Flow Control Devices in PIPE-FLO Professional 15

Using the Flow Control Device in PIPE-FLO® Professional 15

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Two new devices have been added to version 15 of PIPE-FLO® Professional to perform thermal analysis of heat exchangers used in a wide variety of applications throughout various industries. The Heat Source / Sink device and the Heat Exchanger 2-Pipe device are used to evaluate sensible heat transfer into, out of, or between flowing fluids. One of the optional design data fields for these two devices is the Flow Control Device (FCD). Assigning an FCD establishes a process control link to another device in the piping system model to regulate the flow rate through the heat transfer device, and therefore control the heat transfer rate, inlet temperature, or outlet temperature.

Figure 1 shows a model of a typical heat transfer application in the pulp and paper industry that uses two shell and tube heat exchangers in series to cool weak acid from 107 °F to 60 °F prior to strengthening in the Fortification Tower. The production rate of weak acid is established by the Acid Control Valve in the FCV operating mode with a set point of 250 gpm. This defines the hydraulic requirements of the piping system on the acid side. These Heat Source / Sinks are set to calculate the Heat Transfer Rate in the Thermal Calculation dialog to determine the thermal requirements of the acid system which must be met by the two cooling water systems, i.e. how much heat the cooling systems must remove to meet the desired quality assurance temperature requirements of the acid system.

The Heat Source / Sinks on the cooling water sides are set to calculate Flow Rate in the Thermal Calculation dialog and have Control Valves assigned as the Flow Control Devices. This makes the process control link to the valves, allowing the thermal requirements of the acid system to establish the hydraulic requirements of the cooling water systems, i.e. how much flow these systems must deliver to remove the heat from the acid.

Flow Control Device List

The Flow Control Device design data field is a drop down selection list populated with devices that can be selected, shown in Figure 2. Only devices with a flow rate setting can be chosen as a Flow Control Device, limiting the choices to a Control Valve, Sizing Valve, Centrifugal Pump, Sizing Pump, or Flow Demand. The selection list contains only the first Flow Control Device on a direct flow path upstream or downstream of the heat transfer device. Other devices can be in the flow path, such as flow meters and dP Devices, but devices on any open branching path will not be listed, as shown in Figures 2 and 3.

Figure 1. Modeling an Acid Cooling Water System using Heat Source / Sinks with assigned Flow Control Devices.

Figure 2. Control Valves on both downstream open branching flow paths are not shown in the Flow Control Device list and are not selectable FCDs. If one control valve is isolated, the other valve will be available to select as an FCD.
Operations Mode of the Flow Control Device

The Operations mode of the selected Flow Control Device is automatically set to Temperature Control with the Setting showing the name of the heat transfer device it is controlling, as shown in Figure 4. The FCD receives a mass flow rate setting from the heat transfer device.

When an FCD is selected, the flow rate must be either selected for calculation or the Flow Rate Source must be set to User Entered in the Thermal Calculation dialog, otherwise the FCD will not know what value of mass flow rate it must achieve and will be shown as undesigned on the FLO-Sheet. A warning is displayed on the Thermal Calculation dialog to indicate that the flow rate must be user entered if the Calculation is set to Heat Transfer Rate, Inlet Temperature, or Outlet Temperature, as shown in Figure 5.

Un-Assigning the Flow Control Device

The link to an FCD can only be made using the Flow Control Device field in the Design Data section of the Property Grid of the heat transfer device. The Temperature Control mode in the Operation dialog of the pumps, control valves, and flow demand is active only when the device is selected as the FCD.

However, to un-assign the FCD, the Flow Control Device field must be set back to "None" and the Operation Mode in the Operation dialog must be set to a different mode and the appropriate Setting entered (flow rate value, pressure value, valve position, etc.).

Flow Rate (Hydraulic) and Flow Rate (Thermal)

Two flow rates are calculated for the modeled side of the heat transfer devices. Flow Rate (Hydraulic) is calculated from the hydraulic analysis of the system using the pressure drop vs. flow rate performance entered in the Curve design data field. Flow Rate (Thermal) is the calculated value from the thermal analysis when the Thermal Calculation is set to Calculate Flow Rate or the value entered in the Thermal Calculation dialog when the Flow Rate Source is set to User Entered.

Both of these flow rates are the inlet flow rates to the heat transfer device and must be equal so that the thermal analysis results accurately represent what is shown by the results from the hydraulic analysis, and vice versa.

There are two ways to ensure both flow rates are synchronized. Selecting a Flow Control Device will ensure that these two flow rate values are the same. In this case, the thermal analysis will be performed first and the resulting Flow Rate (Thermal) will be sent to the FCD. When no FCD is available as shown in Figure 6, or one is not selected, setting the Flow Rate Source to "From Hydraulic Calculation" will pass the calculated Flow Rate (Hydraulic) to the thermal analysis calculations to keep them in sync.

Figure 6 shows a heat transfer device with an inlet pressure of 75 psig and an outlet pressure of 69 psig will result in a flow rate of 96.82 gpm based on the device’s hydraulic performance curve. For an inlet temperature of 125 °F and an outlet temperature of 80 °F, this flow rate will result in a heat transfer rate of 179.2 tons of refrigeration.

What if they system had to remove 200 tons with the given inlet and outlet temperatures? What flow rate is needed to achieve this thermal requirement?
Figure 7 shows the evaluation of this “what if” analysis. Setting the Thermal Calculation to Flow Rate and entering the desired Heat Transfer Rate shows that a Flow Rate (Thermal) of 108 gpm is required to achieve the desired amount of heat transfer.

The hydraulic analysis still shows a Flow Rate (Hydraulic) of 96.82 gpm. Flow Rate (Hydraulic) and Flow Rate (Thermal) are compared and a message is generated (ID 178) if the values differ by more than the Allowable Deviation specified in the Calculation Settings of the document (defaulted to 1%). This difference must be reconciled by the user because the results from the thermal analysis do not represent the same amount of heat transfer that is being modeled hydraulically. This could be done by placing a Flow Demand at the outlet and selecting it as the Flow Control Device for the Lube Oil Cooler.

Benefits of Using the Flow Control Device

Assigning an FCD establishes a process control link to another device in the piping system model. This provides PIPE-FLO® Professional with more flexibility to model real-world process controls that regulate the flow rate, heat transfer rate, inlet temperature, or outlet temperature of heat exchangers used in a wide variety of sensible heat transfer applications in numerous industries. Understanding and making the connection between the thermal and hydraulic requirements of a system is a critical aspect of designing and safely operating often-times extremely hazardous processes.