**EnergyPlus Ice Rink Module Description**

**Ice Rink Input Data**

The following are the input variable of the new EnergyPlus ice rink module (object):

* *Name*: This field is a unique user assigned name for the ice rink object. It is used by other objects to reference this function.
* *Availability Schedule Name*: This field represents the name of the schedule of the ice rink operation. Acceptable values are 0 and 1 where 0 means that ice rink is off and 1 means it is on. EnergyPlus will not accept any other values and the default is 1 indicating that the ice rink is set to operate all the time.
* *Zone Name*: This field is the name of the thermal zone where the ice rink is located. Any building modeled in EnergyPlus must have at least 1 thermal zone to run the simulation.
* *Surface Name*: This field refers to the surface where the ice rink is assigned to. This surface is where the heat exchanger tubes are embedded. Unlike other similar objects such as low temperature radiant systems, the ice rink feature will accept only one surface.
* *Tube Diameter*: This field refers to the diameter of the secondary coolant heat exchanger tubes. These tubes are embedded in the surface that the ice rink is assigned to and are where ice rink refrigerant flows. The tube diameter is important and is used in different equations that are related to refrigeration load calculations such as effectiveness and circuits number.
* *Tube Length*: This field refers to the length of the heat exchanger tubes. It is not the total length of the tube.
* *Ice Rink Control Strategy*: This field is to assist the user to specify the control strategy of the ice rink refrigeration system. Currently, two inputs are acceptable: either BTOC (Brine Temperature Outlet Control) and STC (Surface Temperature Control). The BTOC strategy controls the operation of the refrigeration system by adjusting the outlet temperature of the refrigerant. As for STC, it is controlling the refrigeration system by monitoring the surface temperature of the ice rink.
* *Hours to freeze water:* This field is the desired number of hours needed to freeze water to become ice at the start of the ice rink operation. The number of hours, entered by the user, is used to calculate the needed capacity for the ice rink’s refrigeration system.
* *Delta Temperature*: This field represents the desired temperature difference between inlet and output of the refrigerant. This value is used to calculate the refrigeration system’s capacity during the design calculations.
* *Refrigerant Inlet Node Name*: This field represents the name of the inlet node to the heat exchanger tubes embedded in the ice rink floor. Since the ice rink is part of a plant loop, this name is used in the branch description to define the demand side of the plant.
* *Refrigerant Outlet Node Name:* This field represents the name of the outlet node to the heat exchanger tubs embedded in the ice rink floor. This name is used in the branch description to define the demand side of the plant.
* *Ice Rink Design Setpoint*: This field represents the lowest setpoint temperature for the ice rink floor. This value is used to calculate the refrigeration capacity of the ice rink. This value does not represent the ice rink operation setpoint temperature instead it represents the worst-case scenario. For example, the refrigeration system can be sized to maintain the ice surface at a design setpoint of -7°C (19.4 oF) as a worst case scenario. However and depending on the activity, the ice surface operational setpoint can be higher such as -3°C (26.6°F).
* *Rink Length*: This field represents the ice rink length.
* *Rink Width*: This field represents the ice rink width.
* *Water temperature:* This field refers to the water temperature within the rink before freezing to ice. The water temperature is used in the design calculations to determine the refrigeration system capacity.
* *Ice Thickness*: This field represents the maximum ice thickness in the ice rink. This value is used in the design calculations to estimate the refrigeration capacity. The module only accepts positive values. If no values entered, the default value is 0.0254 m (1in) which is the typical ice rink thickness.
* *COP*: This field represents the coefficient of performance of the refrigeration system. This field is used for static simulation of a chiller that cools the secondary coolant. However, this field is not required when a chiller is modeled as part of the plant. The default value of this field is 2.5.
* *Ice Rink setpoint temperature*: The field refers to the desired setpoint of the ice rink floor. This setpoint represents the operational setpoint temperature that the refrigeration system needs to maintain. This value cannot be higher than 0°C (32oF) and the default is -3°C (26.6oF).
* *Ice Rink HX spacing*: This field refers to the spacing between the heat exchanger tubes embedded in the floor. This value is required to calculate the number of parallel circuits and is used to estimate the effectiveness of the refrigeration system. For the ice rink application, the tube spacing is typically on average 100 mm (3.9 in) from the center of the tubes.
* *Resurfacer Tank*: This field refers to the volume of resurfacer water tank. The default value is 0.55 m3.
* *Resurfacer Initial Water Temperature*: This field refers to the initial water temperature in the resurfacer tank before it gets heated. The default value is 18 °C.
* *Resurfacer Hot Water Temperature*: This field refers to the desired hot water temperature setpoint used in the resurfacing operations. The default value is 55 °C.
* *Ice Temperature Design Setpoint*: This field refers to the lowest ice surface temperature setpoint. This value represents the worst-case scenario and is used in the design calculations for the ice rink refrigeration system. The default value is -10 °C.

**Engineering reference:**

The ice rink module is based on the model developed by Mun and Krarti (2011) [1] and utilizes a set of equations to calculate the refrigeration needed to maintain the ice rink surface temperature at the desired setpoint.

is the refrigeration load required to bring the surface temperature to the setpoint temperature :

(1)

* , is the coefficient associated with the heat balance at the inside surface including solar, long wave radiation heat exchange and conduction history terms. (°C; °F)
* , is the current cross Conduction Transfer Function term.
* , is the coefficient associated with the current heat source/sink. (m2 °C/W; ft2 h °F/Btu)
* is the coefficient associated with the heat balance at the outside surface including solar, long wave radiation exchange, and conduction history terms. (°C; °F)
* , is the current cross Conduction Transfer Function term.
* , is the coefficient associated with the current heat source/sink. (m2 °C/W; ft2 h °F/Btu)
* , is the sum of temperature and source history terms at the source/sink location. (°C; °F)
* , is the coefficients associated with the current heat source/sink. (m2 °C/W; ft2 h °F/Btu)
* , is the inside term for the current inside surface temperature.
* is the CTF outside term for the current outside surface temperature.

In addition, two other coefficients are used to estimate the heat sink load calculations including which are defined as follows:

(2)

(3)

The ice rink module needs to calculate the refrigerant mass flowrate as well as the refrigeration load to maintain the ice at desired setpoint temperature depending on the user input. In particular,

and are the required mass flow rate of refrigerant and refrigeration load to maintain , respectively. is the heat sink load used in updating the conduction part of the heat balance equations in EnergyPlus.

(4)

(5)

(6)

* , is the maximum possible heat transfer. (J/s; Btu/s)
* , is the temperature at source (°C; °F)
* is the specific heat of the refrigerant. (kJ/(kg.K);Btu/lb.°F)
* is the inlet temperature of the refrigerant. (°C; °F)
* is the effectiveness of heat exchanger.
* is the refrigerant mass flow rate. (Kg/s; lb/s)
* is the refrigeration load required to maintain the surface temperature at the desired setpoint. (J/s; Btu/s)

**Surface Temperature Control**

To operate the refrigeration system, the ice rink module uses the surface temperature control. As indicated in Figure 1, if the ice rink is operating then operation flag is set 1 otherwise it is set to zero. If the ice temperature of the previous time step is lower than the ice setpoint temperature, then no refrigeration is required and hence no mass flowrate is needed in the heat exchanger tubes. However, when the ice temperature of the previous time step is higher than the ice setpoint temperature, the refrigeration system is operated and refrigerant flows in the heat exchanger tubes. The next step, the heat transfer required to maintain the ice setpoint and the maximum heat transfer from the refrigerant are calculated using Eq. (1) and Eq. (5). If the maximum heat flux is more than the required heat flux, then the mass flowrate is set to the required mass flowrate calculated from Eq. (4). Otherwise, the mass flowrate is set to the maximum allowed.

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Figure 1: Ice Surface Temperature Control Algorithm

# **References**

1. Mun, Junghyon, and Moncef Krarti. “An Ice Rink Floor Thermal Model Suitable for Whole-Building Energy Simulation Analysis.” *Building and Environment*, vol. 46, no. 5, Elsevier Ltd, 2011, pp. 1087–93