Modeling Heat Source Sink and Heat Exchanger Devices

Using the Heat Source / Sink and Heat Exchanger 2-Pipe Devices

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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. Both can model devices used in real-world processes that facilitate sensible heat transfer in flowing fluids (heat transfer that results in a change in fluid temperature but not a phase change). The Heat Source / Sink device is used to model heat transferred into or out of a single fluid, whereas the Heat Exchanger 2-Pipe device is used to model sensible heat transfer between two fluids. Both devices model the hydraulic performance of only one side of a heat exchanger.

Which one to use is up to the user based on the actual device being modeled, how much information is available, and what the user needs to evaluate about the system.

The Heat Source / Sink Device

The Heat Source / Sink device is used to calculate one unknown thermal parameter of the heat transfer device being evaluated: the heat transfer rate, flow rate, inlet temperature, or outlet temperature. The other parameters must be defined by creating two unique Fluid Zones and assigning them to the inlet and outlet pipes of the device. Hydraulic calculations are also performed using the Pressure Drop vs. Flow Rate performance curve data.

The Heat Source / Sink device must be used when the actual device contains only one flowing fluid, such as with a solar panel, a nuclear reactor, an engine block, or some other source or sink of thermal energy. For example, the Heat Source / Sink is used to model the Reactor Vessel in the primary coolant system of a pressurized water reactor used in the nuclear industry shown in Figure 1.

Even if the actual device contains two flowing fluids, the user may want to evaluate the effects of heat transfer on just one of the fluids. One reason to do this may be because a phase change occurs on the other side, which occurs in boilers, condensers, and evaporators. The Steam Generators in Figure 1 are modeled as Heat Source / Sinks because the primary coolant releases sensible heat through the tube bundle that results in a phase change on the feed water / steam side of the generator.

Another reason to model a heat exchanger as a Heat Source / Sink could be that the user is only responsible for the piping system on one side and they want to evaluate the hydraulic and thermal performance of the system for which they are responsible. Figure 2 shows a model of two shell and tube heat exchangers used in the pulp and paper industry to cool weak acid from 107 F to 60 F prior to strengthening in the Fortification Tower. The design production rate of the plant determines the hydraulic requirements of the acid system, and the thermal requirements of the acid system determines the hydraulic requirements of the two cooling water systems.

The two real-world heat exchangers in Figure 2 are modeled as four Heat Source / Sinks, one for the hot and cold side of each heat exchanger. A process engineer responsible for just the acid system...
may not even model the cooling water side, and the process engineer responsible for the cooling water may just want to model his systems. If one engineer is responsible for all the systems, they may want to model the entire process.

The two Heat Source / Sinks on the acid system side are set to calculate the Heat Transfer Rate in the Thermal Calculation dialog, and that value is entered as the input to the two Heat Source / Sinks set to calculate the required Flow Rate of the cooling water systems. The Control Valves in the cooling water systems are set as the Flow Control Devices for these Heat Source / Sinks, which automatically sends the calculated mass flow rate to the control valves set to Temperature Control operating mode.

The thermal capacity (UA), effectiveness, Log Mean Temperature Difference (LMTD), and other thermal parameters are not calculated for the Heat Source / Sink because important heat exchanger design data and key fluid properties on the un-modeled side are not known. To evaluate these thermal parameters, the Heat Exchanger 2-Pipe device must be used.

**The Heat Exchanger 2-Pipe Device**

More extensive thermal analysis can be performed with the Heat Exchanger 2-Pipe device using both the Effectiveness-NTU and LMTD solution methods, providing more calculated results to evaluate the performance of an installed heat exchanger during operation or to size and select a heat exchanger during the design phase.

The Heat Exchanger 2-Pipe device can only be used when the actual device has two flowing fluids and thermal energy is transferred from the hot fluid to the cold fluid without a phase change to either fluid. Four unique Fluid Zones must be created, two assigned to inlet and outlet of the side modeled along with its piping system (Side A), and two assigned to the inlet and outlet of the un-modeled side (Side B). Either side can be the hot or cold side of the heat exchanger. One thermal parameter on each side can be unknown and calculated using the Thermal Calculation dialog.

Figure 3 shows the same acid cooling system shown in Figure 2, but uses four Heat Exchanger 2-Pipe devices to model the two heat exchangers. Additional design data is required, including the Configuration of the heat exchanger. There are six standard configurations to choose from, including single pass heat exchangers, shell and tube heat exchangers, and cross flow heat exchangers. There are also two options to set the value of either the NTU or Configuration Factor if the actual heat exchanger is not one of the standard configurations. The heat exchangers in Figure 3 are set to Shell and Tube configurations with 3-shell passes with 6 tube passes.

The available thermal capacity (UA Available) of the heat exchanger can be calculated by entering the heat transfer surface area, the heat transfer coefficient, and a fouling factor, but this design data is optional. The required thermal capacity (UA Required) established by the process conditions and fluid properties (temperatures, specific heat capacities, and flow rates) will be calculated using the Effectiveness-NTU and LMTD methods, providing additional thermal results and warnings for evaluation.

The Heat Exchangers in Figure 3 show the same calculated results for the heat transfer rates and flow rates shown in Figure 2, but also display key thermal parameters including the UA Required, Effectiveness (EFF), Number of Transfer Units (NTU), Heat Capacity Rate Ratio (HCRR), Log Mean Temperature Difference (LMTD), Corrected Mean Temperature Difference (CMTD), and Configuration Factor (CF). Additional results including the Maximum Heat Transfer Rate and Maximum Temperature Difference are not displayed in Figure 3.

The Heat Exchanger 2-Pipe device can also be evaluated for excessive fouling, whereas the Heat Source / Sink cannot. Figure 4
shows that Heat Exchanger A cannot achieve the modeled process conditions when a larger fouling factor causes a reduction in the available thermal capacity of the heat exchanger (UA Available) below the thermal capacity required by the process conditions (UA Required) defined in the model.

The model can now be adjusted to determine the effect of excessive fouling on the cooling water side of the heat exchanger, shown in Figure 5. For production and quality assurance reasons, the flow rate and outlet temperature of the acid must remain constant, so the heat transfer rate out of the acid must remain constant. With the heat exchanger at its maximum thermal capacity, the flow rate of the cooling water of Heat Exchanger A must increase, resulting in less retention time in the heat exchanger and a corresponding decrease in the temperature difference across the cooling water side.

Figure 4. Warnings are generated when increased fouling reduces the available thermal capacity (UA Available) of the heat exchanger below the thermal capacity required by the modeled process conditions.

Figure 5. Excessive fouling results in an increase in cooling water flow rate and a decrease in the delta T across the cold side of Heat Exchanger A.

Summary

The two new heat transfer devices added to version 15 of PIPE-FLO® Professional provide flexibility to model different real-world components that transfer sensible heat into or out of flowing fluids. Which one to use will depend on the actual device being modeled, what information is available about the device, and what the user wants to evaluate by modeling the system.

The flexibility built into the Thermal Calculation dialog, along with the ability to assign a Flow Control Device to the Heat Source / Sink or the Heat Exchanger 2-Pipe, makes PIPE-FLO® Professional ideally suited to model heat transfer processes and process controls in a wide variety of industries that use heat exchangers, including the power generation, pulp and paper, petroleum, chemical manufacturing, and HVAC industries.

With the Commercial Grade Dedication developed in accordance with the ASME NQA-1-2012 standard, Engineered Software provides the highest level of accuracy and quality assurance for modeling safety-critical applications in the nuclear industry or for customers who demand stringent quality assurance requirements from their software vendors.