Direct and indirect evaporative cooling

Using the evaporative process to precool the supply air stream can reduce the energy consumption of mechanical cooling equipment. Two methods of evaporative cooling exist: direct and indirect. The effectiveness of each method depends on the extent to which the dry-bulb temperature of the supply air exceeds the wet-bulb temperature of the supply air.

**Figure 4–14  Examples of evaporative cooling arrangements**

**Inset A**
Direct evaporative cooling

**Inset B**
Indirect evaporative cooling

**Inset C**
Staged evaporative cooling

*Direct evaporative cooling* (Figure 4–14, Inset A) introduces water directly into the supply air stream, usually with a spray or wetted media. The water evaporates as it absorbs heat from the passing air, which lowers the dry-bulb temperature of the air. However, it also increases the moisture content of the air, which raises the dew point.

By contrast, *indirect evaporative cooling* (Inset B) uses an additional waterside coil to cool the supply air. Positioned upstream of the conventional cooling coil, the indirect coil is piped to a cooling tower where the evaporative process occurs. This method of precooling does not increase the moisture content (dew point) of the supply air because evaporation occurs at the tower. It is, however, not as effective as the direct evaporative cooling process.
A third option blends both direct and indirect evaporative processes. Staged evaporative cooling systems (Inset C) are arranged so that the indirect coil activates first, precooling the supply air without increasing the moisture content. The supply air then passes through the direct evaporative coil, where it is cooled further with only a slight increase in humidity. A conventional cooling coil, if used, provides the additional cooling needed to satisfy any remaining load.

**Application considerations**

- Although evaporative cooling can effectively reduce the amount of mechanical cooling an application requires, it seldom eliminates the need for a conventional cooling coil altogether.

- Using evaporative coils in conjunction with a conventional cooling coil typically adds from 0.2 in. wg to 0.4 in. wg to the static pressure of the air-distribution system.

- Direct evaporative cooling systems require additional care to ensure proper cleanliness and operation.

**Sample scenarios**

**Scenario 1: Heat-pipe or fixed-plate heat exchanger (HX) with supply-side on return outside air deck and evaporative precool of exhaust side.** In this configuration, the supply side of an air-to-air heat exchanger (heat pipe, flat plate or wheel) is located upstream of the main cooling coil. The exhaust side of the HX transfers heat to a scavenger outside air stream pretreated by a separate evaporative HX. The example below is shown as a completely recirculated system typical of data centers but a mixed air ventilation deck could be added to provide airside economizer operation for part of the year.

![Figure 4–15 Fixed-plate heat exchanger with evaporative precooling of exhaust-side airflow](image)
In TRACE, this configuration can be created via the Create Systems - Options dialog using the standalone Evaporative Cooling.

1. Click Options next to Indirect Efficiency to change the defaults as follows:

2. **Heat Exchanger Type**: Air-to-air heat exchanger.

3. **Indirect Efficiency**: Overall wet-mode effectiveness at rated supply airflow.

4. **Dry Effectiveness**: Refers to the overall dry-mode effectiveness at rated supply airflow.

5. **Switchover Oadb**: The water circulation pump will not operate below this Oadb which causes the HX to operate in dry mode. Above this Oadb, the HX can operate in wet mode.

6. **Makeup Water Drift and Blowdown Ratio**: Used to model additional water consumed by the cooler from drift and blowdown.

7. **Circulation Pump**: Power per design scavenger OA airflow. Operates at its design value whenever the HX is in wet mode.

- Be sure to include the supply-side static pressure drop across the HX by including it with the primary fan’s static pressure via the Create Systems - Fan Overrides screen. In a similar manner, be sure to include the exhaust-side (scavenger OA) static pressure drop by defining it in the auxiliary fan’s static pressure field via the Create Systems - Fan Overrides screen (see p 4-43).

- The controls are designed to minimize scavenger fan energy consumption rather than minimize water consumption. The scavenger airflow is first modulated between the max and min scavenger airflow settings to achieve the primary air leaving dry bulb setpoint. If the HX is operating in wet mode, the circulation pump (and associated water flow) operates at its maximum. Once the scavenger fan has slowed down to its minimum speed to prevent overcooling, the circulation pump modulates, if necessary, to maintain desired HX leaving setpoint. The circulation pump shuts off when the HX runs in dry mode or when Oawb > primary air leaving dry bulb setpoint or when Oadb < Switchover Db.
Next the scavenger outdoor air fan should be specified on the Create Systems - Fan Overrides screen.

To save fan energy, the scavenger airflow is modulated between the Minimum and Maximum OA% of Supply values to maintain target supply air dry bulb. If both Minimum and Maximum OA % of Supply are set to the same value, then the scavenger fan is constant volume and the ERD is modulated by reducing or shutting down the evaporative cooler first.

**Scenario 2: Polymer tube HX with supply-side on ROA deck with exhaust side using scavenger outside air.** In this configuration, the supply side of a Polymer tube HX is located upstream of the main cooling coil. The exhaust side of the HX transfers heat to a scavenger outside air stream. With this design, outdoor scavenger air is drawn across the exterior of elliptical tubes, which are wetted by a recirculation water pump. The example below is shown as a completely recirculated system typical of data centers but a mixed air ventilation deck could be added to provide airside economizer operation for part of the year.

**Figure 4–16  Wetted plate/tube heat exchanger with scavenger outside air on exhaust deck**
In TRACE, this configuration can be created via the Create Systems - Options dialog.

1. Click Options next to Indirect Efficiency to change the defaults as follows:

2. **Heat Exchanger Type**: Wetted plate/tube heat exchanger.

3. **Indirect Efficiency**: Overall wet-mode effectiveness at rated supply airflow.

4. **Dry Effectiveness**: Refers to the overall dry-mode effectiveness at rated supply airflow.

5. **Switchover Oadb**: The water circulation pump will not operate below this Oadb which causes the HX to operate in dry mode. Above this Oadb, the HX can operate in wet mode.

6. **Makeup Water Drift and Blowdown Ratio**: Used to model additional water consumed by the cooler from drift and blowdown.

7. **Circulation Pump**: Power per design scavenger OA airflow. Operates at its design value whenever the HX is in wet mode.

8. As in the previous scenario, the scavenger OA fan should be designated in Create Systems-Fan Overrides (see p. 4-43)

- Be sure to include the supply-side static pressure drop across the HX by including it with the primary fan’s static pressure via the Create Systems - Fan Overrides screen. In a similar manner, be sure to include the exhaust-side (scavenger OA) static pressure drop by defining it in the auxiliary fan’s static pressure field via the Create Systems - Fan Overrides screen (see p 4-43).

- The controls are designed to minimize scavenger fan energy consumption rather than minimize water consumption. The scavenger airflow is first modulated between the max and min scavenger airflow settings to achieve the primary air leaving dry bulb setpoint. If the HX is operating in wet mode, the circulation pump (and associated water flow) operates at its maximum. Once the scavenger fan has slowed down to its minimum speed to prevent overcooling, the circulation pump modulates, if necessary, to maintain desired HX leaving setpoint. The circulation pump shuts off when the HX runs in dry mode or when Oawb > primary air leaving dry bulb setpoint or when Oadb < Switchover Db.
Scenario 3: **Indirect evaporative cooling via water-to-air HX with cooling tower.** In this configuration, a water-to-air HX is located upstream of the main cooling coil on the supply deck. The water-to-air HX is similar to a regular finned tube water cooling coil except that the "chilled" water comes from a cooling tower rather than a chiller. The example below is shown with a mixed air ventilation deck to provide airside economizer operation for part of the year.

![Indirect evaporative cooling via water-to-air heat exchanger on the ROA deck](image)

Go to **Create Systems - Options** dialog.

1. **Click Options** next to **Indirect Efficiency** to change the defaults as follows:

2. **Heat Exchanger Type**: Water-to-air heat exchanger with tower.

3. **Indirect Efficiency**: Refers to the effectiveness above Switchover Oadb.

4. **Dry Effectiveness**: Refers to the effectiveness below Switchover Oadb

5. **Switchover Oadb**: Used to determine the value of the HX effectiveness. Above this value, the indirect effectiveness is set to equal the **Indirect Efficiency** field; below this value, the indirect effectiveness is set to equal the **Dry Effectiveness** field.

When the Heat Exchanger Type is "Water-to-air heat exchanger with Tower", the makeup water is calculated according to the cooling tower chosen as the **Heat Rejection Type** on the **Create Plants - Cooling Equipment** screen. The Secondary Airflow inputs are disabled because the cooling tower is modeled separately in the **Equipment** section.
The cooling tower and associated pump attached to the water-to-air HX need not be specified for design or system simulation but are needed for the equipment simulation. On the Create Plants - Cooling Equipment screen, create a separate cooling plant (6-10).

6 Category set to Water-cooled Chiller.

7 Equipment Type set to Indirect Evaporative Cooling.

8 Choose Heat Rejection Type that matches your cooling tower or fluid cooler.

9 Leave cooling capacity blank and set cooling energy rate to zero.

10 Choose a Condenser Water Pump and set its Full Load Consumption rate.

Second, on the Assign System Coils screen, attach the Indirect Evaporative Cooling Coil to the above cooling plant.
Scenario 4: Staged direct (wetted media) and indirect evaporative (water-to-air HX) in ROA deck. In this configuration, a direct evaporative heat exchanger is placed upstream of an indirect evaporative heat exchanger located upstream of the main cooling coil on the ROA deck. The example below is shown with a mixed air ventilation deck to provide airside economizer operation for part of the year.

Figure 4–18  Staged direct (wetted media) and indirect evaporative (water-to-air HX) in ROA deck

This configuration is modeled in Evaporative Cooling Options.
Scenario 5: Indirect evaporative (water-to-air) heat exchanger in ventilation deck (DualCool system). This configuration is not used for data centers but was added to implement the DualCool add-on to DX rooftops. In this configuration, a water-to-air heat exchanger integrated with a separate evaporative media coil is placed in the ventilation deck. A submersible pump moves cool water from the reservoir beneath the evaporative media to, and through, the vent air pre-cooling coil, and then back to a distribution tube above the evaporative media. Water flowing by gravity downward through the wetted media cools the air entering the large condenser coil through which refrigerant is discharging heat to the outdoor air.

Figure 4–19 Indirect evaporative (water-to-air) HX in ventilation deck (DualCool system)

The Stage 1 Air-to-Air Energy Recovery/Transfer Type is a standard library member called DualCool (OA Evap Precooling) and would be defined on the Create System - Options screen via the Stage 1 Energy Recovery.

Because the evaporative media is precooling the condenser air, this must be accounted for in the Cooling Equipment library member attached to this system by specifying the Evaporative Precooling Flag = Yes and Evap Precool Effectiveness =65% as illustrated.
Schedule lockouts
Schedule lockouts can be used to limit direct and/or indirect evaporative coil or Energy Recovery operation within a specific Oadb range.

In Schedule Library, create a Utilization Schedule for a specific range

In Create Systems-Options screen select the custom schedule for the respective coil.

Suggested defaults:

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