – database unique ID.

The Cooling Coil Water Detailed Geometry is specified using the CoilCoolingWaterDetailedGeometrySpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**), directly to an Air Loop (**10.2**) or and Air Loop Outdoor Air System (**10.5.1**)), by assigning the specification name (coolingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilCoolingWaterDetailedGeometry** table in the database, corresponding to the Coil:Cooling:Water:Detailed:geometry object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- maximumWaterFlowRate – maximum possible water flow rate through the coil [m^3/s]. 'autosize' option is available;
- tubeOutsideSurfaceArea – outside surface area of the tubes that is exposed to air (i.e. the outside area of the unfinned tubes minus the area of tubes covered by the fins) [m^2]. 'autosize' option is available;
- totalTubeInsideArea – total surface area inside the tubes (water side) [m^2]. 'autosize' option is available;
- finSurfaceArea – total surface area of the fins attached to the coil [m^2]. 'autosize' option is available;
- minimumAirflowArea – minimum cross sectional area available for air passage [m^2]. Amin = (Amin/Afr)*Afr, where Afr is the frontal area of the heat exchanger, and (Amin/Afr) is the ratio of the minimum airflow area to frontal area. 'autosize' option is available;
- coilDepth – distance from the front of the coil to the back of the coil in the airflow direction [m]. Also called the fin depth. 'autosize' option is available;
- finDiameter – outside diameter of the fins [m]. 'autosize' option is available;
- finThickness – thickness of the air side fins [m];
- tubeInsideDiameter – inside diameter of the tubes [m];
- tubeOutsideDiameter – outside diameter of the tubes [m];
- tubeThermalConductivity – thermal conductivity of the tube material [W/m.K];
- finThermalConductivity – thermal conductivity of the fin material [W/m.K];
- finSpacing – spacing of the fins, centerline to centerline [m];
- tubeDepthSpacing – spacing of the tube rows, centerline to centerline [m]. Also called tube longitudinal spacing;
- numberOfTubeRows – number of tube rows in the direction of the airflow;
- numberOfTubesPerRow – number of tubes per row;
- designWaterTemperatureDifference – used for sizing the Design Water Flow Rate (optional). If blank, the Loop Design Temperature Difference value specified in Sizing Plant (**13.2.4**) is used for sizing the Design Water Flow Rate;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve defines the pressure drop across the coil in the cold water loop (see section **9.3**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Water Inlet Node Name – coilName + "Cold_Water_Inlet_node" (for connection to a cold water loop);
- Water Outlet Node Name – coilName + "Cold_Water_Outlet_node" (for connection to a cold water loop);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);

- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node");
- Condensate Collection Water Storage Tank Name – name of the condensate collection water storage tank, assigned in the argument x1 of the CoilCoolingWaterSpec() above

The following fields in the **CoilCoolingWaterDetailedGeometry** table are used if the coil is directly assigned to an air loop (**10.1**) or an outdoor air system (**10.5**), for which a water coil controller is required, corresponding to the Controller:WaterCoil object in EnergyPlus:

- controlVariable – 'Temperature', 'HumidityRatio' or 'TemperatureAndHumidityRatio';
- controllerActuatorVariable – 'Flow';
- controllerConvergenceTolerance – maximum difference between the actual temperature at the setpoint node and the setpoint temperature [°C];
- controllerMaximumActuatedFlow – maximum water flow through the coil [m^3/s]. 'autosize' option is available;
- controllerMinimumActuatedFlow – minimum design water flow for the water coil, normally a shut off valve that is set to zero [m^3/s];
- controllerSetpointManagerType – defines the Setpoint Manager type for the controller Sensor Node (automatically defined as the coil's air outlet node). 'ScheduledSingleSetpoint', 'ScheduledDualSetpoint' or 'OutdoorAirReset' (see section **14** for details);
- controllerSetpointManagerID – ID of the Setpoint Manager assigned to the controller Sensor Node, which is defined in the **setpointManagerSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **setpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**).

Automatic filling fields in EnergyPlus:

- Name – coilName + "Controller";
- Action – chilled water coils are defined as 'Reverse' and hot water coils are defined as 'Normal';
- Sensor Node Name – coil's Air Outlet Node Name;
- Actuator Node Name – coil's Water Inlet Node Name.

This controller is then assigned to the air loop system controller list (**10.1**) or the outdoor air system controller list (**10.5.3**), using the object AirLoopHVAC:ControllerList in EnergyPlus, where all the fields are automatically filled:

- Name – systemName + "Controller_List" (systemName – name of the system for which this list is assigned);
- Controller <x> Object Type – Controller:WaterCoil;
- Controller <x> Name – name of the controller assigned to the list.

8.9.1.11. Water-to-Air Heat Pump Equation Fit

The specification of a Cooling Coil Water-to-Air Heat Pump Equation Fit is defined in the SAPTool_LSP building template, asfollows:

CoilCoolingWaterToAirHeatPumpEquationFitSpec coolingCoilSpec = new CoilCoolingWaterToAirHeatPumpEquationFitSpec() – Cooling Coil Water-to-Air Heat Pump Equation Fit specification (named coolingCoilSpec in this example). With the following CoilCoolingWaterToAirHeatPumpEquationFitSpec() arguments:

- **x1** – ID of the Cooling Coil Water-to-Air Heat Pump Equation Fit properties in the **CoilCoolingWaterToAirHeatPumpEquationFit** table of the database;
- **db** – database unique ID.

The Cooling Coil Water-to-Air Heat Pump Equation Fit is specified using the CoilCoolingWaterToAirHeatPumpEquationFitSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (coolingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilCoolingWaterToAirHeatPumpEquationFit** table in the database, corresponding to the Coil:Cooling:WaterToAirHeatPump:EquationFit object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- ratedAirFlowRate – rated volumetric air flow rate on the load side of the heat pump [m^3/s]. ‘autosize’ option is available;
- ratedWaterFlowRate – rated volumetric water flow rate on the source side of the heat pump [m^3/s]. ‘autosize’ option is available;
- grossRatedTotalCoolingCapacity – gross rated total cooling capacity of the heat pump [W]. ‘autosize’ option is available. The gross rated total cooling capacity should be within 20% of the gross rated heating capacity, otherwise a warning message is issued;
- grossRatedSensibleCoolingCapacity – gross rated sensible cooling capacity of the heat pump [W]. ‘autosize’ option is available;
- grossRatedCoolingCOP – rated cooling coefficient of performance of the heat pump;
- totalCoolingCapacityCoefficient<1-5> – first to fifth coefficient for the heat pump total cooling capacity;
- sensibleCoolingCapacityCoefficient<1-6> – first to sixth coefficient for the heat pump sensible cooling capacity;
- coolingPowerConsumptionCoefficient<1-5> – first to fifth coefficient for the heat pump power consumption;
- nominalTimeForCondensateRemovalToBegin – nominal time (in seconds) after startup for condensate to begin leaving the coil’s condensate drain line at the coil’s rated airflow and temperature conditions, starting with a dry coil. Nominal time is equal to the ratio of the energy of the coil’s maximum condensate holding capacity (J) to the coil’s steady-state latent capacity (W). Suggested value is 1000; zero value (default) means the latent degradation model is disabled;
- ratioOfInitialMoistureEvaporationRateAndSteadyStateLatentCapacity – ratio of the initial moisture evaporation rate from the cooling coil (when the compressor first turns off, in Watts) and the coil’s steady-state latent capacity (Watts) at rated airflow and

temperature conditions. Suggested value is 1.5; zero value (default) means the latent degradation model is disabled;

- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve defines the pressure drop across the coil in the water loop (see section **9.3**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Water Inlet Node Name – coilName + "Cold_Water_Inlet_node" (for connection to a water loop);
- Water Outlet Node Name – coilName + "Cold _Water_Outlet_node" (for connection to a water loop);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node").

8.9.1.12. Water-to-Air Heat Pump Variable Speed Equation Fit

The specification of a Cooling Coil Water-to-Air Heat Pump Variable Speed Equation Fit is defined in the SAPTool_LSP building template, asfollows:

CoilCoolingWaterToAirHeatPumpVariableSpeedEquationFitSpec coolingCoilSpec = new CoilCoolingWaterToAirHeatPumpVariableSpeedEquationFitSpec() – Cooling Coil Water-to-Air Heat Pump Variable Speed Equation Fit specification (named coolingCoilSpec in this example). With the following CoilCoolingWaterToAirHeatPumpVariableSpeedEquationFitSpec() arguments:

- **x1** – ID of the Cooling Coil Water-to-Air Heat Pump Variable Speed Equation Fit properties in the **CoilCoolingWaterToAirHeatPumpVariableSpeedEquationFit** table of the database;
- **db** – database unique ID.

The Cooling Coil Water-to-Air Heat Pump Variable Speed Equation Fit is specified using the CoilCoolingWaterToAirHeatPumpVariableSpeedEquationFitSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (coolingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilCoolingWaterToAirHeatPumpVariableSpeedEquationFit** table in the database, corresponding to the Coil:Cooling:WaterToAirHeatPump:VariableSpeedEquationFit object in EnergyPlus. The following fields are present in the table:

- id – object ID;

- numberOfSpeeds – 1 to 10;
- nominalSpeedLevel – 1 to 10;
- grossRatedTotalCoolingCapacityAtSelectedNominalSpeedLevel – gross rated total cooling capacity at the nominal speed level [W]. 'autosize' option is available;
- ratedAirFlowRateAtSelectedNominalSpeedLevel – rated volumetric air flow rate on the load side of the heat pump corresponding to the nominal speed level [m^3/s]. 'autosize' option is available;
- ratedWaterFlowRateAtSelectedNominalSpeedLevel – rated volumetric water flow rate on the source side of the heat pump at the nominal speed level [m^3/s]. 'autosize' option is available;
- nominalTimeForCondensateToBeginLeavingTheCoil – nominal time (in seconds) after startup for condensate to begin leaving the coil's condensate drain line at the coil's rated airflow and temperature conditions, starting with a dry coil. Nominal time is equal to the ratio of the energy of the coil's maximum condensate holding capacity (J) to the coil's steady-state latent capacity (W). Suggested value is 1000; zero value (default) means the latent degradation model is disabled;
- initialMoistureEvaporationRateDividedBySteadyStateACLatentCapacity – ratio of the initial moisture evaporation rate from the cooling coil (when the compressor first turns off, in Watts) and the coil's steady-state latent capacity (Watts) at rated airflow and temperature conditions. Suggested value is 1.5; zero value (default) means the latent degradation model is disabled;
- flagForUsingHotGasReheat – 0 or 1. Dictates whether to use the recoverable waste heat for reheating the supply air, downstream of the coil: 1 means using the hot gas reheating, and 0 means not using;
- energyPartLoadFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of electrical power input to the unit as a function of the part load ratio (PLR, sensible or latent load/steady-state sensible or latent cooling capacity for Speed 1), in the case that the unit operates under the lowest speed, i.e. on/off;
- speed<1-10>ReferenceUnitGrossRatedTotalCoolingCapacity – total, full load cooling capacity of the water-to-air cooling coil unit at rated conditions for Speed <x> operation [W];
- speed<1-10>ReferenceUnitGrossRatedSensibleHeatRatio – sensible heat transfer ratio (SHR = gross sensible cooling capacity divided by gross total cooling capacity) of the cooling coil unit at rated conditions for Speed <x> operation;
- speed<1-10>ReferenceUnitGrossRatedCoolingCOP – coefficient of performance (COP = gross total cooling capacity in watts divided by electrical power input in watts) of the cooling coil unit at rated conditions for Speed <x> operation;
- speed<1-10>ReferenceUnitRatedAirFlowRate – volume air flow rate across the cooling coil at rated conditions for Speed <x> operation [m^3/s];
- speed<1-10>ReferenceUnitRatedWaterFlowRate – volume water flow rate flowing at the source side of the cooling coil at rated conditions for Speed <x> operation [m^3/s];
- speed<1-10>TotalCoolingCapacityFunctionOfTemperatureCurveID – bi-quadratic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity as a function of the both the indoor wet-bulb and source side entering water temperature, from the Reference Unit, for Speed<x>;

- speed<1-10>TotalCoolingCapacityFunctionOfAirFlowFractionCurveID – quadratic or cubic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity as a function of the ratio of actual air flow rate across the cooling coil to the design air flow rate (i.e., fraction of full load flow), at Speed <x>;
- speed<1-10>TotalCoolingCapacityFunctionOfWaterFlowFractionCurveID – quadratic or cubic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total cooling capacity as a function of the ratio of actual water flow rate across the cooling coil to the design water flow rate (i.e., fraction of full load flow), at Speed <x>;
- speed<1-10>EnergyInputRatioFunctionOfTemperatureCurveID – bi-quadratic, quadratic or cubic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the both the indoor air wet-bulb and entering water temperatures, at Speed <x>;
- speed<1-10>EnergyInputRatioFunctionOfAirFlowFractionCurveID – quadratic or cubic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the ratio of actual air flow rate across the cooling coil to the design air flow rate (i.e., fraction of full load flow, at Speed <x> from the Reference Unit data);
- speed<1-10>EnergyInputRatioFunctionOfWaterFlowFractionCurveID – quadratic or cubic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the ratio of actual water flow rate across the cooling coil to the rated water flow rate (i.e., fraction of full load flow, at Speed <x>);
- speed<1-10>ReferenceUnitWasteHeatFractionOfInputPowerAtRatedConditions – fraction of heat input to cooling that is available as recoverable waste heat at full load and rated conditions for Speed <x> operation;
- speed<1-10>WasteHeatFunctionOfTemperatureCurveID – bi-quadratic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the waste heat recovery as a function of indoor wet-bulb temperature and the entering water temperature for Speed <x>;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve defines the pressure drop across the coil in the water loop (see section **9.3**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Water-to-Refrigerant HX Water Inlet Node Name – coilName + "Cold_Water_Inlet_node" (for connection to a water loop);
- Water-to-Refrigerant HX Water Outlet Node Name – coilName + "Cold_Water_Outlet_node" (for connection to a water loop);
- Indoor Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet

node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);

- Indoor Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + “Outlet_node”).

8.9.2. Heating

8.9.2.1. DX Single Speed

The specification of a Heating Coil DX Single Speed is defined in the SAPTool_LSP building template, as follows:

CoilHeatingDXSingleSpeedSpec heatingCoilSpec = new CoilHeatingDXSingleSpeedSpec() – Heating Coil DX Single Speed specification (named heatingCoilSpec in this example). With the following CoilHeatingDXSingleSpeedSpec() arguments:

- **x1** – ID of a conditioned or unconditioned zone where the secondary coil (evaporator) is to be placed (optional), which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if not defined;
- **x2** – ID of the Heating Coil DX Single Speed properties in the **CoilHeatingDXSingleSpeed** table of the database;
- **db** – database unique ID.

The Heating Coil DX Single Speed is specified using the CoilHeatingDXSingleSpeedSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingDXSingleSpeed** table in the database, corresponding to the Coil:Heating:DX:SingleSpeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- grossRatedHeatingCapacity – total heating capacity in watts of the DX coil unit at rated conditions (outdoor air dry-bulb temperature of 8.33 °C, outdoor air wet-bulb temperature of 6.11 °C, heating coil entering air dry-bulb temperature of 21.11 °C, heating coil entering air wet-bulb temperature of 15.55 °C, and a heating coil air flow rate defined by field rated air flow volume below), not accounting for the effect of supply air fan heat. ‘autosize’ option is available;
- grossRatedHeatingCOP – ratio of the gross heating capacity in watts to electrical power input in watts of the DX coil unit at rated conditions, not accounting for the effect of supply air fan heat or the supply air fan electrical energy;
- ratedAirFlowRate – air volume flow rate across the DX heating coil at rated conditions [m^3/s]. Should be between 0.00004027 m^3/s and 0.00006041 m^3/s per watt of gross rated heating capacity. ‘autosize’ option is available;

- ratedSupplyFanPowerPerVolumeFlowRate – electric power for the evaporator (heating coil) fan per air volume flow rate through the coil at the rated conditions [W/(m^3/s)];
- heatingCapacityFunctionOfTemperatureCurveID – biquadratic, quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the total heating capacity as a function of the both the indoor and outdoor air dry-bulb temperature or just the outdoor air dry-bulb temperature depending on the type of curve selected;
- heatingCapacityFunctionOfFlowFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of total heating capacity as a function of the ratio of actual air flow rate across the heating coil to the rated air flow rate (i.e., fraction of full load flow);
- energyInputRatioFunctionOfTemperatureCurveID – biquadratic, quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the both the indoor and outdoor air dry-bulb temperature or just the outdoor air dry-bulb temperature depending on the type of curve selected;
- energyInputRatioFunctionOfFlowFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the ratio of actual air flow rate across the heating coil to the rated air flow rate (i.e., fraction of full load flow);
- partLoadFractionCorrelationCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of electrical power input to the DX unit as a function of the part load ratio (PLR, sensible cooling load/steady-state sensible cooling capacity);
- defrostEnergyInputRatioFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) during reverse-cycle defrost periods as a function of the outdoor air dry-bulb temperature and the wet-bulb temperature of the air entering the indoor coil. Only required if defrostStrategy = ReverseCycle;
- minimumOutdoorDryBulbTemperatureForCompressorOperation – minimum outdoor air dry-bulb temperature where the cooling coil compressor turns off [°C];
- outdoorDryBulbTemperatureToTurnOnCompressor – outdoor air dry-bulb temperature when the compressor is automatically turned back on following an automatic shut off because of low outdoor temperature [°C];
- maximumOutdoorDryBulbTemperatureForDefrostOperation – outdoor air dry-bulb temperature above which outdoor coil defrosting is disabled [°C];
- crankcaseHeaterCapacity – crankcase heater capacity [W];
- maximumOutdoorDryBulbTemperatureForCrankcaseHeaterOperation – outdoor air dry-bulb temperature above which the compressor s crankcase heater is disabled [°C];
- defrostStrategy – ‘ReverseCycle’ or ‘Resistive’;
- defrostControl – ‘Timed’ or ‘OnDemand’;
- defrostTimePeriodFraction – fraction of compressor runtime when the defrost cycle is active. Only used if defrostControl = Timed;

- resistiveDefrostHeaterCapacity – capacity of the resistive defrost heating element [W]. 'autosize' option is available;
- regionNumberForCalculatingHSPF – region number which is used to calculate HSPF of heating coil (1 to 6);
- secondaryCoilAirflowRate – secondary coil (evaporator) air flow rate when the heat pump is working in heating mode or the secondary coil (condenser) air flow rate when the heat pump is working in cooling mode [m^3/s]. 'autosize' option is available;
- secondaryCoilFanFlowScalingFactor – scaling factor for autosizing the secondary DX coil fan flow rate;
- nominalSensibleHeatRatioOfSecondaryCoil – nominal sensible heat ratio used to split the heat extracted by a secondary DX coil (evaporator) of a heat pump into sensible and latent components (optional);
- sensibleHeatRatioModifierFunctionOfTemperatureCurveID – biquadratic curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). The value of this curve modifies the nominal sensible heat ratio for current time step depending on the secondary zone air node wet-bulb temperature and the heating DX coil entering air dry-bulb temperature;
- sensibleHeatRatioModifierFunctionOfFlowFractionCurveID – quadratic or cubic curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). The value of this curve modifies the nominal sensible heat ratio for current time step depending on the secondary coil air flow fraction;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node");
- Evaporator Air Inlet Node Name – considered null for the outdoor air temperature entering the evaporator to be taken directly from the weather data;
- Zone Name for Evaporator Placement – name of a conditioned or unconditioned zone where the secondary coil (evaporator) is to be placed, assigned in the argument x1 of the CoilHeatingDXSingleSpeedSpec() above.

A heating coil system that provides the controls needed to operate the coil is automatically defined if this coil is directly assigned to an air loop (**10.1**) or an outdoor air system (**10.5**). This corresponds to the CoilSystem:Heating:DX object in EnergyPlus, where all fields are automatically filled:

- Name – coilName + "DX_System";
- Availability Schedule Name – the same schedule defined above for the coil in the availabilityScheduleID field;
- Heating Coil Object Type – Coil:Heating:DX:SingleSpeed;

- Heating Coil Name – coilName.

8.9.2.2. DX Multi Speed

The specification of a Heating Coil DX Multi Speed is defined in the SAPTool_LSP building template, as follows:

CoilHeatingDXMultiSpeedSpec heatingCoilSpec = new CoilHeatingDXMultiSpeedSpec() – Heating Coil DX Multi Speed specification (named heatingCoilSpec in this example). With the following CoilHeatingDXMultiSpeedSpec() arguments:

- **x1** – ID of a conditioned or unconditioned zone where the secondary coil (evaporator) is to be placed (optional), which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if not defined;
- **x2** – ID of the Heating Coil DX Single Speed properties in the **CoilHeatingDXSingleSpeed** table of the database;
- **db** – database unique ID.

The Heating Coil DX Single Speed is specified using the CoilHeatingDXMultiSpeedSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingDXMultiSpeed** table in the database, corresponding to the Coil:Heating:DX:MultiSpeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- minimumOutdoorDryBulbTemperatureForCompressorOperation – minimum outdoor air dry-bulb temperature where the cooling coil compressor turns off [°C];
- outdoorDryBulbTemperatureToTurnOnCompressor – outdoor air dry-bulb temperature when the compressor is automatically turned back on following an automatic shut off because of low outdoor temperature [°C];
- crankcaseHeaterCapacity – crankcase heater capacity [W];
- maximumOutdoorDryBulbTemperatureForCrankcaseHeaterOperation – outdoor air dry-bulb temperature above which the compressor s crankcase heater is disabled [°C];
- defrostEnergyInputRatioFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) during reverse-cycle defrost periods as a function of the outdoor air dry-bulb temperature and the wet-bulb temperature of the air entering the indoor coil. Only required if defrostStrategy = ReverseCycle;
- maximumOutdoorDryBulbTemperatureForDefrostOperation – outdoor air dry-bulb temperature above which outdoor coil defrosting is disabled [°C];
- defrostStrategy – ‘ReverseCycle’ or ‘Resistive’;

- defrostControl – ‘Timed’ or ‘OnDemand’;
- defrostTimePeriodFraction – fraction of compressor runtime when the defrost cycle is active. Only used if defrostControl = Timed;
- resistiveDefrostHeaterCapacity – capacity of the resistive defrost heating element [W]. ‘autosize’ option is available;
- applyPartLoadFractionToSpeedsGreaterThan1 – ‘Yes’ or ‘No’;
- fuelType – ‘Electricity’, ‘NaturalGas’, ‘Propane’, ‘Diesel’, ‘Gasoline’, ‘FuelOil_1’, ‘FuelOil_2’, ‘OtherFuel1’ or ‘OtherFuel2;
- regionNumberForCalculatingHSPF – region number which is used to calculate HSPF of heating coil (1 to 6);
- numberOfSpeeds – 2 to 4;
- speed<x>GrossRatedHeatingCapacity – total heating capacity in watts of the DX coil unit for Speed <x> operation at rated conditions (outdoor air dry-bulb temperature of 8.33 °C, outdoor air wet-bulb temperature of 6.11 °C, heating coil entering air dry-bulb temperature of 21.11 °C, heating coil entering air wet-bulb temperature of 15.55 °C, and a heating coil air flow rate defined by field rated air flow volume below), not accounting for the effect of supply air fan heat. ‘autosize’ option is available;
- speed<x>GrossRatedHeatingCOP – ratio of the gross heating capacity in watts to electrical power input in watts of the DX coil unit at rated conditions for Speed <x> operation, not accounting for the effect of supply air fan heat or the supply air fan electrical energy;
- speed<x>RatedAirFlowRate – air volume flow rate across the DX heating coil at rated conditions for Speed <x> operation [m^3/s]. Should be between 0.00004027 m^3/s and 0.00006041 m^3/s per watt of gross rated heating capacity. ‘autosize’ option is available;
- speed<x>RatedSupplyFanPowerPerVolumeFlowRate – electric power for the evaporator (heating coil) fan per air volume flow rate through the coil at the rated conditions for Speed <x> operation [W/(m^3/s)];
- speed<x>HeatingCapacityFunctionOfTemperatureCurveID – biquadratic, quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the total heating capacity for Speed <x> operation as a function of the both the indoor and outdoor air dry-bulb temperature or just the outdoor air dry-bulb temperature depending on the type of curve selected;
- speed<x>HeatingCapacityFunctionOfFlowFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of total heating capacity for Speed <x> operation as a function of the ratio of actual air flow rate across the heating coil to the rated air flow rate (i.e., fraction of full load flow);
- speed<x>EnergyInputRatioFunctionOfTemperatureCurveID – biquadratic, quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) for Speed <x> operation as a function of the both the indoor and outdoor air dry-bulb temperature or just the outdoor air dry-bulb temperature depending on the type of curve selected;
- speed<x>EnergyInputRatioFunctionOfFlowFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) for Speed <x> operation as a function of the ratio of actual air flow rate across the heating coil to the rated air flow rate (i.e., fraction of full load flow);

- speed<x>PartLoadFractionCorrelationCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of electrical power input to the DX unit for Speed <x> operation as a function of the part load ratio (PLR, sensible cooling load/steady-state sensible cooling capacity);
- speed<x>RatedWasteHeatFractionOfPowerInput – fraction of heat input to heating that is available as recoverable waste heat at full load and rated conditions for Speed <x> operation;
- speed<x>WasteHeatFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the waste heat recovery as a function of outdoor dry-bulb temperature and the entering coil dry-bulb temperature for Speed <x>;
- speed<x>SecondaryCoilAirFlowRate – secondary coil (evaporator) air flow rate for Speed <x> when the heat pump is working in heating mode or the secondary coil (condenser) air flow rate when the heat pump is working in cooling mode [m^3/s]. 'autosize' option is available;
- speed<x>SecondaryCoilFanFlowScalingFactor – scaling factor for autosizing the secondary DX coil fan flow rate for Speed <x>;
- speed<x>NominalSensibleHeatRatioOfSecondaryCoil – nominal sensible heat ratio for Speed <x> used to split the heat extracted by a secondary DX coil (evaporator) of a heat pump into sensible and latent components (optional);
- speed<x>SensibleHeatRatioModifierFunctionOfTemperatureCurveID – biquadratic curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). The value of this curve modifies the nominal sensible heat ratio for current time step for Speed <x> depending on the secondary zone air node wet-bulb temperature and the heating DX coil entering air dry-bulb temperature;
- speed<x>SensibleHeatRatioModifierFunctionOfFlowFractionCurveID – quadratic or cubic curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). The value of this curve modifies the nominal sensible heat ratio for current time step for Speed <x> depending on the secondary coil air flow fraction;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node");
- Zone Name for Evaporator Placement – name of a conditioned or unconditioned zone where the secondary coil (evaporator) is to be placed, assigned in the argument x1 of the CoilHeatingDXMultiSpeedSpec() above.

8.9.2.3. DX Variable Speed

The specification of a Heating Coil DX Variable Speed is defined in the SAPTool_LSP building template, as follows:

CoilHeatingDXVariableSpeedSpec heatingCoilSpec = new CoilHeatingDXVariableSpeedSpec() – Heating Coil DX Variable Speed specification (named heatingCoilSpec in this example). With the following CoilHeatingDXVariableSpeedSpec() arguments:

- **x1** – ID of the Heating Coil DX Variable Speed properties in the **CoilHeatingDXVariableSpeed** table of the database;
- **db** – database unique ID.

The Heating Coil DX Variable Speed is specified using the CoilHeatingDXVariableSpeedSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingDXVariableSpeed** table in the database, corresponding to the Coil:Heating:DX:VariableSpeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- numberOfSpeeds – 1 to 10;
- nominalSpeedLevel – nominal speed level, at which the rated capacity, rated air and volumetric flow rate are correlated;
- ratedHeatingCapacityAtSelectedNominalSpeedLevel – rated capacity at the nominal speed level [W]. 'autosize' option is available;
- ratedAirFlowRateAtSelectedNominalSpeedLevel – rated volumetric air flow rate on the load side of the heat pump corresponding to the nominal speed level [m^3/s]. 'autosize' option is available;
- energyPartLoadFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of electrical power input to the unit as a function of the part load ratio (PLR, heating load/steady-state heating capacity for Speed 1), in the case that the unit operates under the lowest speed, i.e. on/off;
- defrostEnergyInputRatioFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) during reverse-cycle defrost periods as a function of the outdoor air dry-bulb temperature and the wet-bulb temperature of the air entering the indoor coil. Only required if defrostStrategy = ReverseCycle;
- minimumOutdoorDryBulbTemperatureForCompressorOperation – minimum outdoor air dry-bulb temperature where the cooling coil compressor turns off [°C];
- outdoorDryBulbTemperatureToTurnOnCompressor – outdoor air dry-bulb temperature when the compressor is automatically turned back on following an automatic shut off because of low outdoor temperature [°C];
- maximumOutdoorDryBulbTemperatureForDefrostOperation – outdoor air dry-bulb temperature above which outdoor coil defrosting is disabled [°C];
- crankcaseHeaterCapacity – crankcase heater capacity [W];

- maximumOutdoorDryBulbTemperatureForCrankcaseHeaterOperation – outdoor air dry-bulb temperature above which the compressor s crankcase heater is disabled [°C];
- defrostStrategy – ‘ReverseCycle’ or ‘Resistive’;
- defrostControl – ‘Timed’ or ‘OnDemand’;
- defrostTimePeriodFraction – fraction of compressor runtime when the defrost cycle is active. Only used if defrostControl = Timed;
- resistiveDefrostHeaterCapacity – capacity of the resistive defrost heating element [W]. ‘autosize’ option is available;
- speed<x>ReferenceUnitGrossRatedHeatingCapacity – total heating capacity in watts of the DX coil unit for Speed <x> operation at rated conditions, not accounting for the effect of supply air fan heat;
- speed<x>ReferenceUnitGrossRatedHeatingCOP – ratio of the gross heating capacity in watts to electrical power input in watts of the DX coil unit at rated conditions for Speed <x> operation, not accounting for the effect of supply air fan heat or the supply air fan electrical energy;
- speed<x>ReferenceUnitRatedAirFlowRate – air volume flow rate across the heating coil at rated conditions for Speed <x> operation [m^3/s];
- speed<x>HeatingCapacityFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the total heating capacity for Speed <x> operation as a function of the indoor dry-bulb and source side entering air temperature;
- speed<x>TotalHeatingCapacityFunctionOfAirFlowFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross heating capacity for Speed <x> operation as a function of the ratio of actual air flow rate across the heating coil to the design air flow rate (i.e., fraction of full load flow);
- speed<x>EnergyInputRatioFunctionOfTemperatureCurveID – biquadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) for Speed <x> operation as a function of the both the indoor air dry-bulb and entering air temperatures;
- speed<x>EnergyInputRatioFunctionOfAirFlowFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) for Speed <x> operation as a function of the ratio of actual air flow rate across the heating coil to the design air flow rate (i.e., fraction of full load flow, at Speed <x>);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + “Outlet_node”).

The following fields in the **CoilHeatingDXVariableSpeed** table are used if the coil is directly assigned to an air loop (**10.1**) or an outdoor air system (**10.5**), for which the coil is contained in a heating coil system that provides the controls needed to operate the coil. This corresponds to the CoilSystem:Heating:DX object in EnergyPlus, which is automatically defined:

- coilSystemAvailabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available.

Automatic filling fields in EnergyPlus:

- Name – coilName + "DX_System";
- Heating Coil Object Type – Coil:Heating:DX:VariableSpeed;
- Heating Coil Name – coilName.

8.9.2.4. DX Variable Refrigerant Flow

The specification of a Heating Coil DX Variable Refrigerant Flow is defined in the SAPTool_LSP building template, as follows:

CoilHeatingDXVariableRefrigerantFlowSpec heatingCoilSpec = new CoilHeatingDXVariableRefrigerantFlowSpec() – Heating Coil DX Variable Refrigerant Flow specification (named heatingCoilSpec in this example). With the following CoilHeatingDXVariableRefrigerantFlowSpec() arguments:

- **x1** – ID of the Heating Coil DX Variable Refrigerant Flow properties in the **CoilHeatingDXVariableRefrigerantFlow** table of the database;
- **db** – database unique ID.

The Heating Coil DX Variable Refrigerant Flow is specified using the CoilHeatingDXVariableRefrigerantFlowSpec() object and must then be assigned to the specific system (e.g., a Zone HVAC Terminal Unit Variable Refrigerant Flow (**7.1.7**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingDXVariableRefrigerantFlow** table in the database, corresponding to the Coil:Heating:DX:VariableRefrigerantFlow object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- grossRatedHeatingCapacity – total, full load gross heating capacity of the DX coil unit at rated conditions (outside air dry-bulb temperature of 8.33 °C, outside air wet-bulb temperature of 6.11 °C, heating coil entering air dry-bulb temperature of 21.11 °C, heating coil entering air wet-bulb temperature of 15.55 °C, and a heating coil air flow rate defined by field rated air flow volume below) [W]. 'autosize' option is available;
- ratedAirFlowRate – air volume flow rate across the DX heating coil at rated conditions [m3/s]. The rated air volume flow rate should be between 0.00004027 m3/s and 0.00006041 m3/s per watt of gross rated heating capacity (300 to 450 cfm/ton);

- heatingCapacityRatioModifierFunctionOfTemperatureCurveID – linear, quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the heating capacity ratio modifier as a function of indoor dry-bulb temperature or indoor dry-bulb and outdoor wet-bulb temperatures;
- heatingCapacityModifierFunctionOfFlowFractionCurveID – linear, quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of heating capacity as a function of the ratio of actual air flow rate across the heating coil to the rated air flow rate (i.e., fraction of full load flow);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Coil Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Coil Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Coil Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + “Outlet_node”).

8.9.2.5. DX Variable Refrigerant Flow Fluid Temperature Control

The specification of a Heating Coil DX Variable Refrigerant Flow Fluid Temperature Control is defined in the SAPTool_LSP building template, as follows:

CoilHeatingDXVariableRefrigerantFlowFluidTemperatureControlSpec heatingCoilSpec = new CoilHeatingDXVariableRefrigerantFlowFluidTemperatureControlSpec() – Heating Coil DX Variable Refrigerant Flow Fluid Temperature Control specification (named heatingCoilSpec in this example). With the following CoilHeatingDXVariableRefrigerantFlowFluidTemperatureControlSpec() arguments:

- **x1** – ID of the Heating Coil DX Variable Refrigerant Flow Fluid Temperature Control properties in the **CoilHeatingDXVariableRefrigerantFlowFluidTemperatureControl** table of the database;
- **db** – database unique ID.

The Heating Coil DX Variable Refrigerant Flow Fluid Temperature Control is specified using the CoilHeatingDXVariableRefrigerantFlowFluidTemperatureControlSpec() object and must then be assigned to the specific system (e.g., a Zone HVAC Terminal Unit Variable Refrigerant Flow (**7.1.7**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingDXVariableRefrigerantFlowFluidTemperatureControl** table in the database, corresponding to the Coil:Heating:DX:VariableRefrigerantFlow:FluidTemperatureControl object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- ratedTotalHeatingCapacity – total, full load gross heating capacity of the DX coil unit at rated conditions [W]. 'autosize' option is available;
- indoorUnitReferenceSubcooling – reference subcooling degrees of the indoor unit [°C];
- indoorUnitCondensingTemperatureFunctionOfSubcoolingCurveID – quadratic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of indoor unit condensing temperature as a function of subcooling degrees;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Coil Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Coil Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node").

8.9.2.6. Electric

The specification of a Heating Coil Electric is defined in the SAPTool_LSP building template, as follows:

CoilHeatingElectricSpec heatingCoilSpec = new CoilHeatingElectricSpec() – Heating Coil Electric specification (named heatingCoilSpec in this example). With the following CoilHeatingElectricSpec() arguments:

- **x1** – ID of the Heating Coil Electric properties in the **CoilHeatingElectric** table of the database;
- **db** – database unique ID.

The Heating Coil Electric is specified using the CoilHeatingElectricSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingElectric** table in the database, corresponding to the Coil:Heating:Electric object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- efficiency – coil efficiency;
- nominalCapacity – maximum capacity of the coil [W]. 'autosize' option is available;

- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node");
- Temperature Setpoint Node Name – considered null if the coil is contained within another component, such as an air terminal unit, zone HVAC equipment or unitary system. Equal to the Air Outlet Node Name if the coil is located directly in an air loop branch or outdoor air equipment or if it is a supplemental heating coil contained within a setpoint controlled system.

8.9.2.7. Electric Multi Stage

The specification of a Heating Coil Electric Multi Stage is defined in the SAPTool_LSP building template, as follows:

CoilHeatingElectricMultiStageSpec heatingCoilSpec = new CoilHeatingElectricMultiStageSpec() – Heating Coil Electric Multi Stage specification (named heatingCoilSpec in this example). With the following CoilHeatingElectricMultiStageSpec() arguments:

- **x1** – ID of the Heating Coil Electric Multi Stage properties in the **CoilHeatingElectricMultiStage** table of the database;
- **db** – database unique ID.

The Heating Coil Electric Multi Stage is specified using the CoilHeatingElectricMultiStageSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingElectricMultiStage** table in the database, corresponding to the Coil:Heating:Electric:MultiStage object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- numberOfStages – 1 to 4;
- stage1Efficiency – stage 1 coil efficiency;
- stage1NominalCapacity – stage 1 maximum capacity of the coil [W]. 'autosize' option is available;
- stage2Efficiency – stage 2 coil efficiency;

- stage2NominalCapacity – stage 2 maximum capacity of the coil [W]. 'autosize' option is available;
- stage3Efficiency – stage 3 coil efficiency;
- stage3NominalCapacity – stage 3 maximum capacity of the coil [W]. 'autosize' option is available;
- stage4Efficiency – stage 4 coil efficiency;
- stage4NominalCapacity – stage 4 maximum capacity of the coil [W]. 'autosize' option is available;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node");
- Temperature Setpoint Node Name – considered null if the coil is contained within another component, such as an air terminal unit, zone HVAC equipment or unitary system. Equal to the Air Outlet Node Name if the coil is located directly in an air loop branch or outdoor air equipment or if it is a supplemental heating coil contained within a setpoint controlled system.

8.9.2.8. Fuel

The specification of a Heating Coil Fuel is defined in the SAPTool_LSP building template, as follows:

CoilHeatingFuelSpec heatingCoilSpec = new CoilHeatingFuelSpec() – Heating Coil Fuel specification (named heatingCoilSpec in this example). With the following CoilHeatingFuelSpec() arguments:

- **x1** – ID of the Heating Coil Fuel properties in the **CoilHeatingFuel** table of the database;
- **db** – database unique ID.

The Heating Coil Fuel is specified using the CoilHeatingFuelSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingFuel** table in the database, corresponding to the Coil:Heating:Fuel object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;

- fuelType – ‘Gas’, ‘NaturalGas’, ‘Propane’, ‘Diesel’, ‘Gasoline’, ‘FuelOil_1’, ‘FuelOil_2’, ‘OtherFuel1’ or ‘OtherFuel2’;
- burnerEfficiency – gas burner efficiency;
- nominalCapacity – maximum capacity of the coil [W]. ‘autosize’ option is available;
- parasiticElectricLoad – parasitic electric load associated with the coil operation, such as an inducer fan, etc. [W];
- partLoadFractionCorrelationCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This curve parameterizes the variation of fuel consumption rate by the heating coil as a function of the part load ratio (PLR, sensible heating load/nominal capacity of the heating coil);
- parasiticFuelLoad – parasitic fuel load associated with the coil’s operation, such as a standing pilot light [W];
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + “Outlet_node”);
- Temperature Setpoint Node Name – considered null if the coil is contained within another component, such as an air terminal unit, zone HVAC equipment or unitary system. Equal to the Air Outlet Node Name if the coil is located directly in an air loop branch or outdoor air equipment or if it is a supplemental heating coil contained within a setpoint controlled system.

8.9.2.9. Gas Multi Stage

The specification of a Heating Coil Gas Multi Stage is defined in the SAPTool_LSP building template, as follows:

CoilHeatingGasMultiStageSpec heatingCoilSpec = new CoilHeatingGasMultiStageSpec() – Heating Coil Gas Multi Stage specification (named heatingCoilSpec in this example). With the following CoilHeatingGasMultiStageSpec() arguments:

- **x1** – ID of the Heating Coil Gas Multi Stage properties in the **CoilHeatingGasMultistage** table of the database;
- **db** – database unique ID.

The Heating Coil Gas Multi Stage is specified using the CoilHeatingGasMultiStageSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingGasMultistage** table in the database, corresponding to the Coil:Heating:Gas:MultiStage object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- partLoadFractionCorrelationCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This curve parameterizes the variation of gas consumption rate by the heating coil as a function of the part load ratio (PLR, sensible heating load/nominal capacity of the heating coil);
- parasiticGasLoad – parasitic gas load associated with the coil's operation, such as a standing pilot light [W];
- numberOfStages – 1 to 4;
- stage1GasBurnerEfficiency – stage 1 gas burner efficiency;
- stage1NominalCapacity – stage 1 capacity of the coil [W]. 'autosize' option is available;
- stage1ParasiticElectricLoad – stage 1 parasitic electric load associated with the gas coil operation, such as an inducer fan, etc. [W];
- stage2GasBurnerEfficiency – stage 2 gas burner efficiency;
- stage2NominalCapacity – stage 2 capacity of the coil [W]. 'autosize' option is available;
- stage2ParasiticElectricLoad – stage 2 parasitic electric load associated with the gas coil operation, such as an inducer fan, etc. [W];
- stage3GasBurnerEfficiency – stage 3 gas burner efficiency;
- stage3NominalCapacity – stage 3 capacity of the coil [W]. 'autosize' option is available;
- stage3ParasiticElectricLoad – stage 3 parasitic electric load associated with the gas coil operation, such as an inducer fan, etc. [W];
- stage4GasBurnerEfficiency – stage 4 gas burner efficiency;
- stage4NominalCapacity – stage 4 capacity of the coil [W]. 'autosize' option is available;
- stage4ParasiticElectricLoad – stage 4 parasitic electric load associated with the gas coil operation, such as an inducer fan, etc. [W];
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node");
- Temperature Setpoint Node Name – considered null if the coil is contained within another component, such as an air terminal unit, zone HVAC equipment or unitary system. Equal to the Air Outlet Node Name if the coil is located directly in an air loop branch or outdoor air equipment or if it is a supplemental heating coil contained within a setpoint controlled system.

8.9.2.10. Water

The specification of a Heating Coil Water is defined in the SAPTool_LSP building template, as follows:

CoilHeatingWaterSpec heatingCoilSpec = new CoilHeatingWaterSpec() – Heating Coil Water specification (named heatingCoilSpec in this example). With the following CoilHeatingWaterSpec() arguments:

- **x1** – ID of the Heating Coil Water properties in the **CoilHeatingWater** table of the database;
- **db** – database unique ID.

The Heating Coil Water is specified using the CoilHeatingWaterSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**), directly to an Air Loop (**10.2**) or and Air Loop Outdoor Air System (**10.5.1**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingWater** table in the database, corresponding to the Coil:Heating:Water object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- uFactorTimesAreaValue – UA value for the coil needed for the Effectiveness-NTU heat exchanger model. Only used if performanceInputMethod = UFactorTimesAreaAndDesignWaterFlowRate. ‘autosize’ option is available;
- maximumWaterFlowRate – maximum possible water flow rate through the coil [m^3/s]. Only used if performanceInputMethod = UFactorTimesAreaAndDesignWaterFlowRate. ‘autosize’ option is available;
- performanceInputMethod – ‘UFactorTimesAreaAndDesignWaterFlowRate’ or ‘NominalCapacity’;
- ratedCapacity – heating capacity of the coil at the rated inlet and outlet air and water temperatures [W]. Only used if performanceInputMethod = NominalCapacity;
- ratedInletWaterTemperature – inlet water temperature corresponding to the rated heating capacity [°C];
- ratedInletAirTemperature – inlet air temperature corresponding to the rated heating capacity [°C];
- ratedOutletWaterTemperature – outlet water temperature corresponding to the rated heating capacity [°C];
- ratedOutletAirTemperature – outlet air temperature corresponding to the rated heating capacity [°C];
- ratedRatioForAirAndWaterConvection – ratio of convective heat transfers between air side and water side of the heating coil at the rated operating conditions;
- designWaterTemperatureDifference – used for sizing the Design Water Flow Rate (optional). If blank, the Loop Design Temperature Difference value specified in Sizing Plant (**13.2.4**) is used for sizing the Design Water Flow Rate;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve defines the pressure drop across the coil in the hot water loop (see section **9.3**);

- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Water Inlet Node Name – coilName + “Hot_Water_Inlet_node” (for connection to a hot water loop);
- Water Outlet Node Name – coilName + “Hot_Water_Outlet_node” (for connection to a hot water loop);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + “Outlet_node”).

The following fields in the **CoilHeatingWater** table are used if the coil is directly assigned to an air loop (**10.1**) or an outdoor air system (**10.5**)), for which a water coil controller is required, corresponding to the Controller:WaterCoil object in EnergyPlus:

- controlVariable – ‘Temperature’, ‘HumidityRatio’ or ‘TemperatureAndHumidityRatio’;
- controllerActuatorVariable – ‘Flow’;
- controllerConvergenceTolerance – maximum difference between the actual temperature at the setpoint node and the setpoint temperature [°C];
- controllerMaximumActuatedFlow – maximum water flow through the coil [m^3/s]. ‘autosize’ option is available;
- controllerMinimumActuatedFlow – minimum design water flow for the water coil, normally a shut off valve that is set to zero [m^3/s];
- controllerSetpointManagerType – defines the Setpoint Manager type for the controller Sensor Node (automatically defined as the coil’s air outlet node). ‘ScheduledSingleSetpoint’, ‘ScheduledDualSetpoint’ or ‘OutdoorAirReset’ (see section **14** for details);
- controllerSetpointManagerID – ID of the Setpoint Manager assigned to the controller Sensor Node, which is defined in the **setpointManagerSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **setpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**).

Automatic filling fields in EnergyPlus:

- Name – coilName + “Controller”;
- Action – chilled water coils are defined as ‘Reverse’ and hot water coils are defined as ‘Normal’;
- Sensor Node Name – coil’s Air Outlet Node Name;
- Actuator Node Name – coil’s Water Inlet Node Name.

This controller is then assigned to the air loop system controller list (**10.1**) or the outdoor air system controller list (**10.5.3**), using the object AirLoopHVAC:ControllerList in EnergyPlus, where all the fields are automatically filled:

- Name – systemName + “Controller_List” (systemName – name of the system for which this list is assigned);
- Controller <x> Object Type – Controller:WaterCoil;
- Controller <x> Name – name of the controller assigned to the list.

8.9.2.11. Steam

The specification of a Heating Coil Steam is defined in the SAPTool_LSP building template, as follows:

CoilHeatingSteamSpec heatingCoilSpec = new CoilHeatingSteamSpec() – Heating Coil Steam specification (named heatingCoilSpec in this example). With the following CoilHeatingSteamSpec() arguments:

- **x1** – ID of the Heating Coil Steam properties in the **CoilHeatingSteam** table of the database;
- **db** – database unique ID.

The Heating Coil Steam is specified using the CoilHeatingSteamSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingSteam** table in the database, corresponding to the Coil:Heating:Steam object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – coil availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the coil is always available;
- maximumSteamFlowRate – maximum possible steam volumetric flow rate through the steam heating coil [m^3/s]. ‘autosize’ option is available;
- degreeOfSubCooling – degree of condensate sub cooling in the coil before leaving it due to delay, which adds heat to the zone [°C];
- degreeOfLoopSubCooling – degree of condensate sub cooling before it is pumped back to the boiler, which represents the heat loss to the atmosphere due to uninsulated condensate return piping to the boiler [°C];
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve defines the pressure drop across the coil in the steam loop (see section **9.3**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);

- Water Inlet Node Name – coilName + “Hot_Water_Inlet_node” (for connection to a steam loop);
- Water Outlet Node Name – coilName + “Hot_Water_Outlet_node” (for connection to a steam loop);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + “Outlet_node”);
- Coil Control Type – ‘ZoneLoadControl’ if the coil is contained within another component, such as an air terminal unit, zone HVAC equipment or unitary system. ‘TemperatureSetpointControl’ if the coil is located directly in an air loop branch or outdoor air equipment or if it is a supplemental heating coil contained within a setpoint controlled system;
- Temperature Setpoint Node Name – considered null if Coil Control Type = ZoneLoadControl or equal to the Air Outlet Node Name if Coil Control Type = TemperatureSetpointControl.

8.9.2.12. Water-to-Air Heat Pump Equation Fit

The specification of a Heating Coil Water-to-Air Heat Pump Equation Fit is defined in the SAPTool_LSP building template, as follows:

CoilHeatingWaterToAirHeatPumpEquationFitSpec heatingCoilSpec = new CoilHeatingWaterToAirHeatPumpEquationFitSpec() – Heating Coil Water-to-Air Heat Pump Equation Fit specification (named heatingCoilSpec in this example). With the following CoilHeatingWaterToAirHeatPumpEquationFitSpec() arguments:

- **x1** – ID of the Heating Coil Water-to-Air Heat Pump Equation Fit properties in the **CoilHeatingWaterToAirHeatPumpEquationFit** table of the database;
- **db** – database unique ID.

The Heating Coil Water-to-Air Heat Pump Equation Fit is specified using the CoilHeatingWaterToAirHeatPumpEquationFitSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingWaterToAirHeatPumpEquationFit** table in the database, corresponding to the Coil:Heating:WaterToAirHeatPump:EquationFit object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- ratedAirFlowRate – rated volumetric air flow rate on the load side of the heat pump [m^3/s]. ‘autosize’ option is available;
- ratedWaterFlowRate – rated volumetric water flow rate on the source side of the heat pump [m^3/s]. ‘autosize’ option is available;
- grossRatedHeatingCapacity – gross heating capacity of the heat pump at the rated condition [W]. ‘autosize’ option is available;

- grossRatedHeatingCOP – gross rated heating coefficient of performance of the heat pump;
- heatingCapacityCoefficient<1-5> – first to fifth coefficient for the heat pump capacity;
- heatingPowerConsumptionCoefficient<1-5> – first to fifth coefficient for the heat pump power consumption;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve defines the pressure drop across the coil in the water loop (see section **9.3**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Water Inlet Node Name – coilName + "Hot_Water_Inlet_node" (for connection to a water loop);
- Water Outlet Node Name – coilName + "Hot_Water_Outlet_node" (for connection to a water loop);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node").

8.9.2.13. Water-to-Air Heat Pump Parameter Estimation

The specification of a Heating Coil Water-to-Air Heat Pump Parameter Estimation is defined in the SAPTool_LSP building template, as follows:

CoilHeatingWaterToAirHeatPumpParameterEstimationSpec heatingCoilSpec = new CoilHeatingWaterToAirHeatPumpParameterEstimationSpec() – Heating Coil Water-to-Air Heat Pump Parameter Estimation specification (named heatingCoilSpec in this example). With the following CoilHeatingWaterToAirHeatPumpParameterEstimationSpec() arguments:

- **x1** – ID of the Heating Coil Water-to-Air Heat Pump Parameter Estimation properties in the **CoilHeatingWaterToAirHeatPumpParameterEstimation** table of the database;
- **db** – database unique ID.

The Heating Coil Water-to-Air Heat Pump Parameter Estimation is specified using the CoilHeatingWaterToAirHeatPumpParameterEstimationSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingWaterToAirHeatPumpParameterEstimation** table in the database, corresponding to the Coil:Heating:WaterToAirHeatPump:ParameterEstimation object in EnergyPlus. The following fields are present in the table:

- id – object ID;

- compressorType – 'Reciprocating', 'Rotary' or 'Scroll';
- refrigerantType – 'R22';
- designSourceSideFlowRate – water flow rate though the coil [m^3/s];
- grossRatedHeatingCapacity – gross heating capacity for the WatertoAirHP heating coil at the rated condition [W];
- highPressureCutoff – compressor's maximum allowable pressure [Pa];
- lowPressureCutoff – compressor's minimum allowable pressure [Pa];
- loadSideTotalHeatTransferCoefficient – estimated parameter load side total heat transfer coefficient [W/K];
- superheatTemperatureAtTheEvaporatorOutlet – estimated parameter superheat temperature at the evaporator outlet [°C];
- compressorPowerLosses – estimated parameter compressor power losses, which accounts for the loss of work due to mechanical and electrical losses in the compressor [W];
- compressorEfficiency – estimated parameter of the compressor's efficiency;
- compressorPistonDisplacement – estimated parameter piston displacement of the compressor [m^3/s]. Used if compressorType = Reciprocating or Rotary. Should be left blank if compressorType = Scroll;
- compressorSuctionDischargePressureDrop – estimated parameter pressure drop at the compressor suction and discharge [Pa]. Used if compressorType = Reciprocating or Rotary. Should be left blank if compressorType = Scroll;
- compressorClearanceFactor – estimated parameter clearance factor of the compressor. Used if compressorType = Reciprocating. Should be left blank if compressorType = Rotary or Scroll;
- refrigerantVolumeFlowRate – refrigerant volume flow rate at the beginning of the compression [m^3/s]. Used if compressorType = Scroll. Should be left blank if compressorType = Reciprocating or Rotary;
- volumeRatio – built-in-volume ratio. Used if compressorType = Scroll. Should be left blank if compressorType = Reciprocating or Rotary;
- leakRateCoefficient – coefficient for the relationship between pressure ratio and leakage rate. Used if compressorType = Scroll. Should be left blank if compressorType = Reciprocating or Rotary;
- sourceSideHeatTransferCoefficient – estimated parameter source side heat transfer coefficient [W/K]. It should only be used when the Source Side Fluid Name is Water;
- sourceSideHeatTransferResistance1 – estimated parameter source side heat transfer resistance 1. It should only be used when the Source Side Fluid Name is an antifreeze;
- sourceSideHeatTransferResistance2 – estimated parameter source side heat transfer resistance 2 [W/K]. It should only be used when the Source Side Fluid Name is an antifreeze;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve defines the pressure drop across the coil in the water loop (see section **9.3**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);

- Water Inlet Node Name – coilName + “Hot_Water_Inlet_node” (for connection to a water loop);
- Water Outlet Node Name – coilName + “Hot_Water_Outlet_node” (for connection to a water loop);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + “Outlet_node”).

8.9.2.14. Water-to-Air Heat Pump Variable Speed Equation Fit

The specification of a Heating Coil Water-to-Air Heat Pump Variable Speed Equation Fit is defined in the SAPTool_LSP building template, asfollows:

CoilHeatingWaterToAirHeatPumpVariableSpeedEquationFitSpec heatingCoilSpec = new CoilHeatingWaterToAirHeatPumpVariableSpeedEquationFitSpec() – Heating Coil Water-to-Air Heat Pump Variable Speed Equation Fit specification (named heatingCoilSpec in this example). With the following CoilHeatingWaterToAirHeatPumpVariableSpeedEquationFitSpec() arguments:

- **x1** – ID of the Heating Coil Water-to-Air Heat Pump Variable Speed Equation Fit properties in the **CoilHeatingWaterToAirHeatPumpVariableSpeedEquationFit** table of the database;
- **db** – database unique ID.

The Heating Coil Water-to-Air Heat Pump Variable Speed Equation Fit is specified using the CoilHeatingWaterToAirHeatPumpVariableSpeedEquationFitSpec() object and must then be assigned to the specific system (e.g., an Air Loop HVAC Unitary System (**10.4**)), by assigning the specification name (heatingCoilSpec, in this example) to the system specification.

This component is defined in the **CoilHeatingWaterToAirHeatPumpVariableSpeedEquationFit** table in the database, corresponding to the Coil:Heating:WaterToAirHeatPump:VariableSpeedEquationFit object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- numberOfSpeeds – 1 to 10;
- nominalSpeedLevel – 1 to 10;
- ratedHeatingCapacityAtSelectedNominalSpeedLevel – gross rated capacity at the nominal speed level [W]. ‘autosize’ option is available;
- ratedAirFlowRateAtSelectedNominalSpeedLevel – rated volumetric air flow rate on the load side of the heat pump corresponding to the nominal speed level [m^3/s]. ‘autosize’ option is available;
- ratedWaterFlowRateAtSelectedNominalSpeedLevel – rated volumetric water flow rate on the source side of the heat pump at the nominal speed level [m^3/s]. ‘autosize’ option is available;

- energyPartLoadFractionCurveID – quadratic or cubic performance curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of electrical power input to the unit as a function of the part load ratio (PLR, heating load/steady-state heating capacity for Speed 1), in the case that the unit operates under the lowest speed, i.e. on/off;
- speed<1-10>ReferenceUnitGrossRatedHeatingCapacity – total load gross heating capacity of the water-to-air heating coil unit at rated conditions for Speed <x> operation [W];
- speed<1-10>ReferenceUnitGrossRatedHeatingCOP – coefficient of performance (COP = gross heating capacity in watts divided by electrical power input in watts) of the heating coil unit at rated conditions for Speed <x> operation;
- speed<1-10>ReferenceUnitRatedAirFlow – volume air flow rate across the heating coil at rated conditions for Speed <x> operation [m^3/s];
- speed<1-10>ReferenceUnitRatedWaterFlowRate – volume water flow rate flowing at the source side of the heating coil at rated conditions for Speed <x> operation [m^3/s];
- speed<1-10>HeatingCapacityFunctionOfTemperatureCurveID – bi-quadratic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the total heating capacity as a function of the indoor dry-bulb and source side entering water temperature for Speed<x>;
- speed<1-10>TotalHeatingCapacityFunctionOfAirFlowFractionCurveID – quadratic or cubic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the gross total heating capacity as a function of the ratio of actual air flow rate across the heating coil to the design air flow rate (i.e., fraction of full load flow), at Speed <x>;
- speed<1-10>HeatingCapacityFunctionOfWaterFlowFractionCurveID – quadratic or cubic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of total heating capacity as a function of the ratio of actual water flow rate across the heating coil to the design water flow rate (i.e., fraction of full load flow), at Speed <x>;
- speed<1-10>EnergyInputRatioFunctionOfTemperatureCurveID – bi-quadratic, quadratic or cubic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the both the indoor air dry-bulb and entering water temperatures, at Speed <x>;
- speed<1-10>EnergyInputRatioFunctionOfAirFlowFractionCurveID – quadratic or cubic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the ratio of actual air flow rate across the heating coil to the design air flow rate (i.e., fraction of full load flow, at Speed <x> from the Reference Unit data);
- speed<1-10>EnergyInputRatioFunctionOfWaterFlowFractionCurveID – quadratic or cubic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) as a function of the ratio of actual water flow rate across the heating coil to the rated water flow rate (i.e., fraction of full load flow, at Speed <x>);

- speed<1-10>ReferenceUnitWasteHeatFractionOfInputPowerAtRatedConditions – fraction of heat input to heating that is available as recoverable waste heat at full load and rated conditions for Speed <x> operation;
- speed<1-10>WasteHeatFunctionOfTemperatureCurveID – bi-quadratic performance curve ID for Speed <x>, defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the waste heat recovery as a function of indoor dry-bulb temperature and the entering water temperature for Speed <x>;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve defines the pressure drop across the coil in the water loop (see section **9.3**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – coilName = Unit name + Coil type (Unit name – unit name for which the coil is assigned to; Coil type – type of coil in the specific unit);
- Water Inlet Node Name – coilName + "Hot_Water_Inlet_node" (for connection to a water loop);
- Water Outlet Node Name – coilName + "Hot_Water_Outlet_node" (for connection to a water loop);
- Air Inlet Node Name – name of the HVAC system node from which the coil draws its inlet air (normally, the outlet node of the equipment upstream of the coil or the inlet node of the unit for which the coil is assigned to, if the coil is the first equipment in the unit);
- Air Outlet Node Name – name of the HVAC system node to which the coil sends its outlet air (normally, coilName + "Outlet_node").

8.10. Humidifiers

8.10.1. Steam Electric

The specification of a Humidifier Steam Electric is defined in the SAPTool_LSP building template, as follows:

HumidifierSteamElectricSpec humidifierSpec = new HumidifierSteamElectricSpec() – Humidifier Steam Electric specification (named humidifierSpec in this example). With the following HumidifierSteamElectricSpec() arguments:

- **x1** – ID of the zone where the humidistat is located for controlling humidification, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. A Zone Control Humidistat is assigned to the selected zone, for what it should be assigned to the zone (in the Zone table – section **0**) and defined in section **7.2.2**.
  If this argument is **null**, a humidistat is not defined to control the humidifier. In that case, a Setpoint Manager Scheduled Single Setpoint must be assigned to the humidifier in the **HumidifierSteamElectric** table in the database (see below);
- **DBSpaceType.LIVING_ROOM.getID()** – humidistat control zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living Room, in this example). If the previous field is **null**, this argument is not used;
- **x2** – name of the water storage tank, defined in section **5.3**, and assigned to this humidifier. **null** if no water storage tank is assigned;

- **x3** – ID of the Humidifier Steam Electric properties in the **HumidifierSteamElectric** table of the database;
- **db** – database unique ID.

The Humidifier Steam Electric is specified using the HumidifierSteamElectricSpec() object and must then be assigned to the specific system which it serves (e.g., an Air Loop HVAC system (**10.1**)), by assigning the HumidifierSteamElectricSpec() name (humidifierSpec, in this example) to the system specification.

The Humidifier Steam Electric is defined in the **HumidifierSteamElectric** table in the database, corresponding to the Humidifier:Steam:Electric object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – humidifier availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the humidifier is always available;
- ratedCapacity – nominal full output water addition rate of the unit of water at 5.05 °C [m^3/s]. 'autosize' option is available;
- ratedPower – nominal full output power consumption of the unit, exclusive of the blower fan power consumption and any standby power [W]. 'autosize' option is available;
- ratedFanPower – nominal full output power consumption of the blower fan [W];
- standbyPower – standby power consumption [W];
- setpointManagerScheduledSingleSetpointID – ID of the Setpoint Manager Scheduled Single Setpoint (see section **14.1**) assigned to this humidifier. Used only if a humidistat is not assigned to the humidifier (argument x1 of the HumidifierSteamElectricSpec() above);
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – humidifierName = System name + "Humidifier" (System name – system name for which the humidifier is assigned to);
- Air Inlet Node Name – name of the HVAC system node from which the humidifier draws its inlet air (normally, the outlet node of the equipment upstream of the humidifier);
- Air Outlet Node Name – name of the HVAC system node to which the humidifier sends its outlet air (normally, humidifierName + "Outlet_node");
- Water Storage Tank Name – name of other Water Use Storage (if any), defined in the argument x2 of the HumidifierSteamElectricSpec() above.

8.10.2. Steam Gas

The specification of a Humidifier Steam Gas is defined in the SAPTool_LSP building template, as follows:

HumidifierSteamGasSpec humidifierSpec = new HumidifierSteamGasSpec() – Humidifier Steam Gas specification (named humidifierSpec in this example). With the following HumidifierSteamGasSpec() arguments:

- **x1** – ID of the zone where the humidistat is located for controlling humidification, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. A Zone Control Humidistat is assigned to the selected zone, for what it should be assigned to the zone (in the Zone table – section **0**) and defined in section **7.2.2**.
  If this argument is **null**, a humidistat is not defined to control the humidifier. In that case, a Setpoint Manager Scheduled Single Setpoint must be assigned to the humidifier in the **HumidifierSteamGas** table in the database (see below);
- **DBSpaceType.LIVING_ROOM.getID()** – humidistat control zone ID in the Zone table in the database (section **0**), defined using the DBSpaceType list object (Living Room, in this example). If the previous field is **null**, this argument is not used;
- **x2** – name of the water storage tank, defined in section **5.3**, and assigned to this humidifier. **null** if no water storage tank is assigned;
- **x3** – ID of the Humidifier Steam Gas properties in the **HumidifierSteamGas** table of the database;
- **db** – database unique ID.

The Humidifier Steam Gas is specified using the HumidifierSteamGasSpec() object and must then be assigned to the specific system which it serves (e.g., an Air Loop HVAC system (**10.1**)), by assigning the HumidifierSteamGasSpec() name (humidifierSpec, in this example) to the system specification.

The Humidifier Steam Gas is defined in the **HumidifierSteamGas** table in the database, corresponding to the Humidifier:Steam:Gas object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – humidifier availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the humidifier is always available;
- ratedCapacity – nominal full capacity water addition rate of water at 5.05 °C [m^3/s]. ‘autosize’ option is available;
- ratedGasUseRate – nominal gas use rate [W]. ‘autosize’ option is available;
- thermalEfficiency – thermal efficiency of the gas fired humidifier;
- thermalEfficiencyModifierCurveID – thermal efficiency modifier linear, quadratic or cubic curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). If blank, thenconstant efficiency value specified in the previous input field will be used;
- ratedFanPower – nominal full capacity electric power input to the blower fan [W];
- auxiliaryElectricPower – auxiliary electric power input [W];
- inletWaterTemperatureOption – ‘FixedInletWaterTemperature’ or ‘VariableInletWaterTemperature’;
- setpointManagerScheduledSingleSetpointID – ID of the Setpoint Manager Scheduled Single Setpoint (see section **14.1**) assigned to this humidifier. Used only if a humidistat is not assigned to the humidifier (argument x1 of the HumidifierSteamGasSpec () above);
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);

- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – humidifierName = System name + “Humidifier” (System name – system name for which the humidifier is assigned to);
- Air Inlet Node Name – name of the HVAC system node from which the humidifier draws its inlet air (normally, the outlet node of the equipment upstream of the humidifier);
- Air Outlet Node Name – name of the HVAC system node to which the humidifier sends its outlet air (normally, humidifierName + “Outlet_node”);
- Water Storage Tank Name – name of other Water Use Storage (if any), defined in the argument x2 of the HumidifierSteamGasSpec() above.

8.11. Heat Exchangers

8.11.1. Air-to-Air Flat Plate

The specification of a Heat Exchanger Air-to-Air Flat Plate is defined in the SAPTool_LSP building template, as follows:

HeatExchangerAirToAirFlatPlateSpec heatExchangerAirToAirFlatPlateSpec = new HeatExchangerAirToAirFlatPlateSpec() – Heat Exchanger Air-to-Air Flat Plate specification (named heatExchangerAirToAirFlatPlateSpec in this example). With the following HeatExchangerAirToAirFlatPlateSpec() arguments:

- **x1** – ID of the Heat Exchanger Air-to-Air Flat Plate properties in the **HeatExchangerAirToAirFlatPlate** table of the database;
- **db** – database unique ID.

The Heat Exchanger is specified using the HeatExchangerAirToAirFlatPlateSpec() object and must then be assigned to the specific system which it serves (e.g., an Air Loop HVAC system (**10.1**)), by assigning the HeatExchangerAirToAirFlatPlateSpec() name (heatExchangerAirToAirFlatPlateSpec, in this example) to the system specification.

The Heat Exchanger Air-to-Air Flat Plate is defined in the **HeatExchangerAirToAirFlatPlate** table in the database, corresponding to the HeatExchanger:AirToAir:FlatPlate object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – heat exchanger availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the heat exchanger is always available;
- flowArrangementType – ‘CounterFlow’, ‘ParallelFlow’ or ‘CrossFlowBothUnmixed’;
- economizerLockout – ‘Yes’ or ‘No’;
- ratioOfSupplyToSecondaryhAValues – ratio $(h.A)_p$ / $(h.A)_s$ at nominal flow;
- nominalSupplyAirFlowRate – nominal primary side air flow rate [m^3/s]. ‘autosize’ option is available;
- nominalSupplyAirInletTemperature – nominal primary side air inlet temperature [°C];
- nominalSupplyAirOutletTemperature – nominal primary side air outlet temperature [°C];

- nominalSecondaryAirFlowRate – nominal secondary side air flow rate [m^3/s]. 'autosize' option is available, which equals the flow rate to the primary side air flow rate;
- nominalSecondaryAirInletTemperature – nominal secondary side air inlet temperature [°C];
- nominalElectricPower – electric consumption rate of the unit [W];
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – heatExchangerName = System name + "Heat_Exchanger" (System name – system name for which the heat exchanger is assigned to);
- Supply Air Inlet Node Name – name of the HVAC system node from which the heat exchanger draws its primary inlet air (normally, the outlet node of the equipment upstream of the heat exchanger primary side. If connected to an air loop, is its outdoor air inlet node – airLoopName + "OA_Inlet_Node" –, for which an Outdoor Air Node List containing the node is automatically defined with the OutdoorAir:NodeList EnergyPlus object);
- Supply Air Outlet Node Name – name of the HVAC system node to which the heat exchanger sends its primary outlet air (normally, heatExchangerName + "Heat_Recov_Supply_Outlet_Node");
- Secondary Air Inlet Node Name – name of the HVAC system node from which the heat exchanger draws its secondary inlet air (normally, the outlet node of the equipment upstream of the heat exchanger secondary side. If connected to an air loop, is its relief air stream node – airLoopName + "Relief_Air_Outlet_Node");
- Secondary Air Outlet Node Name – name of the HVAC system node to which the heat exchanger sends its secondary outlet air (normally, heatExchangerName + "Heat_Recov_Relief_Outlet_Node").

8.11.2. Air-to-Air Sensible and Latent

The specification of a Heat Exchanger Air-to-Air Sensible and Latent is defined in the SAPTool_LSP building template, as follows:

HeatExchangerAirToAirSensibleAndLatentSpec heatExchangerAirToAirSensibleAndLatentSpec = new HeatExchangerAirToAirSensibleAndLatentSpec() – Heat Exchanger Air-to-Air Sensible and Latent specification (named heatExchangerAirToAirSensibleAndLatentSpec in this example). With the following HeatExchangerAirToAirSensibleAndLatentSpec() arguments:

- **x1** – ID of the Heat Exchanger Air-to-Air Sensible and Latent properties in the **HeatExchangerAirToAirSensibleAndLatent** table of the database;
- **db** – database unique ID.

The Heat Exchanger is specified using the HeatExchangerAirToAirSensibleAndLatentSpec() object and must then be assigned to the specific system which it serves (e.g., an Air Loop HVAC system (**10.1**)), by assigning the HeatExchangerAirToAirSensibleAndLatentSpec() name (heatExchangerAirToAirSensibleAndLatentSpec, in this example) to the system specification.

The Heat Exchanger Air-to-Air Sensible and Latent is defined in the **HeatExchangerAirToAirSensibleAndLatent** table in the database, corresponding to the HeatExchanger:AirToAir:SensibleAndLatent object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – heat exchanger availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the heat exchanger is always available;
- nominalSupplyAirFlowRate – nominal primary side (supply) air flow rate [m^3/s];
- sensibleEffectivenessAt100HeatingAirFlow – sensible heat exchange effectiveness at the heating condition[14] with both the supply and exhaust air volume flow rates equal to 100% of the nominal supply air flow rate specified in the previous field;
- latentEffectivenessAt100HeatingAirFlow – latent heat exchange effectiveness at the heating condition with both the supply and exhaust air volume flow rates equal to 100% of the nominal supply air flow rate. 0.0 if the heat exchanger does not transfer latent energy;
- sensibleEffectivenessAt75HeatingAirFlow – sensible heat exchange effectiveness at the heating condition with both the supply and exhaust air volume flow rates equal to 75% of the nominal supply air flow rate;
- latentEffectivenessAt75HeatingAirFlow – latent heat exchange effectiveness at the heating condition with both the supply and exhaust air volume flow rates equal to 75% of the nominal supply air flow rate. 0.0 if the heat exchanger does not transfer latent energy;
- sensibleEffectivenessAt100CoolingAirFlow – sensible heat exchange effectiveness at the cooling condition[15] with both the supply and exhaust air volume flow rates equal to 100% of the nominal supply air flow rate;
- latentEffectivenessAt100CoolingAirFlow – latent heat exchange effectiveness at the cooling condition with both the supply and exhaust air volume flow rates equal to 100% of the nominal supply air flow rate. 0.0 if the heat exchanger does not transfer latent energy;
- sensibleEffectivenessAt75CoolingAirFlow – sensible heat exchange effectiveness at the cooling condition with both the supply and exhaust air volume flow rates equal to 75% of the nominal supply air flow rate;
- latentEffectivenessAt75CoolingAirFlow – latent heat exchange effectiveness at the cooling condition with both the supply and exhaust air volume flow rates equal to 75% of the nominal supply air flow rate. 0.0 if the heat exchanger does not transfer latent energy;
- nominalElectricPower – electric consumption rate of the unit [W];
- supplyAirOutletTemperatureControl – 'Yes' or 'No';
- setpointManagerScheduledID – ID of the Setpoint Manager Scheduled Single Setpoint, which is defined in the **setpointManagerScheduledSingleSetpoint** table (**14.1**). Only used if supplyAirOutletTemperatureControl = Yes. When an air-side economizer is also

[14] Heating condition: entering supply air temperature at 1.7 °C DB and 0.6 °C WB, entering exhaust air temperature at 21 °C DB and 14 °C WB.
[15] Cooling condition: entering supply air temperature at 35 °C DB and 26 °C WB, entering exhaust air temperature at 24 °C DB and 17 °C WB.

being modeled for this air system, the heat exchanger is deactivated during economizer operation. Additionally, the set point for the supply air outlet temperature control should be equal to the economizer outdoor air temperature lower limit (economizerMinimumLimitDryBulbTemperature field in Controler Outdoor Air – **10.5.3.1**);

- heatExchangerType – 'Plate' or 'Rotary';
- frostControlType – 'None', 'ExhaustAirRecirculation', 'ExhaustOnly' or 'MinimumExhaustTemperature';
- thresholdTemperature – dry-bulb temperature of air which is used to initiate frost control [°C];
- initialDefrostTimeFraction – fraction of the simulation timestep when frost control will be invoked when the threshold temperature is reached. Only used if frostControlType = ExhaustAirRecirculation or ExhaustOnly;
- rateOfDefrostTimeFractionIncrease – rate of increase in the defrost time fraction as the supply (outdoor) air inlet temperature falls below the threshold temperature [1/K]. Only used if frostControlType = ExhaustAirRecirculation or ExhaustOnly;
- economizerLockout – 'Yes' or 'No';
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – heatExchangerName = System name + "Heat_Exchanger" (System name – system name for which the heat exchanger is assigned to);
- Supply Air Inlet Node Name – name of the HVAC system node from which the heat exchanger draws its supply inlet air (normally, the outlet node of the equipment upstream of the heat exchanger supply side. If connected to an air loop, is its outdoor air inlet node – airLoopName + "OA_Inlet_Node" –, for which an Outdoor Air Node List containing the node is automatically defined with the OutdoorAir:NodeList EnergyPlus object);
- Supply Air Outlet Node Name – name of the HVAC system node to which the heat exchanger sends its supply outlet air (normally, heatExchangerName + "Heat_Recov_Supply_Outlet_Node"). This is the node assigned to the Setpoint Manager Scheduled Single Setpoint, if supplyAirOutletTemperatureControl = Yes;
- Exhaust Air Inlet Node Name – name of the HVAC system node from which the heat exchanger draws its exhaust inlet air (normally, the outlet node of the equipment upstream of the heat exchanger exhaust side. If connected to an air loop, is its relief air stream node – airLoopName + "Relief_Air_Outlet_Node");
- Exhaust Air Outlet Node Name – name of the HVAC system node to which the heat exchanger sends its exhaust outlet air (normally, heatExchangerName + "Heat_Recov_Relief_Outlet_Node").

9. HVAC LOOP SYSTEMS

The plant and condenser loops structure is mainly defined in the SAPTool_LSP building templates (SAPTool_LSP>SourcePacakges>lsp.templates), while the properties for each object are defined in the database. The Plant and Condenser Loop option must be active (**PLANT_CONDENSER_LOOP = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The HVAC detailed systems specifications must be defined in the SAPTool_LSP building template, as follows:

HVACSpec hVACSpec = new HVACSpec()

The hVACSpec must then be assigned to the layout specifications object (LayoutSpecs(), in its second to last argument), in the end of the SAPTool_LSP building template.

9.1. Plant Loop

The specification of each loop is defined in the SAPTool_LSP building template, as follows:

PlantLoopSpec pls = new PlantLoopSpec() – loop specification (named pls in this example). With the following PlantLoopSpec() arguments:

- **DBHVACPlantLoopType.ABC.toString()** – loop name/type, defined using the DBHVACPlantLoopType list object (‘ABC’, in this case). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **CircuitType.XX** – circuit type, defined using the CircuitType list object. XX = ‘Heating’ or ‘Cooling’;
- **DBHVACPlantLoopType.ABC.getID()** – ID of the Plant Loop properties in the database, defined using the DBHVACPlantLoopType list object (ID of ‘ABC’, in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The plant loop properties are defined in the **PlantLoop** table in the database, corresponding to the PlantLoop object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- fluidType – ‘Water’, ‘Steam’ or ‘UserDefinedFluidType’;
- userDefinedFluidID – user defined fluid ID, defined in the **UserDefinedFluid** table in the database (see section **9.7**). Used only if fluidType = UserDefinedFluidType;
- maximumLoopTemperature – maximum loop temperature in Celsius;
- minimumLoopTemperature – minimum loop temperature in Celsius;
- maximumLoopFlowRate – maximum loop flow rate in m3/s. ‘autosize’ option is available;
- minimumLoopFlowRate – minimum loop flow rate in m3/s;

- plantLoopVolume – volume of the plant loop in m3. 'autocalculate' option is available, and sets the loop volume to the product of the Maximum Loop Flow Rate and the user input for Loop Circulation Time which defaults to 2 minutes;
- loadDistributionScheme – 'Optimal', 'SequentialLoad', 'UniformLoad', 'SequentialUniformPLR' or 'UniformPLR';
- plantLoopDemandCalculationScheme – defines the demand calculation scheme: 'SingleSetpoint' or 'DualSetpointDeadband'. In the SingleSetpoint scheme the Plant Loop requires that a Setpoint Manager set a single setpoint value – defined in a <u>single</u> setpoint manager in the next two fields. For the DualSetpointDeadband scheme the Plant Loop requires that a Setpoint Manager set the high and low setpoint values – defined in a <u>dual</u> setpoint manager in the next two fields;
- setpointManagerType – defines the Setpoint Manager type for the loop. Currently, 'ScheduledSingleSetpoint', 'ScheduledDualSetpoint' and 'OutdoorAirReset' are available for a plant loop (see section **14** for details);
- setpointManagerID – ID of the Setpoint Manager assigned to the loop, which is defined in the **SetpointManagerScheduledSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; in the **SetpointManagerScheduledDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint; or in the **SetpointManagerOutdoorAirReset** table, if setpointManagerType = OutdoorAirReset (**14**);
- commonPipeSimulation – 'None' (default, if blank), 'CommonPipe' or 'TwoWayCommonPipe'. CommonPipe and TwoWayCommonPipe specify a primary-secondary plant loop simulation: the plant side of the loop is the primary loop and the demand side of the loop is the secondary loop, and a pump object must be placed on the demand side inlet branch (see section **9.4.1** for details);
- twoWayCommonPipeSPNodeLoopSide – 'Plant' or 'Demand'. "Plant" sets the Plant Side Inlet Node as the setpoint node to control the two-way common pipe, and "Demand" sets the Demand Side Inlet Node as the setpoint node to control the two-way common pipe. Only used if commonPipeSimulation = TwoWayCommonPipe;
- twoWayCommonPipeSetpointManagerType – defines the Setpoint Manager type for the two-way common pipe. Currently, 'ScheduledSingleSetpoint', and 'ScheduledDualSetpoint' are available (see section **14** for details). Only used if commonPipeSimulation = TwoWayCommonPipe;
- twoWayCommonPipeSetpointManagerID – ID of the Setpoint Manager assigned to the two-way common pipe simulation, which is defined in the **SetpointManagerScheduledSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; or in the **SetpointManagerScheduledDualSetpoint** table, if setpointManagerType = ScheduledDualSetpoint (**14**). Only used if commonPipeSimulation = TwoWayCommonPipe;
- pressureSimulationType – 'None' (default, if blank), 'PumpPowerCorrection' or 'LoopFlowCorrection';
- loopCirculationTime – loop circulation time in minutes (default = 2 min, if blank);
- sizingPlantID – ID of the sizing plant object assigned to this loop (see section **13.2.4**), required if autosized fields are used.

Automatic filling fields in EnergyPlus:

- Name – loopName + loopID:

    - loopName – loop name assigned in the loop specification (first argument of the PlantLoopSpec() above);
    - loopID – automatically assigned to each loop added;
- User Defined Fluid Type – user defined fluid name, if used (see section **9.7**);
- Plant Equipment Operation Scheme Name – name of the Operation Scheme assigned to this loop – OperationSchemeName = LoopName&ID + "Operation_Scheme" (see section **9.5.4**);
- Loop Temperature Setpoint Node Name – automatically defined as the plant side branch outlet node of the current loop (outlet node of the last equipment in the plant side branch – see section **9.3**). This is the node assigned to the setpoint manager (**14**);
- Plant Side Inlet Node Name – name of the Plant Side Inlet Node of the current loop (inlet node of the first equipment in the plant side branch – see section **9.3**);
- Plant Side Outlet Node Name – name of the Plant Side Outlet Node of the current loop (outlet node of the last equipment in the plant side branch – see section **9.3**);
- Plant Side Branch List Name – name of the Plant Side Branch List (list of all the branches assigned to the plant side of the current loop – see section **9.3**);
- Plant Side Connector List Name – name of the Plant Side Connector List (list of all the connectors assigned to the plant side of the current loop – see section **9.3**);
- Demand Side Inlet Node Name – name of the Demand Side Inlet Node of the current loop (inlet node of the first equipment in the demand side branch – see section **9.3**);
- Demand Side Outlet Node Name – name of the Demand Side Outlet Node of the current loop (outlet node of the last equipment in the demand side branch – see section **9.3**);
- Demand Side Branch List Name – name of the Demand Side Branch List (list of all the branches assigned to the demand side of the current loop – see section **9.3**);
- Demand Side Connector List Name – name of the Demand Side Connector List (list of all the connectors assigned to the demand side of the current loop – see section **9.3**);
- Availability Manager List Name – name of the Availability Manager List assigned to this loop – AvailabManagerListName = LoopName&ID + "Availability_Manager", if used*.

The specification of the loop equipment is defined in the SAPTool_LSP building template, as presented in section **9.3**.

The specification of the loop operation scheme is defined in the SAPTool_LSP building template, as presented in section **9.5**.

*The specification of the loop availability managers, if assigned, is defined in the SAPTool_LSP building template, as presented in section **9.6**.

Finally, the loop (pls) must be added to the HVAC detailed systems specifications in the SAPTool_LSP building template, as follows:

hVACSpec.addPlantLoopSpec(pls)

If more than one loop is required, the above methodology should be repeated and the new loop(s) should also be added to the HVAC detailed systems specifications (hVACSpec in this example).

9.2. Condenser Loop

The specification of each loop is defined in the SAPTool_LSP building template, as follows:

CondenserLoopSpec cls = new CondenserLoopSpec() – loop specification (named cls in this example). With the following CondenserLoopSpec() arguments:

- **DBHVACCondenserLoopType.ABC.toString()** – loop name/type, defined using the DBHVACCondenserLoopType list object (‘ABC’, in this case). Alternatively, a string can be directly inputted here (e.g., **“ABC”**);
- **DBHVACCondenserLoopType.ABC.getID()** – ID of the Condenser Loop properties in the database, defined using the DBHVACCondenserLoopType list object (ID of ‘ABC’, in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The condenser loop properties are defined in the **CondenserLoop** table in the database, corresponding to the CondenserLoop object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- fluidType – ‘Water’ or ‘UserDefinedFluidType’;
- userDefinedFluidID – user defined fluid ID, defined in the **UserDefinedFluid** table in the database (see section **9.7**). Used only if fluidType = UserDefinedFluidType;
- maximumLoopTemperature – maximum loop temperature in Celsius;
- minimumLoopTemperature – minimum loop temperature in Celsius;
- maximumLoopFlowRate – maximum loop flow rate in m3/s. ‘autosize’ option is available;
- minimumLoopFlowRate – minimum loop flow rate in m3/s;
- condenserLoopVolume – volume of the condenser loop in m3. ‘autocalculate’ option is available, and sets the loop volume to the product of the maximumLoopFlowRate and the user input for loopCirculationTime which defaults to 2 minutes;
- loadDistributionScheme – ‘Optimal’, ‘SequentialLoad’, ‘UniformLoad’, ‘SequentialUniformPLR’ or ‘UniformPLR’;
- pressureSimulationType – ‘None’ (default, if blank), ‘PumpPowerCorrection’ or ‘LoopFlowCorrection’;
- loopCirculationTime – loop circulation time in minutes (default = 2 min, if blank);
- setpointManagerType – defines the Setpoint Manager type for the loop. Currently, ‘ScheduledSingleSetpoint’ and ‘FollowOutdoorAirTemperature’ are available for a condenser loop (see section **14** for details);
- setpointManagerID – ID of the Setpoint Manager assigned to the loop, which is defined in the **SetpointManagerScheduledSingleSetpoint** table, if setpointManagerType = ScheduledSingleSetpoint; or in the **Setpoint Manager Follow Outdoor Air Temperature** table, if setpointManagerType = FollowOutdoorAirTemperature (**14**);
- sizingPlantID – ID of the sizing plant object assigned to this loop (see section **13.2.4**), required if autosized fields are used.

Automatic filling fields in EnergyPlus:

- Name – loopName + loopID:
  - loopName – loop name assigned in the loop specification (first argument of the CondenserLoopSpec() above);
  - loopID – automatically assigned to each loop added;
- User Defined Fluid Type – user defined fluid name, if used (see section **9.7**);
- Condenser Equipment Operation Scheme Name – name of the Operation Scheme assigned to this loop – OperationSchemeName = LoopName&ID + "Operation_Scheme" (see section **9.5.4**);
- Condenser Loop Temperature Setpoint Node Name – automatically defined as the condenser side branch outlet node of the current loop (outlet node of the last equipment in the condenser side branch – see section **9.3**). This is the node assigned to the setpoint manager (**14**);
- Condenser Side Inlet Node Name – name of the Condenser Side Inlet Node of the current loop (inlet node of the first equipment in the condenser side branch – see section **9.3**);
- Condenser Side Outlet Node Name – name of the Condenser Side Outlet Node of the current loop (outlet node of the last equipment in the condenser side branch – see section **9.3**);
- Condenser Side Branch List Name – name of the Condenser Side Branch List (list of all the branches assigned to the condenser side of the current loop – see section **9.3**);
- Condenser Side Connector List Name – name of the Condenser Side Connector List (list of all the connectors assigned to the condenser side of the current loop – see section **9.3**);
- Demand Side Inlet Node Name – name of the Demand Side Inlet Node of the current loop (inlet node of the first equipment in the demand side branch – see section **9.3**);
- Demand Side Outlet Node Name – name of the Demand Side Outlet Node of the current loop (outlet node of the last equipment in the demand side branch – see section **9.3**);
- Condenser Demand Side Branch List Name – name of the Condenser Demand Side Branch List (list of all the branches assigned to the demand side of the current loop – see section **9.3**);
- Condenser Demand Side Connector List Name – name of the Condenser Demand Side Connector List (list of all the connectors assigned to the demand side of the current loop – see section **9.3**).

The specification of the loop equipment is defined in the SAPTool_LSP building template, as presented in section **9.3**.

The specification of the loop operation scheme is defined in the SAPTool_LSP building template, as presented in section **9.5**.

Finally, the loop (cls) must be added to the HVAC detailed systems specifications in the SAPTool_LSP building template, as follows:

hVACSpec.addPlantLoopSpec(cls)

If more than one loop is required, the above methodology should be repeated and the new loop(s) should also be added to the HVAC detailed systems specifications (hVACSpec in this example).

9.3. Loop equipment branches

The specification of the loop equipment is defined in the SAPTool_LSP building template, as presented in section **8**.

If the same equipment type (with the same specifications/definitions) is required multiple times in a loop (or loops), it only needs to be specified once. Each time the same component is added, a new ID is assigned to it, depending on the equipment position on the equipment list (and on the loop for which it is assigned). Therefore, one can add the same equipment multiple times, while needing to specify it only once.

Every time an equipment is defined, a corresponding branch object is automatically assigned, with each individual equipment corresponding to one branch object. This corresponds to the Branch object in EnergyPlus, for which all fields are automatically filled:

- Name – equipmentName + “Branch”;
- Pressure Drop Curve Name – name of the pressure drop curve assigned to the equipment, if any;
- Component 1 Object Type – equipment type;
- Component 1 Name – equipmentName;
- Component 1 Inlet Node Name – equipmentName + “Inlet_node”;
- Component 1 Outlet Node Name – equipmentName + “Outlet_node”;
- As the current code is defined, each equipment corresponds to a branch object, therefore, the remaining Component X fields are not used.

The specified equipment can then be added to the plant and demand sides of a plant loop in the SAPTool_LSP building template, as follows:

pls.addPlantSideBranchEquipment(XX) – equipment XX* assignment to the plant side of the loop pls (example of the loop defined in section **9.1**)

pls.addDemandSideBranchEquipment(XX) – equipment XX* assignment to the demand side of the loop pls (example of the loop defined in section **9.1**)

* XX represents the selected equipment specification object. Examples of specification objects defined in the previous sections (with the specification names which were assigned in the correspondent sections):

- Pipe Adiabatic (**8.1.1**): **pipeAdiabaticSpec**;
- Pipe Adiabatic Steam (**8.1.2**): **pipeAdiabaticSteamSpec**;
- Pipe Indoor (**8.1.3**): **pipeIndoorSpec**;
- Pipe Outdoor (**8.1.4**): **pipeOutdoorSpec**;
- Pipe Underground (**8.1.5**): **pipeUndergroudSpec**;

- Pump Constant Speed (**8.2.1**): **pumpConstantSpeedSpec**;
- Pump Variable Speed (**8.2.2**): **pumpVariableSpeedSpec**;
- Pump Variable Speed Condensate (**8.2.3**): **pumpVariableSpeedCondensateSpec**;
- Tempering Valve (**8.3**): **temperingValveSpec**;
- Solar Collector Flat Plate Water (**8.4.1**): **solarCollectorSpec**;
- Boiler Hot Water (**8.5.1**): **boilerHotWaterSpec**;
- Boiler Steam (**8.5.2**): **boilerSteamSpec**;
- Chiler Electric EIR (**8.5.3**): **chillerElectricEIRSideSpec**;
- Chiler Electric (**8.5.4**): **chillerElectricSideSpec**;
- Chiler Constant COP (**8.5.5**): **chillerConstantCOPSideSpec**;
- District Heating (**8.5.6**): **districtHeatingSpec**;
- District Cooling (**8.5.7**): **districtCoolingSpec**;
- Cooling Tower Single Speed (**8.6.1.1**): **coolingTowerSingleSpeedSpec**;
- Cooling Tower Two Speed (**8.6.1.2**): **coolingTowerTwoSpeedSpec**;
- Cooling Tower Variable Speed (**8.6.1.3**): **coolingTowerVariableSpeedSpec**;
- Heat Exchanger Fluid-to-Fluid (**8.6.2.1**): **heatExchangerFluidToFluidSpec**;
- Water Heater Mixed (**8.7.1**): **waterHeaterMixedSideSpec**;
- Zone HVAC Low Temperature Radiant Variable Flow (**7.1.2**): **PlantLoopZoneEquipmentType.RADIANT_ELEMENTS**;
- Zone HVAC Baseboard Convective Water (**7.1.3**): **PlantLoopZoneEquipmentType.BASEBOARD_CONVECTIVE_WATER**;
- Zone HVAC Four Pipe Fan Coil (**7.1.4**): **PlantLoopZoneEquipmentType.FOUR_PIPE_FANCOIL**;
- Zone HVAC Packaged Terminal Air Conditioner (**7.1.5.1**): **PlantLoopZoneEquipmentType.PACKAGED_TERMINAL_AIR_CONDITIONER**
- Zone HVAC Packaged Terminal Heat Pump (**7.1.5.2**): **PlantLoopZoneEquipmentType.PACKAGED_TERMINAL_HEAT_PUMP**;
- Zone HVAC Terminal Unit Variable Refrigerant Flow (**7.1.7**): **PlantLoopZoneEquipmentType.TERMINAL_UNIT_VRF**;
- Zone HVAC Water-to-Air Heat Pump (**7.1.6**): **PlantLoopZoneEquipmentType.WATER_TO_AIR_HEAT_PUMP**;
- Water Use Connections (**5.2**): **waterUseConnectionsSpec**;
- Air Loop HVAC coil or recovery (heat recovery, cooling coil, heating coil, supplemental heating coil or reheat coil) (**7.1.8.2**, **7.1.8.3**, **10.2**, **10.4**, **10.5.1**): **airLoopSystemAndElementType**;
- Air Conditioner Variable Refrigerant Flow (with water cooled condenser) (**11**): **acVRFSpec**.

The specified equipment can then be added to the condenser and demand sides of a condenser loop in the SAPTool_LSP building template, as follows:

cls.addCondenserSideBranchEquipment(XX) – equipment XX** assignment to the condenser side of the loop cls (example of the loop defined in section **9.2**)

cls.addDemandSideBranchEquipment(XX) – equipment XX** assignment to the demand side of the loop cls (example of the loop defined in section **9.2**)

** XX represents the selected equipment specification object. Examples of specification objects defined in the previous sections (with the specification names which were assigned in the correspondent sections):

- Pipe Adiabatic (**8.1.1**): **pipeAdiabaticSpec**;
- Pipe Indoor (**8.1.3**): **pipeIndoorSpec**;
- Pipe Outdoor (**8.1.4**): **pipeOutdoorSpec**;
- Pipe Underground (**8.1.5**): **pipeUndergroudSpec**;
- Pump Constant Speed (**8.2.1**): **pumpConstantSpeedSpec**;
- Pump Variable Speed (**8.2.2**): **pumpVariableSpeedSpec**;
- Chiler Electric EIR (**8.5.3**): **chillerElectricEIRSideSpec**;
- Chiler Electric (**8.5.4**): **chillerElectricSideSpec**;
- Chiler Constant COP (**8.5.5**): **chillerConstantCOPSideSpec**;
- Cooling Tower Single Speed (**8.6.1.1**): **coolingTowerSingleSpeedSpec**;
- Cooling Tower Two Speed (**8.6.1.2**): **coolingTowerTwoSpeedSpec**;
- Cooling Tower Variable Speed (**8.6.1.3**): **coolingTowerVariableSpeedSpec**;
- Heat Exchanger Fluid-to-Fluid (**8.6.2.1**): **heatExchangerFluidToFluidSpec**.

Each pls.addPlantSideBranchEquipment(XX), pls.addDemandSideBranchEquipment(XX), cls.addCondenserSideBranchEquipment(XX) or cls.addDemandSideBranchEquipment(XX) entry represents a new component (branch object) addition to the selected loop side (plant, plant demand, condenser or condenser demand, respectively). Therefore, the user must assign the number and type of components corresponding to the desired equipment number and type on each side of the loop. The order by which the components are added in each side represents the equipment order in each loop side. This defines the loop's plant/condenser side and plant/condenser demand side branch lists, which correspond to the BranchList object in EnergyPlus, where all fields are automatically filled, as follows:

- Name – loopName&ID + plantSide + "Branches" (plantSide = 'PLANT', 'CONDENSER' or 'DEMAND');
- Branch X Name – name of the equipment added to the current loop side, by order of addition.

The loop's plant side and demand side branch list names are then assigned to the 'Plant Side Branch List Name' and 'Demand Side Branch List Name', respectively, in the Plant Loop specification (see section **9.1**); and the loop's condenser side and condenser demand side branch list names are then assigned to the 'Condenser Side Branch List Name' and 'Condenser Demand Side Branch List Name', respectively, in the Condenser Loop specification (see section **9.2**).

In each loop side branch, the first equipment added corresponds to the inlet branch, the last equipment added corresponds to the outlet branch, and the remaining equipment correspond to parallel stream branches between the inlet and outlet branches. This is automatically defined and corresponds to the Connector:Splitter and Connector:Mixer objects in EnergyPlus, where all fields are automatically filled, as follows:

Connector:Splitter

- Name – loopName&ID + plantSide + “Branches” + “Splitter” (plantSide = ‘PLANT’, ‘CONDENSER’ or ‘DEMAND’);
- Inlet Branch Name – branch name of the first equipment in the current loop side;
- Outlet Branch X Name – branch name of the second to second to last equipment in the current loop side.

<u>Connector:Mixer</u>

- Name – loopName&ID + plantSide + “Branches” + “Mixer” (plantSide = ‘PLANT’, ‘CONDENSER’ or ‘DEMAND’);
- Outlet Branch Name – branch name of the last equipment in the current loop side;
- Inlet Branch X Name – branch name of the second to second to last equipment in the current loop side.

Consequently, a connector list for each loop side is automatically defined, and their names assigned to the ‘Plant Side Connector List Name’ and ‘Demand Side Connector List Name’ in the Plant Loop specification (see section **9.1**), and to the ‘Condenser Side Connector List Name’ and ‘Condenser Demand Side Connector List Name’ in the Condenser Loop specification (see section **9.2**). This corresponds to the ConnectorList object in EnergyPlus, where all fields are automatically filled, as follows:

- Name – loopName&ID + plantSide + “Connectors” (plantSide = ‘PLANT’, ‘DEMAND’ or ‘CONDENSER’);
- Connector 1 Object Type – ‘Connector:Splitter’;
- Connector 1 Name – name of the Connector Splitter object for the current loop side;
- Connector 2 Object Type – ‘Connector:Mixer;
- Connector 2 Name – name of the Connector Mixer object for the current loop side.

Notice that a steam plant loop (fluidType = Steam in section **9.1**) requires dedicated steam equipment: Boiler Steam (**8.5.2**), Pipe Adiabatic Steam (**8.1.2**), and Pump Variable Speed Condensate (**8.2.3**).

A Water Heater Mixed equipment may require to be assigned to two loops (a source loop and a use loop). In this case, the Water Heater Mixed specifications must be added to the plant side of both loops (a water heater is always a plant side equipment) in the SAPTool_LSP building template, as follows:

- **pls1.addPlantSideBranchEquipment(waterHeaterMixedSide1Spec)** – assigns the specification of the linkage between the water heater and its loop sides (waterHeaterMixedSide1Spec, in this example) to the loop pls1. If pls1 is the source loop for the water heater, WaterHeaterSideType.Source needs to be defined in the second argument of WaterHeaterMixedSideSpec() for the waterHeaterMixedSide1Spec; otherwise, if pls1 is the use loop for the water heater, WaterHeaterSideType.Use needs to be defined;
- **pls2.addPlantSideBranchEquipment(waterHeaterMixedSide2Spec)** – assigns the specification of the linkage between the water heater and its loop sides (waterHeaterMixedSide2Spec, in this example) to the loop pls2. If pls2 is the source loop

for the water heater, WaterHeaterSideType.Source needs to be defined in the second argument of WaterHeaterMixedSideSpec() for the waterHeaterMixedSide2Spec; otherwise, if pls2 is the use loop for the water heater, WaterHeaterSideType.Use needs to be defined.

Moreover, for a two-loops water heater, two branch objects are defined: a source branch (with the source side inlet and outlet nodes) and a use branch (with the use side inlet and outlet nodes).

A chiller may require to be assigned to two loops (a chilled water plant loop and a condenser loop) if its condenser is water cooled. Moreover, the chillers electric (**8.5.4**) and electric EIR (**8.5.3**) may be assigned to a third loop – heat recovery plant loop. In these cases, the chiller specifications must be added to the plant/condenser or demand sides of the respective loops in the SAPTool_LSP building template, as follows (example for a chiller electric assigned to three loops (chilled water, condenser and heat recovery) – first argument of the ChillerElectricSideSpec(): NumberOfLoopSidesType.ThreeSides):

- Chilled water plant loop – pls1:
  pls1.addPlantSideBranchEquipment(chillerElectricEIRSide1Spec) – assigns the specification of the linkage between the chiller and its loop sides (chillerElectricEIRSide1Spec, in this example) to the plant side of pls1 (a chiller is always in the plant side of chilled water plant loops). In this case, ChillerSideType.Chiller needs to be defined in the second argument of ChillerElectricSideSpec() for the chillerElectricEIRSide1Spec;
- Heat recovery plant loop – pls2:
  pls2.addDemandSideBranchEquipment(chillerElectricEIRSide2Spec) – assigns the specification of the linkage between the chiller and its loop sides (chillerElectricEIRSide2Spec, in this example) to the demand side of pls2 (a chiller is always in the demand side of heat recovery plant loops). In this case, ChillerSideType.HeatRecovery needs to be defined in the second argument of ChillerElectricSideSpec() for the chillerElectricEIRSide2Spec;
- Condenser loop – cls1:
  cls1.addDemandSideBranchEquipment(chillerElectricEIRSide3Spec) – assigns the specification of the linkage between the chiller and its loop sides (chillerElectricEIRSide3Spec, in this example) to the demand side of cls1 (a chiller is always in the demand side of condenser loops). In this case, ChillerSideType.Condenser needs to be defined in the second argument of ChillerElectricSideSpec() for the chillerElectricEIRSide3Spec.

Moreover, for a n-loops chiller, n branch objects are defined, each with an inlet and an outlet node.

Examples of a one-loop radiant floor system and a two-loops domestic hot water solar thermal system (solar collectors + water heater + water use connections) can be found in ANNEX A and ANNEX B, respectively. Example of a stand-alone water heater can be found in ANNEX C.

9.4. Primary and secondary loops

There are two ways to specify primary-secondary loops: the Common pipe method (**9.4.1**) and the Heat exchanger method (**9.4.2**).

9.4.1. Common pipe method

This method is <u>only</u> valid for plant loops (**9.1**). In the **PlantLoop** table in the database, if commonPipeSimulation = CommonPipe or TwoWayCommonPipe, a primary-secondary plant loop simulation is specified, with the plant side of the loop as the primary loop and the demand side of the loop as the secondary loop. In addition, <u>a pump object must be placed on the demand side inlet branch</u> (in addition to the pump object in the supply/primary side).

“CommonPipe” means that the common pipe interface does not attempt any temperature control; it only satisfies secondary (demand side) flow requests. “TwoWayCommonPipe” allows control of the secondary (demand side) inlet temperature or the primary (plant side) inlet temperature by placing a setpoint on the corresponding node. Therefore, a setpoint node must be defined in the primary/plant side inlet node (‘Plant’) or in the secondary/demand side inlet node (‘Demand’), using the twoWayCommonPipeSPNodeLoopSide field in the **PlantLoop** table in the database. In addition, a setpoint manager must be defined for this node, using the twoWayCommonPipeSetpointManagerType and twoWayCommonPipeSetpointManagerID fields in the **PlantLoop** table in the database.

An example of this arrangement (with a two-way common pipe) can be found in the cooling loop in the SingleStoreyFamilyHouse_HVAC_Fancoils_DOAS_HotColdCndWaterLoops template in the SAPTool_LSP.

9.4.2. Heat exchanger method

This method is valid for both plant and condenser loops. It requires two loops to be specified: one as the primary loop and the other as the secondary loop. The loops are then coupled using a fluid-to-fluid heat exchanger (**8.6.2.1**), which couples the supply side of one plant or condenser loop to the demand side of another plant or condenser loop.

One side of the heat exchanger (“Loop Supply Side”) must be connected to the supply side of one loop and the other side (“Loop Demand Side”) connected to the demand side of a different loop. The heat exchanger is intended to act as a supply component for the loop connected to it as the “Loop Supply Side” and as a demand component for the loop connected to it as the “Loop Demand Side”.

An example of this arrangement can be found in the heating loops in the SingleStoreyFamilyHouse_HVAC_Fancoils_DOAS_HotColdCndWaterLoops template in the SAPTool_LSP.

9.5. Plant and Condenser Equipment Operation Scheme

Only plant side equipment (in plant loops) and condenser side equipment (in condenser loops) are listed on a control scheme for the objects Plant Equipment Operation Schemes and Condenser Equipment Operation Schemes, respectivelly. Currently, there are three operation scheme types implemented: Heating Load, Cooling Load, and Uncontrolled. The user should assign the selected operation scheme type(s) to the desired plant side and condenser side equipment in the SAPTool_LSP building template, as follows:

9.5.1. Heating Load

PlantEquipmentOperationHeatingLoadSpec peohls = new PlantEquipmentOperationHeatingLoadSpec() – Heating Load operation scheme specification (named peohls in this example). With the following PlantEquipmentOperationHeatingLoadSpec() argument:

- **new ScheduleSpec(DBScheduleType.SCH1.getID(), db)** – operation scheme schedule ID in the database db, defined using the DBScheduleType list object ("SCH1", in this example).

The equipment list and its load ranges are assigned to this operation scheme as follows:

peohls.addLoadEquipment(new LoadEquipment(new int[]{x, y ,…}, a, b)) – {x, y, …} represents the selected equipment IDs (only loop plant side or condenser side equipment), according to the order for which they are assigned to the plant or condenser side branch (see section **9.3**) – the first equipment is 0, the second equipment is 1, etc. (at least one equipment needs to be assigned to this list); a represents the Load Range Lower Limit (double type input); and b represents the Load Range Upper Limit (double type input).

The equipment list {x, y, …} corresponds to the PlantEquipmentList or CondenserEquipmentList object in EnergyPlus (depending on the loop type), where all the fields are automatically filled, according to the equipment listed:

- Name – OperSchemeListName = "LST" + OperationSchemeName + HeatLoadSchemeID (HeatLoadSchemeID – ID of each Heating Load scheme list added to peohls);
- Equipment X Object Type – equipment X type;
- Equipment X Name – equipment X name.

The Heating Load scheme type corresponds to the PlantEquipmentOperation:HeatingLoad object in EnergyPlus, where all the fields are automatically filled, according to inputs above:

- Name – OperationSchemeTypeName = OperationSchemeName + "OP" + ControlSchemeID (ControlSchemeID – ID of each control scheme added to pls – see section **9.5.4**);
- Load Range 1 Lower Limit – value a assigned above;
- Load Range 1 Upper Limit – value b assigned above;
- Range 1 Equipment List Name – OperSchemeListName;
- …

- One ranged is added (with its 3 fields) for each equipment list added to peohls.

To add more equipment lists, with different load ranges, to this control scheme type, one should simply add them to peohls, as follows (note that the same equipment ID can be assigned to more than one list, however care should be taken for the load range limit values do not overlap):

peohls.addLoadEquipment(new LoadEquipment(new int[]{…}, …, …))

9.5.2. Cooling Load

PlantEquipmentOperationCoolingLoadSpec peocls = new PlantEquipmentOperationCoolingLoadSpec () – Cooling Load operation scheme specification (named peocls in this example). With the following PlantEquipmentOperationHeatingLoadSpec() argument:

- **new ScheduleSpec(DBScheduleType.SCH2.getID(), db)** – operation scheme schedule ID in the database db, defined using the DBScheduleType list object ("SCH2", in this example).

The equipment list and its load ranges are assigned to this operation scheme as follows:

peocls.addLoadEquipment(new LoadEquipment(new int[]{x, y ,…}, a, b)) – {x, y, …} represents the selected equipment IDs (only loop plant side or condenser side equipment), according to the order for which they are assigned to the plant or condenser side branch (see section **9.3**) – the first equipment is 0, the second equipment is 1, etc. (at least one equipment needs to be assigned to this list); a represents the Load Range Lower Limit (double type input); and b represents the Load Range Upper Limit (double type input).

To add more equipment lists, with different load ranges, to this control scheme type, one should simply add them to peocls, as follows (note that the same equipment ID can be assigned to more than one list, however care should be taken for the load range limit values do not overlap):
peocls.addLoadEquipment(new LoadEquipment(new int[]{…}, …, …))

The equipment list {x, y, …} corresponds to the PlantEquipmentList or CondenserEquipmentList object in EnergyPlus (depending on the loop type), where all the fields are automatically filled, according to the equipment listed:

- Name – OperSchemeListName = "LST" + OperationSchemeName + CoolLoadSchemeID (CoolLoadSchemeID – ID of each Cooling Load scheme list added to peocls);
- Equipment X Object Type – equipment X type;
- Equipment X Name – equipment X name.

The Cooling Load scheme type corresponds to the PlantEquipmentOperation:CoolingLoad object in EnergyPlus, where all the fields are automatically filled, according to inputs above:

- Name – OperationSchemeTypeName = OperationSchemeName + “OP” + ControlSchemeID (ControlSchemeID – ID of each control scheme added to pls – see section **9.5.4**);
- Load Range 1 Lower Limit – value a assigned above;
- Load Range 1 Upper Limit – value b assigned above;
- Range 1 Equipment List Name – OperSchemeListName;
- …
- One ranged is added (with its 3 fields) for each equipment list added to peocls.

9.5.3. Uncontrolled

PlantEquipmentOperationUncontrolledSpec peous = new PlantEquipmentOperationUncontrolledSpec() – Uncontrolled operation scheme specification (named peous in this example). With the following PlantEquipmentOperationUncontrolledSpec() arguments:

- **new int[]{x, y, …}** – {x, y, …} represents the selected equipment IDs (only loop plant side or condenser side equipment), according to the order for which they are assigned to the plant or condenser side branch (see section **9.3**) – the first equipment is 0, the second equipment is 1, etc. (at least one equipment needs to be assigned to this list);
- **new ScheduleSpec(DBScheduleType.SCH3.getID(), db)** – operation scheme schedule ID in the database db, defined using the DBScheduleType list object (“SCH3”, in this example).

The equipment list {x, y, …} corresponds to the PlantEquipmentList or CondenserEquipmentList object in EnergyPlus (depending on the loop type), where all the fields are automatically filled, according to the equipment listed:

- Name – OperSchemeListName = “LST” + OperationSchemeName;
- Equipment X Object Type – equipment X type;
- Equipment X Name – equipment X name.

The Uncontrolled scheme type corresponds to the PlantEquipmentOperation:Uncontrolled object in EnergyPlus, where all the fields are automatically filled, according to inputs above:

- Name – OperationSchemeTypeName = OperationSchemeName + “OP” + ControlSchemeID (ControlSchemeID – ID of each control scheme added to pls – see section **9.5.4**);
- Equipment List Name – OperSchemeListName.

9.5.4. Operation Schemes

Each loop requires, at least, one control scheme to be assigned to it (multiple control schemes can be assigned). The order for which they are assigned defines the control priority order. The control schemes are assigned to the loop in the SAPTool_LSP building template, as follows (example where the three above defined control schemes are assigned to the same loop):

- **pls.addPlantEquipmentOperation(peohls)** – assigns the peohls operation scheme type (Heating Load type, defined in section **9.5.1**) to the loop pls (Note: **cls.addCondenserEquipmentOperation(peohls)** – assigns the peohls operation scheme type to the loop cls);
- **pls.addPlantEquipmentOperation(peocls)** – assigns the peocls operation scheme type (Cooling Load type, defined in section **9.5.2**) to the loop pls (Note: **cls.addCondenserEquipmentOperation(peocls)** – assigns the peocls operation scheme type to the loop cls);
- **pls.addPlantEquipmentOperation(peous)** – assigns the peous operation scheme type (Uncontrolled type, defined in section **9.5.3**) to the loop pls (Note: **cls.addCondenserEquipmentOperation(peous)** – assigns the peous operation scheme type to the loop cls).

When defining multiple control schemes, care should be taken regarding the control priority order and if there are no overlapping schedules or ranges, if for the same equipment different control schemes are assigned. Also, to each control scheme corresponds a ControlSchemeID.

This corresponds to the PlantEquipmentOperationSchemes or CondenserEquipmentOperationSchemes object in EnergyPlus (depending on the loop type), where all the fields are automatically filled, according to above input:

- Name – OperationSchemeName = LoopName&ID + “Operation_Scheme”;
- Control Scheme X Object Type – PlantEquipmentOperation:HeatingLoad, PlantEquipmentOperation:CoolingLoad or PlantEquipmentOperation:Uncontrolled;
- Control Scheme X Name – OperationSchemeTypeName of control scheme X;
- Control Scheme X Schedule Name – schedule assigned to the operation scheme type X;
- …
- One control scheme is added (with its 3 fields – type, name and schedule name) for each control scheme added to pls or cls.

9.6. Availability Manager

Currently, there are five availability manager types implemented to be assigned to a plant loop: High Temperature Turn On (**15.2**), High Temperature Turn Off (**15.3**), Low Temperature Turn On (**15.4**), Low Temperature Turn Off (**15.5**), and Differential Thermostat (**15.6**).

The availability managers must be assigned to the loop (to each availability manager corresponds an AvailabManagerID), as follows (example where the five above defined availability managers are assigned to the same loop):

- **pls.addAvailabilityManager(amhtton)** – assigns the amhtton availability manager (High Temperature Turn On, defined in section **15.2**) to the loop pls;
- **pls.addAvailabilityManager(amhttoff)** – assigns the amhttoff availability manager (High Temperature Turn Off, defined in section **15.3**) to the loop pls;

- **pls.addAvailabilityManager(amltton)** – assigns the amltton availability manager (Low Temperature Turn On, defined in section **15.4**) to the loop pls;
- **pls.addAvailabilityManager(amlttoff)** – assigns the amlttoff availability manager (Low Temperature Turn Off, defined in section **15.5**) to the loop pls;
- **pls.addAvailabilityManager(amdt)** – assigns the amdt availability manager (Differential Thermostat, defined in section **15.6**) to the loop pls.

9.7. User Defined Fluid

The User Defined Fluid properties are defined in the **UserDefinedFluid** table in the database, corresponding to the FluidPropertied:GlycolConcentration object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – fluid name;
- glycolType – 'EthyleneGlycol' or 'PropyleneGlycol';
- glycolConcentration – glycol concentration.

10. AIR LOOP HVAC

The air loop structure is mainly defined in the SAPTool_LSP building templates (SAPTool_LSP>SourcePacakges>lsp.templates), while the properties for each object are defined in the database. The Air Loop HVAC option must be active (**AIR_LOOP_HVAC = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The HVAC detailed systems specifications must be defined in the SAPTool_LSP building template, as follows:

HVACSpec hVACSpec = new HVACSpec()

The hVACSpec must then be assigned to the layout specifications object (LayoutSpecs(), in its second to last argument), in the end of the SAPTool_LSP building template.

10.1. Air Loop HVAC System

The specification of each air loop is defined in the SAPTool_LSP building template, as follows:

AirLoopHVACSpec airLoopHVACSpec = new AirLoopHVACSpec() – air loop specification (named airLoopHVACSpec in this example). With the following AirLoopHVACSpec() arguments:

- **DBAirLoopHVACType.ABC.toString()** – air loop name, defined using the DBAirLoopHVACType list object ('ABC', in this case). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **DBAirLoopHVACType.ABC.getID()** – ID of the Air Loop HVAC properties in the database, defined using the DBAirLoopHVACType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The air loop properties are defined in the **AirLoopHVAC** table in the database, corresponding to the AirLoopHVAC object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- designSupplyAirFlowRate – system primary air design volumetric flow rate [m^3/s];
- designReturnAirFlowFractionOfSupplyAirFlow – design air loop return air flow rate as a fraction of the supply flow rate when there is no exhaust flow;
- sizingSystemID – ID of the sizing system object assigned to this air loop (see section **13.2.3**), required if autosized fields are used;
- coilHeatingSetpointManagerType – defines the Setpoint Manager type for the heating coil outlet node, in the case a heating coil is assigned to the air loop and a unitary system is not assigned to the air loop. If the air loop comprises a unitary system, the unitary system is controlled by its own setpoint managers. Currently, the available types are 'ScheduledSingleSetpoint and 'ScheduledDualSetpoint' (see section **14** for details);
- coilHeatingSetpointManagerID – ID of the Setpoint Manager assigned in the previous field, which is defined in the **setpointManagerSingleSetpoint** table, if

coilHeatingSetpointManagerType = ScheduledSingleSetpoint; or in the **setpointManagerDualSetpoint** table, if coilHeatingSetpointManagerType = ScheduledDualSetpoint (**14**);

- coilCoolingSetpointManager1Type – defines the Setpoint Manager type for the cooling coil outlet node, in the case a cooling coil is assigned to the air loop and a unitary system is not assigned to the air loop. If the air loop comprises a unitary system, the unitary system is controlled by its own setpoint managers. Currently, the available types are 'ScheduledSingleSetpoint', 'ScheduledDualSetpoint' and 'Warmest' (see section **14** for details);
- coilCoolingSetpointManager1ID – ID of the Setpoint Manager assigned in the previous field, which is defined in the **setpointManagerSingleSetpoint** table, if coilCoolingSetpointManager1Type = ScheduledSingleSetpoint; in the **setpointManagerDualSetpoint** table, if coilCoolingSetpointManager1Type = ScheduledDualSetpoint; or in the **setpointManagerWarmest** table, if coilCoolingSetpointManager1Type = Warmest (**14**);
- coilCoolingSetpointManager2Type – defines an additional Setpoint Manager type for the cooling coil outlet node (*e.g.*, to define a humidity setpoint in addition to the temperature setpoint[16]), in the case a cooling coil is assigned to the air loop and a unitary system is not assigned to the air loop. If the air loop comprises a unitary system, the unitary system is controlled by its own setpoint managers. Currently, the available types are 'ScheduledSingleSetpoint' and 'ScheduledDualSetpoint' (see section **14** for details);
- coilCoolingSetpointManager2ID – ID of the Setpoint Manager assigned in the previous field, which is defined in the **setpointManagerSingleSetpoint** table, if coilCoolingSetpointManager2Type = ScheduledSingleSetpoint; or in the **setpointManagerDualSetpoint** table, if coilCoolingSetpointManager2Type = ScheduledDualSetpoint (**14**);
- outletSetpointManagerType – if an Outdoor Air System (**10.5**) is assigned to the air loop, a corresponding Setpoint Manager Mixed Air (**14.9**) is automatically defined. In this case, its reference setpoint node is the air loop outlet node, for which the temperature setpoint should be set by a setpoint manager defined in this field. Currently, the available types are 'ScheduledSingleSetpoint' and 'ScheduledDualSetpoint' (see section **14** for details). <u>However</u>, if the air loop outlet node corresponds to the outlet node of a cooling or heating coil, for which the correspondent setpoint managers are already assigned in the previous fields, or if the air loop comprises a unitary system, which is controlled by its own setpoint managers, this field is not used;
- outletSetpointManagerID – ID of the Setpoint Manager assigned in the previous field, which is defined in the **setpointManagerScheduledSingleSetpoint** table, if outletSetpointManagerType = ScheduledSingleSetpoint or in the **setpointManagerScheduledDualSetpoint** table, if outletSetpointManagerType = ScheduledDualSetpoint (**14**);

[16] If a Cooling Coil DX Two Speed with Humidity Control Mode (**8.9.1.5**) is assigned to the air loop, a Cooling Coil System containing the selected coil is automatically defined and assigned to the air loop. In that case, if the coilSystemDehumidificationControlType is other that 'None' (in the coil specifications), a setpoint manager must be assigned to the coil to define the humidity setpoint, besides the setpoint manager assigned to define the temperature setpoint.

- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve defines the pressure drop across all the equipment assigned to the air loop;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – airLoopName = name assigned in the air loop specification (first argument of the AirLoopHVACSpec() above);
- Controller List Name – name of a controller list comprising the controls for the water coils directly assigned to the air loop (refer to the water coils in section **8.9** for details). null if no water coils are assigned;
- Availability Manager List Name – name of the availability manager list*;
- Branch List Name – name of the branch list defined in section **10.2**;
- Connector List Name – null, as the entire air loop is defined in a single branch (as presented in section **10.2**);
- Supply Side Inlet Node Name – airLoopName + "Air_Loop_Inlet_Node”;
- Demand Side Outlet Node Name – airLoopName + "Return_Air_Node";
- Demand Side Inlet Node Name – airLoopName + "Supply_Path_Inlet_Node";
- Supply Side Outlet Node Name – name of the outlet node of the last component assigned to the air loop (**10.2**).

The air loop components are assigned to the loop as presented in section **10.2**.

* The availability manager, if defined, must be assigned to the air loop, as follows:

airLoopHVACSpec.addAvailabilityManager(ams) – assigns the ams availability manager to the air loop airLoopHVACSpec. Currently, there are two availability manager types implemented that can be used by an air loop: Scheduled (**15.1**) and Night Cycle (**15.7**).

Finally, the air loop (airLoopHVACSpec) must be added to the HVAC detailed systems specifications in the SAPTool_LSP building template, as follows:

hVACSpec.addAirLoopHVACSpec(airLoopHVAC1Spec)

If more than one air loop is required, the above methodology should be repeated and the new loop(s) should also be added to the HVAC detailed systems specifications (hVACSpec in this example).

Examples of this air loop object usage can be found in the SingleStoreyFamilyHouse_HVAC_UnitarySystem_HotWaterLoop and SingleStoreyFamilyHouse_HVAC_VAV_Reheat_HotColdWaterLoops templates in the SAPTool_LSP:

- HVAC_UnitarySystem_HotWaterLoop – air loop comprising a return fan, an outdoor air system, a unitary system, and a humidifier, to supply zone air terminal single duct uncontrolled units. The outdoor air system contains a heat exchanger, the unitary system comprises a supply fan, heating, cooling and supplemental heating coils, and the heating coil is connected to a hot water plant loop;

- HVAC_VAV_Reheat_HotColdWaterLoops – air loop comprising an outdoor air system, a main heating coil, a main cooling coil, and a supply fan, to supply zone air terminal single duct VAV reheat units. The outdoor air system contains pre-heating and pre-cooling coils, and some of the heating coils are connected to a hot water plant loop and some of the cooling coils are connected to a chilled water plant loop.

10.2. Air Loop Branch Components

The air loop corresponds to a single air branch, with each equipment assigned corresponding to its branch components. The components are assigned as follows:

airLoopHVACSpec.addComponentList(XX) – equipment XX assignment to the air loop specification (defined in section **10.1**). XX represents the selected equipment specification object. Examples of specification objects currently available (with the specification names which were assigned in the correspondent sections):

- Return or supply fan (only a Fan constant volume (**8.8.3**) or a fan variable volume (**8.8.4**) are accepted): **bedroomsSupplyFanSpec**;
- Outdoor air system (**10.5**): **outdoorAirSystemSpec**;
- Unitary system (**10.4.1**): **livingRoomAirLoopHVACUnitarySystemSpec**;
- Heating Coil DX Single Speed (**8.9.2.1**)[17], Heating Coil DX Variable Speed (**8.9.2.3**)[17], Heating Coil Electric (**8.9.2.6**), Heating Coil Fuel (**8.9.2.8**), Heating Coil Water (**8.9.2.10**)[18] or Heating Coil Steam (**8.9.2.11**)[18]: **heatingCoilSpec**;
- Cooling Coil DX Single Speed (**8.9.1.1**)[19], Cooling Coil DX Two Speed (**8.9.1.2**)[19], Cooling Coil DX Variable Speed (**8.9.1.4**)[19], Cooling Coil DX Two Speed with Humidity Control Mode (**8.9.1.5**)[19], Cooling Coil Water (**8.9.1.9**)[20] or Cooling Coil Water Detailed Geometry (**8.9.1.10**)[20]: **coolingCoilSpec**;
- Humidifier (Electric Steam (**8.10.1**) or Gas Steam (**8.10.2**)): **humidifierSpec**.

Each airLoopHVACSpec.addComponentList(XX) represents a new component addition to the air loop. Therefore, the user must assign the number and type of components corresponding to the desired equipment number and type. The order by which the components are added represents the equipment order in the air loop, thus defining the air loop branch order. This corresponds to the Branch object in EnergyPlus, for which all fields are automatically filled:

- Name – airBranchName = airLoopName + "Branch";
- Pressure Drop Curve Name – name of the pressure drop curve assigned to the air loop, if any (pressureDropCurveID field in the **AirLoopHVAC** table in the database – see section **10.1**);

[17] If a Heating Coil DX is assigned to the air loop, a Heating Coil System containing the selected coil is automatically defined and assigned to the air loop branch.

[18] If a Heating Coil Water or Steam is assigned to the air loop, it must also be assigned to a plant loop for heat source – see section Connection to a plant loop below.

[19] If a Cooling Coil DX is assigned to the air loop, a Cooling Coil System containing the selected coil is automatically defined and assigned to the air loop branch.

[20] If a Cooling Coil Water is assigned to the air loop, it must also be assigned to a plant loop for chilled water source – see section Connection to a plant loop below.

- Component X Object Type – type of equipment assigned to the air loop;
- Component X Name – equipment names associated with the equipment types of the previous field;
- Component X Inlet Node Name – equipment inlet nodes associated with the equipment names;
- Component X Outlet Node Name – equipment outlet nodes associated with the equipment names.

This air branch is automatically assigned to a Branch List, which corresponds to the BranchList object in EnergyPlus, where all fields are automatically filled, as follows:

- Name – airLoopName + "BranchList";
- Branch 1 Name – airBranchName defined above;
- The remaining Branch Names are not used.

Connection to a plant loop

If the heating coil assigned to the air loop is a water or steam coil or if the cooling coil assigned to the air loop is a water coil, it must be assigned to a plant loop for heat/cold source (hot/chilled water loop or steam loop, depending on the coil type). This is defined in the SAPTool_LSP building template, as follows:

AirLoopSystemAndElementType airLoopSystemAndElementType = new AirLoopSystemAndElementType() – air loop system and element type specification (named airLoopSystemAndElementType in this example). With the following AirLoopSystemAndElementType() arguments:

- **x1** – name of the Air Loop HVAC specification to which the unitary system is assigned (airLoopName);
- **AirLoopSystemAndElementType.AirLoopHVACSystemType.XX** – system type, defined with the AirLoopHVACSystemType list object. In this case, XX = **AIR_LOOP**;
- **x2** – air terminal zone ID, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Used only if a zone air terminal component is defined in the previous field. Otherwise, **null**;
- **AirLoopSystemAndElementType.ElementType.XX** – element type for which the plant loop is assigned, defined with the ElementType list object: XX = **COOLING_COIL**, **HEATING_COIL**, **SUPPLEMENTAL_HEATING_COIL**, **REHEAT_COIL** or **HEAT_RECOVERY**. In this case = **HEATING_COIL** or **COOLING_COIL**.

The air loop system and element type specification name (airLoopSystemAndElementType, in this example) must then be assigned to the proper loop branch, as shown in section **9.3**. A branch object is automatically assigned to the element type together with its pressure drop curve, if defined (see section **9.3** for details).

Notice that for each element type assignment to a plant loop, a different air loop system and element type specification must be defined.

10.3. Air Loop Paths

The Air Loop HVAC supplies air for each of the zone HVAC air terminals assigned to it. The air terminals are assigned to the air loops by including the air loop name (defined in section **10.1**) in the argument x1 of the air terminal unit specification.

The air loop supply path is split for all the zone units assigned to it using a zone splitter object. This corresponds to the AirLoopHVAC:ZoneSplitter object in EnergyPlus, where all fields are automatically filled, as follows:

- Name – zoneSplitterName = airLoopName + "Zone_Splitter";
- Inlet Node Name – Demand Side Inlet Node Name of the Air Loop HVAC (airLoopName + "Supply_Path_Inlet_Node" – see section **10.1**);
- Outlet X Node Name – inlet node names of the air terminal units assigned to the air loop. If the air terminal unit has only an outlet node (zone supply air node) (e.g., the Zone HVAC Air Terminal Single Duct Uncontrolled unit), that is the node here assigned.

The air loop supply path is defined with a supply path object, corresponding to the AirLoopHVAC:SupplyPath object in EnergyPlus, where all fields are automatically filled, as follows:

- Name – airLoopName + "Supply_Path";
- Supply AirPath Inlet Node Name – Demand Side Inlet Node Name of the Air Loop HVAC (airLoopName + "Supply_Path_Inlet_Node" – see section **10.1**);
- Component 1 Object Type – AirLoopHVAC:ZoneSplitter;
- Component 1 Name – zoneSplitterName defined above;
- The components 2-25 are not used.

The return air from the zones which have terminal units assigned to the air loop is mixed in the air loop return path using a zone mixer object. This corresponds to the AirLoopHVAC:ZoneMixer object in EnergyPlus, where all fields are automatically filled, as follows:

- Name – zoneMixerName = airLoopName + "Zone_Mixer";
- Outlet Node Name – Demand Side Outlet Node Name of the Air Loop HVAC (airLoopName + " Return_Air_Node" – see section **10.1**);
- Inlet X Node Name – Zone Return Air Node Names of each of the zones which have terminal units assigned to the air loop (zoneName + "RETURN_NODE").

The air loop return path is defined with a return path object, corresponding to the AirLoopHVAC:ReturnPath object in EnergyPlus, where all fields are automatically filled, as follows:

- Name – airLoopName + "Return_Path";
- Return AirPath Outlet Node Name – Demand Side Outlet Node Name of the Air Loop HVAC (airLoopName + " Return_Air_Node" – see section **10.1**);

- Component 1 Object Type – AirLoopHVAC:ZoneMixer;
- Component 1 Name – zoneMixerName defined above;
- The components 2-25 are not used.

10.4. Unitary Systems

10.4.1. System

The specification of the Air Loop HVAC Unitary System is defined in the SAPTool_LSP building template, as follows:

AirLoopHVACUnitarySystemSpec livingRoomAirLoopHVACUnitarySystemSpec = new AirLoopHVACUnitarySystemSpec() – unitary system specification (named livingRoomAirLoopHVACUnitarySystemSpec in this example). With the following AirLoopHVACUnitarySystemSpec() arguments:

- **x1** – ID of the Control or Thermostat Zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. It <u>also</u> defines the humidistat control zone, used when dehumidificationControlType ≠ None (or null) in the **AirLoopHVACUnitarySystem** table in the database (see below);
- **x2** – if dehumidificationControlType ≠ None (or null) in the **AirLoopHVACUnitarySystem** table in the database (see below), the ID of the humidistat control zone in the **Zone** table (zoneControlHumidistatID in section **0**) must be defined here (corresponding to the zone defined in argument x1), using the DBSpaceType list object (for example, **DBSpaceType.LIVING_ROOM.getID()** to assign the humidistat to the Living Room zone). Alternatively, the proper database ID can be directly inputted here. **null** if not defined;
- **FanPlacementType.XX.toString()** – fan placement type, defined using the FanPlacementType list object. XX = 'BlowThrough' or 'DrawThrough';
- **x3** – name of the supply fan specification assigned to this system (optional), which is defined in section **8.8**. **null** if not assigned;
- **x4** – name of the heating coil specification assigned to this system (optional), which is defined in section **8.9.2**. **null** if not assigned;
- **x5** – name of the cooling coil specification assigned to this system (optional), which is defined in section **8.9.1**. **null** if not assigned;
- **x6** – name of the supplemental heating coil specification assigned to this system (optional), which is defined in section **8.9.2**. **null** if not assigned;
- **DBAirLoopHVACUnitarySystemType.ABC.getID()** – ID of the unitary system properties in the database, defined using the DBAirLoopHVACUnitarySystemType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The unitary system properties are defined in the **AirLoopHVACUnitarySystem** table in the database, corresponding to the AirLoopHVAC:UnitarySystem object in EnergyPlus. The following fields are present in the table:

- id – object ID;

- controlType – ‘Load’, ‘SetPoint’ or ‘SingleZoneVAV’. SingleZoneVAV is only valid with coolingCoilType = CoilCoolingWater or CoilCoolingDXSingleSpeed, and heatingCoilType = CoilHeatingWater, CoilHeatingFuel, CoilHeatingElectric or CoilHeatingDXSingleSpeed. SetPoint control requires set points at each coil (assigned in the coil setpoint manager fields below);
- dehumidificationControlType – ‘None’, ‘Multimode’ or ‘CoolReheat’. None is required if controlType = SingleZoneVAV. Multimode is only valid with coolingCoilType = CoilCoolingDXTwoStageWithHumidityControlMode;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the unitary system is always available;
- supplyAirFanOperatingModeScheduleID – fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). If blank, constant fan mode is assigned for the entire simulation period. Constant fan mode is required if controlType = SingleZoneVAV. This field is not used if controlType = SetPoint;
- dxHeatingCoilSizingRatio – used to adjust heat pump heating capacity with respect to DX cooling capacity. Used only for DX heat pump configurations (i.e., a DX cooling and heating coil is used);
- useDOASdxCoolingCoil – ‘Yes’ or ‘No’. No should be specified when controlType = SingleZoneVAV;
- minimumSupplyAirTemperature – if useDOASdxCoolingCoil = Yes, this field defines the minimum DOAS DX cooling coil leaving air temperature that should be maintained to avoid frost formation. If controlType = SingleZoneVAV, enter the minimum air temperature limit for reduced fan speed in cooling mode. ‘autosize’ option is available if controlType = SingleZoneVAV;
- latentControlLoad – ‘SensibleOnlyLoadControl’, ‘LatentOnlyLoadControl’, ‘LatentWithSensibleLoadControl’ or ‘LatentOrSensibleLoadControl’;
- coolingSupplyAirFlowRateMethod – ‘None’, ‘SupplyAirFlowRate’, ‘FlowPerFloorArea’, ‘FractionOfAutosizedCoolingValue’ or ‘FlowPerCoolingCapacity’;
- coolingSupplyAirFlowRate – supply air flow rate leaving the unitary system when the cooling coil is operating [m^3/s]. Required if coolingSupplyAirFlowRateMethod = SupplyAirFlowRate. ‘autosize’ option is available;
- coolingSupplyAirFlowRatePerFloorArea – supply air flow rate per floor area leaving the unitary system when the cooling coil is operating [$m^3/(s.m^2)$]. Required if coolingSupplyAirFlowRateMethod = FlowPerFloorArea;
- coolingFractionOfAutosizedCoolingSupplyAirFlowRate – fraction of autosized supply air flow rate leaving the unitary system when the cooling coil is operating. Required if coolingSupplyAirFlowRateMethod = FractionOfAutosizedCoolingValue;
- coolingSupplyAirFlowRatePerUnitOfCapacity – supply air flow rate per unit of capacity leaving the unitary system when the cooling coil is operating [$m^3/(s.W)$]. Required if coolingSupplyAirFlowRateMethod = FlowPerCoolingCapacity;
- heatingSupplyAirFlowRateMethod – ‘None’, ‘SupplyAirFlowRate’, ‘FlowPerFloorArea’, ‘FractionOfAutosizedHeatingValue’ or ‘FlowPerHeatingCapacity’;
- heatingSupplyAirFlowRate – supply air flow rate leaving the unitary system when the heating coil is operating [m^3/s]. Required if heatingSupplyAirFlowRateMethod = SupplyAirFlowRate. ‘autosize’ option is available;

- heatingSupplyAirFlowRatePerFloorArea – supply air flow rate per floor area leaving the unitary system when the heating coil is operating [$m^3/(s.m^2)$]. Required if heatingSupplyAirFlowRateMethod = FlowPerFloorArea;
- heatingFractionOfAutosizedHeatingSupplyAirFlowRate – fraction of autosized supply air flow rate leaving the unitary system when the heating coil is operating. Required if heatingSupplyAirFlowRateMethod = FractionOfAutosizedHeatingValue;
- heatingSupplyAirFlowRatePerUnitOfCapacity – supply air flow rate per unit of capacity leaving the unitary system when the heating coil is operating [$m^3/(s.W)$]. Required if heatingSupplyAirFlowRateMethod = FlowPerHeatingCapacity;
- noLoadSupplyAirFlowRateMethod – 'None', 'SupplyAirFlowRate', 'FlowPerFloorArea', 'FractionOfAutosizedCoolingValue', 'FractionOfAutosizedHeatingValue', 'FlowPerCoolingCapacity' or 'FlowPerHeatingCapacity';
- noLoadSupplyAirFlowRate – supply air flow rate leaving the unitary system when neither cooling or heating is required (i.e., main cooling/heating coils and supplemental heater are off but the supply air fan operates) [m^3/s]. This field is only used when the unitary system operating mode is specified as continuous fan operation. Required if noLoadSupplyAirFlowRateMethod = SupplyAirFlowRate. 'autosize' option is available;
- noLoadSupplyAirFlowRatePerFloorArea – supply air flow rate per floor area leaving the unitary system when neither cooling or heating coil is operating [$m^3/(s.m^2)$]. Required if noLoadSupplyAirFlowRateMethod = FlowPerFloorArea;
- noLoadFractionOfAutosizedCoolingSupplyAirFlowRate – fraction of autosized supply air flow rate leaving the unitary system when neither cooling or heating coil is operating. Required if noLoadSupplyAirFlowRateMethod = FractionOfAutosizedCoolingValue;
- noLoadFractionOfAutosizedHeatingSupplyAirFlowRate – fraction of autosized supply air flow rate leaving the unitary system when neither cooling or heating coil is operating. Required if noLoadSupplyAirFlowRateMethod = FractionOfAutosizedHeatingValue;
- noLoadSupplyAirFlowRatePerUnitOfCapacityDuringCoolingOperation – supply air flow rate per unit of capacity leaving the unitary system when neither cooling or heating is operating. Required if noLoadSupplyAirFlowRateMethod = FlowPerCoolingCapacity;
- noLoadSupplyAirFlowRatePerUnitOfCapacityDuringHeatingOperation – supply air flow rate per unit of capacity leaving the unitary system when neither cooling or heating is operating. Required if noLoadSupplyAirFlowRateMethod = FlowPerHeatingCapacity;
- maximumSupplyAirTemperature – design operating air outlet temperature when the unitary system is heating [°C]. When controlType = SingleZoneVAV, enter the maximum air temperature limit for reduced fan speed in heating model. 'autosize' option is available;
- maximumOutdoorDryBulbTemperatureForSupplementalHeaterOperation – outdoor air dry-bulb temperature above which the heat pump supplemental heating coil is disabled [°C];
- maximumCyclingRate – maximum on-off cycling rate for the compressor, which occurs at 50% run time fraction [cycles/h]. Suggested values depending on the heat pump condition: good/typical - 2.5, poor - 3.0;
- heatPumpTimeConstant – time constant for the cooling coil's capacity to reach steady state after startup [s]. Suggested values depending on the heat pump condition: good/typical - 60, poor - 60;
- fractionOfOnCyclePowerUse – fraction of on-cycle power use to adjust the part load fraction based on the off-cycle power consumption due to crankcase heaters, controls,

fans, etc. Suggested values depending on the heat pump condition: good/typical - 2.5, poor - 3.0;

- heatPumpFanDelayTime – time delay for the heat pump supply air fan to shut off after the compressor cycles off [s]. Enter a value of zero when the heat pump's fan operating mode is continuous;
- ancillaryOnCycleElectricPower – ancillary electrical power consumed during the on-cycle period (i.e., when the cooling or heating coil is operating) [W];
- ancillaryOffCycleElectricPower – ancillary electrical power consumed during the off-cycle period (i.e., when the cooling and heating coils are not operating) [W];
- designHeatRecoveryWaterFlowRate – design water flow rate used if the heat recovery option is being simulated (optional). If this value is greater than 0.0 then a heat recovery loop must be specified (see section Connection to a plant loop below);
- maximumTemperatureForHeatRecovery – maximum temperature that this heat pump can produce for heat recovery [°C];
- unitarySystemPerformanceMultispeedID – ID of the unitary system performance multispeed object assigned to the unitary system, which is defined in the **UnitarySystemPerformanceMultispeed** table (see below), which is required when a multispeed cooling and/or heating coil is specified;
- systemSetpointManagerType – defines the Setpoint Manager type for the entire unitary system, if controlType ≠ SetPoint. Currently, 'SingleZoneCooling' and 'SingleZoneHeating' are available for a unitary system (see section **14** for details);
- systemSetpointManagerID – ID of the Setpoint Manager assigned to the unitary system. It is defined in the **SetpointManagerSingleZoneCooling** table, if systemSetpointManagerType = SingleZoneCooling; or in the **SetpointManagerSingleZoneHeating** table, if systemSetpointManagerType = SingleZoneHeating (**14**);
- heatingCoilSetpointManagerType – defines the Setpoint Manager type for the heating coil (if existent), if controlType = SetPoint. Currently, 'SingleZoneCooling' and 'SingleZoneHeating' are available for a unitary system coil (see section **14** for details);
- heatingCoilSetpointManagerID – ID of the Setpoint Manager assigned to the heating coil. It is defined in the **SetpointManagerSingleZoneCooling** table, if heatingCoilSetpointManagerType = SingleZoneCooling; or in the **SetpointManagerSingleZoneHeating** table, if heatingCoilSetpointManagerType = SingleZoneHeating (**14**);
- coolingCoilSetpointManagerType – defines the Setpoint Manager type for the cooling coil (if existent), if controlType = SetPoint. Currently, 'SingleZoneCooling' and 'SingleZoneHeating' are available for a unitary system coil (see section **14** for details);
- coolingCoilSetpointManagerID – ID of the Setpoint Manager assigned to the cooling coil. It is defined in the **SetpointManagerSingleZoneCooling** table, if coolingCoilSetpointManagerType = SingleZoneCooling; or in the **SetpointManagerSingleZoneHeating** table, if coolingCoilSetpointManagerType = SingleZoneHeating (**14**);
- supplementalHeatingCoilSetpointManagerType – defines the Setpoint Manager type for the supplemental heating coil (if existent), if controlType = SetPoint. Currently, 'SingleZoneCooling' and 'SingleZoneHeating' are available for a unitary system coil (see section **14** for details);

- supplementalHeatingCoilSetpointManagerID – ID of the Setpoint Manager assigned to the supplemental heating coil. It is defined in the **SetpointManagerSingleZoneCooling** table, if supplementalHeatingCoilSetpointManagerType = SingleZoneCooling; or in the **SetpointManagerSingleZoneHeating** table, if supplementalHeatingCoilSetpointManagerType = SingleZoneHeating (**14**);
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve defines the pressure drop across the unitary system only in the case it is assigned to a heat recovery loop (see section Connection to a plant loop below);
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – unitarySystemName = airLoopName + "Unitary_System" (airLoopName – name of the air loop for which this unitary system is assigned);
- Controlling Zone or Thermostat Location – zone name defined in the argument x1 of the AirLoopHVACUnitarySystemSpec() above;
- Air Inlet Node Name – air outlet node of the equipment upstream of the unitary system in the air loop. If the unitary system is the first equipment in the air loop: airLoopName + "Air_Loop_Inlet_Node";
- Air Outlet Node Name – unitarySystemName + "Outlet_node";
- Supply Fan Object Type – supply fan type assigned in the argument x3 of the AirLoopHVACUnitarySystemSpec() above, if any;
- Supply Fan Name – name of the supply fan assigned in the argument x3 of the AirLoopHVACUnitarySystemSpec() above, if any;
- Fan Placement – fan placement type, defined with the FanPlacementType object in the AirLoopHVACUnitarySystemSpec() above;
- Heating Coil Object Type – heating coil type assigned in the argument x4 of the AirLoopHVACUnitarySystemSpec() above, if any;
- Heating Coil Name – name of the heating coil assigned in the argument x4 of the AirLoopHVACUnitarySystemSpec() above, if any;
- Cooling Coil Object Type – cooling coil type assigned in the argument x5 of the AirLoopHVACUnitarySystemSpec() above, if any;
- Cooling Coil Name – name of the cooling coil assigned in the argument x5 of the AirLoopHVACUnitarySystemSpec() above, if any;
- Supplemental Heating Coil Object Type – supplemental heating coil type assigned in the argument x6 of the AirLoopHVACUnitarySystemSpec() above, if any;
- Supplemental Heating Coil Name – name of the supplemental heating coil assigned in the argument x6 of the AirLoopHVACUnitarySystemSpec() above, if any;
- Outdoor Dry-Bulb Temperature Sensor Node Name – considered null for the outdoor air temperature which controls the operation of the supplemental heating coil to be taken directly from the weather data;
- Heat Recovery Water Inlet Node Name – unitarySystemName + "Heat_Recovery_Inlet_node", only in the case that the unitary system is assigned to a heat recovery loop (see section Connection to a plant loop below);

- Heat Recovery Water Outlet Node Name – unitarySystemName + “Heat_Recovery_Outlet_node”, only in the case that the unitary system is assigned to a heat recovery loop (see section Connection to a plant loop below);

If controlType = SetPoint and dehumidificationControlType ≠ None, a Single Zone Humidity Maximum Setpoint Manager (**14.6**) is automatically defined for each coil, in order to control the maximum humidity level of the zone assigned in arguments x1 and x2 of the AirLoopHVACUnitarySystemSpec() above (see section **10.6**).

The multispeed performance properties for the unitary system are defined in the **UnitarySystemPerformanceMultispeed** table in the database, corresponding to the UnitarySystemPerformance:Multispeed object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- numberOfSpeedsForHeating – 1 to 10;
- numberOfSpeedsForCooling – 1 to 10;
- singleModeOperation – ‘Yes’ or ‘No’;
- noLoadSupplyAirFlowRateRatio – no load operating air flow rate ratio when the system fan is specified to operate continuously;
- heatingSpeed<x>SupplyAirFlowRatio – ratio of supply air flow rate leaving the unitary system to the maximum air flow rate specified in the coil object at maximum speed when the heating coil is operating at Speed <x>;
- coolingSpeed<x>SupplyAirFlowRatio – ratio of supply air flow rate leaving the unitary system to the maximum air flow rate specified in the coil object at maximum speed when the cooling coil is operating at Speed <x>;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – unitarySystemName + "Performance_Multispeed".

Connection to a plant loop

If heatingCoilType or supplementalHeatingCoilType = CoilHeatingWater or CoilHeatingSteam or coolingCoilType = CoilCoolingWater, the coil must be assigned to a plant loop for heat/cold source (hot/chilled water loop or steam loop, depending on the coil type). Also, if designHeatRecoveryWaterFlowRate is greater than 0.0, then the unitary system must be assigned to a heat recovery loop. This is defined in the SAPTool_LSP building template, as follows:

AirLoopSystemAndElementType airLoopSystemAndElementType = new AirLoopSystemAndElementType() – air loop system and element type specification (named airLoopSystemAndElementType in this example). With the following AirLoopSystemAndElementType() arguments:

- **x1** – name of the Air Loop HVAC specification to which the unitary system is assigned (airLoopName);

- **AirLoopSystemAndElementType.AirLoopHVACSystemType.XX** – system type, defined with the AirLoopHVACSystemType list object. In this case, XX = **UNITARY_SYSTEM**;
- **x2** – air terminal zone ID, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Used only if a zone air terminal component is defined in the previous field. Otherwise, **null**;
- **AirLoopSystemAndElementType.ElementType.XX** – element type for which the plant loop is assigned, defined with the ElementType list object: XX = **COOLING_COIL**, **HEATING_COIL**, **SUPPLEMENTAL_HEATING_COIL**, **REHEAT_COIL** or **HEAT_RECOVERY**.

The air loop system and element type specification name (airLoopSystemAndElementType, in this example) must then be assigned to the proper loop branch, as shown in section **9.3**. A branch object is automatically assigned to the element type together with its pressure drop curve, if defined (see section **9.3** for details).

Notice that for each element type assignment to a plant loop, a different air loop system and element type specification must be defined.

An example of the air loop unitary system usage with connection to a plant loop usage can be found in the SingleStoreyFamilyHouse_HVAC_UnitarySystem_HotWaterLoop template in the SAPTool_LSP.

10.4.2. Heat Pump Air-to-Air

The specification of the Air Loop HVAC Unitary Heat Pump Air-to-Air is defined in the SAPTool_LSP building template, as follows:

AirLoopHVACUnitaryHeatPumpAirToAirSpec livingRoomAirLoopHVACUnitaryHPSpec = new AirLoopHVACUnitaryHeatPumpAirToAirSpec() – unitary heat pump specification (named livingRoomAirLoopHVACUnitaryHPSpec in this example). With the following AirLoopHVACUnitaryHeatPumpAirToAirSpec() arguments:

- **x1** – ID of the Control or Thermostat Zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. It <u>also</u> defines the humidistat control zone, used when dehumidificationControlType ≠ None (or null) in the **AirLoopHVACUnitaryHeatPumpAirToAir** table in the database (see below);
- **x2** – if dehumidificationControlType ≠ None (or null) in the **AirLoopHVACUnitaryHeatPumpAirToAir** table in the database (see below), the ID of the humidistat control zone in the **Zone** table (zoneControlHumidistatID in section **0**) must be defined here (corresponding to the zone defined in argument x1), using the DBSpaceType list object (for example, **DBSpaceType.LIVING_ROOM.getID()** to assign the humidistat to the Living Room zone). Alternatively, the proper database ID can be directly inputted here. **null** if not defined;
- **FanPlacementType.XX.toString()** – fan placement type, defined using the FanPlacementType list object. XX = 'BlowThrough' or 'DrawThrough';
- **x3** – name of the supply fan specification assigned to this system, which is defined in section **8.8**;
- **x4** – name of the heating coil specification assigned to this system, which is defined in section **8.9.2**;

- **x5** – name of the cooling coil specification assigned to this system, which is defined in section **8.9.1**.;
- **x6** – name of the supplemental heating coil specification assigned to this system, which is defined in section **8.9.2**;
- **DBAirLoopHVACUnitaryHeatPumpAirToAirType.ABC.getID()** – ID of the unitary heat pump properties in the database, defined using the DBAirLoopHVACUnitaryHeatPumpAirToAirType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The unitary heat pump properties are defined in the **AirLoopHVACUnitaryHeatPumpAirToAir** table in the database, corresponding to the AirLoopHVAC:Unitary:HeatPump:AirToAir object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the unitary system is always available;
- coolingSupplyAirFlowRate – supply air flow rate leaving the furnace when the DX cooling coil is operating [m3/s]. 'autosize' option is available;
- heatingSupplyAirFlowRate – supply air flow rate leaving the furnace when the DX heating coil and/or supplemental heater are operating [m3/s]. 'autosize' option is available;
- noLoadSupplyAirFlowRate – supply air flow rate leaving the furnace when neither cooling or heating is required (i.e., DX coils and supplemental heater are off but the supply air fan operates) [m3/s]. This field is only used when the furnace operating mode is specified as continuous fan operation. 'autosize' option is available;
- maximumSupplyAirTemperatureFromSupplementalHeater – maximum allowed supply air temperature exiting the heat pump supplemental heating coil [°C]. 'autosize' option is available;
- maximumOutdoorDryBulbTemperatureForSupplementalHeaterOperation – outdoor air dry-bulb temperature above which the heat pump supplemental heating coil is disabled [°C]. The temperature for this input field must be less than or equal to 21 °C;
- supplyAirFanOperatingModeScheduleID – fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). 0 – the furnace supply air fan and the heating or cooling coil cycle on and off together to meet the heating or cooling load (auto fan). ≠ 0 – the supply fan runs continuously while the heating or cooling coil cycles to meet the load;
- dehumidificationControlType – 'None', 'Multimode' or 'CoolReheat'. Multimode is only valid with coolingCoilType = CoilSystemCoolingDXHeatExchangerAssisted (not yet implemented);
- setpointManagerType – defines the Setpoint Manager type for the unitary heat pump. Currently, 'SingleZoneCooling' and 'SingleZoneHeating' are available for a unitary heat pump (see section **14** for details);
- setpointManagerID – ID of the Setpoint Manager assigned to the unitary heat pump. It is defined in the **SetpointManagerSingleZoneCooling** table, if setpointManagerType = SingleZoneCooling; or in the **SetpointManagerSingleZoneHeating** table, if setpointManagerType = SingleZoneHeating (**14**);

- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – unitaryHPName = airLoopName + “Unitary_Heat_Pump_Air_Air” (airLoopName – name of the air loop for which this unitary system is assigned);
- Air Inlet Node Name – air outlet node of the equipment upstream of the unitary heat pump in the air loop. If the unitary heat pump is the first equipment in the air loop: airLoopName + "Air_Loop_Inlet_Node";
- Air Outlet Node Name – unitaryHPName + “Outlet_node”;
- Controlling Zone or Thermostat Location – zone name defined in the argument x1 of the AirLoopHVACUnitaryHeatPumpAirToAirSpec() above;
- Supply Fan Object Type – supply fan type assigned in the argument x3 of the AirLoopHVACUnitaryHeatPumpAirToAirSpec() above;
- Supply Fan Name – name of the supply fan assigned in the argument x3 of the AirLoopHVACUnitaryHeatPumpAirToAirSpec() above;
- Heating Coil Object Type – heating coil type assigned in the argument x4 of the AirLoopHVACUnitaryHeatPumpAirToAirSpec() above;
- Heating Coil Name – name of the heating coil assigned in the argument x4 of the AirLoopHVACUnitaryHeatPumpAirToAirSpec() above;
- Cooling Coil Object Type – cooling coil type assigned in the argument x5 of the AirLoopHVACUnitaryHeatPumpAirToAirSpec() above;
- Cooling Coil Name – name of the cooling coil assigned in the argument x5 of the AirLoopHVACUnitaryHeatPumpAirToAirSpec() above;
- Supplemental Heating Coil Object Type – supplemental heating coil type assigned in the argument x6 of the AirLoopHVACUnitaryHeatPumpAirToAirSpec() above;
- Supplemental Heating Coil Name – name of the supplemental heating coil assigned in the argument x6 of the AirLoopHVACUnitaryHeatPumpAirToAirSpec() above;
- Fan Placement – fan placement type, defined with the FanPlacementType object in the AirLoopHVACUnitaryHeatPumpAirToAirSpec() above.

Connection to a plant loop

If supplementalHeatingCoilType = CoilHeatingWater or CoilHeatingSteam, the coil must be assigned to a plant loop for heat source (hot water loop or steam loop, depending on the coil type). This is defined in the SAPTool_LSP building template, as follows:

AirLoopSystemAndElementType airLoopSystemAndElementType = new AirLoopSystemAndElementType() – air loop system and element type specification (named airLoopSystemAndElementType in this example). With the following AirLoopSystemAndElementType() arguments:

- **x1** – name of the Air Loop HVAC specification to which the unitary furnace is assigned (airLoopName);
- **AirLoopSystemAndElementType.AirLoopHVACSystemType.XX** – system type, defined with the AirLoopHVACSystemType list object. In this case, XX = **UNITARY_HEAT_PUMP_AIR_TO_AIR**;

- **x2** – air terminal zone ID, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Used only if a zone air terminal component is defined in the previous field. Otherwise, **null**;
- **AirLoopSystemAndElementType.ElementType.XX** – element type for which the plant loop is assigned, defined with the ElementType list object: XX = **COOLING_COIL**, **HEATING_COIL**, **SUPPLEMENTAL_HEATING_COIL**, **REHEAT_COIL** or **HEAT_RECOVERY**. In this case = **SUPPLEMENTAL_HEATING_COIL**.

The air loop system and element type specification name (airLoopSystemAndElementType, in this example) must then be assigned to the proper loop branch, as shown in section **9.3**. A branch object is automatically assigned to the element type together with its pressure drop curve, if defined (see section **9.3** for details).

Notice that for each element type assignment to a plant loop, a different air loop system and element type specification must be defined.

An example of the air loop unitary heat pump usage with connection to a plant loop usage can be found in the SingleStoreyFamilyHouse_HVAC_Unitary_HP_AirToAir template in the SAPTool_LSP.

10.4.3. Furnace Heat Cool

The specification of the Air Loop HVAC Unitary Furnace Heat Cool is defined in the SAPTool_LSP building template, as follows:

AirLoopHVACUnitaryFurnaceHeatCoolSpec livingRoomAirLoopHVACUnitaryFurnaceSpec = new AirLoopHVACUnitaryFurnaceHeatCoolSpec() – unitary furnace specification (named livingRoomAirLoopHVACUnitaryFurnaceSpec in this example). With the following AirLoopHVACUnitaryFurnaceHeatCoolSpec() arguments:

- **x1** – ID of the Control or Thermostat Zone, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. It <u>also</u> defines the humidistat control zone, used when dehumidificationControlType ≠ None (or null) in the **AirLoopHVACUnitaryFurnaceHeatCool** table in the database (see below);
- **x2** – if dehumidificationControlType ≠ None (or null) in the **AirLoopHVACUnitaryFurnaceHeatCool** table in the database (see below), the ID of the humidistat control zone in the **Zone** table (zoneControlHumidistatID in section **0**) must be defined here (corresponding to the zone defined in argument x1), using the DBSpaceType list object (for example, **DBSpaceType.LIVING_ROOM.getID()** to assign the humidistat to the Living Room zone). Alternatively, the proper database ID can be directly inputted here. **null** if not defined;
- **FanPlacementType.XX.toString()** – fan placement type, defined using the FanPlacementType list object. XX = ‘BlowThrough’ or ‘DrawThrough’;
- **x3** – name of the supply fan specification assigned to this system, which is defined in section **8.8**;
- **x4** – name of the heating coil specification assigned to this system, which is defined in section **8.9.2**;

- **x5** – name of the cooling coil specification assigned to this system, which is defined in section **8.9.1**.;
- **x6** – name of the reheat coil specification assigned to this system (optional), which is defined in section **8.9.2**. **null** if not assigned;
- **DBAirLoopHVACUnitaryFurnaceHeatCoolType.ABC.getID()** – ID of the unitary furnace properties in the database, defined using the DBAirLoopHVACUnitaryFurnaceHeatCoolType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The unitary furnace properties are defined in the **AirLoopHVACUnitaryFurnaceHeatCool** table in the database, corresponding to the AirLoopHVAC:Unitary:Furnace:HeatCool object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the unitary system is always available;
- supplyAirFanOperatingModeScheduleID – fan operating mode schedule ID, defined in the **Schedules** table in the database (**21**). 0 – the furnace supply air fan and the heating or cooling coil cycle on and off together to meet the heating or cooling load (auto fan). ≠ 0 – the supply fan runs continuously while the heating or cooling coil cycles to meet the load;
- maximumSupplyAirTemperature – design operating furnace air outlet temperature when the furnace is heating [°C];
- coolingSupplyAirFlowRate – supply air flow rate leaving the furnace when the DX cooling coil is operating [m3/s]. 'autosize' option is available;
- heatingSupplyAirFlowRate – supply air flow rate leaving the furnace when the DX heating coil and/or supplemental heater are operating [m3/s]. 'autosize' option is available;
- noLoadSupplyAirFlowRate – supply air flow rate leaving the furnace when neither cooling or heating is required (i.e., DX coils and supplemental heater are off but the supply air fan operates) [m3/s]. This field is only used when the furnace operating mode is specified as continuous fan operation. 'autosize' option is available;
- dehumidificationControlType – 'None', 'Multimode' or 'CoolReheat'. Multimode is only valid with coolingCoilType = CoilSystemCoolingDXHeatExchangerAssisted (not yet implemented). If the dehumidification control type is specified as CoolReheat, then a reheat coil must be specified (argument x6 in the AirLoopHVACUnitaryFurnaceHeatCoolSpec() above). If the reheat coil is present and the dehumidification control type is not specified as CoolReheat, the reheat coil will not be active;
- setpointManagerType – defines the Setpoint Manager type for the unitary furnace. Currently, 'SingleZoneCooling' and 'SingleZoneHeating' are available for a unitary furnace (see section **14** for details);
- setpointManagerID – ID of the Setpoint Manager assigned to the unitary furnace. It is defined in the **SetpointManagerSingleZoneCooling** table, if setpointManagerType = SingleZoneCooling; or in the **SetpointManagerSingleZoneHeating** table, if setpointManagerType = SingleZoneHeating (**14**);

- costID – equipment cost ID, defined in the **Cost** table in the database (**24**);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – unitaryFurnaceName = airLoopName + “Unitary_Furnace_Heat_Cool” (airLoopName – name of the air loop for which this unitary system is assigned);
- Furnace Air Inlet Node Name – air outlet node of the equipment upstream of the unitary furnace in the air loop. If the unitary furnace is the first equipment in the air loop: airLoopName + "Air_Loop_Inlet_Node";
- Furnace Air Outlet Node Name – unitaryFurnaceName + “Outlet_node”;
- Controlling Zone or Thermostat Location – zone name defined in the argument x1 of the AirLoopHVACUnitaryFurnaceHeatCoolSpec() above;
- Supply Fan Object Type – supply fan type assigned in the argument x3 of the AirLoopHVACUnitaryFurnaceHeatCoolSpec() above;
- Supply Fan Name – name of the supply fan assigned in the argument x3 of the AirLoopHVACUnitaryFurnaceHeatCoolSpec() above;
- Fan Placement – fan placement type, defined with the FanPlacementType object in the AirLoopHVACUnitaryFurnaceHeatCoolSpec() above;
- Heating Coil Object Type – heating coil type assigned in the argument x4 of the AirLoopHVACUnitaryFurnaceHeatCoolSpec() above;
- Heating Coil Name – name of the heating coil assigned in the argument x4 of the AirLoopHVACUnitaryFurnaceHeatCoolSpec() above;
- Cooling Coil Object Type – cooling coil type assigned in the argument x5 of the AirLoopHVACUnitaryFurnaceHeatCoolSpec() above;
- Cooling Coil Name – name of the cooling coil assigned in the argument x5 of the AirLoopHVACUnitaryFurnaceHeatCoolSpec() above;
- Reheat Coil Object Type – reheat coil type assigned in the argument x6 of the AirLoopHVACUnitaryFurnaceHeatCoolSpec() above, if any;
- Reheat Coil Name – name of the reheat coil assigned in the argument x6 of the AirLoopHVACUnitaryFurnaceHeatCoolSpec() above, if any.

Connection to a plant loop

If heatingCoilType and/or reheatCoilType = CoilHeatingWater or CoilHeatingSteam, the coil must be assigned to a plant loop for heat source (hot water loop or steam loop, depending on the coil type). This is defined in the SAPTool_LSP building template, as follows:

AirLoopSystemAndElementType airLoopSystemAndElementType = new AirLoopSystemAndElementType() – air loop system and element type specification (named airLoopSystemAndElementType in this example). With the following AirLoopSystemAndElementType() arguments:

- **x1** – name of the Air Loop HVAC specification to which the unitary furnace is assigned (airLoopName);
- **AirLoopSystemAndElementType.AirLoopHVACSystemType.XX** – system type, defined with the AirLoopHVACSystemType list object. In this case, XX = **UNITARY_FURNACE_HEAT_COOL**;

- **x2** – air terminal zone ID, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Used only if a zone air terminal component is defined in the previous field. Otherwise, **null**;
- **AirLoopSystemAndElementType.ElementType.XX** – element type for which the plant loop is assigned, defined with the ElementType list object: XX = **COOLING_COIL**, **HEATING_COIL**, **SUPPLEMENTAL_HEATING_COIL**, **REHEAT_COIL** or **HEAT_RECOVERY**. In this case = **HEATING_COIL** or **REHEAT_COIL**.

The air loop system and element type specification name (airLoopSystemAndElementType, in this example) must then be assigned to the proper loop branch, as shown in section **9.3**. A branch object is automatically assigned to the element type together with its pressure drop curve, if defined (see section **9.3** for details).

Notice that for each element type assignment to a plant loop, a different air loop system and element type specification must be defined.

An example of the air loop unitary furnace usage with connection to a plant loop usage can be found in the SingleStoreyFamilyHouse_HVAC_Unitary_Furnace_HeatCool template in the SAPTool_LSP.

10.5. Outdoor Air System

The specification of the Air Loop HVAC Outdoor Air System is defined in the SAPTool_LSP building template, as follows:

AirLoopHVACOutdoorAirSystemSpec outdoorAirSystemSpec = new AirLoopHVACOutdoorAirSystemSpec() – outdoor air system specification (named outdoorAirSystemSpec in this example). With the following AirLoopHVACOutdoorAirSystemSpec() arguments:

- **x1** – ID of the Outdoor Air System properties in the **AirLoopHVACOutdoorAirSystem** table of the database;
- **db** – database unique ID.

The Outdoor Air System properties are defined in the **AirLoopHVACOutdoorAirSystem** table in the database. The following fields are present in the table:

- id – object ID;
- minimumTemperatureAtCoolingCoilOutletToPreventFreezing – minimum temperature at cooling coil outlet node to prevent freezing [°C] (optional), which is assigned to the Mixed Air Setpoint Manager (**14.9**) automatically assigned to the Controler Outdoor Air of this Outdoor Air System. If blank, is not defined;
- coilHeatingSetpointManagerType – defines the Setpoint Manager type for the heating coil outlet node, in the case a heating coil is assigned to the Outdoor Air System (**10.5.1**). Currently, the available types are 'ScheduledSingleSetpoint' and 'ScheduledDualSetpoint' (see section **14** for details);

- coilHeatingSetpointManagerID – ID of the Setpoint Manager assigned in the previous field, which is defined in the **setpointManagerSingleSetpoint** table, if coilHeatingSetpointManagerType = ScheduledSingleSetpoint; or in the **setpointManagerDualSetpoint** table, if coilHeatingSetpointManagerType = ScheduledDualSetpoint (**14**);
- coilCoolingSetpointManager1Type – defines the Setpoint Manager type for the cooling coil outlet node, in the case a cooling coil is assigned to the Outdoor Air System (**10.5.1**). Currently, the available types are 'ScheduledSingleSetpoint' and 'ScheduledDualSetpoint' (see section **14** for details);
- coilCoolingSetpointManager1ID – ID of the Setpoint Manager assigned in the previous field, which is defined in the **setpointManagerSingleSetpoint** table, if coilCoolingSetpointManager1Type = ScheduledSingleSetpoint; or in the **setpointManagerDualSetpoint** table, if coilCoolingSetpointManager1Type = ScheduledDualSetpoint (**14**);
- coilCoolingSetpointManager2Type – defines an additional Setpoint Manager type for the cooling coil outlet node (*e.g.*, to define a humidity setpoint in addition to the temperature setpoint[21]), in the case a cooling coil is assigned to the Outdoor Air System (**10.5.1**). Currently, the available types are 'ScheduledSingleSetpoint' and 'ScheduledDualSetpoint' (see section **14** for details);
- coilCoolingSetpointManager2ID – ID of the Setpoint Manager assigned in the previous field, which is defined in the **setpointManagerSingleSetpoint** table, if coilCoolingSetpointManager2Type = ScheduledSingleSetpoint; or in the **setpointManagerDualSetpoint** table, if coilCoolingSetpointManager2Type = ScheduledDualSetpoint (**14**);
- description – optional object description, for guidance.

An outdoor air system availability manager, if defined, must be assigned to the outdoor air system, as follows:

outdoorAirSystemSpec.addAvailabilityManager(ams) – assigns the ams availability manager to the outdoor air system outdoorAirSystemSpec. Currently, there are two availability manager types implemented that can be used by an outdoor air system: Scheduled (**15.1**) and Night Cycle (**15.7**).

The Outdoor Air System corresponds to the AirLoopHVAC:OutdoorAirSystem object in EnergyPlus, where all the fields are automatically filled:

- Name – outdoorAirSystemName = airLoopName + "OA_System" (airLoopName – name of the air loop for which this outdoor air system is assigned);
- Controller List Name – name of the controller list defined in section **10.5.3**;

[21] If a Cooling Coil DX Two Speed with Humidity Control Mode (**8.9.1.5**) is assigned to the outdoor air system, a Cooling Coil System containing the selected coil is automatically defined and assigned to the outdoor air system. In that case, if the coilSystemDehumidificationControlType is other that 'None' (in the coil specifications), a setpoint manager must be assigned to the coil to define the humidity setpoint, besides the setpoint manager assigned to define the temperature setpoint.

- Outdoor Air Equipment List Name – name of the equipment list defined in section **10.5.1**;
- Availability Manager List Name – name of the availability manager list defined above (outdoorAirSystemName + "AM_List").

10.5.1. Equipment List

The outdoor air system components are assigned as follows:

outdoorAirSystemSpec.addComponentList(XX) – equipment XX assignment to the outdoor air system specification (defined in section **10.5**). XX represents the selected equipment specification object. Examples of specification objects (with the specification names which were assigned in the correspondent sections):

- Outdoor air mixer (**10.5.2**): **livingRoomOutdoorAirMixerSpec**;
- Heating Coil DX Single Speed (**8.9.2.1**)[22], Heating Coil DX Variable Speed (**8.9.2.3**)[22], Heating Coil Electric (**8.9.2.6**), Heating Coil Fuel (**8.9.2.8**), Heating Coil Water (**8.9.2.10**)[23] or Heating Coil Steam (**8.9.2.11**)[23]: **heatingCoilSpec**;
- Cooling Coil DX Single Speed (**8.9.1.1**)[24], Cooling Coil DX Two Speed (**8.9.1.2**)[24], Cooling Coil DX Variable Speed (**8.9.1.4**)[24], Cooling Coil DX Two Speed with Humidity Control Mode (**8.9.1.5**)[24], Cooling Coil Water (**8.9.1.9**)[25] or Cooling Coil Water Detailed Geometry (**8.9.1.10**)[25]: **coolingCoilSpec**;
- Heat exchanger (Air-to-Air Flat Plate (**8.11.1**) or Air-to-Air Sensible and Latent (**8.11.2**)): **heatExchangerAirToAirFlatPlateSpec** or **heatExchangerAirToAirSensibleAndLatentSpec**.

Each outdoorAirSystemSpec.addComponentList(XX) represents a new component addition to the outdoor air system. Therefore, the user must assign the number and type of components corresponding to the desired equipment number and type. The order by which the components are added represents the equipment order in the outdoor air system, thus defining the equipment list. It corresponds to the AirLoopHVAC:OutdoorAirSystem:EquipmentList object in EnergyPlus, where all the fields are automatically filled:

- Name – OASytemName + “Equipment_List” (OASytemName – name of the outdoor air system for which this equipment list is assigned);
- Component <x> Object Type – type of the equipment assigned to the list;
- Component <x> Name – name of the equipment assigned to the list.

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[22] If a Heating Coil DX is assigned to the outdoor air system, a Heating Coil System containing the selected coil is automatically defined and assigned to the outdoor air system equipment list.

[23] If a Heating Coil Water or Steam is assigned to the outdoor air system, it must also be assigned to a plant loop for heat source – see section Connection to a plant loop below.

[24] If a Cooling Coil DX is assigned to the outdoor air system, a Cooling Coil System containing the selected coil is automatically defined and assigned to the outdoor air system equipment list.

[25] If a Cooling Coil Water is assigned to the outdoor air system, it must also be assigned to a plant loop for chilled water source – see section Connection to a plant loop below.

Connection to a plant loop

If the heating coil assigned to the outdoor air system is a water or steam coil or if the cooling coil assigned to the outdoor air system is a water coil, it must be assigned to a plant loop for heat/cold source (hot/chilled water loop or steam loop, depending on the coil type). This is defined in the SAPTool_LSP building template, as follows:

AirLoopSystemAndElementType airLoopSystemAndElementType = new AirLoopSystemAndElementType() – air loop system and element type specification (named airLoopSystemAndElementType in this example). With the following AirLoopSystemAndElementType() arguments:

- **x1** – name of the Air Loop HVAC specification to which the unitary system is assigned (airLoopName);
- **AirLoopSystemAndElementType.AirLoopHVACSystemType.XX** – system type, defined with the AirLoopHVACSystemType list object. In this case, XX = **OUTDOOR_AIR_SYSTEM**;
- **x2** – air terminal zone ID, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. Used only if a zone air terminal component is defined in the previous field. Otherwise, **null**;
- **AirLoopSystemAndElementType.ElementType.XX** – element type for which the plant loop is assigned, defined with the ElementType list object: XX = **COOLING_COIL**, **HEATING_COIL**, **SUPPLEMENTAL_HEATING_COIL**, **REHEAT_COIL** or **HEAT_RECOVERY**. In this case = **HEATING_COIL** or **COOLING_COIL**.

The air loop system and element type specification name (airLoopSystemAndElementType, in this example) must then be assigned to the proper loop branch, as shown in section **9.3**. A branch object is automatically assigned to the element type together with its pressure drop curve, if defined (see section **9.3** for details).

Notice that for each element type assignment to a plant loop, a different air loop system and element type specification must be defined.

10.5.2. Outdoor Air Mixer

The specification of the Outdoor Air Mixer is defined in the SAPTool_LSP building template, as follows:

OutdoorAirMixerSpec livingRoomOutdoorAirMixerSpec = new OutdoorAirMixerSpec() – outdoor air mixer specification (named livingRoomOutdoorAirMixerSpec in this example). With the following OutdoorAirMixerSpec() arguments:

- **x1** – ID of the Controller Outdoor Air properties in the **ControllerOutdoorAir** table of the database (**10.5.3.1**), that must be assigned to the outdoor air mixer;
- **db** – database unique ID.

This mixer corresponds to the OutdoorAir:Mixer object in EnergyPlus, where all the fields are automatically filled:

- Name – OASytemName + “Mixer” (OASytemName – name of the outdoor air system for which this mixer is assigned);
- Mixed Air Node Name – OASytemName + “Outlet_node”;
- Outdoor Air Stream Node Name – air outlet node of the equipment upstream of the outdoor air mixer. If the outdoor air system is the first equipment in the air loop and the mixer the first equipment in the system: OASytemName + "OA_Inlet_Node";
- Relief Air Stream Node Name – OASytemName + "Relief_Air_Outlet_Node";
- Return Air Stream Node Name – air outlet node of the equipment upstream of the outdoor air system. If the outdoor air system is the first equipment in the air loop: airLoopName + "Air_Loop_Inlet_Node" (airLoopName – name of the air loop for which the outdoor air system is assigned).

10.5.3. Controller List

Every time an Outdoor Air Mixer (**10.5.2**) or a Water Coil (**8.9**) are assigned to the Outdoor Air System, a proper controller must also be defined: Controller Outdoor Air (**10.5.3.1**) for the Outdoor Air Mixer or Controller Water Coil (**10.5.3.2**) for the Water Coils. The controllers are automatically assigned to an Air Loop HVAC Controller List. This corresponds to the AirLoopHVAC:ControllerList object in EnergyPlus, where all the fields are automatically filled:

- Name – OASytemName + “Controller_List” (OASytemName – name of the outdoor air system for which this list is assigned);
- Controller <x> Object Type – Controller:OutdoorAir or Controller:WaterCoil, depending on the controller type assigned to the list;
- Controller <x> Name – name of the controller assigned to the list.

10.5.3.1. Controller Outdoor Air

The Controller Outdoor Air properties are defined in the **ControllerOutdoorAir** table in the database, corresponding to the Controller:OutdoorAir object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- minimumOutdoorAirFlowRate – minimum outdoor air flow rate for the system [m^3/s]. ‘autosize’ option is available;
- maximumOutdoorAirFlowRate – maximum outdoor air flow rate for the system [m^3/s]. ‘autosize’ option is available;
- economizerControlType – ‘NoEconomizer’, ‘FixedDryBulb’, ‘FixedEnthalpy’, ‘DifferentialDryBulb’, ‘DifferentialEnthalpy’, ‘FixedDewPointAndDryBulb’, ‘ElectronicEnthalpy’ or ‘DifferentialDryBulbAndEnthalpy’;
- economizerControlActionType – ‘ModulateFlow’ or ‘MinimumFlowWithBypass’. ‘MinimumFlowWithBypass’ is used exclusively in conjunction with air-to-air heat exchanger objects (Flat Plate – **8.11.1**, Sensible and Latent – **8.11.2**) for providing free cooling operation in the absence of a conventional air-side economizer (i.e., when

outdoor air flow rate is not increased during economizer mode). The ModulateFlow option can also be used with the with air-to-air heat exchanger objects;

- economizerMaximumLimitDryBulbTemperature – outdoor air temperature high limit for economizer operation [°C]. Required if economizerControlType = FixedDryBulb or FixedDewPointAndDryBulb. If blank, there is no outdoor air temperature high limit control. If non-blank, this limit is applied regardless of the specified Economizer Control Type;
- economizerMaximumLimitEnthalpy – outdoor air enthalpy limit for economizer operation [J/kg]. Required if economizerControlType = FixedEnthalpy. If blank, there is no outdoor air enthalpy limit control. If non-blank, this limit is applied regardless of the specified Economizer Control Type;
- economizerMaximumLimitDewpointTemperature – outdoor air dewpoint limit for economizer operation [°C]. Required if economizerControlType = FixedDewPointAndDryBulb. If blank, there is no outdoor air dewpoint limit control. If non-blank, this limit is applied regardless of the specified Economizer Control Type.
- electronicEnthalpyLimitCurveID – quadratic or cubic curve ID, defined in the **PerformanceCurve** table in the database (**22**), which provides the maximum outdoor air humidity ratio (function of outdoor air dry-bulb temperature) for economizer operation. If blank, there is no electronic enthalpy limit control. If non-blank, this limit is applied regardless of the specified Economizer Control Type;
- economizerMinimumLimitDryBulbTemperature – outdoor air temperature low limit for economizer operation [°C]. If blank, there is no outdoor air temperature low limit control. If non-blank, this limit is applied regardless of the specified Economizer Control Type;
- lockoutType – 'NoLockout', 'LockoutWithHeating' or 'LockoutWithCompressor';
- minimumLimitType – 'ProportionalMinimum' or 'FixedMinimum';
- minimumOutdoorAirScheduleID – minimum outdoor air schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- minimumFractionOfOutdoorAirScheduleID – minimum fraction of outdoor air schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- maximumFractionOfOutdoorAirScheduleID – maximum fraction of outdoor air schedule ID, defined in the **Schedules** table in the database (**21**) (optional);
- mechanicalVentilationControllerID – ID of the mechanical ventilation controller object to be used in conjunction with this outdoor air controller (optional). Not yet implemented;
- timeOfDayEconomizerControlScheduleID –schedule ID, defined in the **Schedules** table in the database (**21**), which controls the outdoor air flow rate based on a time-of-day economizer (optional);
- highHumidityControl – 'Yes' or 'No';
- highHumidityOutdoorAirFlowRatio – ratio of the modified outdoor air flow rate to the maximum outdoor air flow rate. Only used if highHumidityControl = Yes;
- controlHighIndoorHumidityBasedOnOutdoorHumidityRatio – 'Yes' or 'No';
- heatRecoveryBypassControlType – 'BypassWhenWithinEconomizerLimits' or 'BypassWhenOAFlowGreaterThanMinimum';
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – controllerOAName = OAMixerName + "OA_Controller" (OAMixerName – name of the outdoor air mixer for which this controller is assigned);
- Relief Air Outlet Node Name – Relief Air Stream Node Name of the outdoor air mixer for which this controller is assigned;
- Return Air Node Name – Return Air Stream Node Name of the outdoor air mixer for which this controller is assigned;
- Mixed Air Node Name – Mixed Air Node Name of the outdoor air mixer for which this controller is assigned;
- Actuator Node Name – air inlet node name of the Outdoor Air System (OASytemName) containing the outdoor air mixer for which this controller is assigned: OASystemName + "OA_Inlet_Node". An Outdoor Air Node List containing this node is automatically defined with the OutdoorAir:NodeList EnergyPlus object;
- Humidistat Control Zone Name – zone name where the humidistat is located for controlling humidification (defined in the humidifier – see section **8.10**), if a humidifier is assigned to the air loop in section **10.2** and if highHumidityControl = Yes.

This controller is then assigned to the outdoor air system controller list (object AirLoopHVAC:ControllerList in EnergyPlus).

10.5.3.2. Controller Water Coil

Refer to the water coils in section **8.9** for details.

10.6. Setpoint Managers

A Mixed Air Setpoint Manager (**14.9**) is automatically defined and used in conjunction with a Controller Outdoor Air object (**10.5.3.1**) to establish a temperature setpoint at the mixed air node.

A Scheduled Single Setpoint (**14.1**) or a Scheduled Dual Setpoint (**14.2**) Setpoint Manager is automatically assigned to the air loop outlet node if the air loop does not comprise a Unitary System, and to the cooling and heating coils outlet nodes assigned to the Outdoor Air System. The Setpoint Managers are defined in the **AirLoopHVAC** and **AirLoopHVACOutdoorAirSystem** tables in the database, as referred in sections **10.1** and **10.5**, respectively.

A Single Zone Humidity Minimum Setpoint Manager (**14.5**) is automatically defined whenever a humidifier is assigned to the air loop (argument x4 of the AirLoopHVACSpec() in section **10.1**), to control the single zone minimum humidity level.

A Single Zone Humidity Maximum Setpoint Manager (**14.6**) is automatically assigned to each unitary system coil (**10.4**) to control the single zone maximum humidity level when the system is setpoint controlled (controlType = SetPoint) and its dehumidification control type is CoolReheat or Multimode (dehumidificationControlType = CoolReheat or Multimode).

11. AIR CONDITIONER VARIABLE REFRIGERANT FLOW

The air conditioner VRF structure is mainly defined in the SAPTool_LSP building templates (SAPTool_LSP>SourcePacakges>lsp.templates), while the properties for each object are defined in the database. The Air Conditioner VRF option must be active (**AIR_CONDITIONER_VRF = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The HVAC detailed systems specifications must be defined in the SAPTool_LSP building template, as follows:

HVACSpec hVACSpec = new HVACSpec()

The hVACSpec must then be assigned to the layout specifications object (LayoutSpecs(), in its second to last argument), in the end of the SAPTool_LSP building template.

The specification of each air conditioner VRF system is defined in the SAPTool_LSP building template, as follows:

AirConditionerVariableRefrigerantFlowSpec acVRFSpec = new AirConditionerVariableRefrigerantFlowSpec() – air conditioner VRF specification (named acVRFSpec in this example). With the following AirConditionerVariableRefrigerantFlowSpec() arguments:

- **DBAirConditionerVRFType.ABC.toString()** – air conditioner VRF name, defined using the DBAirConditionerVRFType list object ('ABC', in this case). Alternatively, a string can be directly inputted here (e.g., **"ABC"**);
- **CondenserType.XX.toString()** – type of condenser will be modeled with this system, defined using the CondenserType list object. The available options are: XX = 'AirCooled', 'EvaporativelyCooled' or 'WaterCooled'. 'AirCooled' and 'EvaporativelyCooled' do not require a Mixed Water Loop to be specified, whereas the 'WaterCooled' option requires the full specification of the Mixed Water Loop and its associated equipment;
- **x1** – ID of the zone where the master thermostat is located, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if not specified;
- **x2** – name of the supply water storage tank specification (if any), defined in section **5.3**. **null** if not present;
- **DBAirConditionerVRFType.ABC.getID()** – ID of the Air Conditioner Variable Refrigerant Flow properties in the database, defined using the DBAirConditionerVRFType list object (ID of 'ABC', in this case). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The air conditioner VRF properties are defined in the **AirConditionerVariableRefrigerantFlow** table in the database, corresponding to the AirConditioner:VariableRefrigerantFlow object in EnergyPlus. The following fields are present in the table:

- id – object ID;

- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the system is always available;
- grossRatedTotalCoolingCapacity – total cooling capacity (sensible + latent) of the heat pump at rated conditions [W]. 'autosize' option is available;
- grossRatedCoolingCOP – cooling coefficient of performance at rated conditions;
- minimumOutdoorTemperatureInCoolingMode – minimum source temperature allowed for cooling operation [°C]. For air-cooled equipment outdoor dry-bulb temperature is used. For water-cooled equipment inlet water temperature is used;
- maximumOutdoorTemperatureInCoolingMode – maximum source temperature allowed for cooling operation[°C]. For air-cooled equipment outdoor dry-bulb temperature is used. For water-cooled equipment inlet water temperature is used;
- coolingCapacityRatioModifierFunctionOfLowTemperatureCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the cooling capacity ratio modifier at low outdoor dry-bulb temperatures. If the Condenser Type is WaterCooled, then the cooling capacity modifier curve will be function of weighted average indoor air wet-bulb temperature and outdoor condenser entering water temperature;
- coolingCapacityRatioBoundaryCurveID – linear, quadratic or cubic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines a change in cooling capacity at a specific condenser entering air dry-bulb temperature as a function of indoor air wet-bulb temperature;
- coolingCapacityRatioModifierFunctionOfHighTemperatureCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the cooling capacity ratio modifier at high outdoor temperatures;
- coolingEnergyInputRatioModifierFunctionOfLowTemperatureCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines he cooling energy input ratio modifier at low outdoor temperatures. If the Condenser Type is WaterCooled, then the cooling energy input ratio modifier curve will be function of weighted average indoor air wet-bulb temperature and outdoor condenser entering water temperature;
- coolingEnergyInputRatioBoundaryCurveID – linear, quadratic or cubic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines a change in cooling energy at a specific condenser entering air dry-bulb temperature as a function of indoor air wet-bulb temperature;
- coolingEnergyInputRatioModifierFunctionOfHighTemperatureCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines he cooling energy input ratio modifier at high outdoor temperatures;
- coolingEnergyInputRatioModifierFunctionOfLowPartLoadRatioCurveID – linear, quadratic or cubic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the cooling energy input ratio modifier (function of part-load ratio when PLR is less than or equal to 1);
- coolingEnergyInputRatioModifierFunctionOfHighPartLoadRatioCurveID – linear, quadratic or cubic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the cooling energy input ratio modifier (function of part-load ratio when PLR is greater than 1);
- coolingCombinationRatioCorrectionFactorCurveID – linear, quadratic or cubic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This

curve defines the cooling combination ratio (CR) correction factor for combination ratios greater than or equal to 1. The combination ratio is defined as the total rated indoor terminal unit cooling capacity divided by this heat pump's gross rated total cooling capacity;

- coolingPartLoadFractionCorrelationCurveID – performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the cycling losses when the condenser's compressors cycle on and off;
- grossRatedHeatingCapacity – gross total heat pump heating capacity at rated conditions [W]. 'autosize' option is available;
- ratedHeatingCapacitySizingRatio – ratio of gross heating to gross cooling capacity;
- grossRatedHeatingCOP – heating coefficient of performance at rated conditions;
- minimumOutdoorTemperatureInHeatingMode – minimum outdoor temperature allowed for heating operation [°C];
- maximumOutdoorTemperatureInHeatingMode – maximum outdoor temperature allowed for heating operation [°C];
- heatingCapacityRatioModifierFunctionOfLowTemperatureCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the heating capacity ratio modifier at low temperature;
- heatingCapacityRatioBoundaryCurveID – quadratic or cubic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines a change in heating capacity at a specific condenser entering air dry-bulb or wet-bulb temperature as a function of indoor air dry-bulb temperature;
- heatingCapacityRatioModifierFunctionOfHighTemperatureCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the heating capacity ratio modifier at high temperature;
- heatingEnergyInputRatioModifierFunctionOfLowTemperatureCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the heating energy input ratio modifier at low temperature;
- heatingEnergyInputRatioBoundaryCurveID – quadratic or cubic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines a change in heating energy at a specific condenser entering air dry-bulb or wet-bulb temperature as a function of indoor air dry-bulb temperature;
- heatingEnergyInputRatioModifierFunctionOfHighTemperatureCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the heating energy input ratio modifier at high temperature;
- heatingPerformanceCurveOutdoorTemperatureType – 'DryBulbTemperature' or 'WetBulbTemperature';
- heatingEnergyInputRatioModifierFunctionOfLowPartLoadRatioCurveID – linear, quadratic or cubic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the heating energy input ratio modifier (function of part-load ratio when PLR is less than or equal to 1);
- heatingEnergyInputRatioModifierFunctionOfHighPartLoadRatioCurveID – linear, quadratic or cubic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the heating energy input ratio modifier (function of part-load ratio when PLR is greater than 1);
- heatingCombinationRatioCorrectionFactorCurveID – quadratic or cubic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines

the heating combination ratio (CR) correction factor for combination ratios greater than or equal to 1. The combination ratio is defined as the total rated indoor heating capacity divided by the rated heat pump heating capacity;

- heatingPartLoadFractionCorrelationCurveID – performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the cycling losses when the condenser's compressors cycle on and off;
- minimumHeatPumpPartLoadRatio – minimum operating part-load ratio (PLR) of the heat pump;
- masterThermostatPriorityControlType – 'MasterThermostatPriority', 'LoadPriority', 'ZonePriority', 'ThermostatOffsetPriority' or 'Scheduled';
- thermostatPriorityScheduleID – thermostat priority schedule ID, defined in the **Schedules** table in the database (**21**). Used only if masterThermostatPriorityControlType = Scheduled. 0 – heating mode, 1 – cooling mode, other values – system off;
- hasHeatPumpWasteHeatRecovery – 'Yes' or 'No'. If Yes is selected, heat recovery is enabled and the heat pump can independently cool and heat different zones. If No is selected, the heat pump is only able to cool or heat for any given time step;
- equivalentPipingLengthUsedForPipingCorrectionFactorInCoolingMode – equivalent pipe length in meters between the farthest terminal unit and the heat pump condenser in cooling mode [m];
- verticalHeightUsedForPipingCorrectionFactor – vertical pipe height in meters between the highest or lowest terminal unit and the heat pump condenser [m];
- pipingCorrectionFactorForLengthInCoolingModeCurveID – linear, quadratic or cubic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the piping correction factor for length in cooling mode;
- pipingCorrectionFactorForHeightInCoolingModeCoefficient – coefficient used to calculate the piping correction factor for height in cooling mode;
- equivalentPipingLengthUsedForPipingCorrectionFactorInHeatingMode – equivalent pipe length in meters between the farthest terminal unit and the heat pump condenser in heating mode [m];
- pipingCorrectionFactorForLengthInHeatingModeCurveID – linear, quadratic or cubic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the piping correction factor for length in heating mode;
- pipingCorrectionFactorForHeightInHeatingModeCoefficient – coefficient used to calculate the piping correction factor for height in heating mode;
- crankcaseHeaterPowerPerCompressor – electrical power consumed by the crankcase heater for each compressor [W];
- numberOfCompressors – number of compressors in the heat pump condensing unit;
- ratioOfCompressorSizeToTotalCompressorCapacity – size of the first stage compressor to the total compressor capacity;
- maximumOutdoorDryBulbTemperatureForCrankcaseHeater – maximum outdoor temperature below which the crankcase heater will operate [°C];
- defrostStrategy – 'Resistive' or 'ReverseCycle';
- defrostControl – 'Timed' or 'OnDemand';
- defrostEnergyInputRatioModifierFunctionOfTemperatureCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve parameterizes the variation of the energy input ratio (EIR) during reverse-cycle defrost periods as a function of the weighted average wet-bulb temperature of the air

entering the indoor terminal units (variable x) and the outdoor air dry-bulb temperature (variable y);

- defrostTimePeriodFraction – fraction of compressor runtime when the defrost cycle is active;
- resistiveDefrostHeaterCapacity – capacity of the resistive defrost heating element [W]. Only used if defrostStrategy = Resistive;
- maximumOutdoorDryBulbTemperatureForDefrostOperation – outdoor air dry-bulb temperature above which outdoor coil defrosting is disabled [°C];
- waterCondenserVolumeFlowRate – condenser water volume flow rate that is only used for water-cooled systems [m3/s]. 'autosize' option is available;
- evaporativeCondenserEffectiveness – effectiveness of the evaporative condenser, which is used to determine the temperature of the air entering the outdoor condenser coil;
- evaporativeCondenserAirFlowRate – air volume flow rate entering the evaporative condenser [m3/s]. 'autosize' option is available. Only used if Condenser Type = AirCooled;
- evaporativeCondenserPumpRatedPowerConsumption – rated power of the evaporative condenser water pump [W]. 'autosize' option is available. Only used if Condenser Type = AirCooled;
- basinHeaterCapacity – capacity of the heat pump's electric basin heater [W/K]. Only used if Condenser Type = EvaporativelyCooled;
- basinHeaterSetpointTemperature – set point temperature for the basin heater [°C]. Only used if Condenser Type = EvaporativelyCooled;
- basinHeaterOperatingScheduleID – basin heater operating schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the basin heater is always available. Only used if Condenser Type = EvaporativelyCooled;
- fuelType – 'Electricity', 'NaturalGas', 'PropaneGas', 'Diesel', 'Gasoline', 'FuelOil_1', 'FuelOil_2', 'OtherFuel1' or 'OtherFuel2';
- minimumOutdoorTemperatureInHeatRecoveryMode – minimum outdoor dry-bulb temperature allowed for heat recovery operation [°C]. If blank, the default value is the higher of the Minimum Outdoor Temperature in Cooling Mode or Minimum Outdoor Temperature in Heating Mode inputs. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- maximumOutdoorTemperatureInHeatRecoveryMode – maximum outdoor dry-bulb temperature allowed for heat recovery operation [°C]. If blank, the default value is the lower of the Maximum Outdoor Temperature in Cooling Mode or Maximum Outdoor Temperature in Heating Mode inputs. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- heatRecoveryCoolingCapacityModifierCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the cooling capacity modifier when heat recovery mode is active. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- initialHeatRecoveryCoolingCapacityFraction – fraction of cooling capacity available when the system transitions from cooling only operation to simultaneous cooling and heating. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- heatRecoveryCoolingCapacityTimeConstant – cooling capacity time constant used to model the time it takes for the system to change from cooling only operation to

simultaneous cooling and heating [h]. Only used if hasHeatPumpWasteHeatRecovery = Yes;

- heatRecoveryCoolingEnergyModifierCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the cooling energy modifier when heat recovery mode is active. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- initialHeatRecoveryCoolingEnergyFraction – fraction of cooling energy consumed when the system transitions from cooling only operation to simultaneous cooling and heating. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- heatRecoveryCoolingEnergyTimeConstant – cooling energy time constant used to model the time it takes for the system to transition from cooling only operation to simultaneous cooling and heating [h]. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- heatRecoveryHeatingCapacityModifierCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the heating capacity modifier when heat recovery mode is active. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- initialHeatRecoveryHeatingCapacityFraction – fraction of heating capacity available when the system changes from heating only operation to simultaneous heating and cooling. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- heatRecoveryHeatingCapacityTimeConstant – heating capacity time constant used to model the time it takes for the system to transition from cooling only operation to simultaneous cooling and heating [h]. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- heatRecoveryHeatingEnergyModifierCurveID – biquadratic performance curve ID defined in the **PerformanceCurve** table in the database (**22**). This curve defines the heating energy modifier when heat recovery mode is active. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- initialHeatRecoveryHeatingEnergyFraction – fraction of heating energy consumed when the system changes from heating only operation to simultaneous heating and cooling. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- heatRecoveryHeatingEnergyTimeConstant – heating energy time constant used to model the time it takes for the system to change from cooling only operation to simultaneous cooling and heating [h]. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- pressureDropCurveID – pressure drop curve ID, defined in the **PerformanceCurve** table in the database (**22**) (optional). This pressure drop curve defines the pressure drop across all the air conditioner VRF system. Only used if hasHeatPumpWasteHeatRecovery = Yes;
- costID – system cost ID, defined in the **Cost** table in the database (**24**).
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Heat Pump Name – acVRFName = name assigned in the air conditioner VRF specification (first argument of the AirConditionerVariableRefrigerantFlowSpec() above);

- Zone Name for Master Thermostat Location – zone for which the master thermostat is assigned (if any), defined in argument x1 of the AirConditionerVariableRefrigerantFlowSpec() above;
- Zone Terminal Unit List Name – acVRFName + "TU_List". Name of the list comprising all the Zone HVAC Terminal Unit Variable Refrigerant Flow (see section **7.1.7**) assigned to this air conditioner VRF system;
- Condenser Type – condenser type defined in the second argument of the AirConditionerVariableRefrigerantFlowSpec() above;
- Condenser Inlet Node Name – acVRFName + "Inlet_node". If Condenser Type = AirCooled, this node is automatically assigned to an OutdoorAir Node object, which is automatically created in EnergyPlus;
- Condenser Outlet Node Name – acVRFName + "Outlet_node";
- Supply Water Storage Tank Name – supply water storage tank name defined in argument x2 of the AirConditionerVariableRefrigerantFlowSpec() above.

Finally, the air loop (acVRFSpec) must be added to the HVAC detailed systems specifications in the SAPTool_LSP building template, as follows:

hVACSpec.addAirConditionerVariableRefrigerantFlowSpec(acVRFSpec)

If more than one air conditioner VRF system is required, the above methodology should be repeated and the new system(s) should also be added to the HVAC detailed systems specifications (hVACSpec in this example).

<u>Connection to a plant loop</u>

If the air conditioner VRF system's condenser is water cooled, it must be assigned to a mixed water plant loop for condensation. The air conditioner VRF specification name (acVRFSpec, in this example) must be assigned to the proper loop branch, as shown in section **9.3**. A branch object is automatically assigned to the element type together with its pressure drop curve, if defined (see section **9.3** for details).

An example of this air conditioner VRF system object usage can be found in the SingleStoreyFamilyHouse_HVAC_VRF_MixedWaterLoop template in the SAPTool_LSP.

12. ELECTRIC LOAD CENTER

The Electric Load Center is mainly defined in the SAPTool_LSP building templates (SAPTool_LSP>SourcePacakges>lsp.templates), while the properties for each object are defined in the database. The Electric Load Center option must be active (**ELECTRIC_LOAD_CENTER_DISTRIBUTION = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

An example of this system usage can be found in the SingleStoreyFamilyHouse_PV_WT template in the SAPTool_LSP.

12.1. Distribution

The specification of the Electric Load Center Distribution is defined in the SAPTool_LSP building template, as follows:

ElectricLoadCenterDistributionSpec electricLoadCenterDistributionSpec = new ElectricLoadCenterDistributionSpec() – Electric Load Center Distribution specification (named electricLoadCenterDistributionSpec in this example). With the following ElectricLoadCenterDistributionSpec() arguments:

- **“ABC”** – Electric Load Center Distribution name;
- **DBElectricLoadCenterGeneratorOperationSchemeType.XX.toString()** – generator operation scheme type, defined using the DBElectricLoadCenterGeneratorOperationSchemeType list object. XX = ‘Baseload’, ‘DemandLimit’, ‘TrackElectrical’, ‘TrackSchedule’, ‘TrackMeter’, ‘FollowThermal’ or ‘FollowThermalLimitElectrical’;
- **x1** – Demand Limit Scheme Purchased Electric Demand Limit [W] (double type input). **null** if not specified;
- **DBScheduleType.SCH1.getID** – ID of the Track Schedule Name Scheme Schedule, defined using the DBScheduleType list object (ID of ‘SCH1’, in this example). Alternatively, the proper database ID can be directly inputted here. **null** if not specified;
- **DBElectricLoadCenterElectricalBussType.XX.toString()** – electrical buss type, defined using the DBElectricLoadCenterElectricalBussType list object. XX = ‘AlternatingCurrent’, ‘AlternatingCurrentWithStorage’, ‘DirectCurrentWithInverter’, ‘DirectCurrentWithInverterDCStorage’ or ‘DirectCurrentWithInverterACStorage’;
- **x2** – Inverter object, defined in section **12.2**. **null** if not specified;
- **x3** – Electrical Storage object, defined in section **12.3**. **null** if not specified;
- **x4** – Transformer object, defined in section **12.4**. **null** if not specified.

This corresponds to the ElectricLoadCenter:Distribution object in EnergyPlus, with the following fields automatically filled:

- Name – electLoadCentName = name of the electric load center, defined in the first argument of the ElectricLoadCenterDistributionSpec() above;
- Generator List Name – “LST_GEN” + elecLoadCentName. List of generators connected to this load center (defined in section **12.5**);

- Generator Operation Scheme Type – type of operating scheme for the generator set, defined in the second argument of the ElectricLoadCenterDistributionSpec() above;
- Demand Limit Scheme Purchased Electric Demand Limit – demand limit above which the generators will try and meet the entire electrical load on the building minus the photovoltaic array if available. Defined in the argument x1 of the ElectricLoadCenterDistributionSpec() above;
- Track Schedule Name Scheme Schedule Name – schedule that contains values (in W) for the demand loads placed on the generator(s). Defined in the fourth argument of the ElectricLoadCenterDistributionSpec() above;
- Track Meter Scheme Meter Name – not yet implemented;
- Electrical Buss Type – describes how the electric load center is configured with respect to any power conditioning and/or storage equipment. Defined in the fifth argument of the ElectricLoadCenterDistributionSpec() above;
- Inverter Object Name – inverter connected to this load center (if any), defined in the argument x2 of the ElectricLoadCenterDistributionSpec() above;
- Electrical Storage Object Name – electrical storage connected to this load center (if any), defined in the argument x3 of the ElectricLoadCenterDistributionSpec() above;
- Transformer Object Name – transformer connected to this load center (if any), defined in the argument x4 of the ElectricLoadCenterDistributionSpec() above;

The following fields are defined in section **12.3**, and only assigned and used if an electrical storage is connected to the load center:

- Storage Operation Scheme
- Storage Control Track Meter Name
- Storage Converter Object Name
- Maximum Storage State of Charge Fraction
- Minimum Storage State of Charge Fraction
- Design Storage Control Charge Power
- Storage Charge Power Fraction Schedule Name
- Design Storage Control Discharge Power
- Storage Discharge Power Fraction Schedule Name
- Storage Control Utility Demand Target
- Storage Control Utility Demand Target Fraction Schedule Name

This object (electricLoadCenterDistributionSpec) must then be entered as the 11th argument in the layout specifications (LayoutSpecs()), in the end of the SAPTool_LSP building template.

12.2. Inverter

If there is an inverter connected to the load center, its specification is defined in the argument x2 of the ElectricLoadCenterDistributionSpec() in section **12.1**, as follows:

new ElectricLoadCenterInverterSpec() – inverter specification, with the following arguments:

- **x** – ID of the zone for which the inverter is assigned, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if not specified;
- **DBElectricLoadCenterInverterType.ABC.getID()** – ID of the inverter type and properties in the database (see below), defined using the DBElectricLoadCenterInverterType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The inverter type and properties are defined in the **ElectricLoadCenterInverter** table in the database:

- id – object ID;
- type – electrical storage specification in the corresponding Type table. There are three inverter types available: 'Simple' (**ElectricLoadCenterInverterSimple** table in the database – **12.2.1**), 'FunctionOfPower' (**ElectricLoadCenterInverterFunctionOfPower** table in the database – **12.2.2**), and 'LookUpTable' (**ElectricLoadCenterInverterLookUpTable** table in the database – **12.2.3**);
- inverterID – inverter type ID in the corresponding table.

12.2.1. Simple

The simple inverter properties are defined in the **ElectricLoadCenterInverterSimple** table in the database, corresponding to the ElectricLoadCenter:Inverter:Simple object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – simple inverter name (simpleInverterName);
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the simple inverter is always available;
- radiativeFraction – fraction of inverter thermal losses that enter the zone as long-wave thermal radiation, defined in argument x of the ElectricLoadCenterInverterSpec() above. Only used if the simple inverter is assigned to a zone;
- inverterEfficiency – inverter efficiency value;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – electLoadCentName + simpleInverterName (electLoadCentName is defined in section **12.1**);
- Zone Name – name of the zone for which this simple inverter is assigned (if any), defined in argument x of the ElectricLoadCenterInverterSpec() above.

12.2.2. Function of Power

The function of power inverter properties are defined in the **ElectricLoadCenterInverterFunctionOfPower** table in the database, corresponding to the

ElectricLoadCenter:Inverter:FunctionOfPower object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – function of power inverter name (functPowerInverterName);
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the function of power inverter is always available;
- radiativeFraction – fraction of inverter thermal losses that enter the zone as long-wave thermal radiation, defined in argument x of the ElectricLoadCenterInverterSpec() above. Only used if the simple inverter is assigned to a zone;
- efficiencyFunctionOfPowerCurveID – efficiency function of power curve ID, defined in the **PerformanceCurve** table in the database (**22**). This curve can be linear, quadratic or cubic;
- ratedMaximumContinuousInputPower – rated power input [W];
- minimumEfficiency – minimum bound on the inverter efficiency;
- maximumEfficiency – maximum bound on the inverter efficiency;
- minimumPowerOutput – lower limit on the AC power produced by the inverter [W];
- maximumPowerOutput – upper limit on the AC power produced by the inverter [W];
- ancillaryPowerConsumedInStandby – ancillary power used by the inverter when not producing AC power [W];
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – electLoadCentName + functPowerInverterName (electLoadCentName is defined in section **12.1**);
- Zone Name – name of the zone for which this function of power inverter is assigned (if any), defined in argument x of the ElectricLoadCenterInverterSpec() above.

12.2.3. Look Up Table

The look up table inverter properties are defined in the **ElectricLoadCenterInverterLookUpTable** table in the database, corresponding to the ElectricLoadCenter:Inverter:LookUpTable object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – look up table inverter name (lookUpInverterName);
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the look up table inverter is always available;
- radiativeFraction – fraction of inverter thermal losses that enter the zone as long-wave thermal radiation, defined in argument x of the ElectricLoadCenterInverterSpec() above. Only used if the look up table inverter is assigned to a zone;
- ratedMaximumContinuousOutputPower – rated maximum continuous output power [W];
- nightTareLossPower – night tare loss [W];
- nominalVoltageInput – nominal DC input voltage [V];
- efficiencyAt10PowerAndNominalVoltage – fractional efficiency at nominal voltage and 10% power;

- efficiencyAt20PowerAndNominalVoltage – fractional efficiency at nominal voltage and 20% power;
- efficiencyAt30PowerAndNominalVoltage – fractional efficiency at nominal voltage and 30% power;
- efficiencyAt50PowerAndNominalVoltage – fractional efficiency at nominal voltage and 50% power;
- efficiencyAt75PowerAndNominalVoltage – fractional efficiency at nominal voltage and 75% power;
- efficiencyAt100PowerAndNominalVoltage – fractional efficiency at nominal voltage and 100% power;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – electLoadCentName + lookUpInverterName (electLoadCentName is defined in section **12.1**);
- Zone Name – name of the zone for which this look up table inverter is assigned (if any), defined in argument x of the ElectricLoadCenterInverterSpec() above.

12.3. Electrical Storage

If there is an electrical storage connected to the load center, its specification is defined in the argument x3 of the ElectricLoadCenterDistributionSpec() in section **12.1**, as follows:

new ElectricLoadCenterStorageSpec() – electrical storage specification, with the following arguments:

- **x1** – ID of the zone for which the electrical storage is assigned, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if not specified;
- **x2** – ID of the zone for which the electrical storage converter is assigned, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if not specified;
- **DBElectricLoadCenterStorageType.ABC.getID()** – ID of the electrical storage type and properties in the database (see below), defined using the DBElectricLoadCenterStorageType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The electrical storage type and properties are defined in the **ElectricLoadCenterStorage** table in the database:

- id – object ID;
- type – electrical storage specification in the corresponding Type table. There are two electrical storage types available: 'Simple' (**ElectricLoadCenterStorageSimple** table in the database – **12.3.1**) and 'Battery' (detailed) (**ElectricLoadCenterStorageBattery** table in the database – **12.3.2**);
- storageID – electrical storage type ID in the corresponding table;

The following fields correspond to the last 11 fields in the ElectricLoadCenter:Distribution object in EnergyPlus (see section **12.1**):

- storageOperationScheme – 'TrackFacilityElectricDemandStoreExcessOnSite', 'TrackMeterDemandStoreExcessOnSite', 'TrackChargeDischargeSchedules' or 'FacilityDemandLeveling';
- storageControlTrackMeterID – custom meter only used if storageOperationScheme = TrackMeterDemandStoreExcessOnSite. Not yet implemented;
- storageConverterID – AC to DC converter ID, defined in the **ElectricLoadCenterStorageConverter** table in the database (**12.3.3**). Required if Electrical Buss Type = DirectCurrentWithInverterDCStorage (see section **12.1**) and storageOperationScheme = TrackChargeDischargeSchedules or FacilityDemandLeveling;
- maximumStorageStateOfChargeFraction – fraction of storage capacity used as an upper limit for controlling charging;
- minimumStorageStateOfChargeFraction – fraction of storage capacity used as lower limit for controlling discharging;
- designStorageControlChargePower – design maximum rate that electric power can be charged into storage [W]. Required if storageOperationScheme = TrackChargeDischargeSchedules or FacilityDemandLeveling;
- storageChargePowerFractionScheduleID – storage charge power fraction schedule ID, defined in the **Schedules** table in the database (**21**). Required if storageOperationScheme = TrackChargeDischargeSchedules;
- designStorageControlDischargePower – design maximum rate that electric power can be discharged from storage [W]. Required if storageOperationScheme = TrackChargeDischargeSchedules or FacilityDemandLeveling;
- storageDischargePowerFractionScheduleID – storage discharge power fraction schedule ID, defined in the **Schedules** table in the database (**21**). Required if storageOperationScheme = TrackChargeDischargeSchedules;
- storageControlUtilityDemandTarget – design demand target [W]. Only used if storageOperationScheme = FacilityDemandLeveling;
- storageControlUtilityDemandTargetFractionScheduleID – storage control utility demand target fraction schedule ID, defined in the **Schedules** table in the database (**21**). Required if storageOperationScheme = FacilityDemandLeveling.

12.3.1. Simple

The simple storage properties are defined in the **ElectricLoadCenterStorageSimple** table in the database, corresponding to the ElectricLoadCenter:Storage:Simple object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – simple storage name (simpleStorageName);
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the simple storage is always available;

- radiativeFractionForZoneHeatGains – fraction of storage thermal losses that enter the zone as long-wave thermal radiation, defined in argument x1 of the ElectricLoadCenterStorageSpec() above. Only used if the simple storage is assigned to a zone;
- nominalEnergeticEfficiencyForCharging – charging efficiency;
- nominalDischargingEnergeticEfficiency – discharging efficiency;
- maximumStorageCapacity – maximum amount of energy that can be stored in the device [J];
- maximumPowerForDischarging – maximum rate at which electrical power can be discharged from the storage device [W];
- maximumPowerForCharging – maximum rate at which electrical power can be stored in the storage device [W];
- initialStateOfCharge – value for the initial state of charge [J];
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – electLoadCentName + simpleStorageName (electLoadCentName is defined in section **12.1**);
- Zone Name – name of the zone for which this simple storage is assigned (if any), defined in argument x1 of the ElectricLoadCenterStorageSpec() above.

12.3.2. Battery

The detailed battery storage properties are defined in the **ElectricLoadCenterStorageBattery** table in the database, corresponding to the ElectricLoadCenter:Storage:Battery object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – battery storage name (batteryStorageName);
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the battery storage is always available;
- radiativeFractionForZoneHeatGains – fraction of storage thermal losses that enter the zone as long-wave thermal radiation, defined in argument x1 of the ElectricLoadCenterStorageSpec() above. Only used if the battery storage is assigned to a zone;
- numberOfBatteryModulesInParallel – number of modules connected in parallel in the battery bank;
- numberOfBatteryModulesInSeries – number of modules connected in series in the battery bank. Total number of modules in a battery bank = numberOfBatteryModulesInParallel * numberOfBatteryModulesInSeries;
- maximumModuleCapacity – maximum capacity of one battery module [Ah];
- initialFractionalStateOfCharge – initial state of charge in terms of the fraction of maximum capacity as defined in the previous field;
- fractionOfAvailableChargeCapacity – ratio of available charge capacity to total capacity;
- changeRateFromBoundChargeToAvailableCharge – rate at which the charge flows between the available tank and the bound tank [1/h];

- fullyChargedModuleOpenCircuitVoltage – open circuit voltage for a fully charged battery module [V];
- fullyDischargedModuleOpenCircuitVoltage – open circuit voltage for a fully discharged battery module [V];
- voltageChangeCurveForChargingID – voltage change for charging curve ID, defined in the **PerformanceCurve** table in the database (**22**);
- voltageChangeCurveForDischargingID – voltage change for discharging curve ID, defined in the **PerformanceCurve** table in the database (**22**);
- moduleInternalElectricalResistance – battery internal resistance in ohms;
- maximumModuleDischargingCurrent – maximum current at which the battery can be discharged continuously [A];
- moduleCutOffVoltage – minimum allowable voltage, below which the battery is generally regarded as empty (defined for an individual battery module) [V];
- moduleChargeRateLimit – limit on charging current relative to the remaining charge until the battery is full;
- batteryLifeCalculation – 'Yes' or 'No';
- numberOfCycleBins – number of equally ranged cycle bins in battery life simulation;
- batteryCycleLifeCurveID – battery cycle life curve ID, defined in the **PerformanceCurve** table in the database (**22**). A double exponential decay curve is required;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – electLoadCentName + batteryStorageName (electLoadCentName is defined in section **12.1**);
- Zone Name – name of the zone for which this battery storage is assigned (if any), defined in argument x1 of the ElectricLoadCenterStorageSpec() above.

12.3.3. Storage Converter

The AC to DC converter properties are defined in the **ElectricLoadCenterStorageConverter** table in the database, corresponding to the ElectricLoadCenter:Storage:Converter object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – converter name (converterName);
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the converter is always available;
- powerConversionEfficiencyMethod – 'SimpleFixed' or 'FunctionOfPower';
- simpleFixedEfficiency – constant efficiency for conversion of AC to DC at all power levels. Only used if powerConversionEfficiencyMethod = SimpleFixed;
- designMaximumContinuousInputPower – size of the power converter in terms of its design input power level [W]. Required when powerConversionEfficiencyMethod = FunctionOfPower;
- efficiencyFunctionOfPowerCurveID – efficiency function of power curve ID, defined in the **PerformanceCurve** table in the database (**22**). Required only if powerConversionEfficiencyMethod = FunctionOfPower;

- ancillaryPowerConsumedInStandby – ancillary power consumed by the converter when it is available but not converting power [W] (optional);
- radiativeFraction – fraction of zone heat gains that are handled as infrared thermal radiation, defined in argument x2 of the ElectricLoadCenterStorageSpec() above. Only used if the converter is assigned to a zone;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – electLoadCentName + converterName (electLoadCentName is defined in section **12.1**);
- Zone Name – name of the zone for which this converter is assigned (if any), defined in argument x2 of the ElectricLoadCenterStorageSpec() above.

12.4. Transformer

If there is a transformer connected to the load center, its specification is defined in the argument x4 of the ElectricLoadCenterDistributionSpec() in section **12.1**, as follows:

new ElectricLoadCenterTransformerSpec() – transformer specification, with the following arguments:

- **x** – ID of the zone for which the transformer is assigned, which corresponds to the order for which the zone is added to the spaceSpec list in the building template. **null** if not specified;
- **DBElectricLoadCenterTransformerType.ABC.getID()** – ID of the transformer properties in the database (see below), defined using the DBElectricLoadCenterTransformerTypelist object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The transformer properties are defined in the **ElectricLoadCenterTransformer** table in the database, corresponding to the ElectricLoadCenter:Transformer object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – transformer name (transformerName);
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the transformer is always available;
- transformerUsage – 'PowerInFromGrid', 'PowerOutToGrid' or 'LoadCenterPowerConditioning';
- radiativeFraction – fraction of inverter thermal losses that enter the zone as long-wave thermal radiation, defined in argument x2 of the ElectricLoadCenterTransformerSpec() above. Only used if the transformer is assigned to a zone;
- ratedCapacity – rated capacity of the transformer in VA;
- phase – '1' or '3';
- conductorMaterial – 'Aluminum' or 'Copper';

- fullLoadTemperatureRise – temperature rise of the windings above the ambient temperature, when the transformer is loaded at its nameplate rating [°C];
- fractionOfEddyCurrentLosses – fraction of load losses resulting from the eddy currents;
- performanceInputMethod – 'RatedLosses' or 'NominalEfficiency';
- ratedNoLoadLoss – no load loss at rated load and conditions [W]. Only used if performanceInputMethod = RatedLosses;
- ratedLoadLoss – load loss at rated load and conditions [W]. Only used if performanceInputMethod = RatedLosses;
- nameplateEfficiency – transformer efficiency at a given per unit load and specified reference temperature. Only used if performanceInputMethod = NominalEfficiency;
- perUnitLoadForNameplateEfficiency – percentage of the rated capacity at which the nameplate efficiency is measured;
- referenceTemperatureForNameplateEfficiency – conductor temperature at which the nameplate efficiency is measured [°C]. Only used if performanceInputMethod = NominalEfficiency;
- perUnitLoadForMaximumEfficiency – percentage of the rated capacity at which the maximum efficiency is obtained. Only used if performanceInputMethod = NominalEfficiency;
- considerTransformerLossForUtilityCost – 'Yes' or 'No';
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – electLoadCentName + transformerName (electLoadCentName is defined in section **12.1**);
- Zone Name – name of the zone for which this transformer is assigned (if any), defined in argument x2 of the ElectricLoadCenterTransformerSpec() above;
- Electric Meter 1-10 Name – list of electric meters wired to the transformer. Not yet implemented.

12.5. Generators

The generator equipment is assigned to the Electric Load Center defined in the SAPTool_LSP building template, following the Electric Load Center Distribution specification (named electricLoadCenterDistributionSpec in the example of section **12.1**), as follows:

electricLoadCenterDistributionSpec.addGeneratorSpec(XX) – generator X assignment to the Electric Load Center. Currently, there are two generator types implemented: Photovoltaic (**12.5.1**) and Wind turbine (**12.5.2**). XX represents the selected generator specification object.

Multiple generators can be added to the Electric Load Center. For this purpose, a generator list is automatically defined, with each entry corresponding to one generator assignment to the Electric Load Center. The list corresponds to the ElectricLoadCenter:Generator object in EnergyPlus, with automatically filled fields, where X represents the assigned generator position in the equipment list (the list position corresponds to the addition order):

- Name – "LST_GEN" + elecLoadCentName (defined in section **12.1**);
- Generator X Name – name of the generator X;

- Generator X Object Type – type of the generator X. Currently, only two types are implemented: Photovoltaic generator (**12.5.1**) and Wind Turbine generator (**12.5.2**);
- Generator X Rated Electric Power Output – nominal electric power output to be requested from generator X [W]. Defined in the generator X specifications;
- Generator X Availability Schedule Name – availability schedule for generator X. Defined in the generator X specifications;
- Generator X Rated Thermal to Electrical Power Ratio – ratio of the rated thermal output to the rated electric output of generator X. Defined in the generator X specifications. Only required if the Electric Load Center Generator Operation Scheme Type = FollowThermal or FollowThermalLimitElectrical, defined in the second argument of the ElectricLoadCenterDistributionSpec(), in section **12.1**.

12.5.1. Photovoltaic

The addition of a photovoltaic generator to the load center is as follows:

electricLoadCenterDistributionSpec.addGeneratorSpec(new GeneratorPhotovoltaicSpec()) – addition of the photovoltaic generator specification to the load center, with the following arguments in GeneratorPhotovoltaicSpec():

- "**ABC"** – photovoltaic generator name;
- **ModulePlacementType.ROOF** – photovoltaic module location, defined using the ModulePlacementType list object (currently, only a **roof** surface is available);
- **x1** – photovoltaic module tilt angle (double type input);
- **x2** – photovoltaic module azimuth angle (double type input);
- **PVModuleOrientationType.XX.toString()** – photovoltaic module orientation, defined using the PVModuleOrientationType list object. XX = 'Vertical' or 'Horizontal';
- **x3** – number of series Strings in parallel;
- **x4** – number of modules in series;
- **DBGeneratorPhotovoltaicType.ABC.getID()** – ID of the Photovoltaic generator properties in the database (see below), defined using the DBGeneratorPhotovoltaicType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Photovoltaic generator properties are defined in the **GeneratorPhotovoltaic** table in the database, corresponding to the Generator:Photovoltaic object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- width – photovoltaic module width [m];
- height – photovoltaic module height [m];
- photovoltaicPerformanceType – photovoltaic performance model type in the corresponding Type table. There are three performance model types available: 'Simple' (**PhotovoltaicPerformanceSimple** table in the database – **12.5.1.1**), 'EquivalentOneDiode' (**PhotovoltaicPerformanceEquivalentOneDiode** table in the

database – **12.5.1.2**), and 'Sandia' (**PhotovoltaicPerformanceSandia** table in the database – **12.5.1.3**);

- photovoltaicPerformanceID – photovoltaic performance model type ID in the corresponding table;
- heatTransferIntegrationMode – 'Decoupled', 'DecoupledUllebergDynamic', 'IntegratedSurfaceOutsideFace', 'IntegratedTranspiredCollector', 'IntegratedExteriorVentedCavity' or 'PhotovoltaicThermalSolarCollector';
- generatorRatedElectricPower – nominal electric power output to be requested from generator [W]. This value is assigned to the 'Generator X Rated Electric Power Output' field in the ElectricLoadCenter:Generators object in EnergyPlus, if the photovoltaic generator is connected to the Electric Load Center. X represents the photovoltaic generator position in the equipment list;
- generatorAvailabilityScheduleID – photovoltaic generator availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the photovoltaic generator is always available. This value is assigned to the 'Generator X Availability Schedule Name' field in the ElectricLoadCenter:Generators object in EnergyPlus, if the photovoltaic generator is connected to the Electric Load Center. X represents the photovoltaic generator position in the equipment list;
- generatorRatedThermalToElectricalPowerRatio – ratio of the rated thermal output to the rated electric output. This value is assigned to the 'Generator X Rated Thermal to Electrical Power Ratio' field in the ElectricLoadCenter:Generators object in EnergyPlus, if the photovoltaic generator is connected to the Electric Load Center. X represents the photovoltaic generator position in the equipment list. Only required if the Electric Load Center Generator Operation Scheme Type = FollowThermal or FollowThermalLimitElectrical, defined in the second argument of the ElectricLoadCenterDistributionSpec(), in section **12.1**;
- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – generatorName = photovoltaic generator name (defined in the first argument of the GeneratorPhotovoltaicSpec() above);
- Surface Name – name of the surface where the photovoltaic module is placed*;
- Number of Series Strings in Parallel – number of series-wired strings of PV modules that are in parallel to form the PV array, defined in the argument x3 of the GeneratorPhotovoltaicSpec() above;
- Number of Modules in Series – number of modules wired in series (on each string) to form the PV array, defined in the argument x4 of the GeneratorPhotovoltaicSpec() above.

* For each photovoltaic generator added, a shading surface is automatically created in order to place it. This surface acts as a shading element to the building surface for which it is assigned with the ModulePlacementType object (see above). It corresponds to a Shading:Building object in EnergyPlus, where all fields are automatically filled:

- Name – "MODULE" + generatorName;
- Azimuth Angle – argument x2 in the GeneratorPhotovoltaicSpec() above;
- Tilt Angle – argument x1 in the GeneratorPhotovoltaicSpec() above;

- Starting X Coordinate – related to the *width* value defined in the **GeneratorPhotovoltaic** table in the database;
- Starting Y Coordinate – related to the *height* value defined in the **GeneratorPhotovoltaic** table in the database;
- Starting Z Coordinate – related to the building height;
- Length – *width* or *height* defined in the **GeneratorPhotovoltaic** table in the database, depending on the module orientation (PVModuleOrientationType);
- Height – *height* or *width* defined in the **GeneratorPhotovoltaic** table in the database, depending on the module orientation (PVModuleOrientationType).

12.5.1.1. Simple Performance Model

The Simple Performance Photovoltaic Model properties are defined in the **PhotovoltaicPerformanceSimple** table in the database, corresponding to the Photovoltaic:Performance:Simple object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – simple performance model name (simplePerfName);
- fractionOfSurfaceAreaWithActiveSolarCells – fraction for the area of surface named in the parent PV object that will have active PV cells on it;
- conversionEfficiencyInputMode – ‘Fixed’ or ‘Scheduled’;
- valueForCellEfficiencyIfFixed – efficiency with which solar incident energy is converted to electricity. Used if conversionEfficiencyInputMode = Fixed;
- efficiencyScheduleID – efficiency schedule ID, defined in the **Schedules** table in the database (**21**). Used if conversionEfficiencyInputMode = Scheduled.

Automatic filling fields in EnergyPlus:

- Name – generatorName + simplePerfName.

12.5.1.2. Equivalent One-Diode Performance Model

The Equivalent One-Diode Photovoltaic Performance Model properties are defined in the **PhotovoltaicPerformanceEquivalentOneDiode** table in the database, corresponding to the Photovoltaic:Performance:EquivalentOne-Diode object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – equivalent one-diode performance model name (EqOneDiodePerfName);
- cellType – ‘CrystallineSilicon’ or ‘AmorphousSilicon’;
- numberOfCellsInSeries – number of individual cells wired in series to make up a single module;
- activeArea – active area of the PV module in m2;
- transmittanceAbsorptanceProduct – transmittance-absorptance product at normal incidence angles for the PV modules;
- semiconductorBandgap – semiconductor bandgap for the PV material [eV];

- shuntResistance – shunt (parallel) resistance in the single diode electrical model of the PV [ohm];
- shortCircuitCurrent – short circuit current for an individual module in the PV array at reference conditions [A];
- openCircuitVoltage – open circuit voltage for an individual module in the PV array at reference conditions [V];
- referenceTemperature – ambient temperature at reference conditions [K];
- referenceInsolation – radiation level at reference conditions [W/m2];
- moduleCurrentAtMaximumPower – module current at the maximum power point and reference conditions [A];
- moduleVoltageAtMaximumPower – module voltage at the maximum power point and reference conditions [V];
- temperatureCoefficientOfShortCircuitCurrent – temperature coefficient of short circuit current [A/K];
- temperatureCoefficientOfOpenCircuitVoltage – temperature coefficient of open circuit voltage [V/K];
- nominalOperatingCellTemperatureTestAmbientTemperature – ambient temperature from the Nominal Operating Cell Temperature (NOCT) test [K];
- nominalOperatingCellTemperatureTestCellTemperature – cell temperature from the Nominal Operating Cell Temperature (NOCT) test [K];
- nominalOperatingCellTemperatureTestInsolation – insolation level from the Nominal Operating Cell Temperature (NOCT) test [W/m2];
- moduleHeatLossCoefficient – heat loss coefficient for the array [W/m2.K];
- totalHeatCapacity – heat capcaity of the modules in the array [J/m2.K].

Automatic filling fields in EnergyPlus:

- Name – generatorName + EqOneDiodePerfName.

12.5.1.3. Sandia Performance Model

The Sandia Photovoltaic Performance Model properties are defined in the **PhotovoltaicPerformanceSandia** table in the database, corresponding to the Photovoltaic:Performance:Sandia object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – sandiaPerfName;
- activeArea – area of active solar electric cell for the entire module [m2];
- numberOfCellsInSeries – number of cells in series (Series_Cells in Sandia Database);
- numberOfCellsInParallel – number of cells in parallel (Parallel_Cells in Sandia Database);
- shortCircuitCurrent – short-circuit current [A] (Isco in Sandia Database);
- openCircuitVoltage – open-circuit voltage [V] (Voco in Sandia Database);
- currentAtMaximumPowerPoint – current at maximum powerpoint [A] (Impo in Sandia Database);
- voltageAtMaximumPowerPoint – voltage at maximum powerpoint [V] (Vmpo in Sandia Database);
- aIsc – aIsc in Sandia Database [1/°C];

- aImp – aImp in Sandia Database [1/°C];
- c0-c7 – C0 to C7 in Sandia Database;
- BVoc0 – Bvoco in Sandia Database [V/°C];
- mBVoc – mBVoc in Sandia Database [V/°C];
- BVmp0 – BVmp0 in Sandia Database [V/°C];
- mBVmp – mBVmp in Sandia Database [V/°C];
- diodeFactor – n in Sandia Database;
- a0-a4 – A0 to A4 in Sandia Database;
- b0-b5 – B0 to B5 in Sandia Database;
- deltaTc – d(Tc) in Sandia Database [°C];
- fd – fd in Sandia Database;
- a – a in Sandia Database;
- b – b in Sandia Database;
- Ix0 – Ix0 in Sandia Database [A];
- Ixx0 – Ixx0 in Sandia Database [A].

Automatic filling fields in EnergyPlus:

- Name – generatorName + sandiaPerfName.

12.5.2. Wind Turbine

The addition of a wind turbine generator to the load center is as follows:

electricLoadCenterDistributionSpec.addGeneratorSpec(new GeneratorWindTurbineSpec()) – addition of the wind turbine generator specification to the load center, with the following arguments in GeneratorWindTurbineSpec():

- "**ABC"** – wind turbine generator name;
- **DBGeneratorWindTurbineType.ABC.getID()** – ID of the Wind Turbine generator properties in the database (see below), defined using the DBGeneratorWindTurbineType list object (ID of 'ABC', in this example). Alternatively, the proper database ID can be directly inputted here;
- **db** – database unique ID.

The Wind Turbine generator properties are defined in the **GeneratorWindTurbine** table in the database, corresponding to the Generator:WindTurbine object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- availabilityScheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the wind turbine is always available;
- rotorType – 'HorizontalAxisWindTurbine' or 'VerticalAxisWindTurbine';
- powerControl – 'VariableSpeedVariablePitch', 'FixedSpeedFixedPitch', 'FixedSpeedVariablePitch' or 'VariableSpeedFixedPitch';

- ratedRotorSpeed – maximum rotational speed of the rotor at the rated power of the wind turbine in rev/min;
- rotorDiameter – diameter of the rotor in meters;
- overallHeight – height of the hub of the horizontal axis wind turbine (HAWT) system or of the pole of the vertical axis wind turbine (VAWT) system in meters;
- numberOfBlades – number of blades of the wind turbine;
- ratedPower – nominal power output of the wind turbine system at the rated wind speed in W;
- ratedWindSpeed – wind speed that the wind turbine system indicates the peak in the power curve in m/s;
- cutInWindSpeed – lowest wind speed where the wind turbine system can be operated in m/s;
- cutOutWindSpeed – greatest wind speed where the wind turbine system can be operated in m/s;
- fractionSystemEfficiency – overall system efficiency of the wind turbine system;
- maximumTipSpeedRatio – maximum tip speed ratio between the rotor velocity and ambient wind velocity;
- maximumPowerCoefficient – maximum fraction of power extraction from ambient wind;
- annualLocalAverageWindSpeed – local annual average wind speed that represents a representative wind profile at the location of the system in m/s;
- heightForLocalAverageWindSpeed – height that the local wind speed is measured in meters;
- bladeChordArea – blade chord area of a single blade of VAWT system in m2. Only valid for VAWT systems;
- bladeDragCoefficient – blade drag coefficient for a specific blade. Only valid for VAWT systems;
- bladeLiftCoefficient – blade lift coefficient for a specific blade. Only valid for VAWT systems;
- c1-c6 – parameters for the power coefficient equation. Only valid for HAWT systems
- generatorRatedElectricPower – nominal electric power output to be requested from generator [W]. This value is assigned to the 'Generator X Rated Electric Power Output' field in the ElectricLoadCenter:Generators object in EnergyPlus, if the wind turbine generator is connected to the Electric Load Center. X represents the wind turbine generator position in the equipment list;
- generatorAvailabilityScheduleID – wind turbine generator availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the wind turbine generator is always available. This value is assigned to the 'Generator X Availability Schedule Name' field in the ElectricLoadCenter:Generators object in EnergyPlus, if the wind turbine generator is connected to the Electric Load Center. X represents the wind turbine generator position in the equipment list;
- generatorRatedThermalToElectricalPowerRatio – ratio of the rated thermal output to the rated electric output. This value is assigned to the 'Generator X Rated Thermal to Electrical Power Ratio' field in the ElectricLoadCenter:Generators object in EnergyPlus, if the wind turbine generator is connected to the Electric Load Center. X represents the wind turbine generator position in the equipment list. Only required if the Electric Load Center Generator Operation Scheme Type = FollowThermal or

FollowThermalLimitElectrical, defined in the second argument of the ElectricLoadCenterDistributionSpec(), in section **12.1**;

- costID – equipment cost ID, defined in the **Cost** table in the database (**24**).

Automatic filling fields in EnergyPlus:

- Name – windTurbineName = wind turbine generator name (defined in the first argument of the GeneratorWindTurbineSpec() above).

13.HVAC DESIGN

13.1. Design Specification

13.1.1. Outdoor Air

The Design Specification Outdoor Air properties are defined in the **DesignSpecificationOutdoorAir** table in the database, corresponding to the DesignSpecification:OutdoorAir object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- outdoorAirMethod – 'None', 'Flow_Person', 'Flow_Area', 'Flow_Zone', 'AirChanges_Hour', 'Sum' or 'Maximum';
- outdoorAirFlowPerPerson – design outdoor air flow rate per person for this zone in m3/s. Only used if outdoorAirMethod = Flow_Person, Sum or Maximum;
- outdoorAirFlowPerZoneFloorArea – design outdoor air volumetric flow rate per square meter of floor area [m3/s.m2]. Only used if outdoorAirMethod = Flow_Area, Sum or Maximum;
- outdoorAirFlowPerZone – design outdoor air flow rate for this zone in m3/s. Only used if outdoorAirMethod = Flow_Zone, Sum or Maximum;
- outdoorAirFlowChangesPerHour – design outdoor air volume flow rate in air changes per hour;
- outdoorAirFlowAutoSchedule – '0'/null (false) or '1' (true). If true, it automatically reads the weather file assigned for the simulation and sets 1.0 for the Spring and Summer months (i.e., allows outdoor air flow during the warmer months), and 0.0 for the Autumn and Winter months (i.e., does not allows outdoor air flow during the colder months). In this case, the next field is automatically set to blank;
- outdoorAirFlowScheduleID – outdoor air flow rate schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the schedule defaults to 1.0;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "DS_OUTDOOR_AIR" + Zone Name (Zone Name – name of the zone for which this object is assigned).

13.1.2. Zone Air Distribution

The Design Specification Zone Air Distribution properties are defined in the **DesignSpecificationZoneAirDistribution** table in the database, corresponding to the DesignSpecification:ZoneAirDistribution object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- distributionEffectivenessInCoolingMode – zone air distribution effectiveness when the zone is in cooling mode;
- distributionEffectivenessInHeatingMode – zone air distribution effectiveness when the zone is in heating mode;

- distributionEffectivenessScheduleID – zone air distribution effectiveness schedule ID, defined in the **Schedules** table in the database (**21**) (optional). If the schedule is specified, the zone air distribution effectiveness in cooling mode and heating mode will be ignored;
- zoneSecondaryRecirculationFraction – fraction of a zone's recirculation air that does not directly mix with the outdoor air (optional);
- minimumZoneVentilationEfficiency – minimum on the ventilation efficiency for the zone (optional);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – "DS_ZONEAIR_DISTRIBUTION" + Zone Name (Zone Name – name of the zone for which this object is assigned).

13.1.3. Zone HVAC Sizing

The Design Specification Zone HVAC Sizing properties are defined in the **DesignSpecificationZoneHVACSizing** table in the database, corresponding to the DesignSpecification:ZoneHVAC:Sizing object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- coolingSupplyAirFlowRateMethod – 'SupplyAirFlowRate', 'FlowPerFloorArea', 'FractionOfAutosizedCoolingAirflow', 'FlowPerCoolingCapacity' or 'None';
- coolingSupplyAirFlowRate – cooling supply air volume flow rate [m^3/s]. 'autosize' option is available. Only required when coolingSupplyAirFlowRateMethod = 'SupplyAirFlowRate'. It may be left blank if a cooling coil is not included in the zone HVAC equipment associated with this sizing object;
- coolingSupplyAirFlowRatePerFloorArea – cooling supply air volume flow rate per zone conditioned floor area [$m^3/s.m^2$]. Only required when coolingSupplyAirFlowRateMethod = 'FlowPerFloorArea'. It may be left blank if a cooling coil is not included in the zone HVAC equipment associated with this sizing object. Zone sizing object (see section **13.2.2**) is not required;
- coolingFractionOfAutosizedCoolingSupplyAirFlowRate – cooling supply air volume flow rate as a fraction of the autosized cooling supply air flow rate. Only required when coolingSupplyAirFlowRateMethod = 'FractionOfAutosizedCoolingAirflow'. It may be left blank if a cooling coil is not included in the zone HVAC equipment associated with this sizing object. Zone sizing object (see section **13.2.2**) is required;
- coolingSupplyAirFlowRatePerUnitCoolingCapacity – cooling supply air volume flow rate per unit cooling capacity [$m^3/s.W$]. Only required when coolingSupplyAirFlowRateMethod = 'FlowPerCoolingCapacity'. It may be left blank if a cooling coil is not included in the zone HVAC equipment associated with this sizing object. Zone sizing object (see section **13.2.2**) is required;
- noLoadSupplyAirFlowRateMethod – 'SupplyAirFlowRate', 'FlowPerFloorArea', 'FractionOfAutosizedCoolingAirflow', 'FractionOfAutosizedHeatingAirflow' or 'None';
- noLoadSupplyAirFlowRate – supply air volume flow rate when no cooling or heating is required [m^3/s]. 'autosize' option is available. Only required when

noLoadSupplyAirFlowRateMethod = ‘SupplyAirFlowRate’. It may be left blank if a cooling coil is not included in the zone HVAC equipment associated with this sizing object;

- noLoadSupplyAirFlowRatePerFloorArea – supply air volume flow rate per zone floor area [$m^3/s.m^2$]. Only required when noLoadSupplyAirFlowRateMethod = ‘FlowPerFloorArea’;
- noLoadFractionOfCoolingSupplyAirFlowRate – fraction of supply air volume flow rate as a fraction of the autosized cooling supply air flow rate. Only required when noLoadSupplyAirFlowRateMethod = ‘FractionOfAutosizedCoolingAirflow’;
- noLoadFractionOfHeatingSupplyAirFlowRate – fraction of supply air volume flow rate as a fraction of the autosized heating supply air flow rate. Only required when noLoadSupplyAirFlowRateMethod = ‘FractionOfAutosizedHeatingAirflow’;
- heatingSupplyAirFlowRateMethod – ‘SupplyAirFlowRate’, ‘FlowPerFloorArea’, ‘FractionOfAutosizedHeatingAirflow’, ‘FlowPerHeatingCapacity’ or ‘None’;
- heatingSupplyAirFlowRate – heating supply air volume flow rate [m^3/s]. ‘autosize’ option is available. Only required when heatingSupplyAirFlowRateMethod = ‘SupplyAirFlowRate’. It may be left blank if a heating coil is not included in the zone HVAC equipment associated with this sizing object;
- heatingSupplyAirFlowRatePerFloorArea – heating supply air volume flow rate per zone conditioned floor area [$m^3/s.m^2$]. Only required when heatingSupplyAirFlowRateMethod = ‘FlowPerFloorArea’;
- heatingFractionOfHeatingSupplyAirFlowRate – heating supply air volume flow rate as a fraction of the autosized heating supply air flow rate. Only required when heatingSupplyAirFlowRateMethod = ‘FractionOfAutosizedHeatingAirflow’. It may be left blank if a heating coil is not included in the zone HVAC equipment associated with this sizing object;
- heatingSupplyAirFlowRatePerUnitHeatingCapacity – heating supply air volume flow rate per unit heating capacity [$m^3/s.W$]. Only required when coolingSupplyAirFlowRateMethod = ‘FlowPerHeatingCapacity’. It may be left blank if a heating coil is not included in the zone HVAC equipment associated with this sizing object;
- coolingDesignCapacityMethod – ‘None’, ‘CoolingDesignCapacity’, ‘CapacityPerFloorArea’ or ‘FractionOfAutosizedCoolingCapacity’;
- coolingDesignCapacity – cooling capacity [W]. autosize’ option is available. Only required when coolingDesignCapacityMethod = ‘CoolingDesignCapacity’. It may be left blank if a cooling coil is not included in the zone HVAC equipment associated with this sizing object. Design day sizing run must be specified;
- coolingDesignCapacityPerFloorArea – cooling capacity per unit floor area [W/m^2]. Only required when coolingDesignCapacityMethod = ‘CapacityPerFloorArea’. It may be left blank if a cooling coil is not included in the zone HVAC equipment associated with this sizing object;
- fractionOfAutosizedCoolingDesignCapacity – cooling capacity as a fraction of the autosized cooling capacity. Only required when coolingDesignCapacityMethod = ‘FractionOfAutosizedCoolingCapacity’. It may be left blank if a cooling coil is not included in the zone HVAC equipment associated with this sizing object. Design day sizing run must be specified;

- heatingDesignCapacityMethod – ‘None’, ‘HeatingDesignCapacity’, ‘CapacityPerFloorArea’ or ‘FractionOfAutosizedHeatingCapacity’;
- heatingDesignCapacity – heating capacity [W]. autosize’ option is available. Only required when heatingDesignCapacityMethod = ‘HeatingDesignCapacity’. It may be left blank if a heating coil is not included in the zone HVAC equipment associated with this sizing object. Design day sizing run must be specified;
- heatingDesignCapacityPerFloorArea – heating capacity per unit floor area [W/m^2]. Only required when heatingDesignCapacityMethod = ‘CapacityPerFloorArea’. It may be left blank if a heating coil is not included in the zone HVAC equipment associated with this sizing object;
- fractionOfAutosizedHeatingDesignCapacity – heating capacity as a fraction of the autosized heating capacity. Only required when heatingDesignCapacityMethod = ‘FractionOfAutosizedHeatingCapacity’. It may be left blank if a heating coil is not included in the zone HVAC equipment associated with this sizing object. Design day sizing run must be specified;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – “DS_ZHVAC_SIZ” + Unit name (Unit name – name of the Zone HVAC equipment for which this sizing object is assigned).

13.1.4. Air Terminal Sizing

The Design Specification Air Terminal Sizing properties are defined in the **DesignSpecificationAirTerminalSizing** table in the database, corresponding to the DesignSpecification:AirTerminal:Sizing object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- fractionOfDesignCoolingLoad – fraction of the design sensible cooling load to be met by this terminal unit;
- coolingDesignSupplyAirTemperatureDifferenceRatio – ratio that adjusts the supply air temperature difference used to calculate the cooling design supply air flow rate for this terminal unit;
- fractionOfDesignHeatingLoad – fraction of the design sensible heating load to be met by this terminal unit;
- heatingDesignSupplyAirTemperatureDifferenceRatio – ratio that adjusts the supply air temperature difference used to calculate the heating design supply air flow rate for this terminal unit;
- fractionOfMinimumOutdoorAirFlow – fraction of the zone minimum outdoor air requirement to be met by this terminal unit;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – “DS_AIR_TERM_SIZ” + Zone Name (Zone Name – name of the zone for which this object is assigned).

13.2. Sizing

13.2.1. Parameters

The Sizing Parameters are assigned to the simulation in the SAPTool_LSP building templates (SAPTool_LSP>Source Pacakges>lsp.templates), in the 13th argument of the Dynamic Simulation Specifications (DynamicSimulationSpec()), as follows:

new SizingParametersSpec(x, db) – specification of the sizing parameters, defined in the ID x of the table **SizingParameters** in the database db, corresponding to the Sizing:Parameters object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- heatingSizingFactor – global heating sizing ratio applied to all of the zone design heating loads and air flow rates;
- coolingSizingFactor – global cooling sizing ratio applied to all of the zone design cooling loads and air flow rates;
- timestepsInAveragingWindow – number of load timesteps in the zone design flow sequence averaging window.

13.2.2. Zone

This object provides the data needed to perform a zone design air flow calculation for a single zone. This is required for all the Zone HVAC equipment (**7.1**) when its Heating and/or Cooling Design Capacity is autosized.

The 'Do Zone Sizing Calculation' option must be turned on in the Simulation Control to allow for the zone sizing required for autosized fields (see section **17**), and a sizing period must be specified (see section **13.2.5**).

In order to perform a zone sizing, a Sizing Zone object must be assigned to the zone in the 'sizingZoneID' column of the **Zone** table in the database (**0**), and defined in the **SizingZone** table in the database, which corresponds to the Sizing:Zone object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- zoneCoolingDesignSupplyAirTemperatureMethod – 'SupplyAirTemperature' or 'TemperatureDifference';
- zoneCoolingDesignSupplyAirTemperature – supply air temperature in degrees Celsius for the zone cooling design air flow rate calculation. Only used if zoneCoolingDesignSupplyAirTemperatureMethod = SupplyAirTemperature;
- zoneCoolingDesignSupplyAirTemperatureDifference – temperature difference between cooling design supply air temperature and room air temperature in degrees Celsius for the zone cooling design air flow rate calculation. Only used if zoneCoolingDesignSupplyAirTemperatureMethod = TemperatureDifference;
- zoneHeatingDesignSupplyAirTemperatureMethod – 'SupplyAirTemperature' or 'TemperatureDifference';

- zoneHeatingDesignSupplyAirTemperature – supply air temperature in degrees Celsius for the zone heating design air flow rate calculation. Only used if zoneHeatingDesignSupplyAirTemperatureMethod = SupplyAirTemperature;
- zoneHeatingDesignSupplyAirTemperatureDifference – temperature difference between heating design supply air temperature and room air temperature in degrees Celsius for the zone heating design air flow rate calculation. Only used if zoneHeatingDesignSupplyAirTemperatureMethod = TemperatureDifference;
- zoneCoolingDesignSupplyAirHumidityRatio – humidity ratio in kilograms of water per kilogram of dry air of the supply air in the zone cooling design air flow rate calculation;
- zoneHeatingDesignSupplyAirHumidityRatio – humidity ratio in kilograms of water per kilogram of dry air of the supply air in the zone heating design air flow rate calculation;
- designSpecificationOutdoorAirID – ID of the Design Specification Outdoor Air object which specifies the design outdoor air flow rate for the zone (optional). This object is defined in table **DesignSpecificationOutdoorAir** in the database (**13.1.1**);
- zoneHeatingSizingFactor – zone level heating sizing ratio. The zone design heating air flow rates and load will be multiplied by the number input in this field. If blank or zero, the global Heating Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- zoneCoolingSizingFactor – zone level cooling sizing ratio. The zone design cooling air flow rates and load will be multiplied by the number input in this field. If blank or zero, the global Cooling Sizing Factor from Sizing Parameters (**13.2.1**) will be used;
- coolingDesignAirFlowMethod – 'DesignDay', 'Flow_Zone' or 'DesignDayWithLimit';
- coolingDesignAirFlowRate – design zone cooling air flow rate in m3/s. Only used if coolingDesignAirFlowMethod = Flow_Zone;
- coolingMinimumAirFlowPerFloorArea – minimum zone cooling volumetric flow rate per square meter [m3/s.m2]. Only used if coolingDesignAirFlowMethod = DesignDayWithLimit;
- coolingMinimumAirFlow – minimum zone cooling volumetric flow rate in m3/s. Only used if coolingDesignAirFlowMethod = DesignDayWithLimit;
- coolingMinimumAirFlowFraction – minimum zone design cooling volumetric flow rate expressed as a fraction of the zone design cooling volumetric flow rate;
- heatingDesignAirFlowMethod – 'DesignDay', 'Flow_Zone' or 'DesignDayWithLimit';
- heatingDesignAirFlowRate – design zone heating air flow rate in m3/s. Only used if heatingDesignAirFlowMethod = Flow_Zone;
- heatingMaximumAirFlowPerFloorArea – maximum zone heating volumetric flow rate per square meter [m3/s.m2]. Only used if heatingDesignAirFlowMethod = DesignDayWithLimit;
- heatingMaximumAirFlow – maximum zone heating volumetric flow rate in m3/s. Only used if heatingDesignAirFlowMethod = DesignDayWithLimit;
- heatingMaximumAirFlowFraction – maximum zone design heating volumetric flow rate expressed as a fraction of the zone design heating volumetric flow rate;
- designSpecificationZoneAirID – ID of the he Design Specification Zone Air Distribution object, defining the air distribution effectiveness and secondary recirculation air fraction, that applies to the zone (optional). This object is defined in table **DesignSpecificationZoneAirDistribution** in the database (**13.1.2**);
- accountForDedicatedOutdoorAirSystem – 'Yes' or 'No';
- dedicatedOutdoorAirSystemControlStrategy – 'NeutralSupplyAir', 'NeutralDehumidifiedSupplyAir' or 'ColdSupplyAir';

- dedicatedOutdoorAirLowTemperatureSetpoint – lower setpoint temperature to be used with the Dedicated Outdoor Air System design control strategy [°C]. 'autosize' option is available;
- dedicatedOutdoorAirHighTemperatureSetpoint – higher setpoint temperature to be used with the Dedicated Outdoor Air System design control strategy [°C]. 'autosize' option is available;
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Zone Name – name of the zone for which this object is assigned.

When specifying a zone sizing, a zone control thermostat must also be assigned to the zone. The definition of a Zone Control Thermostat is presented in section **7.2.1**. Furthermore, in order to run a zone sizing, Zone HVAC Equipment Connections must be defined (see section **7.1.9**).

13.2.3. System

This object contains the input needed to perform a central forced air system design air flow, heating capacity, and cooling capacity calculation for a system serving one or more zones. This is required for the Unitary System in an Air Loop HVAC (**10.4**).

The 'Do System Sizing Calculation' option must be turned on in the Simulation Control to allow for the system sizing required for autosized fields (see section **17**), and a sizing period must be specified (see section **13.2.5**).

The Sizing System properties are defined in the **SizingSystem** table in the database, corresponding to the Sizing:System object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- typeOfLoadToSizeOn – 'Sensible', 'Total' or 'VentilationRequirement';
- designOutdoorAirFlowRate – design outdoor air flow rate [m^3/s]. Generally, this should be the minimum outdoor air flow. 'autosize' option is available;
- centralHeatingMaximumSystemAirFlowRatio – ratio of the maximum system air flow rate for heating to the maximum system air flow rate. 'autosize' option is available;
- preheatDesignTemperature – design air temperature exiting the preheat coil (if any) [°C];
- preheatDesignHumidityRatio – design humidity ratio exiting the preheat coil (if any) [kg_{water}/kg_{dryAir}];
- precoolDesignTemperature – design air temperature exiting the precooling coil (if any) [°C];
- precoolDesignHumidityRatio – design humidity ratio exiting the precooling coil (if any) [kg_{water}/kg_{dryAir}];
- centralCoolingDesignSupplyAirTemperature – design supply air temperature for cooling (temperature of the air exiting the central cooling coil) [°C];
- centralHeatingDesignSupplyAirTemperature – design supply air temperature for heating (temperature of the air exiting the main heating coil) [°C];

- typeOfZoneSumToUse – ‘NonCoincident’ or ‘Coincident’;
- oneHundredPercentOutdoorAirInCooling – ‘Yes’ or ‘No’;
- oneHundredPercentOutdoorAirInHeating – ‘Yes’ or ‘No’;
- centralCoolingDesignSupplyAirHumidityRatio – design humidity ratio in kilograms of water per kilogram of dry air at the exit of the central cooling coil [kg_{water}/kg_{dryAir}];
- centralHeatingDesignSupplyAirHumidityRatio – design humidity ratio in kilograms of water per kilogram of dry air at the exit of the central heating coil [kg_{water}/kg_{dryAir}];
- coolingSupplyAirFlowRateMethod – ‘DesignDay’, ‘Flow_System’, ‘FlowPerFloorArea’, ‘FractionOfAutosizedCoolingAirflow’ or ‘FlowPerCoolingCapacity’;
- coolingSupplyAirFlowRate – design system cooling air flow rate [m^3/s]. Required if coolingSupplyAirFlowRateMethod = Flow_System;
- coolingSupplyAirFlowRatePerFloorArea – cooling supply air volume flow rate per zone conditioned floor area [$m^3/(s.m^2)$]. Required if coolingSupplyAirFlowRateMethod = FlowPerFloorArea;
- coolingFractionOfAutosizedCoolingSupplyAirFlowRate – cooling supply air volume flow rate as a fraction of the airloop autosized cooling supply air flow rate. Required if coolingSupplyAirFlowRateMethod = FractionOfAutosizedCoolingAirflow;
- coolingSupplyAirFlowRatePerUnitCoolingCapacity – cooling supply air volume flow rate per unit cooling capacity. Required if coolingSupplyAirFlowRateMethod = FlowPerCoolingCapacity;
- heatingSupplyAirFlowRateMethod – ‘DesignDay’, ‘Flow_System’, ‘FlowPerFloorArea’, ‘FractionOfAutosizedHeatingAirflow’, ‘FractionOfAutosizedCoolingAirflow’ or ‘FlowPerHeatingCapacity’;
- heatingSupplyAirFlowRate – design system heating air flow rate [m^3/s]. Required if heatingSupplyAirFlowRateMethod = Flow_System;
- heatingSupplyAirFlowRatePerFloorArea – heating supply air volume flow rate per zone conditioned floor area [$m^3/(s.m^2)$]. Required if heatingSupplyAirFlowRateMethod = FlowPerFloorArea;
- heatingFractionOfAutosizedHeatingSupplyAirFlowRate – heating supply air volume flow rate as a fraction of the airloop autosized heating supply air flow rate. Required if heatingSupplyAirFlowRateMethod = FractionOfAutosizedHeatingAirflow;
- heatingFractionOfAutosizedCoolingSupplyAirFlowRate – heating supply air volume flow rate per unit cooling capacity. Required if heatingSupplyAirFlowRateMethod = FractionOfAutosizedCoolingAirflow;
- heatingSupplyAirFlowRatePerUnitHeatingCapacity – heating supply air volume flow rate as a fraction of the airloop autosized cooling supply air flow rate [$m^3/(s.W)$]. Required if heatingSupplyAirFlowRateMethod = FlowPerHeatingCapacity;
- systemOutdoorAirMethod – ‘ZoneSum’ or ‘VentilationRateProcedure’;
- zoneMaximumOutdoorAirFraction – zone maximum outdoor air fraction;
- coolingDesignCapacityMethod – ‘CoolingDesignCapacity’, ‘None’, ‘CapacityPerFloorArea’ or ‘FractionOfAutosizedCoolingCapacity’;
- coolingDesignCapacity – cooling capacity [W]. Required if coolingDesignCapacityMethod = CoolingDesignCapacity. ‘autosize’ option is available;
- coolingDesignCapacityPerFloorArea – cooling capacity per unit floor area [W/m^2]. Required if coolingDesignCapacityMethod = CapacityPerFloorArea;

- fractionOfAutosizedCoolingDesignCapacity – cooling capacity as a fraction of the autosized cooling capacity. Required if coolingDesignCapacityMethod = FractionOfAutosizedCoolingCapacity;
- heatingDesignCapacityMethod – 'HeatingDesignCapacity', 'None', 'CapacityPerFloorArea' or 'FractionOfAutosizedHeatingCapacity';
- heatingDesignCapacity – heating capacity [W]. Required if heatingDesignCapacityMethod = HeatingDesignCapacity. 'autosize' option is available;
- heatingDesignCapacityPerFloorArea – heating capacity per unit floor area [W/m^2]. Required if heatingDesignCapacityMethod = CapacityPerFloorArea;
- fractionOfAutosizedHeatingDesignCapacity – heating capacity as a fraction of the autosized heating capacity. Required if heatingDesignCapacityMethod = FractionOfAutosizedHeatingCapacity;
- centralCoolingCapacityControlMethod – 'OnOff', 'VAV', 'Bypass' or 'VT';
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- AirLoop Name – name of the air loop containing the system for which this sizing system object is assigned.

13.2.4. Plant

The 'Do Plant Sizing Calculation' option must be turned on in the Simulation Control to allow for the plant sizing required for autosized fields (see section **17**), and a sizing period must be specified (see section **13.2.5**).

The Sizing Plant properties are defined in the **SizingPlant** table in the database, corresponding to the Sizing:Plant object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- loopType – 'Heating', 'Steam', 'Cooling' or 'Condenser';
- designLoopExitTemperature – water temperature in Celsius at the exit of the supply side of the plant loop;
- loopDesignTemperatureDifference – design temperature rise (for cooling or condenser loops) or fall (for heating loops) in Celsius across the demand side of a plant loop;
- sizingOption – 'NonCoincident' (default, if blank) or 'Coincident';
- zoneTimestepsInAveragingWindow – number of zone timesteps used in a moving average to determine the design flow rate from HVAC Sizing Simulation approach (optional, and used only if sizingOption = Coincident; default = 1, if blank);
- coincidentSizingFactorMode – controls the behaviour of coincident sizing with respect to what, if any, sizing factor should be applied to further modify the flow rate measured while running HVAC Sizing Simulations. 'None', 'GlobalHeatingSizingFactor', 'GlobalCoolingSizingFactor' or 'LoopComponentSizingFactor' (optional). Used only if sizingOption = Coincident.

Automatic filling fields in EnergyPlus:

- Plant or Condenser Loop Name – loop name and ID (loopName&ID) for which this sizing object is assigned.

13.2.5. Period

A Sizing Period object describes the parameters to affect a design period simulation, often used for load calculations or sizing equipment. Currently, the only Sizing Period object implemented is the Sizing Period Weather File Days, which uses a selected period from the "attached" weather file to be used in load calculations or sizing equipment.

The Sizing Period Weather File Days must be defined in the SAPTool_LSP building template in the 12th argument of the Dynamic Simulation specification object (DynamicSimulationSpec()). It is defined through a Sizing Period Weather File Days specification object (**new SizingPeriodWeatherFileDaysSpec()**), with the following arguments:

- **x** – ID of the Sizing Period Weather File Day properties in the database (see below);
- **db** – database unique ID.

The Sizing Period Weather File Day properties are defined in the **SizingPeriodWeatherFileDays** table in the database, corresponding to the SizingPeriod:WeatherFileDays object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- name – name for this run period;
- beginMonth – starting month number for the annual run period desired;
- beginDayOfMonth – starting day of the starting month for the annual run period desired;
- endMonth – ending month number for the annual run period desired;
- endDayOfMonth – ending day of the ending month for the annual run period desired;
- dayOfWeekForStartDay – 'Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'Sunday', 'SummerDesignDay', 'WinterDesignDay', 'CustomDay1' or 'CustomDay2';
- useWeatherFileDaylightSavingPeriod – '1' (yes) or '0' (no);
- useWeatherFileRainAndSnowIndicators – '1' (yes) or '0' (no).

14. SETPOINT MANAGERS

14.1. Scheduled Single Setpoint

The Setpoint Manager Scheduled Single Setpoint properties are defined in the **SetpointManagerScheduledSingleSetpoint** table in the database, corresponding to the SetpointManager:Scheduled object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- controlVariable – ‘Flow’, ‘Temperature’, ‘TemperatureAndHumidityRatio’, ‘HumidityRatio’, ‘MaximumHumidityRatio’, ‘MinimumHumidityRatio’, ‘MaximumTemperature’, ‘MinimumTemperature’ or ‘MassFlowRate’;
- scheduleID – setpoint schedule ID, defined in the **Schedules** table in the database (**21**).

Automatic filling fields in EnergyPlus:

- Name – “SM_SCH_SingleSP” + loopName&ID, if the setpoint manager is assigned to a loop; or “SM_SCH_SingleSP” + equipmentName, if the setpoint manager is assigned to an equipment;
- Setpoint Node Name – setpoint node of the loop or equipment for which the setpoint manager is assigned.

14.2. Scheduled Dual Setpoint

The Setpoint Manager Scheduled Dual Setpoint properties are defined in the **SetpointManagerScheduledDualSetpoint** table in the database, corresponding to the SetpointManager:Scheduled:DualSetpoint object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- controlVariable – ‘Flow’, ‘Temperature’, ‘TemperatureAndHumidityRatio’, ‘HumidityRatio’, ‘MaximumHumidityRatio’, ‘MinimumHumidityRatio’, ‘MaximumTemperature’, ‘MinimumTemperature’ or ‘MassFlowRate’;
- highSetpointScheduleID – high setpoint schedule ID, defined in the **Schedules** table in the database (**21**);
- lowSetpointScheduleID – low setpoint schedule ID, defined in the **Schedules** table in the database (**21**).

Automatic filling fields in EnergyPlus:

- Name – “SM_SCH_DualSP” + loopName&ID, if the setpoint manager is assigned to a loop; or “SM_SCH_DualSP” + equipmentName, if the setpoint manager is assigned to an equipment;
- Setpoint Node Name – setpoint node of the loop or equipment for which the setpoint manager is assigned.

14.3. Single Zone Cooling

The Setpoint Manager Single Zone Cooling properties are defined in the **SetpointManagerSingleZoneCooling** table in the database, corresponding to the SetpointManager:SingleZone:Cooling object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- controlVariable – only 'Temperature' is available;
- minimumSupplyAirTemperature – minimum supply air temperature that is allowed for this system [°C];
- maximumSupplyAirTemperature – maximum supply air temperature that is allowed for this system [°C].

Automatic filling fields in EnergyPlus:

- Name – "SM_SZ_Cool" + systemName (systemName – name of the system for which the setpoint manager is assigned);
- Control Zone Name – zoneName = name of the zone for which the system using this setpoint manager is assigned;
- Zone Node Name – zoneName + "AIR_NODE";
- Zone Inlet Node Name – Zone Supply Air Node Name of the zone inlet unit assigned to the system;
- Setpoint Node Name – setpoint node of the system for which the setpoint manager is assigned (usually, the outlet node).

14.4. Single Zone Heating

The Setpoint Manager Single Zone Heating properties are defined in the **SetpointManagerSingleZoneHeating** table in the database, corresponding to the SetpointManager:SingleZone:Heating object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- controlVariable – only 'Temperature' is available;
- minimumSupplyAirTemperature – minimum supply air temperature that is allowed for this system [°C];
- maximumSupplyAirTemperature – maximum supply air temperature that is allowed for this system [°C].

Automatic filling fields in EnergyPlus:

- Name – "SM_SZ_Heat" + systemName (systemName – name of the system for which the setpoint manager is assigned);
- Control Zone Name – zoneName = name of the zone for which the system using this setpoint manager is assigned;
- Zone Node Name – zoneName + "AIR_NODE";
- Zone Inlet Node Name – Zone Supply Air Node Name of the zone inlet unit assigned to the system;
- Setpoint Node Name – setpoint node of the system for which the setpoint manager is assigned (usually, the outlet node).

14.5. Single Zone Humidity Minimum

A Single Zone Humidity Minimum Setpoint Manager is automatically defined whenever a humidifier is assigned to an air loop (see section **10.6**). It corresponds to the SetpointManager:SingleZone:Humidity:Minimum object in EnergyPlus, where all the fields are automatically filled:

- Name – "SM_SZ_Humid_Min" + airLoopName (airLoopName – name of the air loop for which this setpoint manager is assigned);
- Setpoint Node Name – humidifier Air Outlet Node Name (humidifierName + “Outlet_node” – see section **8.10**);
- Control Zone Air Node Name – zoneName + “AIR_NODE” (zoneName – zone name where the humidistat is located for controlling humidification, defined in the humidifier – see section **8.10**).

14.6. Single Zone Humidity Maximum

A Single Zone Humidity Maximum Setpoint Manager is automatically assigned to unitary system coils (**10.4**) in an air loop when certain conditions are met (see section **10.6**). The setpoint manager corresponds to the SetpointManager:SingleZone:Humidity:Maximum object in EnergyPlus, where all the fields are automatically filled:

- Name – "SM_SZ_Humid_Max" + airLoopName (airLoopName – name of the air loop for which this setpoint manager is assigned);
- Setpoint Node Name – supplemental heating coil Outlet Air Node Name (coilName + “Outlet_node” – see section **8.9.2**);
- Control Zone Air Node Name – zoneName + “AIR_NODE” (zoneName – zone name where the humidistat is located for controlling humidification, defined in the argument x2 of the AirLoopHVACUnitarySystemSpec() – see section **10.4**).

14.7. Outdoor Air Reset

The Setpoint Manager Outdoor Air Reset properties are defined in the **SetpointManagerOutdoorAirReset** table in the database, corresponding to the SetpointManager:OutdoorAirReset object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- controlVariable – ‘Temperature’;
- setpointAtOutdoorLowTemperature – supply air temperature setpoint in Celsius at the outdoor low temperature for the first reset rule;
- outdoorLowTemperature – outdoor air low temperature in Celsius for the first supply air temperature reset rule. Generally, at this outdoor air temperature the supply temperature is at its maximum;
- setpointAtOutdoorHighTemperature – supply air temperature setpoint in Celsius at the outdoor high temperature for the first reset rule;

- outdoorHighTemperature – outdoor air high temperature in Celsius for the first supply air temperature reset rule. Generally, at this outdoor air temperature the supply temperature is at its minimum;
- scheduleID – ID of the schedule indicating which reset rule to use: 1 – first reset rule, 2 – second reset rule. Defined in the **Schedules** table in the database (**21**);
- setpointAtOutdoorLowTemperature2 – supply air temperature setpoint in Celsius at the outdoor low temperature for the second reset rule;
- outdoorLowTemperature2 – outdoor air low temperature in Celsius for the second supply air temperature reset rule. Generally, at this outdoor air temperature the supply temperature is at its maximum;
- setpointAtOutdoorHighTemperature2 – supply air temperature setpoint in Celsius at the outdoor high temperature for the second reset rule;
- outdoorHighTemperature2 – outdoor air high temperature in Celsius for the second supply air temperature reset rule. Generally, at this outdoor air temperature the supply temperature is at its minimum.

Automatic filling fields in EnergyPlus:

- Name – “SM_OAReset” + loopName&ID, if the setpoint manager is assigned to a loop; or “SM_OAReset” + equipmentName, if the setpoint manager is assigned to an equipment;
- Setpoint Node Name – setpoint node of the loop or equipment for which the setpoint manager is assigned.

14.8. Follow Outdoor Air Temperature

The Setpoint Manager Follow Outdoor Air Temperature properties are defined in the **SetpointManagerFollowOutdoorAirTemperature** table in the database, corresponding to the SetpointManager:FollowOutdoorAirTemperature object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- controlVariable – ‘Temperature’, ‘MaximumTemperature’ or ‘MinimumTemperature’;
- referenceTemperatureType – ‘OutdoorDryBulb’ or ‘OutdoorWetBulb’;
- offsetTemperatureDifference – temperature offset that will be applied to the value of the reference temperature (outdoor air wetbulb/drybulb) [ΔT]. If this value is zero, and the limits are met, then the resulting setpoint will be exactly the same as the outdoor air wetbulb/drybulb temperature;
- maximumSetpointTemperature – upper limit to the resulting setpoint value [°C];
- minimumSetpointTemperature – lower limit to the resulting setpoint value [°C];

Automatic filling fields in EnergyPlus:

- Name – "SM_FOAT" + loopName&ID, if the setpoint manager is assigned to a loop; or “SM_FOAT” + equipmentName, if the setpoint manager is assigned to an equipment;
- Setpoint Node Name – setpoint node of the loop or equipment for which the setpoint manager is assigned.

14.9. Mixed Air

A Mixed Air Setpoint Manager is automatically defined and used in conjunction with a Controller Outdoor Air object in an Air Loop HVAC (see section **10.6**). It corresponds to the SetpointManager:MixedAir object in EnergyPlus, where all the fields are automatically filled:

- Name – "SM_Mixed_Air" + airLoopName (airLoopName – name of the air loop for which this setpoint manager is assigned);
- Control Variable – there is only one choice for this type of setpoint manager: 'Temperature';
- Reference Setpoint Node Name – if the air loop contains a Unitary System, is the outlet node of the Unitary System. If not, is the outlet node of the air loop (outlet node of its last component). However, if the last component is a humidifier, the node is defined as the outlet node of the second from last component;
- Fan Inlet Node Name – inlet node of the supply or return fan assigned to the air loop. If a supply or return fan is not assigned, the inlet node of the Unitary System supply fan (**10.4**) (if assigned) is used instead. If not, the outlet node of the air loop outdoor air system (**10.5**) is considered;
- Fan Outlet Node Name – outlet node of the supply or return fan assigned to the air loop. If a supply or return fan is not assigned, the outlet node of the unitary system supply fan (**10.4**) (if assigned) is used instead. If not, the outlet node of the air loop is considered;
- Setpoint Node or NodeList Name – node list containing the outlet node of the air loop outdoor air system (**10.5**);
- Cooling Coil Inlet Node Name – Air Inlet Node Name of the cooling coil directly assigned to the air loop, if any. If the coil is not assigned, the Air Inlet Node Name of the cooling coil (if present) defined for the Unitary System (**10.4**) assigned to the air loop is considered. If not, no node is assigned. Also, this node is only defined here if the 'Minimum Temperature at Cooling Coil Outlet Node' field below is not blank;
- Cooling Coil Outlet Node Name – Air Outlet Node Name of the cooling coil directed assigned to the air loop, if any. If the coil is not assigned, the Air Outlet Node Name of the cooling coil (if present) defined for the Unitary System (**10.4**) assigned to the air loop is considered. If not, no node is assigned. Also, this node is only defined here if the 'Minimum Temperature at Cooling Coil Outlet Node' field below is not blank;
- Minimum Temperature at Cooling Coil Outlet Node – temperature defined in the Outdoor Air System specification assigned to the air loop (**10.5**) (optional).

14.10. Warmest

The Setpoint Manager Warmest properties are defined in the **SetpointManagerWarmest** table in the database, corresponding to the SetpointManager:Warmest object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- controlVariable – 'Temperature';
- minimumSetpointTemperature – minimum allowed setpoint temperature [°C];
- maximumSetpointTemperature – maximum allowed setpoint temperature [°C];
- strategy – 'MaximumTemperature'.

Automatic filling fields in EnergyPlus:

- Name – “SM_WARMEST” + airLoopName (airLoopName – name of the air loop for which this setpoint manager is assigned);
- HVAC Air Loop Name – airLoopName;
- Setpoint Node Name – setpoint node of the loop or equipment for which the setpoint manager is assigned.

15. AVAILABILITY MANAGERS

The user should assign the selected availability manager type(s) to the desired equipment/loop/air loop in the SAPTool_LSP building template, as follows (to each availability manager added to an equipment/loop/air loop corresponds an AvailabManagerID):

15.1. Scheduled

AvailabilityManagerScheduledSpec ams = new AvailabilityManagerScheduledSpec() – Scheduled availability manager specification (named ams in this example). With the following AvailabilityManagerScheduledSpec() argument:

- **new ScheduleSpec(DBScheduleType.SCH.getID(), db)** – schedule ID in the database db, defined using the DBScheduleType list object ("SCH", in this example).

This corresponds to the AvailabilityManager:Scheduled object in EnergyPlus, where all the fields are automatically filled, according to the input above:

- Name – AvailabManagerListName + "AM" + AvailabManagerID (AvailabManagerID – ID of each availability manager added to the air loop; AvailabManagerListName – name of the list for which this availability manager is assigned (see section **15.8**));
- Schedule Name – schedule defined in the AvailabilityManagerScheduledSpec().

15.2. High Temperature Turn On

AvailabilityManagerHighTemperatureTurnOnSpec amhtton = new AvailabilityManagerHighTemperatureTurnOnSpec() – High Temperature Turn On availability manager specification (named amhtton in this example). With the following AvailabilityManagerHighTemperatureTurnOnSpec() arguments:

- **LoopSideType.XX** – loop side for which the selected equipment is assigned. XX = 'PLANT' or 'DEMAND';
- **x1** – selected equipment ID in the branch side defined in the previous argument (plant/demand) – the first equipment is 0, the second equipment is 1, etc. <u>If a negative value is inputted here, the availability manager setpoint is assigned to an outdoor air node instead</u> (named loopName + loopID + "SP_OA_node"), which is automatically defined in an outdoor air node list with the OutdoorAir:NodeList object in EnergyPlus;
- **x2** – temperature setpoint in Celsius (double type input).

This corresponds to the AvailabilityManager:HighTemperatureTurnOn object in EnergyPlus, where all the fields are automatically filled, according to the input above:

- Name – AvailabManagerListName + "AM" + AvailabManagerID (AvailabManagerID – ID of each availability manager added);
- Sensor Node Name – output node name of the selected equipment, defined in the argument x1 of the AvailabilityManagerHighTemperatureTurnOnSpec() above;

- Temperature – temperature setpoint, defined in the argument x2 of the AvailabilityManagerHighTemperatureTurnOnSpec().

15.3. High Temperature Turn Off

AvailabilityManagerHighTemperatureTurnOffSpec amhttoff = new AvailabilityManagerHighTemperatureTurnOffSpec() – High Temperature Turn Off availability manager specification (named amhttoff in this example). With the following AvailabilityManagerHighTemperatureTurnOffSpec() arguments:

- **LoopSideType.XX** – loop side for which the selected equipment is assigned. XX = 'PLANT' or 'DEMAND';
- **x1** – selected equipment ID in the branch side defined in the previous argument (plant/demand) – the first equipment is 0, the second equipment is 1, etc. <u>If a negative value is inputted here, the availability manager setpoint is assigned to an outdoor air node instead</u> (named loopName + loopID + "SP_OA_node"), which is automatically defined in an outdoor air node list with the OutdoorAir:NodeList object in EnergyPlus;
- **x2** – temperature setpoint in Celsius (double type input).

This corresponds to the AvailabilityManager:HighTemperatureTurnOff object in EnergyPlus, where all the fields are automatically filled, according to the input above:

- Name – AvailabManagerListName + "AM" + AvailabManagerID (AvailabManagerID – ID of each availability manager added);
- Sensor Node Name – output node name of the selected equipment, defined in the argument x1 of the AvailabilityManagerHighTemperatureTurnOffSpec() above;
- Temperature – temperature setpoint, defined in the argument x2 of the AvailabilityManagerHighTemperatureTurnOffSpec() above.

15.4. Low Temperature Turn On

AvailabilityManagerLowTemperatureTurnOnSpec amltton = new AvailabilityManagerLowTemperatureTurnOnSpec() – Low Temperature Turn On availability manager specification (named amltton in this example). With the following AvailabilityManagerLowTemperatureTurnOnSpec() arguments:

- **LoopSideType.XX** – loop side for which the selected equipment is assigned. XX = 'PLANT' or 'DEMAND';
- **x1** – selected equipment ID in the branch side defined in the previous argument (plant/demand) – the first equipment is 0, the second equipment is 1, etc. <u>If a negative value is inputted here, the availability manager setpoint is assigned to an outdoor air node instead</u> (named loopName + loopID + "SP_OA_node"), which is automatically defined in an outdoor air node list with the OutdoorAir:NodeList object in EnergyPlus;
- **x2** – temperature setpoint in Celsius (double type input).

This corresponds to the AvailabilityManager:LowTemperatureTurnOn object in EnergyPlus, where all the fields are automatically filled, according to the input above:

- Name – AvailabManagerListName + "AM" + AvailabManagerID (AvailabManagerID – ID of each availability manager added);
- Sensor Node Name – output node name of the selected equipment, defined in the argument x1 of the AvailabilityManagerLowTemperatureTurnOnSpec() above;
- Temperature – temperature setpoint, defined in the argument x2 of the AvailabilityManagerLowTemperatureTurnOnSpec() above.

15.5. Low Temperature Turn Off

AvailabilityManagerLowTemperatureTurnOffSpec amlttoff = new AvailabilityManagerLowTemperatureTurnOffSpec() – Low Temperature Turn Off availability manager specification (named amlttoff in this example). With the following AvailabilityManagerLowTemperatureTurnOffSpec() arguments:

- **LoopSideType.XX** – loop side for which the selected equipment is assigned. XX = 'PLANT' or 'DEMAND';
- **x1** – selected equipment ID in the branch side defined in the previous argument (plant/demand) – the first equipment is 0, the second equipment is 1, etc. <u>If a negative value is inputted here, the availability manager setpoint is assigned to an outdoor air node instead</u> (named loopName + loopID + "SP_OA_node"), which is automatically defined in an outdoor air node list with the OutdoorAir:NodeList object in EnergyPlus;
- **x2** – temperature setpoint in Celsius (double type input).

This corresponds to the AvailabilityManager:LowTemperatureTurnOff object in EnergyPlus, where all the fields are automatically filled, according to the input above:

- Name – AvailabManagerListName + "AM" + AvailabManagerID (AvailabManagerID – ID of each availability manager added);
- Sensor Node Name – output node name of the selected equipment, defined in the argument x1 of the AvailabilityManagerLowTemperatureTurnOffSpec() above;
- Temperature – temperature setpoint, defined in the argument x2 of the AvailabilityManagerLowTemperatureTurnOffSpec() above.

15.6. Differential Thermostat

AvailabilityManagerDifferentialThermostatSpec amdt = new AvailabilityManagerDifferentialThermostatSpec() – Differential Thermostat availability manager specification (named amdt in this example). With the following AvailabilityManagerDifferentialThermostatSpec() arguments:

- **LoopSideType.XX** – loop side for which the selected hot node equipment is assigned. XX = 'PLANT' or 'DEMAND';
- **x1** – selected hot node equipment ID in the branch side defined in the previous argument (plant/demand) – the first equipment is 0, the second equipment is 1, etc. <u>If</u>

a negative value is inputted here, the availability manager hot setpoint is assigned to an outdoor air node instead (named loopName + loopID + "Hot_SP_OA_node"), which is automatically defined in an outdoor air node list with the OutdoorAir:NodeList object in EnergyPlus;

- **LoopSideType.XX** – loop side for which the selected cold node equipment is assigned. XX = 'PLANT' or 'DEMAND';
- **x2** – selected cold node equipment ID in the branch side defined in the previous argument (plant/demand) – the first equipment is 0, the second equipment is 1, etc. If a negative value is inputted here, the availability manager cold setpoint is assigned to an outdoor air node instead (named loopName + loopID + "Cold_SP_OA_node"), which is automatically defined in an outdoor air node list with the OutdoorAir:NodeList object in EnergyPlus;
- **x3** – temperature difference on limit in Celsius (double type input);
- **x4** – temperature difference off limit in Celsius (double type input).

This corresponds to the AvailabilityManager:DifferentialThermostat object in EnergyPlus, where all the fields are automatically filled, according to the input above:

- Name – AvailabManagerListName + "AM" + AvailabManagerID (AvailabManagerID – ID of each availability manager added);
- Hot Node Name – output node name of the selected equipment, defined in the argument x1 of the AvailabilityManagerDifferentialThermostatSpec() above;
- Cold Node Name – output node name of the selected equipment, defined in the argument x2 of the AvailabilityManagerDifferentialThermostatSpec() above;
- Temperature Difference On Limit – temperature difference, defined in the argument x3 of the AvailabilityManagerDifferentialThermostatSpec() above;
- Temperature Difference Off Limit – temperature difference, defined in the argument x4 of the AvailabilityManagerDifferentialThermostatSpec() above.

15.7. Night Cycle

AvailabilityManagerNightCycleSpec ams = new AvailabilityManagerNightCycleSpec() – Night cycle availability manager specification (named ams in this example). With the following AvailabilityManagerNightCycleSpec() arguments:

- **new ScheduleSpec(DBScheduleType.SCH.getID(), db)** – applicability schedule ID in the database db, defined using the DBScheduleType list object ("SCH", in this example);
- **new ScheduleSpec(DBScheduleType.SCH.getID(), db)** – fan schedule ID in the database db, defined using the DBScheduleType list object ("SCH", in this example);
- **ControlType.XX.toString()** – XX = 'StayOff', 'CycleOnAny', 'CycleOnControlZone', 'CycleOnAnyZoneFansOnly', 'CycleOnAnyCoolingOrHeatingZone', 'CycleOnAnyCoolingZone', 'CycleOnAnyHeatingZone' or 'CycleOnAnyHeatingZoneFansOnly';
- **x1** – thermostat tolerance in Celsius that defines the amount by which the zone temperature must fall outside the current zone heating and cooling setpoints for the Night Cycle manager to turn the system on;

- **CyclingRunTimeControlType.XX.toString()** – XX = 'FixedRunTime', 'Thermostat' or 'ThermostatWithMinimumRunTime';
- **x2** – time in seconds for which the system will run after it has cycled on;
- **new int[]{a, b, c, …}** – ID of the control zone(s) (a, b, c, in this example), which corresponds to the order for which the zone(s) is added to the spaceSpec list in the building template (). **null** if no control zone(s) assignment;
- **new int[]{a, b, c, …}** – ID of the cooling control zone(s) (a, b, c, in this example), which corresponds to the order for which the zone(s) is added to the spaceSpec list in the building template (). **null** if no cooling control zone(s) assignment;
- **new int[]{a, b, c, …}** – ID of the heating control zone(s) (a, b, c, in this example), which corresponds to the order for which the zone(s) is added to the spaceSpec list in the building template (). **null** if no heating control zone(s) assignment;
- **new int[]{a, b, c, …}** – ID of the heating zone fans only zone(s) (a, b, c, in this example), which corresponds to the order for which the zone(s) is added to the spaceSpec list in the building template (). **null** if no heating zone fans only zone(s) assignment.

This corresponds to the AvailabilityManager:NightCycle object in EnergyPlus, where all the fields are automatically filled, according to the input above:

- Name – AvailabManagerListName + "AM" + AvailabManagerID (AvailabManagerID – ID of each availability manager added to the air loop; AvailabManagerListName – name of the list for which this availability manager is assigned (see section **15.8**));
- Applicability Schedule Name – schedule defined in the first argument of the AvailabilityManagerScheduledSpec() above;
- Fan Schedule Name – schedule defined in the second argument of the AvailabilityManagerScheduledSpec() above;
- Control Type – availability manager control type defined in the third argument of the AvailabilityManagerScheduledSpec() above;
- Thermostat Tolerance – thermostat tolerance defined in the argument x1 of the AvailabilityManagerScheduledSpec() above;
- Cycling Run Time Control Type – cycling run time control type defined in the fifth argument of the AvailabilityManagerScheduledSpec() above;
- Cycling Run Time – cycling run time defined in the argument x2 of the AvailabilityManagerScheduledSpec() above;
- Control Zone or Zone List Name – name of the control zone(s) (if any) defined in the seventh argument of the AvailabilityManagerScheduledSpec() above;
- Cooling Control Zone or Zone List Name – name of the cooling control zone(s) (if any) defined in the eight argument of the AvailabilityManagerScheduledSpec() above;
- Heating Control Zone or Zone List Name – name of the heating control zone(s) (if any) defined in the ninth argument of the AvailabilityManagerScheduledSpec() above;
- Heating Zone Fans Only or Zone List Name – name of the heating zone fans only zone(s) (if any) defined in the tenth argument of the AvailabilityManagerScheduledSpec() above.

15.8. Availability Manager List

The availability manager list corresponds to the AvailabilityManagerAssignmentList object in EnergyPlus, where all the fields are automatically filled, according to the availability manager objects added to the equipment/loop/air loop:

- Name – AvailabManagerListName = name + “AM_List” (name – name of the equipment, loop or air loop for which this availability manager list is assigned);
- Availability Manager X Object Type – AvailabilityManager:Scheduled, AvailabilityManager:HighTemperatureTurnOn, AvailabilityManager:HighTemperatureTurnOff, AvailabilityManager:LowTemperatureTurnOn, AvailabilityManager:LowTemperatureTurnOff, or AvailabilityManager:DifferentialThermostat;
- Availability Manager X Name – AvailabManagerListName of availability manager X;
- …
- One availability manager is added (with its two fields – type and name) for each availability manager added to an equipment/loop/air loop.

16. THERMAL COMFORT

The thermal comfort is a performance assessment which the user is able to choose for the simulation output. The thermal comfort levels for each zone are assigned in the 'thermalComfortLimitsID' column of the **Zone** table in the database (**0**), and defined in the **ThermalComfortLimits** table in the database:

- id – object ID;
- lowerTemperature – lower temperature comfort limit in Celsius;
- upperTemperature – upper temperature comfort limit in Celsius;
- description – optional object description, for guidance.

17. SIMULATION CONTROL

The simulation control must be defined in the SAPTool_LSP building template in the 8^{th} argument of the Dynamic Simulation specification object (DynamicSimulationSpec()). It is defined through a Simulation Control specification object (**new SimulationControlSpec()**), corresponding to the SimulationControl object in EnergyPlus, with the following arguments:

- **x1** – Do Zone Sizing Calculation. x1 = ‘true’ or ‘false’;
- **x2** – Do System Sizing Calculation. x2 = ‘true’ or ‘false’. Notice that System Sizing cannot be done without Zone Sizing;
- **x3** – Do Plant Sizing Calculation. x3 = ‘true’ or ‘false’;
- **x4** – Run Simulation for Sizing Periods. x4 = ‘true’ or ‘false’;
- **x5** – Run Simulation for Weather File Run Periods. x5 = ‘true’ or ‘false’;
- **x6** – Do HVAC Sizing Simulation for Sizing Periods (optional). x6 = ‘true’ or ‘false’. If **null**, = false;
- **x7** – Maximum Number of HVAC Sizing Simulation Passes. Only used if x6 = true.

18. DAYLIGHTING CONTROLS

When this object is used, daylighting illuminance levels are calculated and then used to determine how much the electric lighting can be reduced.

The Daylighting Controls option must be activated (**DAYLIGHTING_CONTROLS = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The daylighting control objects are assigned to each zone in the database, in the 'daylightingControlsID' column of the **Zone** table (**0**). The daylighting control objects are defined in the **DaylightingControls** table in the database, corresponding to the Daylighting:Controls object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- dElightGriddingResolution – maximum surface area for nodes in gridding (subdividing) all surfaces in the zone [m2]. Only used if daylightingMethod = DElight;
- lightingControlType – 'Continuous', 'Stepped' or 'Continuous_Off';
- maximumAllowableDiscomfortGlareIndex – if a daylit zone has windows with shading devices (except exterior screens), the shades will be deployed if the daylight glare in the 'Glare Calculation Daylighting Reference Point Name' field exceeds the value of this field. Only used if daylightingMethod = SplitFlux;
- glareCalculationAzimuthAngleOfViewDirectionClockwisefromZoneYAxis – view direction for calculating glare. Angle, measured clockwise in the horizontal plane, between the zone y-axis and the occupant view direction. Only used if daylightingMethod = SplitFlux;
- minimumInputPowerFractionForContinuousDimmingControl – lowest power the lighting system can dim down to, expressed as a fraction of maximum input power, if lightingControlType = Continuous. Power fraction reached just before the lights switch off completely, if lightingControlType = Continuous_Off;
- minimumLightOutputFractionForContinuousDimmingControl – lowest lighting output the lighting system can dim down to, expressed as a fraction of maximum light output, if lightingControlType = Continuous. Light output fraction reached just before the lights switch off completely, if lightingControlType = Continuous_Off;
- numberOfSteppedControlSteps – number of steps, excluding off, in a stepped lighting control system;
- probabilityLightingwillbeResetWhenNeededInManualSteppedControl – probability the occupants of a daylit zone will set the electric lights to the correct level to obtain the required illuminance;
- referencePointSets – set of values of 'Illuminance Setpoint at Reference Point X' [lux] and 'Z-Coordinate of Reference Point X' [m]. For each set of values added, a new daylighting reference point X is assigned to the zone*;
- daylightingMethod – 'SplitFlux' or 'DElight';
- scheduleID – availability schedule ID, defined in the **Schedules** table in the database (**21**). If blank, the controls are always available.

Automatic filling fields in EnergyPlus:

- Name – dayLightCtrlName = "DAYLIGHTING_CON" + Zone Name;
- Zone Name – name of the zone for which the steam equipment is assigned;

- Glare Calculation Daylighting Reference Point Name – name of the first daylighting reference point assigned to the zone: dayLightCtrlName + “PT” + 0;
- Daylighting Reference Point Name X – dayLightCtrlName + “PT” + X. For each set of values added in the referencePointSets field, a new daylighting reference point X is assigned to the zone*;
- Fraction of Zone Controlled by Reference Point X – fraction of the zone’s floor-area whose electric lighting is controlled by the daylight illuminance. A value of 1 is always assumed.

* For each daylighting reference point X assigned to the zone, a new DayLighting:ReferencePoint object is automatically created in EnergyPlus, with the following fields:

- Name – dayLightCtrlName + “PT” + X;
- Zone Name – name of the zone for which the steam equipment is assigned;
- X-Coordinate of Reference Point – the middle point of the zone along X is assumed;
- Y-Coordinate of Reference Point – the middle point of the zone along Y is assumed;
- Z-Coordinate of Reference Point – sum of the zone’s storey floor altitude and the z-coordinate of reference point X value (assigned in the referencePointSets field for the current reference point X, in the **DaylightingControls** table).

19. WINDOW SHADING CONTROL

The Window Shading Control is defined and assigned to the desired windows (and/or glass doors) in the SAPTool_LSP building templates (SAPTool_LSP>Source Pacakges>lsp.templates), while the shading material properties are defined in the database. The Window Shading Control option must be active (**WINDOW_SHADING_CONTROL = true**) in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables.

The specification of the Window Shading Control is defined in the SAPTool_LSP building template, prior to the windows specifications (WindowSpec(()), as presented below. Multiple window shading controls can be specified and assigned to different windows (and/or glass doors).

WindowShadingControlSpec windowShadingControl = new WindowShadingControlSpec() – Window Shading Control specification (named windowShadingControl in this example). With the following WindowShadingControlSpec() arguments:

- **"ABC"** – name of the window shading control;
- **x1** – shading control sequence number. If multiple window shading control objects are used in the same zone, then the order that they deploy the window shades can be set with this field. The first Window Shading Control should be 1 and subsequent Window Shading Control should 2, 3, etc.;
- **x2 –** specification of the shading material. There are three shading types currently implemented: blind, shade and screen. The specification for the blind, shade and screen materials, respectively, is the following:
    - **new WindowMaterialBlindSpec(DBWindowMaterialBlindType.ABC.getID(), db)** – specification of the blind material, using the DBWindowMaterialBlindType list object ('ABC', in this example), and defined in table **WindowMaterialBlind** in the database db (**19.1**). Alternatively, the proper ID can be directly inputted in the first argument;
    - **new WindowMaterialShadeSpec(DBWindowMaterialShadeType.ABC.getID(), db)** – specification of the shade material, using the DBWindowMaterialShadeType list object ('ABC', in this example), and defined in table **WindowMaterialShade** in the database db (**19.2**). Alternatively, the proper ID can be directly inputted in the first argument;
    - **new WindowMaterialScreenSpec(DBWindowMaterialScreenType.ABC.getID(), db)** – specification of the screen material, using the DBWindowMaterialScreenType list object ('ABC', in this example), and defined in table **WindowMaterialScreen** in the database db (**19.3**). Alternatively, the proper ID can be directly inputted in the first argument;
- **DBShadingType.XX.toString()** – shading type, defined using the DBShadingType list object. There are 5 shading types currently available: XX = 'InteriorShade', 'ExteriorShade', 'ExteriorScreen', 'InteriorBlind' or 'ExteriorBlind';
- **DBShadingControlType.XX.toString()** – shading control type, defined using the DBShadingControlType list object: XX = 'AlwaysOn', 'AlwaysOff', 'OnIfScheduleAllows', 'OnIfHighSolarOnWindow', 'OnIfHighHorizontalSolar', 'OnIfHighOutdoorAirTemperature', 'OnIfHighZoneAirTemperature', 'OnIfHighZoneCooling', 'OnIfHighGlare', 'MeetDaylightIlluminanceSetpoint',

'OnNightIfLowOutdoorTempAndOffDay', 'OnNightIfLowInsideTempAndOffDay', 'OnNightIfHeatingAndOffDay', 'OnNightIfLowOutdoorTempAndOnDayIfCooling', 'OnNightIfHeatingAndOnDayIfCooling', 'OffNightAndOnDayIfCoolingAndHighSolarOnWindow', 'OnNightAndOnDayIfCoolingAndHighSolarOnWindow', 'OnIfHighOutdoorAirTempAndHighSolarOnWindow' or 'OnIfHighOutdoorAirTempAndHighHorizontalSolar';

- **DBScheduleType.SCH1.getID** – ID of the Schedule Name, defined using the DBScheduleType list object (ID of 'SCH1', in this example). Alternatively, the proper database ID can be directly inputted here. Only required if the Shading Control is scheduled. **null** if not specified;
- **x3** – setpoint for activating window shading (double input type) [W/m2, W or °C, depending on the setpoint type]. Not required if the Shading Control Type = AlwaysOn, OnIfScheduleAllows, OnIfHighGlare or MeetDaylightIlluminanceSetpoint. **null** if not specified;
- **x4** – x4 = **true** if the glare control is active or **false** otherwise;
- **x5** – x5 = **true** if the shading control is scheduled (a Schedule Name is required above) or **false** otherwise (Schedule Name is not used);
- **DBSlatAngleControlForBlindType.XX.toString()** – blind slat angle control type, defined using the DBSlatAngleControlForBlindType list object: XX = 'FixedSlatAngle', 'BlockBeamSolar' or 'ScheduledSlatAngle'. Required only if Shading Type = InteriorBlind or ExteriorBlind;
- **DBScheduleType.SCH2.getID** – ID of the name of a schedule of slat angles, defined using the DBScheduleType list object (ID of 'SCH2', in this example). Alternatively, the proper database ID can be directly inputted here. Only required if the Type of Slat Angle Control for Blinds = ScheduledSlatAngle. **null** if not specified;
- **x6** – second setpoint (double input type) for the following two-setpoint control types: OnIfHighOutdoorAirTempAndHighSolarOnWindow, OnIfHighOutdoorAirTempAndHighHorizontalSolar, OnIfHighZoneAirTempAndHighSolarOnWindow, and OnIfHighZoneAirTempAndHighHorizontalSolar;
- **MultipleSurfaceControlType.XX.toString()** – multiple surface control type, defined using the MultipleSurfaceControlType list object: XX = 'Sequential' or 'Group'. If this argument is **null**, it defaults to 'Sequential'. Sequential – the list of windows for which this window shading control object is assigned are controlled individually in the order specified (see below). Group – the entire list of windows for which this window shading control object is assigned is controlled simultaneously, and if glare control is needed, the entire group of window shades are deployed together at the same time.

The above specification corresponds to the WindowShadingControl object in EnergyPlus, with the following fields automatically filled:

- Name – Zone Name + windowshadingcontrolName (windowshadingcontrolName – name of the Window Shading Control defined in the first argument of the WindowShadingControlSpec() above);
- Zone Name – name of the zone where the windows for which this object is assigned are located;

- Construction with Shading Name – name of the window Construction that has the shading in place. Considered null, as the material name of the shading device is assigned instead;
- Shading Device Material Name – “WPSCWM” + fenestrationName. Name of a shade material (**19.1**), screen material (**19.2**) or blind material (**19.3**) object;
- Daylighting Controls Object Name – name of the daylighting controls object assigned to the zone in the Zone table in the database (see section **0** – daylightingControlsID), if any: "DAYLIGHTING_CON_" + Zone Name;
- Fenestration Surface <n> Name – list of the n fenestration surfaces (in a zone) for which this object is assigned. When Multiple Surface Control Type is set to Sequential (in the last argument of the WindowShadingControlSpec() above), the order of the Fenestration Surface Names is the order that the shades will be deployed.

The Window Shading Control specification (named windowShadingControl in this example) must then be assigned to the desired windows (and/or glass doors), by entering it as the sixth argument of the respective WindowSpec() object (or as the seventh argument of the respective WindowDetailedSpec()[26] object), which is defined in the ExteriorOpeningSpec() or InteriorOpeningSpec() object for the given window or glass door.

The order by which a given fenestration surface is assigned to a Window Shading Control object’s fenestration surface list must be defined in the seventh argument of the respective WindowSpec() object (or the eight argument of the respective WindowDetailedSpec()[26] object). This argument may be null if there is only one fenestration assigned to the Window Shading Control object (i.e., only one fenestration in the fenestration surface list) or if there is no Window Shading Control object assigned to the fenestration.

An example of this object usage can be found in the SingleStoreyFamilyHouse_HVACT_Fancoil template in the SAPTool_LSP, where for two of the living room windows a Window Shading Control (first in the control sequence) with sequential control type is assigned, while for the third living room window a Window Shading Control (second in the control sequence) with group control type is assigned.

19.1. Blind Material

The blind material properties are defined in the **WindowMaterialBlind** table in the database, corresponding to the WindowMaterial:Blind object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- slatOrientation – ‘Horizontal’ or ‘Vertical’;
- slatWidth – width of the slat measured from edge to edge [m];
- slatSeparation – distance between the front of a slat and the back of the adjacent slat [m];
- slatThickness – distance between the faces of a slat [m];

[26] Used when a detailed window with frame and divider is specified.

- slatAngle – angle between the glazing outward normal and the slat outward normal, where the outward normal points away from the front face of the slat [degrees];
- slatConductivity – thermal conductivity of the slat [W/m.K];
- slatBeamSolarTransmittance – beam solar transmittance of the slat, assumed to be independent of angle of incidence on the slat;
- frontSideSlatBeamSolarReflectance – beam solar reflectance of the front side of the slat, assumed to be independent of angle of incidence (matte finish);
- backSideSlatBeamSolarReflectance – beam solar reflectance of the back side of the slat, assumed to be independent of angle of incidence (matte finish);
- slatDiffuseSolarTransmittance – slat transmittance for hemispherically diffuse solar radiation. This value should equal the slatBeamSolarTransmittance;
- frontSideSlatDiffuseSolarReflectance – front-side slat reflectance for hemispherically diffuse solar radiation. This value should equal the frontSideSlatBeamSolarReflectance;
- backSideSlatDiffuseSolarReflectance – back-side slat reflectance for hemispherically diffuse solar radiation. This value should equal the backSideSlatBeamSolarReflectance;
- slatBeamVisibleTransmittance – beam visible transmittance of the slat, assumed to be independent of angle of incidence on the slat;
- frontSideSlatBeamVisibleReflectance – beam visible reflectance on the front side of the slat, assumed to be independent of angle of incidence (matte finish);
- backSideSlatBeamVisibleReflectance – beam visible reflectance on the front side of the slat, assumed to be independent of angle of incidence (matte finish);
- slatDiffuseVisibleTransmittance – slat transmittance for hemispherically diffuse visible radiation. This value should equal the slatBeamVisibleTransmittance;
- frontSideSlatDiffuseVisibleReflectance – front-side slat reflectance for hemispherically diffuse visible radiation. This value should equal the frontSideSlatBeamVisibleReflectance;
- backSideSlatDiffuseVisibleReflectance – back-side slat reflectance for hemispherically diffuse visible radiation. This value should equal the backSideSlatBeamVisibleReflectance;
- slatInfraredHemisphericalTransmittance – slat infrared transmittance;
- frontSideSlatInfraredHemisphericalEmissivity – front-side hemispherical emissivity of the slat;
- backSideSlatInfraredHemisphericalEmissivity – back-side hemispherical emissivity of the slat
- blindToGlassDistance – for interior and exterior blinds, the distance from the mid-plane of the blind to the adjacent glass [m];
- blindTopOpeningMultiplier – effective area for air flow at the top of the blind divided by sW, the horizontal area between glass and blind;
- blindBottomOpeningMultiplier – effective area for air flow at the bottom of the blind divided by sW, the horizontal area between glass and blind;
- blindLeftOpeningMultiplier – effective area for air flow at the left side of the blind divided by sH, the vertical area between glass and blind;
- blindRightOpeningMultiplier – effective area for air flow at the right side of the blind divided by sH, the vertical area between glass and blind;
- minimumSlatAngle – minimum allowed slat angle [degrees]. Used only if Type of Slat Angle Control for Blinds = ScheduledSlatAngle or BlockBeamSolar, in the Window Shading Control (see above);

- maximumSlatAngle – maximum allowed slat angle [degrees]. Used only if Type of Slat Angle Control for Blinds = ScheduledSlatAngle or BlockBeamSolar, in the Window Shading Control (see above);
- description – optional object description, for guidance.

Automatic filling fields in EnergyPlus:

- Name – “WPSCWM” + fenestrationName (fenestrationName – name of the window or glass door for which the shading blind is assigned).

19.2. Shade Material

The shade material properties are defined in the **WindowMaterialShade** table in the database, corresponding to the WindowMaterial:Shade object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- solarTransmittance – transmittance averaged over the solar spectrum;
- solarReflectance – reflectance averaged over the solar spectrum;
- visibleTransmittance – transmittance averaged over the solar spectrum and weighted by the response of the human eye;
- visibleReflectance – reflectance averaged over the solar spectrum and weighted by the response of the human eye;
- infraredHemisphericalEmissivity – effective long-wave emissivity;
- infraredTransmittance – effective long-wave transmittance;
- thickness – thickness of the shade material [m];
- conductivity – Shade material conductivity [W/m.K];
- shadeToGlassDistance – Distance from shade to adjacent glass [m];
- topOpeningMultiplier – effective area for air flow at the top of the shade divided by sW, the horizontal area between glass and shade;
- bottomOpeningMultiplier – effective area for air flow at the bottom of the shade divided by sW, the horizontal area between glass and shade;
- leftSideOpeningMultiplier
- – effective area for air flow at the left side of the shade divided by sH, the vertical area between glass and shade;
- rightSideOpeningMultiplier – effective area for air flow at the right side of the shade divided by sH, the vertical area between glass and shade;
- airflowPermeability – fraction of the shade surface that is open to air flow, i.e., the total area of openings (“holes”) in the shade surface divided by the shade area, HW.

Automatic filling fields in EnergyPlus:

- Name – “WPSCWM” + fenestrationName (fenestrationName – name of the window or glass door for which the shading shade is assigned).

19.3. Screen Material

The shade material properties are defined in the **WindowMaterialScreen** table in the database, corresponding to the WindowMaterial:Screen object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- reflectedBeamTransmittanceAccountingMethod – ‘ModelAsDiffuse’, ‘DoNotModel’ or ‘ModelAsDirectBeam’;
- diffuseSolarReflectance – solar reflectance (beam-to-diffuse) of the screen material itself;
- diffuseVisibleReflectance – visible reflectance (beam-to-diffuse) of the screen material itself;
- thermalHemisphericalEmissivity – long-wave emissivity of the screen material itself;
- conductivity – screen material conductivity [W/m.K];
- screenMaterialSpacing – distance from the center of one strand of screen to the center of the adjacent one [m];
- screenMaterialDiameter – diameter of individual strands or wires of the screen material [m];
- screenToGlassDistance – distance from the window screen to the adjacent glass surface [m];
- topOpeningMultiplier – effective area for air flow at the top of the screen divided by sW, the horizontal area between glass and screen;
- bottomOpeningMultiplier – effective area for air flow at the bottom of the screen divided by sW, the horizontal area between glass and screen;
- leftSideOpeningMultiplier
- – effective area for air flow at the left side of the screen divided by sH, the vertical area between glass and screen;
- rightSideOpeningMultiplier – effective area for air flow at the right side of the screen divided by sH, the vertical area between glass and screen;
- angleOfResolutionForScreenTransmittanceOutputMap – angle of resolution for the overall screen beam transmittance (direct and reflected) output map [degrees].

Automatic filling fields in EnergyPlus:

- Name – “WPSCWM” + fenestrationName (fenestrationName – name of the window or glass door for which the shading screen is assigned).

20. INTERNAL MASS

Whenever a stairway zone is assigned to the building, its internal mass is automatically defined using the InternalMass object in EnergyPlus, with the following fields automatically filled:

- Name – Zone Name + “Internal_Mass”;
- Construction Name – name of the construction object assigned to the stairway;
- Zone Name – name of the stairway zone for which this object is assigned;
- Surface Area – entire surface area of the surface exposed to the zone [m2]. The total area of the stairwell horizontal surfaces is considered, to simulate the surface area of one side of an equivalent slab.

Note: this method is not yet implemented for storeys repetition.

21. SCHEDULES

The schedules are defined in the **Schedules** table in the database, with the following fields:

- id – object ID;
- type – schedule specification in the corresponding Type table. Currently, three Schedule Types are available: 'Compact' (**ScheduleCompact** table in the database – **21.1**), 'Constant' (**ScheduleConstant** table in the database – **21.2**), and 'Hourly' (**ScheduleHourly** table in the database – **21.3**);
- scheduleIDs – ID(s) of the schedule type(s) in the corresponding table(s). It is only possible to assign multiple IDs for the compact schedule type case (**21.1**). The multiple compact schedules will then define a single total compact schedule. Two distinct cases are possible:
  - Each compact schedule ID defines a different schedule period. For example, ID x defines the schedule from January 1 until June 30 ("06/30" in the 'through' field – see section **21.1**), and ID y defines the schedule from July 1 until December 31 ("12/31" in the 'through' field – see section **21.1**). Then 'x, y' should be assigned to the 'scheduleIDs' field;
  - Each compact schedule ID defines a different schedule day type. For example, ID x defines the schedule for weekends ("Weekends" in 'for' field – see section **21.1**), and ID y defines the schedule for the remaining day types ("weekends" in the 'for' field – see section **21.1**). Then 'x, y' should be assigned to the 'scheduleIDs' field. Notice that <u>the 'through' field must only be filled for the first compact schedule ID</u> (in ID x, for weekends, in this example), as the remaining day types (in ID y, in this example) will be automatically assigned for the same schedule period.
- lowerLimitValue – lower limit value for the schedule type*;
- upperLimitValue – upper limit value for the schedule type*;
- numericType – 'Continuous' or 'Discrete'*;
- unitType – 'Dimensionless', 'Temperature', 'DeltaTemperature', 'PrecipitationRate', 'Angle', 'Convection_Coefficient', 'Activity_Level', 'Velocity', 'Capacity', 'Power', 'Availability, 'Percent', 'Control', 'Mode' or 'Any_Number'*;
- description – optional object description, for guidance.

* These fields correspond to the ScheduleTypeLimits object in EnergyPlus, with the following automatically filled fields:

- Name – "TYPE_LIMITS" + scheduleName (schedule name automatically assigned in the object which it serves).

21.1. Compact

The compact schedule is defined in the **ScheduleCompact** table in the database, corresponding to the Schedule:Compact object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- through – ending date for the schedule period (mm/dd);
- for – 'Weekdays', 'Weekends', 'Holidays', 'Alldays', 'SummerDesignDay', 'WinterDesignDay', 'Sunday', 'Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'CustomDay1', 'CustomDay2' or 'AllOtherDays';

- until – ending time (hh:mm) and schedule value for the specified time interval (double type value). The user must define the necessary number of time-value entries (hh:mm, value; hh:mm, value; …).

Automatic filling fields in EnergyPlus:

- Name – schedule name automatically assigned in the object which it serves (scheduleName);
- Schedule Type Limits Name – “TYPE_LIMITS” + scheduleName;

21.2. Constant

The constant schedule is defined in the **ScheduleConstant** table in the database, corresponding to the Schedule:Constant object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- value – constant real value.

Automatic filling fields in EnergyPlus:

- Name – schedule name automatically assigned in the object which it serves (scheduleName);
- Schedule Type Limits Name – “TYPE_LIMITS” + scheduleName;

21.3. Hourly

The hourly schedule is defined in the **ScheduleHourly** table in the database, corresponding to the Schedule:Day:Hourly object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- H00-H23 – hourly values for the 24 hours in a day.

Automatic filling fields in EnergyPlus:

- Name – schedule name automatically assigned in the object which it serves (scheduleName);
- Schedule Type Limits Name – “TYPE_LIMITS” + scheduleName;

22. SITE

22.1. Water Mains Temperature

This object is used to calculate water temperatures delivered by underground water main pipes and is automatically defined. It corresponds to the Site:WaterMainsTemperature object in EnergyPlus, where all fields are automatically filled:

- Calculation Method – automatically defined as 'CorrelationFromWeatherFile';
- Temperature Schedule Name – not used;
- Annual Average Outdoor Air Temperature – not used. EnergyPlus calculates this value internally from either ".stat" or weather file (annual average outdoor air temperature, automatically computed from the weather file data assigned to the simulation);
- Maximum Difference In Monthly Average Outdoor Air Temperatures – not used. EnergyPlus calculates this value internally from either ".stat" or weather file (maximum difference in monthly average outdoor air temperatures, automatically computed from the weather file data assigned to the simulation).

22.2. Ground Temperature

22.2.1. Undisturbed

22.2.1.1. Finite Difference

This component is defined in the **SiteGroundTemperatureUndisturbedFiniteDifference** table in the database, corresponding to the Site:GroundTemperature:Undisturbed:FiniteDifference object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- soilThermalConductivity – thermal conductivity of the soil [W/m.K];
- soilDensity – bulk density of the soil [kg/m^3];
- soilSpecificHeat – specific heat of dry soil [J/kg.K];
- soilMoistureContentVolumeFraction – a nominal value of soil moisture content to be used when evaluating soil thermal properties;
- soilMoistureContentVolumeFractionAtSaturation – a nominal value of soil moisture content when the soil is saturated, this is used in evaluating thermal properties of freezing soil
- evapotranspirationGroundCoverParameter – ground cover effects used in the evapotranspiration model at the ground surface heat balance. The values range from 0 (solid, non-permeable ground surface) to 1.5 (wild growth).

Automatic filling fields in EnergyPlus:

- Name – "SGT_Undist" + Unit name (Unit name – name of the Zone HVAC equipment for which this object is assigned).

22.2.1.2. Kusuda Achenbach

This component is defined in the **SiteGroundTemperatureUndisturbedKusudaAchenbach** table in the database, corresponding to the Site:GroundTemperature:Undisturbed:KusudaAchenbach object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- soilThermalConductivity – thermal conductivity of the soil [W/m.K];
- soilDensity – bulk density of the soil [kg/m^3];
- soilSpecificHeat – specific heat of dry soil [J/kg.K];
- averageSoilSurfaceTemperature – average ground surface temperature throughout the entire year [°C][27];
- averageAmplitudeOfSurfaceTemperature – average amplitude of the ground surface temperature [°C][27];
- phaseShiftOfMinimumSurfaceTemperature – day of the year which has the lowest ground surface temperature [days][27].

Automatic filling fields in EnergyPlus:

- Name – "SGT_Undist" + Unit name (Unit name – name of the Zone HVAC equipment for which this object is assigned).

22.2.1.3. Xing

This component is defined in the **SiteGroundTemperatureUndisturbedXing** table in the database, corresponding to the Site:GroundTemperature:Undisturbed:Xing object in EnergyPlus. The following fields are present in the table:

- id – object ID;
- description – optional object description, for guidance;
- soilThermalConductivity – thermal conductivity of the soil [W/m.K];
- soilDensity – bulk density of the soil [kg/m^3];
- soilSpecificHeat – specific heat of dry soil [J/kg.K];
- averageSoilSurfaceTemperature – average annual surface temperature of the soil [°C];
- soilSurfaceTemperatureAmplitude1 – first soil surface temperature amplitude parameter [°C];
- soilSurfaceTemperatureAmplitude2 – second soil surface temperature amplitude parameter [°C];
- phaseShiftOfTemperatureAmplitude1 – phase shift of surface temperature amplitude 1 [days];
- phaseShiftOfTemperatureAmplitude2 – phase shift of surface temperature amplitude 2 [days].

Automatic filling fields in EnergyPlus:

- Name – "SGT_Undist" + Unit name (Unit name – name of the Zone HVAC equipment for which this object is assigned).

[27] If these 3 parameters are left blank, they are autocalculated using the soil surface temperatures in the SiteGroundTemperatureShallow object (see section **22.2.2**), which is automatically defined.

22.2.2. Shallow

This object is used to calculate shallow ground temperatures, and is automatically defined by getting the monthly calculated "undisturbed" ground temperatures at 0.5 m deep from the weather stat file. It corresponds to the Site:GroundTemperature:Shallow object in EnergyPlus, where all fields are automatically filled:

- Month Surface Ground Temperatures (12 fields) – monthly surface ground temperature used for the indicated month [°C].

23. PERFORMANCE CURVES

The performance curves are defined in the **PerformanceCurve** table in the database, with the following fields:

- id – object ID;
- type – 'Bicubic', 'Biquadratic', 'ChillerPartLoadWithLift', 'Cubic', 'CubicLinear', 'DoubleExponentialDecay', 'Exponent', 'ExponentialDecay', 'ExponentialSkewNormal', 'FanPressureRise', 'Functional', 'Linear', 'QuadLinear', 'Quadratic', 'QuadraticLinear', 'Quartic', 'RectangularHyperbola1', 'RectangularHyperbola2', 'Sigmoid' or 'Triquadratic';
- vals – coefficients and minimum and maximum values for the selected curve type;
- unitTypes – optional input and output unit types for the selected curve type.

The proper curve type object in EnergyPlus is automatically created according to the type defined in the 'type' field:

Bicubic

Curve:Bicubic object in EnergyPlus

vals – coefficient1 constant, coefficient2 x, coefficient3 x**2, coefficient4 y, coefficient5 y**2, coefficient6 x*y, coefficient7 x**3, coefficient8 y**3, coefficient9 x**2*y, coefficient10 x*y**2, minimum value of x, maximum value of x, minimum value of y, maximum value of y, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) ('Dimensionless', 'Temperature', 'VolumetricFlow', 'MassFlow', 'Power' or 'Distance'), input unit type for Y (optional) ('Dimensionless', 'Temperature', 'VolumetricFlow', 'MassFlow', 'Power' or 'Distance'), output unit type (optional) ('Dimensionless', 'Capacity' or 'Power').

Biquadratic

Curve:Biquadratic object in EnergyPlus

vals – coefficient1 constant, coefficient2 x, coefficient3 x**2, coefficient4 y, coefficient5 y**2, coefficient6 x*y, minimum value of x, maximum value of x, minimum value of y, maximum value of y, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) ('Dimensionless', 'Temperature', 'VolumetricFlow', 'MassFlow', 'Power' or 'Distance'), input unit type for Y (optional) ('Dimensionless', 'Temperature', 'VolumetricFlow', 'MassFlow', 'Power' or 'Distance'), output unit type (optional) ('Dimensionless', 'Capacity' or 'Power').

ChillerPartLoadWithLift

Curve:ChillerPartLoadWithLiftobject in EnergyPlus vals – coefficient1 C1, coefficient2 C2, coefficient3 C3, coefficient4 C4, coefficient5 C5, coefficient6 C6, coefficient7 C7, coefficient8 C8, coefficient9 C9, coefficient10 C10, coefficient11 C11, coefficient12 C12, minimum value of x, maximum value of x, minimum value of y, maximum value of y, minimum value of z, maximum value of z, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) (the only option is 'Dimensionless'), input unit type for Y (optional) (the only option is 'Dimensionless'), input unit type for Z (optional) (the only option is 'Dimensionless'), output unit type (optional) (the only option is 'Dimensionless').

Cubic

Curve:Cubic object in EnergyPlus

vals – coefficient1 constant, coefficient2 x, coefficient3 x**2, coefficient4 x**3, minimum value of x, maximum value of x, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) ('Dimensionless', 'Temperature', 'VolumetricFlow', 'MassFlow', 'Power' or 'Distance'), output unit type (optional) ('Dimensionless', 'Capacity' or 'Power').

CubicLinear

Curve:CubicLinear object in EnergyPlus

vals – coefficient1 constant, coefficient2 x, coefficient3 x**2, coefficient4 x**3, coefficient5 y, coefficient6 x*y, minimum value of x, maximum value of x, minimum value of y, maximum value of y, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) (the only option is 'Dimensionless'), input unit type for Y (optional) (the only option is 'Dimensionless'), output unit type (optional) (the only option is 'Dimensionless').

DoubleExponentialDecay

Curve:DoubleExponentialDecay object in EnergyPlus

vals – coefficient1 C1, coefficient2 C2, coefficient3 C3, coefficient4 C4, coefficient5 C5, minimum value of x, maximum value of x, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) (the only option is 'Dimensionless'), output unit type (optional) (the only option is 'Dimensionless').

Exponent

Curve:Exponent object in EnergyPlus

vals – coefficient1 constant, coefficient2 constant, coefficient3 constant, minimum value of x, maximum value of x, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) ('Dimensionless', 'Temperature', 'VolumetricFlow', 'MassFlow', 'Power' or 'Distance'), output unit type (optional) ('Dimensionless', 'Capacity' or 'Power').

ExponentialDecay

Curve:ExponentialDecay object in EnergyPlus

vals – coefficient1 C1, coefficient2 C2, coefficient3 C3, minimum value of x, maximum value of x, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) (the only option is 'Dimensionless'), output unit type (optional) (the only option is 'Dimensionless').

ExponentialSkewNormal

Curve:ExponentialSkewNormal object in EnergyPlus

vals – coefficient1 C1, coefficient2 C2, coefficient3 C3, coefficient4 C4, minimum value of x, maximum value of x, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) (the only option is 'Dimensionless'), output unit type (optional) (the only option is 'Dimensionless').

FanPressureRise

Curve:FanPressureRise object in EnergyPlus

vals – coefficient1 C1, coefficient2 C2, coefficient3 C3, coefficient4 C4, minimum value of Qfan [m3/s], maximum value of Qfan [m3/s], minimum value of Psm [Pa], maximum value of Psm [Pa], minimum curve output [Pa] (optional), maximum curve output [Pa] (optional);

unitTypes – null.

Functional

Curve:Functional:PressureDrop object in EnergyPlus

vals – diameter [m], minor loss coefficient (optional), length [m] (optional), roughness [m] (optional), fixed friction factor (optional).

unitTypes – null.

Linear

Curve:Linear object in EnergyPlus

vals – coefficient1 constant, coefficient2 x, minimum value of x, maximum value of x, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) (‘Dimensionless’, ‘Temperature’, ‘VolumetricFlow’, ‘MassFlow’, ‘Power’ or ‘Distance’), output unit type (optional) (‘Dimensionless’, ‘Capacity’ or ‘Power’).

QuadLinear

Curve:QuadLinear object in EnergyPlus

vals – coefficient1 constant, coefficient2 w, coefficient3 x, coefficient4 y, coefficient5 z, minimum value of w, maximum value of w, minimum value of x, maximum value of x, minimum value of y, maximum value of y, minimum value of z, maximum value of z, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for W (optional) (‘Dimensionless’, ‘Temperature’, ‘VolumetricFlow’, ‘MassFlow’, ‘Power’ or ‘Distance’), input unit type for X (optional) (‘Dimensionless’, ‘Temperature’, ‘VolumetricFlow’, ‘MassFlow’, ‘Power’ or ‘Distance’), input unit type for Y (optional) (‘Dimensionless’, ‘Temperature’, ‘VolumetricFlow’, ‘MassFlow’, ‘Power’ or ‘Distance’), input unit type for Z (optional) (‘Dimensionless’, ‘Temperature’, ‘VolumetricFlow’, ‘MassFlow’, ‘Power’ or ‘Distance’).

Quadratic

Curve:Quadratic object in EnergyPlus

vals – coefficient1 constant, coefficient2 x, coefficient2 x**2, minimum value of x, maximum value of x, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) (‘Dimensionless’, ‘Temperature’, ‘VolumetricFlow’, ‘MassFlow’, ‘Power’ or ‘Distance’), output unit type (optional) (‘Dimensionless’, ‘Capacity’ or ‘Power’).

QuadraticLinear

Curve:QuadraticLinear object in EnergyPlus

vals – coefficient1 constant, coefficient2 x, coefficient3 x**2, coefficient4 y, coefficient5 x*y, coefficient6 x**2*y, minimum value of x, maximum value of x, minimum value of y, maximum value of y, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) (‘Dimensionless’, ‘Temperature’, ‘VolumetricFlow’, ‘MassFlow’, ‘Power’ or ‘Distance’), input unit type for Y (optional) (‘Dimensionless’, ‘Temperature’, ‘VolumetricFlow’, ‘MassFlow’, ‘Power’ or ‘Distance’), output unit type (optional) (‘Dimensionless’, ‘Capacity’ or ‘Power’).

Quartic

Curve:Quartic object in EnergyPlus

vals – coefficient1 constant, coefficient2 x, coefficient3 x**2, coefficient4 x**3, coefficient5 x**4, minimum value of x, maximum value of x, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) (‘Dimensionless’, ‘Temperature’, ‘VolumetricFlow’, ‘MassFlow’, ‘Power’ or ‘Distance’), output unit type (optional) (‘Dimensionless’, ‘Capacity’ or ‘Power’).

RectangularHyperbola1

Curve:RectangularHyperbola1 object in EnergyPlus

vals – coefficient1 C1, coefficient2 C2, coefficient3 C3, minimum value of x, maximum value of x, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) (the only option is ‘Dimensionless’), output unit type (optional) (the only option is ‘Dimensionless’).

RectangularHyperbola2

Curve:RectangularHyperbola2 object in EnergyPlus

vals – coefficient1 C1, coefficient2 C2, coefficient3 C3, minimum value of x, maximum value of x, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) (the only option is ‘Dimensionless’), output unit type (optional) (the only option is ‘Dimensionless’).

Sigmoid

Curve:Sigmoid object in EnergyPlus

vals – coefficient1 C1, coefficient2 C2, coefficient3 C3, coefficient4 C4, coefficient5 C5, minimum value of x, maximum value of x, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) (the only option is ‘Dimensionless’), output unit type (optional) (the only option is ‘Dimensionless’).

Triquadratic

Curve:Triquadratic object in EnergyPlus

vals – coefficient1 constant, coefficient2 x**2, coefficient3 x, coefficient4 y**2, coefficient5 y, coefficient6 z**2, coefficient7 z, coefficient8 x**2*y**2, coefficient9 x*y, coefficient10 x*y**2, coefficient11 x**2*y, coefficient12 x**2*z**2, coefficient13 x*z, coefficient14 x*z**2, coefficient15 x**2*z, coefficient16 y**2*z**2, coefficient17 y*z, coefficient18 y*z**2, coefficient19 y**2*z, coefficient20 x**2*y**2*z**2, coefficient21 x**2*y**2*z, coefficient22 x**2*y*z**2, coefficient23 x*y**2*z**2, coefficient24 x**2*y*z, coefficient25 x*y**2*z, coefficient26 x*y*z**2, coefficient27 x*y*z, minimum value of x, maximum value of x, minimum value of y, maximum value of y, minimum value of z, maximum value of z, minimum curve output (optional), maximum curve output (optional);

unitTypes – input unit type for X (optional) ('Dimensionless', 'Temperature', 'VolumetricFlow', 'MassFlow', 'Power' or 'Distance'), input unit type for Y (optional) ('Dimensionless', 'Temperature', 'VolumetricFlow', 'MassFlow', 'Power' or 'Distance'), input unit type for Z (optional) ('Dimensionless', 'Temperature', 'VolumetricFlow', 'MassFlow', 'Power' or 'Distance'), output unit type (optional) ('Dimensionless', 'Capacity' or 'Power').

All curves with the following automatic filling fields in EnergyPlus:

- Name – performance curve name automatically assigned in the object which it serves.

24. COST

The material and equipment cost is summed up and presented in the simulation output, divided in the proper categories. The cost is defined in the **Cost** table in the database, with the following fields:

- id – object ID;
- value – cost value;
- type – 'LINEAR_METER', 'SQUARE_METER', 'CUBIC_METER' or 'UNIT';
- description – optional object description, for guidance.

25. OUTPUT REPORTS AND METERS

The following simulation output reports are generated depending on the selected variables in SAPTool_FPOP_EnergyPlus>SourcePackages>fpop.energyplus.parser>LayoutObjectsExportVariables:

Environment Data

- Site Outdoor Air Drybulb Temperature

If **REPORT SITE = true**:

- Site Outdoor Air Barometric Pressure
- Site Outdoor Air Humidity Ratio
- Site Outdoor Air Relative Humidity
- Site Wind Speed
- Site Diffuse Solar Radiation Rate per Area
- Site Direct Solar Radiation Rate per Area

Zone Data

- Zone Operative Temperature

If **REPORT_ZONE = true**:

- Zone Air Temperature
- Zone Air Relative Humidity
- Zone Air Humidity Ratio

Systems

If **REPORT_SYSTEMS = true**:

If **REPORT_WATER_USE = true** (section **5.1** reports):

- Water Use Equipment Cold Water Volume
- Water Use Equipment Hot Water Volume

If **REPORT_LIGHTS = true** (section **4.2** reports):

- Zone Lights Electric Energy

If **REPORT_ELECTRICAL_EQUIPMENT = true** (section **4.3.1** reports):

- Zone Electric Equipment Electric Energy

If **REPORT_GAS_EQUIPMENT = true** (section **4.3.2** reports):

- Zone Gas Equipment Gas Energy

If **REPORT_STEAM_EQUIPMENT = true** (section **4.3.3** reports):

- Zone Steam Equipment District Heating Energy

If **REPORT_PEOPLE = true** (section **4.1** reports):

- People Total Heating Energy

If **REPORT_CARBON_DIOXIDE = true** (sections **3** and **4.4.1** reports):

- System Node CO2 Concentration (specifically in the "Contaminant_Balance_Outdoor_Air_Node")
- Zone Air CO2 Concentration
- Zone Air CO2 Internal Gain Volume Flow Rate

If **REPORT_GENERIC_CONTAMINANT = true** (sections **3** and **4.4.2** reports):

- System Node Generic Air Contaminant Concentration (specifically in the "Contaminant_Balance_Outdoor_Air_Node")
- Zone Air Generic Air Contaminant Concentration
- Zone Generic Air Contaminant Generation Volume Flow Rate

If **REPORT_INFILTRATION = true** (section **2.1.1** reports):

- Zone Infiltration Air Change Rate

If **REPORT_AIRFLOW_NETWORK = true** (section **2.2** reports)**:**

- AFN Zone Infiltration Air Change Rate

If **REPORT_VENTILATION = true** (section **2.1.2** reports):

If **REPORT_VENTILATION_AIR_CHANGES_RATE = true**:

- Zone Ventilation Air Change Rate

If **REPORT_VENTILATION_FAN_ELECTRIC_ENERGY = true**:

- Zone Ventilation Fan Electric Energy

If **REPORT_VENTILATION_CURRENT_DENSITY_VOLUME = true**:

- Zone Ventilation Current Density Volume

If **REPORT_HVAC_TEMPLATE_PLANT_BOILER = true** (section **6.16.1** reports):

If Boiler Type = District Hot Water:

- District Heating Hot Water Energy

Else:

If Boiler Fuel Type = Natural Gas:

- Boiler Gas Energy

If Boiler Fuel Type = Propane Gas:

- Boiler Propane Energy

If Boiler Fuel Type = Diesel:

- Boiler Diesel Energy

If Boiler Fuel Type = Coal:

- Boiler Coal Energy

If Boiler Fuel Type = Gasoline:

- Boiler Gasoline Energy

If **REPORT_HVAC_TEMPLATE_PLANT_CHILLER = true** (section **6.16.2** reports):

If Chiller Type = District Chilled Water:

- District Cooling Chilled Water Energy

If **REPORT_HVAC_TEMPLATE_ZONE_IDEAL_LOADS_AIR_SYSTEM = true** (section **6.3** reports) or **REPORT_ZONE_HVAC_IDEAL_LOADS_AIR_SYSTEM = true** (section **7.1.1** reports):

- Zone Ideal Loads Zone Total Heating Energy
- Zone Ideal Loads Zone Latent Heating Energy
- Zone Ideal Loads Zone Total Cooling Energy
- Zone Ideal Loads Zone Latent Cooling Energy
- Zone Ideal Loads Supply Air Total Cooling Energy
- Zone Ideal Loads Supply Air Latent Cooling Energy
- Zone Ideal Loads Supply Air Total Heating Energy
- Zone Ideal Loads Supply Air Latent Heating Energy

If **REPORT_HVAC_TEMPLATE_ZONE_BASEBOARD_HEAT = true** (section **6.4** reports):

- Baseboard Total Heating Energy
- Zone Air System Sensible Cooling Energy
- Zone Air System Sensible Heating Energy

If **REPORT_HVAC_TEMPLATE_ZONE_FANCOIL = true** (section **6.5** reports) or **REPORT_ZONE_HVAC_FOUR_PIPE_FAN_COIL = true** (section **7.1.4** reports):

- Fan Coil Heating Energy
- Fan Coil Total Cooling Energy
- Fan Coil Sensible Cooling Energy
- Fan Coil Fan Electric Energy

If **REPORT_HVAC_TEMPLATE_ZONE_PTAC = true** (section **6.6** reports) or **REPORT_ZONE_HVAC_PACKAGED_TERMINAL_AIR_CONDITIONER = true** (section **7.1.5.1** reports):

- Zone Packaged Terminal Air Conditioner Total Heating Energy
- Zone Packaged Terminal Air Conditioner Total Cooling Energy
- Zone Packaged Terminal Air Conditioner Sensible Heating Energy
- Zone Packaged Terminal Air Conditioner Sensible Cooling Energy
- Zone Packaged Terminal Air Conditioner Latent Heating Energy
- Zone Packaged Terminal Air Conditioner Latent Cooling Energy
- Zone Air System Sensible Cooling Energy
- Zone Air System Sensible Heating Energy

If **REPORT_HVAC_TEMPLATE_ZONE_PTHP = true** (section **6.7** reports) or **REPORT_ZONE_HVAC_PACKAGED_TERMINAL_HEAT_PUMP = true** (section **7.1.5.2** reports):

- Zone Packaged Terminal Heat Pump Total Heating Energy
- Zone Packaged Terminal Heat Pump Total Cooling Energy
- Zone Packaged Terminal Heat Pump Sensible Heating Energy
- Zone Packaged Terminal Heat Pump Sensible Cooling Energy
- Zone Packaged Terminal Heat Pump Latent Heating Energy
- Zone Packaged Terminal Heat Pump Latent Cooling Energy
- Zone Air System Sensible Cooling Energy
- Zone Air System Sensible Heating Energy

If **REPORT_HVAC_TEMPLATE_ZONE_WATER_TO_AIR_HEAT_PUMP = true** (section **6.8** reports) or **REPORT_ZONE_HVAC_WATER_TO_AIR_HEAT_PUMP = true** (section **7.1.6** reports):

- Zone Water to Air Heat Pump Total Heating Energy
- Zone Water to Air Heat Pump Total Cooling Energy
- Zone Water to Air Heat Pump Sensible Heating Energy
- Zone Water to Air Heat Pump Sensible Cooling Energy
- Zone Water to Air Heat Pump Latent Heating Energy
- Zone Water to Air Heat Pump Latent Cooling Energy
- Zone Air System Sensible Cooling Energy
- Zone Air System Sensible Heating Energy

If **REPORT_HVAC_TEMPLATE_ZONE_VRF = true** (section **6.11** reports) or **REPORT_ZONE_HVAC_TERMINAL_UNIT_VRF = true** (section **7.1.7** reports):

- Zone VRF Air Terminal Total Heating Energy
- Zone VRF Air Terminal Total Cooling Energy
- Zone VRF Air Terminal Sensible Heating Energy
- Zone VRF Air Terminal Sensible Cooling Energy
- Zone VRF Air Terminal Latent Heating Energy
- Zone VRF Air Terminal Latent Cooling Energy
- Zone Air System Sensible Cooling Energy
- Zone Air System Sensible Heating Energy

If **REPORT_HVAC_TEMPLATE_ZONE_UNITARY = true** (section **6.9** reports) or **REPORT_HVAC_TEMPLATE_ZONE_DUAL_DUCT = true** (section **6.10** reports) or **REPORT_HVAC_TEMPLATE_ZONE_CONSTANT_VOLUME = true** (section **6.12** reports) or **REPORT_HVAC_TEMPLATE_ZONE_VAV = true** (section **6.13** reports):

- Zone Air Terminal Sensible Cooling Energy
- Zone Air Terminal Sensible Heating Energy

If **REPORT_ZONE_HVAC_BASEBOARD_CONVECTIVE_ELECTRIC_SYSTEM = true** (section **7.1.3.2** reports):

- Baseboard Total Heating Energy
- Baseboard Electric Energy

If **REPORT_WATER_HEATER = true** (section **8.7.1** report):

- Water Heater Tank Temperature
- Water Heater Heating Energy
- Water Heater Use Side Heat Transfer Energy
- Water Heater Source Side Heat Transfer Energy

If **REPORT_PLANT_CONDENSER_LOOP = true** (section **9** reports):

If a Boiler is assigned to the loop (section **8.5.1** or **8.5.2** reports):

- Boiler Gas Energy (if Boiler Fuel Type = Natural Gas)
- Boiler Propane Energy (if Boiler Fuel Type = Propane Gas)
- Boiler Diesel Energy (if Boiler Fuel Type = Diesel)
- Boiler Coal Energy (if Boiler Fuel Type = Coal)
- Boiler Gasoline Energy (if Boiler Fuel Type = Gasoline)

If a Chiller Electric EIR is assigned to the loop (section **8.5.3** report):

- Chiller Total Recovered Heat Energy

If a Chiller Electric is assigned to the loop (section **8.5.4** report):

- Chiller Total Recovered Heat Energy

If a District Heating is assigned to the loop (section **8.5.6** report):

- District Heating Hot Water Energy

If a District Cooling is assigned to the loop (section **8.5.7** report):

- District Heating Hot Water Energy

If a Water Heater is assigned to the loop (section **8.7** report):

- Water Heater Tank Temperature
- Water Heater Heating Energy

If a Solar Collector Flat Plate Water is assigned to the loop (section **8.4.1** report):

- Solar Collector Heat Transfer Energy

If **REPORT_ZONE_HVAC_LOW_TEMPERATURE_RADIANT_SYSTEM = true** (section **7.1.2** reports):

If Loop Circuit Type = Cooling:

- Zone Radiant HVAC Heating Energy

If Loop Circuit Type = Heating:

- Zone Radiant HVAC Cooling Energy

If **REPORT_ZONE_HVAC_BASEBOARD_CONVECTIVE_WATER_SYSTEM = true** (section **7.1.3.1** reports):

- Baseboard Total Heating Energy

If **REPORT_AIR _LOOP_HVAC = true** (section **10** reports):

If **REPORT_ZONE_HVAC_AIR_TERMINAL_SINGLE_DUCT_UNCONTROLLED = true** (section **7.1.8.1** reports):

- Zone Air Terminal Sensible Heating Energy
- Zone Air Terminal Sensible Cooling Energy

If **REPORT_ZONE_HVAC_AIR_TERMINAL_Single_DUCT_SERIESPIU_REHEAT = true** (section **7.1.8.1** reports):

- Zone Air Terminal Heating Energy
- Zone Air Terminal Sensible Cooling Energy

If **REPORT_ REPORT_HEATEXCHANGER = true** (section **8.11** reports):

- Heat Exchanger Total Heating Energy
- Heat Exchanger Total Cooling Energy
- Heat Exchanger Electric Energy

If **REPORT_HUMIDIFIER_ELECTRIC = true** (section **8.10.1** reports):

- Humidifier Electric Energy

If **REPORT_HUMIDIFIER_GAS = true** (section **8.10.2** reports):

- Humidifier Gas Use Energy

If **REPORT_FAN_ELECTRIC_ENERGY = true** (return fan and/or unitary system supply fan reports – section **8.8**):

- Fan Electric Energy

If **REPORT_ELECTRIC_LOAD_CENTER_DISTRIBUTION = true** (section **12** reports):

- Inverter AC Output Electric Energy

The following simulation output meters are activated and generated according to the source type of the selected systems and equipment:

- Electricity – Lights (**4.2**), Electrical equipment (**4.3.1**), HVAC Template equipment with electricity fuel type (**6**), HVAC equipment with electricity fuel type (**7**, **8**), Air Loop HVAC components with electricity fuel type (**10**) and Electric load center distribution (**12**);
- Natural gas – Gas equipment (**4.3.2**), HVAC Template equipment with natural gas fuel type (**6**), HVAC equipment with natural gas fuel type (**7**, **8**) and Air Loop HVAC components with gas fuel type (**10**);
- Propane gas – HVAC Template equipment with propane gas fuel type (**6**) and HVAC equipment with propane gas fuel type (**7**, **8**);
- Diesel – HVAC Template equipment with diesel fuel type (**6**) and HVAC equipment with diesel fuel type (**7**, **8**);

- Water – Water use equipment (**5.1**), Water heater mixed if not assigned to a loop (**8.7.1**), and Humidifiers (**8.10**);
- Steam – Steam equipment (**4.3.3**).

Moreover, in selected equipment/systems the respective meter type is activated depending on the equipment/system fuel type.

ANNEX A ONE-LOOP RADIANT FLOOR SYSTEM

Example of a one-loop radiant floor system assigned to two zones (living room and single bedroom). This example can be found in the SingleStoreyFamilyHouse_RadiantFloor template in the SAPTool_LSP.

SAPTool_FPOP_EnergyPlus/fpop.energyplus.parser.LayoutObjectsExportVariables:

public final boolean PLANT_CONDENSER_LOOP = true;
public final boolean ZONE_HVAC_LOW_TEMPERATURE_RADIANT_SYSTEM = true;

SAPTool_LSP/lsp.templates/SingleStoreyFamilyHouse_RadiantFloor:

(…)

// HVAC Detailed Systems

HVACSpec hVACSpec = new HVACSpec(); // HVAC detailed systems specification. The hVACSpec must then be assigned to the layout specifications object (**LayoutSpecs()**, in its second to last argument), in the end of the template.

// HVAC Plant Loops

// Radiant Floor Loop

```
PlantLoopSpec pls = new PlantLoopSpec( // Loop specification
    DBHVACPlantLoopType.RadiantFloorLoop.toString(), // Loop name
    CircuitType.Heating, // Loop type
    DBHVACPlantLoopType.RadiantFloorLoop.getID(), // Loop ID in the database
    db); // Database
```

// Plant side branch equipment

// 0. Pump:ConstantSpeed

```
pls.addPlantSideBranchEquipment( // Pump assignment to the plant side branch
    new PumpConstantSpeedSpec( // Pump specification
        DBPumpConstantSpeedType.ConstantPump.toString(), // Pump name
        null, // Pump zone ID (corresponds to the order for which the zone is added to the
        spaceSpec list in the building template)
        DBPumpConstantSpeedType.ConstantPump.getID(), // Pump ID in the database
        db)); // Database
```

// 1. Boiler:HotWater

```
pls.addPlantSideBranchEquipment( // Boiler assignment to the plant side branch
    new BoilerHotWaterSpec( // Boiler specification
        DBBoilerType.BoilerHotWater.toString(), // Boiler name
```

DBBoilerType.BoilerHotWater.getID(), // Boiler ID in the database
db)); // Database

// Adiabatic pipe specification (identical for all pipes, in this example)

PipeAdiabaticSpec pipeAdiabaticSpec = new PipeAdiabaticSpec(// Pipe specification
DBPipeAdiabaticType.CommonAdiabaticPipe.toString(), // Pipe name
DBPipeAdiabaticType.CommonAdiabaticPipe.getID(), // Pipe ID in the database
db); // Database

// 2. Pipe:Adiabatic (bypass)

pls.addPlantSideBranchEquipment(pipeAdiabaticSpec); // Pipe assignment to the plant side branch

// 3. Pipe:Adiabatic

pls.addPlantSideBranchEquipment(pipeAdiabaticSpec); // Pipe assignment to the plant side branch

// Demand side branch equipment

// 0. Pipe:Adiabatic

pls.addDemandSideBranchEquipment(pipeAdiabaticSpec); // Pipe assignment to the demand side branch

// 1. ZoneHVAC:LowTemperatureRadiant:VariableFlow

pls.addDemandSideBranchEquipment(PlantLoopZoneEquipmentType.RADIANT_ELEMENTS); // Zone HVAC Low Temperature Radiant Variable Flow assignment to the demand side branch (specified below, in the zone)

// 2. Pipe:Adiabatic (bypass)

pls.addDemandSideBranchEquipment(pipeAdiabaticSpec); // Pipe assignment to the demand side branch

// 3. Pipe:Adiabatic

pls.addDemandSideBranchEquipment(pipeAdiabaticSpec); // Pipe assignment to the demand side branch

// Operation schemes

PlantEquipmentOperationHeatingLoadSpec peohls = new PlantEquipmentOperationHeatingLoadSpec(// Operation Scheme type specification (HeatingLoad, in this example)

new ScheduleSpec(DBScheduleType.ALWAYS_ON.getID(), // Schedule ID in the database
db)); // Database

peohls.addLoadEquipment(// Equipment assignment to the operation scheme
new LoadEquipment(// (Plant side) equipment specification and its limits
new int[]{1}, // Equipment IDs (1 = 1.Boiler:HotWater, in this example)
0.0, // Load range lower limit for the assigned equipment
1000000000.0)); // Load range upper limit for the assigned equipment

pls.addPlantEquipmentOperation(peohls); // Operation Scheme Type (peohls) assignment to the Plant Loop (pls)

// Loop specification

hVACSpec.addPlantLoopSpec(pls); // Plant Loop (pls) assignment to hVACSpec

(…)

// Spaces

(…)

// Living Room

ZoneHVACLowTemperatureRadiantVariableFlowSpec zoneHVACLowTemperatureRadiantVariableFlowSpec_LivingRoom = new ZoneHVACLowTemperatureRadiantVariableFlowSpec(// Zone HVAC Low Temperature Radiant Variable Flow specification for the Living Room zone
1, // Zone HVAC Low Temperature Radiant Variable Flow ID in the database for the Living Room zone
db); // Database

ZoneHVACSpec zoneHVACSpec_LivingRoom = new ZoneHVACSpec(// Zone HVAC systems specification for the current zone
DBLoadDistributionScheme.SequentialLoad.toString(), // Load distribution scheme of the different equipment defined for this zone
new ArrayList<>(), // array list which will include the Zone HVAC Low Temperature Radiant Variable Flow specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction
null, // Used only for Fan Zone Exhaust cooling and heating or no-load sequences
null, // Used only for Fan Zone Exhaust sequential cooling fraction schedule
null, // Used only for Fan Zone Exhaust sequential heating fraction schedule
DBSpaceType.LIVING_ROOM.getID(), // Living Room zone ID in the Zone table in the database
db); // Database

zoneHVACSpec_LivingRoom.addSpec(// Used to add the Zone HVAC Low Temperature Radiant Variable Flow specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_LivingRoom in this example)

zoneHVACLowTemperatureRadiantVariableFlowSpec_LivingRoom,

new Integer[]{1,1}, // Defines the Zone HVAC Low Temperature Radiant Variable Flow cooling sequence = 1 and the heating or no-load sequence = 1

null, // Defines the Zone HVAC Low Temperature Radiant Variable Flow sequential cooling fraction schedule. Blank (null) indicates a constant schedule of 1.0

null); // Defines the Zone HVAC Low Temperature Radiant Variable Flow sequential heating fraction schedule. Blank (null) indicates a constant schedule of 1.0

livingRoom = new RoomSpec(// Living Room zone specification

(…)

new ZoneSpec(// ZoneSpec specification in the Living Room zone

null, // Used only for HVAC Template specifications

zoneHVACSpec_LivingRoom, // Living Room zone HVAC systems specification assignment to the Living Room zone specification

DBSpaceType.LIVING_ROOM.getID(), // Living Room zone ID in the Zone table in the database

db), // Database

(…)

);

(…)

// Single Bedroom

ZoneHVACLowTemperatureRadiantVariableFlowSpec zoneHVACLowTemperatureRadiantVariableFlowSpec_SingleBedroom = new ZoneHVACLowTemperatureRadiantVariableFlowSpec(// Zone HVAC Low Temperature Radiant Variable Flow specification for the Single Bedroom zone

2, // Zone HVAC Low Temperature Radiant Variable Flow ID in the database for the Single Bedroom zone

db); // Database

ZoneHVACSpec zoneHVACSpec_SingleBedroom = new ZoneHVACSpec(// Zone HVAC systems specification for the current zone

DBLoadDistributionScheme.SequentialLoad.toString(), // Load distribution scheme of the different equipment defined for this zone

new ArrayList<>(), // array list which will include the Zone HVAC Low Temperature Radiant Variable Flow specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction

null, // Used only for Fan Zone Exhaust cooling and heating or no-load sequences

null, // Used only for Fan Zone Exhaust sequential cooling and heating fractions

DBSpaceType.SINGLE_BEDROOM.getID(), // Single Bedroom zone ID in the Zone table in the database

db); // Database

zoneHVACSpec_SingleBedroom.addSpec(// Used to add the Zone HVAC Low Temperature Radiant Variable Flow specification and the respective values for cooling sequence, heating or no-load sequence, sequential cooling fraction and sequential heating fraction to the Zone HVAC systems specification (named zoneHVACSpec_SingleBedroom in this example)

zoneHVACLowTemperatureRadiantVariableFlowSpec_SingleBedroom,
new Integer[]{1,1} // Defines the Zone HVAC Low Temperature Radiant Variable Flow cooling sequence = 1 and the heating or no-load sequence = 1
null, // Defines the Zone HVAC Low Temperature Radiant Variable Flow sequential cooling fraction schedule. Blank (null) indicates a constant schedule of 1.0
null); // Defines the Zone HVAC Low Temperature Radiant Variable Flow sequential heating fraction schedule. Blank (null) indicates a constant schedule of 1.0

singleBedroom = new RoomSpec(// Single Bedroom zone specification
(…)
new ZoneSpec(// ZoneSpec specification in the Living Room zone
null, // Used only for HVAC Template specifications
zoneHVACSpec_SingleBedroom, // zoneHVACSpec_SingleBedroom assignment to the ZoneSpec
DBSpaceType.SINGLE_BEDROOM.getID(), // Single Bedroom zone ID in the Zone table in the database
db), // Database
(…)
);

ANNEX B TWO-LOOPS DOMESTIC HOT WATER SOLAR THERMAL SYSTEM

Example of a two-loops solar thermal and domestic hot water system (solar collectors + water heater + water use connections), with a main water heater assigned to both loops (solar collectors loop – source loop, and domestic hot water loop – use loop), and an instantaneous water heater immediately after the main one, serving as backup (and assigned only to the domestic hot water loop). This example can be found in the SingleStoreyFamilyHouse_DHW_SolarCollectors template in the SAPTool_LSP.

SAPTool_FPOP_EnergyPlus/fpop.energyplus.parser.LayoutObjectsExportVariables:

public final boolean PLANT_CONDENSER_LOOP = true;
public final boolean WATER_USE = true;

SAPTool_LSP/lsp.templates/SingleStoreyFamilyHouse_DHW_SolarCollectors:

(…)

// HVAC Detailed Systems

HVACSpec hVACSpec = new HVACSpec(); // HVAC detailed systems specification. The hVACSpec must then be assigned to the layout specifications object (**LayoutSpecs()**, in its second to last argument), in the end of the template.

// HVAC Plant Loops

// Domestic Hot Water Loop

PlantLoopSpec pls1 = new PlantLoopSpec(// Loop 1 specification
DBHVACPlantLoopType.DHWLoop.toString(), // Loop name
CircuitType.Heating, // Loop type
DBHVACPlantLoopType.DHWLoop.getID(), // Loop ID in the database
db); // Database

// Plant side branch equipment

// Water heater specification (main water heater)

WaterHeaterMixedSpec storageTankSpec = new WaterHeaterMixedSpec(// Water heater specification
DBWaterHeaterMixedType.DHWStorageTank.toString(), // Water heater name
2, // Water heater zone ID (corresponds to the order for which the zone is added to the spaceSpec list in the building template – 2 = Kitchen, in the SingleStoreyFamilyHouse_DHW_SolarCollectors example)
DBWaterHeaterMixedType.DHWStorageTank.getID(), // Water heater ID in the database
db); // Database

// Adiabatic pipe specification (identical for all pipes, in this example)

PipeAdiabaticSpec pipeAdiabaticSpec = new PipeAdiabaticSpec(// Pipe specification
DBPipeAdiabaticType.CommonAdiabaticPipe.toString(), // Pipe name
DBPipeAdiabaticType.CommonAdiabaticPipe.getID(), // Pipe ID in the database
db); // Database

// 0. Pump:VariableSpeed

pls1.addPlantSideBranchEquipment(// Pump assignment to the plant side branch
new PumpVariableSpeedSpec (// Pump specification
DBPumpVariableSpeedType.IntermittentPumpDHW.toString(), // Pump name
null, // Pump zone ID (corresponds to the order for which the zone is added to the spaceSpec list in the building template)
DBPumpVariableSpeedType.IntermittentPumpDHW.getID // Pump ID in the database
db)); // Database

// 1. TemperingValve (mixing valve for the water heater below [equipment 2])

pls1.addPlantSideBranchEquipment(// Valve assignment to the plant side branch
new TemperingValveSpec(// Valve specification
DBTemperingValveType.DHWAntiScaldDiverter.toString(), // Valve name
DBTemperingValveType.DHWAntiScaldDiverter.getID(), // Valve ID in the database
db); // Database

// 2. WaterHeater:Mixed (main water heater, assigned to both loops – pls1 and pls2)

pls1.addPlantSideBranchEquipment(// Water heater assignment to the plant side branch
new WaterHeaterMixedSideSpec(// Specification of the linkage between the water heater and one of its loop sides
NumberOfLoopSidesType.TwoSides, // Number of water heater sides
WaterHeaterSideType.Use, // Water heater side for the current loop
storageTankSpec)); // Water heater specification (storageTankSpec, defined above) assignment to the WaterHeaterMixedSideSpec

// 3. WaterHeater:Mixed (instantaneous water heater [not assigned to a zone], assigned only to pls1)

pls1.addPlantSideBranchEquipment(// Water heater assignment to the plant side branch
new WaterHeaterMixedSideSpec(// Water heater loop side specification
NumberOfLoopSidesType.OneSide, // Number of loop sides
WaterHeaterSideType.Use, // Loop side type for the current loop
new WaterHeaterMixedSpec(// Water heater specification
DBWaterHeaterMixedType.DHWInstantaneousWaterHeater.toString(), // Water heater name
null, // Water heater zone ID (corresponds to the order for which the zone is added to the spaceSpec list in the building template). No zone assignment in this example

DBWaterHeaterMixedType.DHWInstantaneousWaterHeater.getID(), // Water heater ID in the database
db); // Database

// Demand side branch equipment

// 0. Pipe:Adiabatic

pls1.addDemandSideBranchEquipment(pipeAdiabaticSpec); // Pipe assignment to the demand side branch

// 1. WaterUseConnections (specified in the zones, in the database)

pls1.addDemandSideBranchEquipment(// Water use connections assignment to the demand side branch
new PlantLoopZoneWaterUseConnectionsSpec(// Water use connections specification
DBWaterUseConnectionType.Hot_Water.getID())); // Water use connections ID in the database

// 2. Pipe:Adiabatic

pls1.addDemandSideBranchEquipment(pipeAdiabaticSpec); // Pipe assignment to the demand side branch

// Operation schemes

PlantEquipmentOperationHeatingLoadSpec peohls1 = new PlantEquipmentOperationHeatingLoadSpec(// Operation scheme type specification (HeatingLoad, in this example)
new ScheduleSpec(DBScheduleType.ALWAYS_ON.getID(), // Schedule ID in the database
db)); // Database

peohls1.addLoadEquipment(// Equipment assignment to the operation scheme
new LoadEquipment(// (Plant side) equipment specification and its limits
new int[]{1,2,3}, // Equipment IDs (1 = 1.TemperingValve, 2 = 2.WaterHeater:Mixed, 3 = 3.WaterHeater:Mixed, in this example)
0.0, // Load range lower limit for the assigned equipment
1000000000.0)); // Load range upper Limit for the assigned equipment

pls1.addPlantEquipmentOperation(peohls1); // Operation Scheme Type (peohls1) assignment to the Plant Loop 1 (pls1)

// Loop specification

hVACSpec.addPlantLoopSpec(pls1); // Plant Loop 1 (pls1) assignment to hVACSpec

// Solar Collectors Loop

PlantLoopSpec pls2 = new PlantLoopSpec(// Loop 2 specification
DBHVACPlantLoopType.SolarCollectorsLoop.toString(), // Loop name
CircuitType.Heating, // Loop type
DBHVACPlantLoopType.SolarCollectorsLoop.getID(), // Loop ID in the database
db); // Database

// Plant side branch equipment

// 0. Pump:VariableSpeed

pls2.addPlantSideBranchEquipment(// Pump assignment to the plant side branch
new PumpVariableSpeedSpec (// Pump specification
DBPumpVariableSpeedType.IntermittentPumpSolarCollectors.toString(), // Pump name
null, // Pump zone ID (corresponds to the order for which the zone is added to the spaceSpec list in the building template)
DBPumpVariableSpeedType.IntermittentPumpSolarCollectors.getID // Pump ID in the database
db)); // Database

// 1. WaterHeater:Mixed (main water heater, assigned to both loops – pls1 and pls2)

pls2.addPlantSideBranchEquipment(// Water heater assignment to the plant side branch
new WaterHeaterMixedSideSpec(// Specification of the linkage between the water heater and one of its loop sides
NumberOfLoopSidesType.TwoSides, // Number of water heater sides
WaterHeaterSideType.Source, // Water heater side for the current loop
storageTankSpec)); // Water heater specification (storageTankSpec) assignment to the WaterHeaterMixedSideSpec

// 2. Pipe:Adiabatic

pls2.addPlantSideBranchEquipment(pipeAdiabaticSpec); // Pipe assignment to the plant side branch

// Demand side branch equipment

// 0. Pipe:Adiabatic

pls2.addDemandSideBranchEquipment(pipeAdiabaticSpec); // Pipe assignment to the demand side branch

// Solar collector specification (identical for both solar collectors, in this example)

SolarCollectorFlatPlateWaterSpec solarCollectorSpec = new SolarCollectorFlatPlateWaterSpec(// Solar collector specification
"Collector", // Solar collector name

ModulePlacementType.ROOF, // Surface type for the solar collector module placement
40.0, // Solar collector tilt
180.0, // Solar collector azimuth
PVModuleOrientationType.HORIZONTAL.toString(), // Solar collector orientation
DBSolarCollectorFlatPlateType.AlternateEnergyTechnologiesMSC24E.getID(), // Solar collector ID in the database
db); // Database

// 1. SolarCollector:FlatPlate:Water

pls2.addDemandSideBranchEquipment(solarCollectorSpec); // Solar collector assignment to the demand side branch

// 2. SolarCollector:FlatPlate:Water

pls2.addDemandSideBranchEquipment(solarCollectorSpec); // Solar collector assignment to the demand side branch

// 3. Pipe:Adiabatic (bypass)

pls2.addDemandSideBranchEquipment(pipeAdiabaticSpec); // Pipe assignment to the demand side branch

// 4. Pipe:Adiabatic

pls2.addDemandSideBranchEquipment(pipeAdiabaticSpec); // Pipe assignment to the demand side branch

// Operation schemes

PlantEquipmentOperationHeatingLoadSpec peohls2 = new PlantEquipmentOperationHeatingLoadSpec(// Operation Scheme type specification (HeatingLoad, in this example)
new ScheduleSpec(DBScheduleType.ALWAYS_ON.getID(), // Schedule ID in the database
db)); // Database

peohls2.addLoadEquipment(// Equipment assignment to the Operation Scheme
new LoadEquipment(// (Plant side) equipment specification and their limits
new int[]{1}, // Equipment IDs (1 = 1.WaterHeater:Mixed, in this example)
0.0, // Load range lower limit for the assigned equipment
1000000000.0)); // Load range upper limit for the assigned equipment

pls2.addPlantEquipmentOperation(peohls2); // Operation Scheme Type (peohls2) assignment to the Plant Loop 2 (pls2)

// Availability managers

AvailabilityManagerHighTemperatureTurnOffSpec amhttoff = new AvailabilityManagerHighTemperatureTurnOffSpec(// Availability manager type specification (in this example, HighTemperatureTurnOff)

LoopSideType.PLANT, // Loop side of the target equipment

1, // Target equipment ID on the loop side defined in the previous argument (in this example, 1 = 1.WaterHeater:Mixed on the plant side)

60.0); // Temperature setpoint

pls2.addAvailabilityManager(amhttoff); // Availability manager (amhttoff) assignment to the Plant Loop 2 (pls2)

AvailabilityManagerLowTemperatureTurnOnSpec amhtton = new AvailabilityManagerLowTemperatureTurnOnSpec(// Availability manager type specification (in this example, LowTemperatureTurnOn)

LoopSideType.DEMAND, // Loop side of the target equipment

2, // Target equipment ID on the loop side defined in the previous argument (in this example, 2 = 2.SolarCollector:FlatPlate on the demand side)

0.0); // Temperature setpoint

pls2.addAvailabilityManager(amhtton); // Availability manager (amhtton) assignment to the Plant Loop 2 (pls2)

AvailabilityManagerDifferentialThermostatSpec amdt = new AvailabilityManagerDifferentialThermostatSpec(// Availability manager type specification (in this example, DifferentialThermostat)

LoopSideType.DEMAND, // Loop side of the target equipment

2, // Target equipment ID on the loop side defined in the previous argument (in this example, 2 = 2.SolarCollector:FlatPlate on the demand side)

LoopSideType.PLANT, // Loop side of the target equipment

1, // Target equipment ID on the loop side defined in the previous argument (in this example, 1 = 1.WaterHeater:Mixed on the plant side)

10.0, // Temperature difference on limit

2.0); // Temperature difference off limit

pls2.addAvailabilityManager(amdt); // Availability manager (amdt) assignment to the Plant Loop 2 (pls2)

// Loop specification

hVACSpec.addPlantLoopSpec(pls2); // Plant Loop 2 (pls2) assignment to hVACSpec

ANNEX C STAND-ALONE WATER HEATER

This example can be found in the SingleStoreyFamilyHouse_DHW_SolarCollectors template in the SAPTool_LSP.

SAPTool_LSP/lsp.templates/SingleStoreyFamilyHouse_DHW_SolarCollectors:

(…)

// HVAC Detailed Systems

HVACSpec hVACSpec = new HVACSpec(); // HVAC detailed systems specification. The hVACSpec must then be assigned to the layout specifications object (**LayoutSpecs()**, in its second to last argument), in the end of the template.

// HVAC Stand-alone equipment

WaterHeaterMixedSpec waterHeaterMixedStandAloneSpec = new WaterHeaterMixedSpec(// Water heater specification

DBWaterHeaterMixedType.DHWStandAloneWaterHeater.toString(), // Water heater name

null, // Water heater zone ID (corresponds to the order for which the zone is added to the spaceSpec list in the building template). No zone assignment in this example

DBWaterHeaterMixedType.DHWStandAloneWaterHeater.getID(), // Water heater ID in the database

db); // Database

hVACSpec.addWaterHeaterMixedSpec(waterHeaterMixedStandAloneSpec); // Water heater assignment to the hVACSpec