# TYPE 657: HEAT EXCHANGER WITH COLD-SIDE BYPASS TO KEEP HOT-SIDE OUTLET BELOW ITS SETPOINT

## General Description

Type657 models a constant effectiveness / $C_{min}$ heat exchanger that is able to automatically bypass cold-side fluid around the heat exchanger in order to maintain the hot-side outlet temperature below a user specified, time dependent set point. The bypass may be enabled or disabled at any point during the simulation if desired.

## Nomenclature

| | | |
|---|---|---|
| $C_{HotSide}$ | [kJ/hr.K] | Thermal capacitance of the hot-side fluid. |
| $C_{ColdSide}$ | [kJ/hr.K] | Thermal capacitance of the cold-side fluid. |
| $\dot{m}_{hot}$ | [kg/hr] | Mass flow rate of hot-side fluid. |
| $\dot{m}_{cold}$ | [kg/hr] | Mass flow rate of cold-side fluid. |
| $Cp_{hot}$ | [kJ/kg.K] | Specific heat of hot-side fluid. |
| $Cp_{cold}$ | [kJ/kg.K] | Specific heat of cold-side fluid. |
| $\gamma$ | [0..1] | Fraction of fluid bypassing the heat exchanger |
| $Q_{HX}$ | [kJ/hr] | Heat transferred from hot-side to cold side of the heat exchanger |
| $\varepsilon$ | [0..1] | Heat exchanger effectiveness. |
| $T_{hot,in}$ | [ºC] | Temperature of fluid entering the hot-side of the heat exchanger. |
| $T_{cold,in}$ | [ºC] | Temperature of fluid entering the cold-side of the heat exchanger. |
| $T_{hot,out}$ | [ºC] | Temperature of fluid exiting the hot-side of the heat exchanger *after* mixing with bypass fluid. |
| $T_{hot,HXout}$ | [ºC] | Temperature of fluid exiting the hot-side of the heat exchanger *before* mixing with bypass fluid. |
| $T_{cold,out}$ | [ºC] | Temperature of fluid exiting the cold-side of the heat exchanger. |
| $N_{steps}$ | - | Number of discrete settings at which the bypass valve can operate. |

## Detailed Description

Along with its sister Types (650: Heat Exchanger With Hot-Side Bypass to Keep Cold-Side Outlet Below Its Set Point, 652: Heat Exchanger With Hot-Side Bypass to Keep Cold-Side Outlet Above Its Set Point, and 699: Heat Exchanger With Cold-Side Bypass to Keep Hot-Side Outlet Above Its Set Point), Type657 uses a constant effectiveness / $C_{min}$ approach to predict heat exchanger performance. The heat exchanger, shown schematically in Figure 1, is designed to automatically determine the fraction of cold-side fluid that should be bypassed around the heat exchanger in order to maintain the hot-side outlet temperature at or below it's time dependent set point. Through the use of INPUT 6, Type657 may also be set up such that the automatic control on the hot-side outlet temperature is disabled and the entire cold-side flow is passes through the exchanger. This of course, may result in the hot-side outlet temperature exceeding its set point.

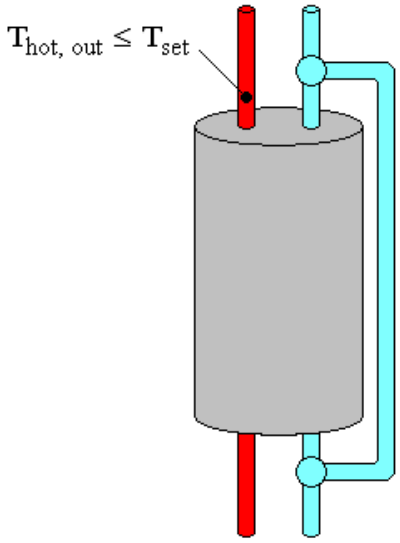



**Figure 1: Heat Exchanger Schematic**

The minimum capacitance ($C_{min}$) is determined by comparing the capacitance of the hot-side fluid flow to the capacitance of the cold-side fluid flow. The capacitances of each side are computed based on equations 657.1a and 657.1b.

$$C_{HotSide} = \dot{m} Cp_{hot} \quad \text{(Eq. 657.1a)}$$

$$C_{ColdSide} = \dot{m} Cp_{cold} (1-\gamma) \quad \text{(Eq. 657.1b)}$$

where gamma ($\gamma$) is the fraction of the cold-side fluid that bypasses the heat exchanger. The energy transferred across the heat exchanger is given by equation 657.2

$$Q_{HX} = \varepsilon C_{\min} \left(T_{hot,in} - T_{cold,in}\right) \quad \text{(Eq. 657.2)}$$

where epsilon ($\varepsilon$) is the heat exchanger's effectiveness and $C_{min}$ is the minimum of the hot and cold-side fluid thermal capacitances. The temperature of fluid leaving the cold and hot-sides of the heat exchanger and before any remixing with bypassed fluid has occurred are given by equations 657.3a and 657.3b respectively.

$$T_{hot,out} = T_{hot,in} - \frac{Q_{HX}}{C_{HotSide}} \quad \text{(Eq. 657.3a)}$$

$$T_{cold,HXout} = T_{cold,in} + \frac{Q_{HX}}{C_{ColdSide}} \quad \text{(Eq. 657.3b)}$$

The temperature of the cold-side outlet after it has been remixed with the bypass fluid is given by 657.4.

$$T_{cold,out} = \gamma T_{cold,in} + (1-\gamma) T_{cold,HXout} \quad \text{(Eq. 657.4)}$$

Type657 uses an iterative approach to calculate the appropriate value of gamma at a given time step. The initial guess value is unity (all cold-side fluid passes through the heat exchanger). If the resulting hot-side outlet temperature exceeds the set point, the iteration counter is incremented and a new value of gamma is chosen based on equation 657.5.

$$\gamma = 1 - \frac{IterationNumber}{N_{steps}} \qquad \text{(Eq. 657.5)}$$

where $N_{steps}$ is the user specified number of discrete settings at which the bypass valve can operate. Setting $N_{steps}$ (PARAMETER 3) to a high number approximates analog control (where the valve can adjust itself to exactly meet the required outlet temperature. However, due to the iterative nature of the solution, approximating analog control can have negative effects on the speed of simulations.