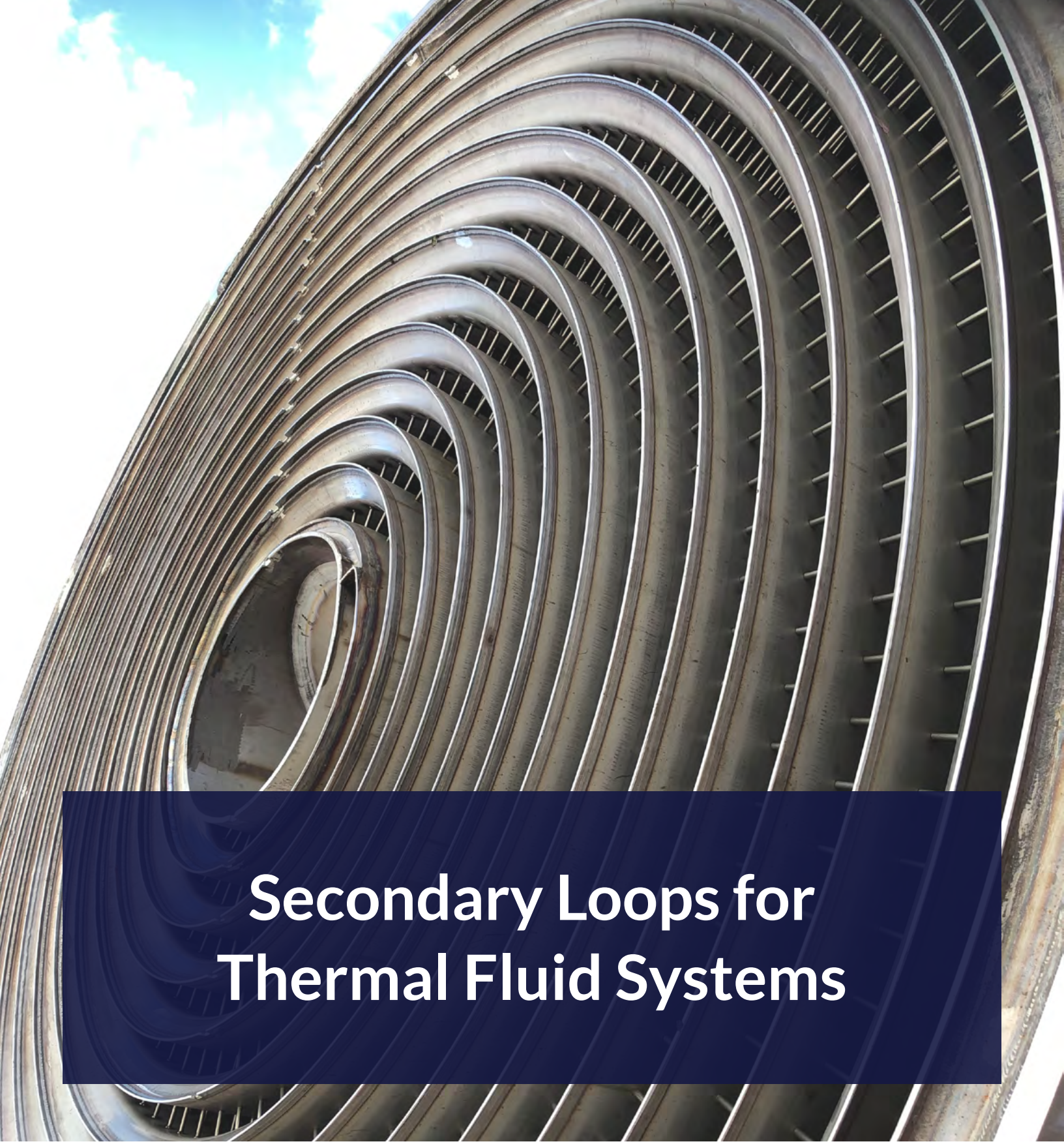


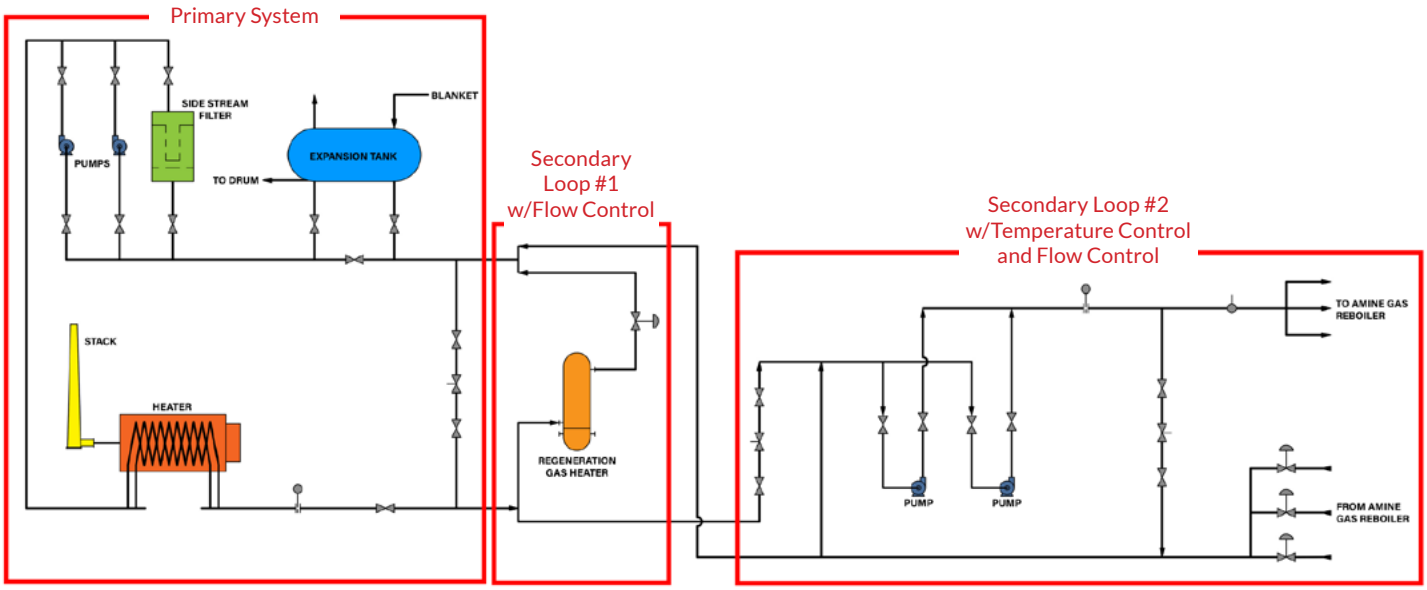
Secondary Loops for Thermal Fluid Systems

SIGMA THERMAL INC.

INDUSTRIAL PROCESS HEATING SYSTEMS,
AUTOMATION, SERVICES AND PARTS

PRIMARY VS. SECONDARY LOOPS

Thermal fluid heating is a type of indirect heating in which a liquid phase heat transfer medium is heated and circulated to one or more heat energy users within a closed-loop system. Thermal oil, glycol, and water are common heat transfer media for these systems. If you are purchasing, designing, or operating a thermal fluid heating system, you need to understand exactly how these systems work. This means understanding the primary loop and any secondary loop(s) within the system. This guide is a good starting point to learning more about the different parts of a thermal fluid system.





A **primary loop** in a thermal fluid heating system supplies thermal fluid at a constant temperature and flow rate to a user or users, regardless of the return temperature. A primary loop will typically consist of a heater, circulation pump(s), expansion tank, and a drain tank. In many cases, the primary loop will also have a flow bypass valve to supply the constant flow to the heater while the users are modulating.

The purpose of a **secondary loop** is to satisfy the demands of the user(s) by consuming the energy from the thermal fluid at the temperature and flow rate required by that user. The two most common secondary loops are flow control loops and temperature control loops.

SECONDARY CONTROL TYPES

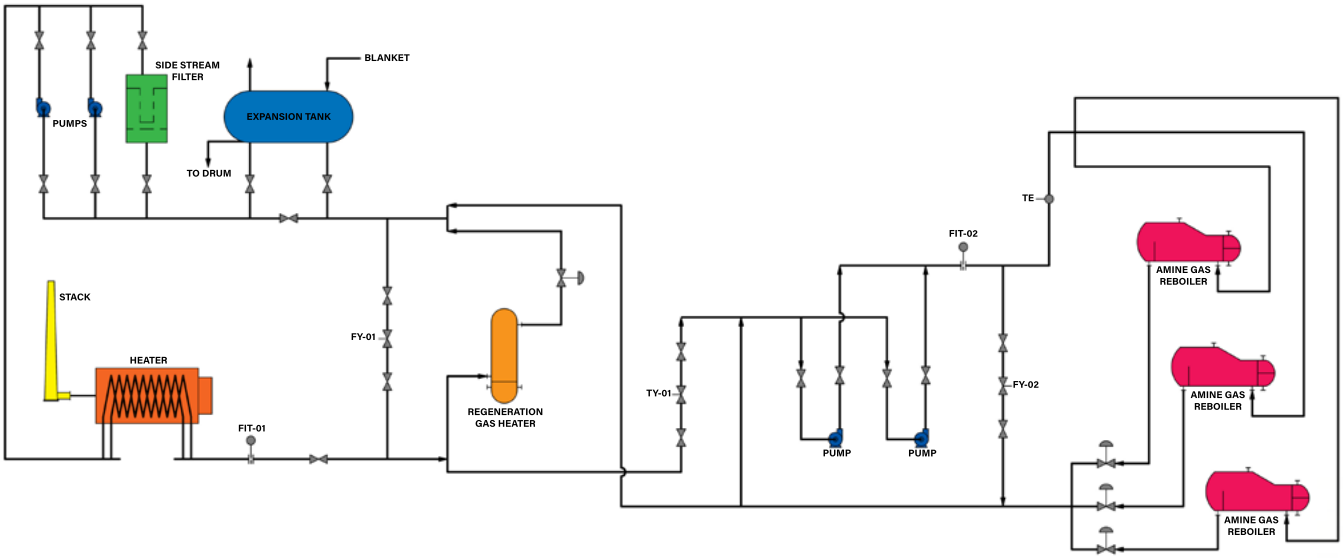
There are many types of heat consumers and heat exchangers (which will be discussed later in further detail). Regardless of the type of heat consumer used in a thermal fluid system, the secondary loop must control the amount of energy that flows into that heat consumer. For example, controlling the process outlet temperature, the surface temperature of a platen, the bulk temperature of a tank, or any other process variables. The goal of a secondary control loop is to meet the energy demands of the process, however that may be measured.

There are two primary mechanisms for controlling the heat energy supplied to a user (heat consumer). The first mechanism is **varying the thermal fluid flow rate to the user**. The second mechanism is **varying the thermal fluid temperature to the user**. There are more complex control methods that utilize both of these mechanisms in tandem, but for the purposes of this discussion, the focus will be on these two primary mechanisms.

A flow control loop is a secondary loop that utilizes thermal fluid at the temperature provided by the primary loop. Adding a control valve gives you the ability to modulate the thermal fluid flow rate through the user. In contrast, a temperature control loop gives you the ability to measure and control the thermal fluid temperature through the user. This type of secondary loop receives thermal fluid at the temperature above the desired loop temperature and, through the use of a pump and control valve, controls the secondary loop to a temperature below the primary loop temperature. In some cases, flow control loops are used within temperature control loops. In other cases, temperature and flow control loops are used in parallel within the same system.

Parallel Secondary Loops & Nesting

An example of a system with multiple secondary loops can be seen in the model below, which shows the use of thermal fluid at two different temperatures in a natural gas processing application. In this example, hot thermal fluid from the heater is used to meet the needs of both a regeneration gas heater and three amine reboilers. The regeneration gas heater uses the thermal fluid at the temperature delivered directly from the primary loop. Since the amine reboilers require a lower temperature of thermal fluid than the regeneration gas heater, the hot fluid coming in from the primary loop mixes with cooler fluid returned from the reboiler to achieve a new lower temperature set point.

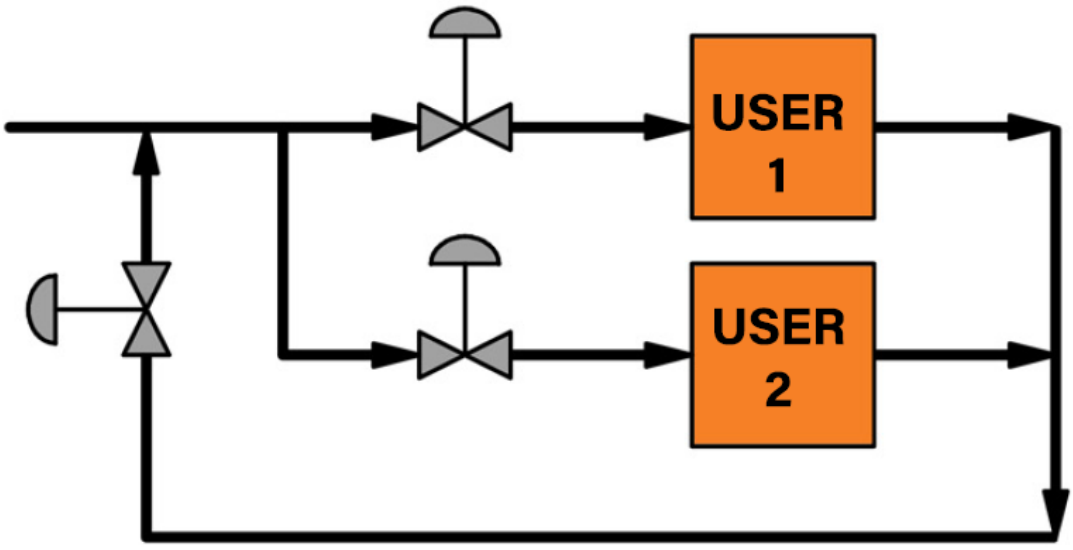


The secondary loops are controlled by monitoring different variables. In the amine reboiler loop, there is a thermocouple in the thermal fluid supply piping that leads to the amine reboiler. Depending on the temperature of the fluid, the valve at the connection point to the loop (TY-01) might open or close to change the amount of primary loop hot fluid that enters that secondary loop. The bypass valve in the primary loop (FY-01) is modulated based on the flow rate through the heater (FIT-01) to ensure that the flow rate is constant through the heater.

TWO-WAY VS. THREE-WAY VALVES

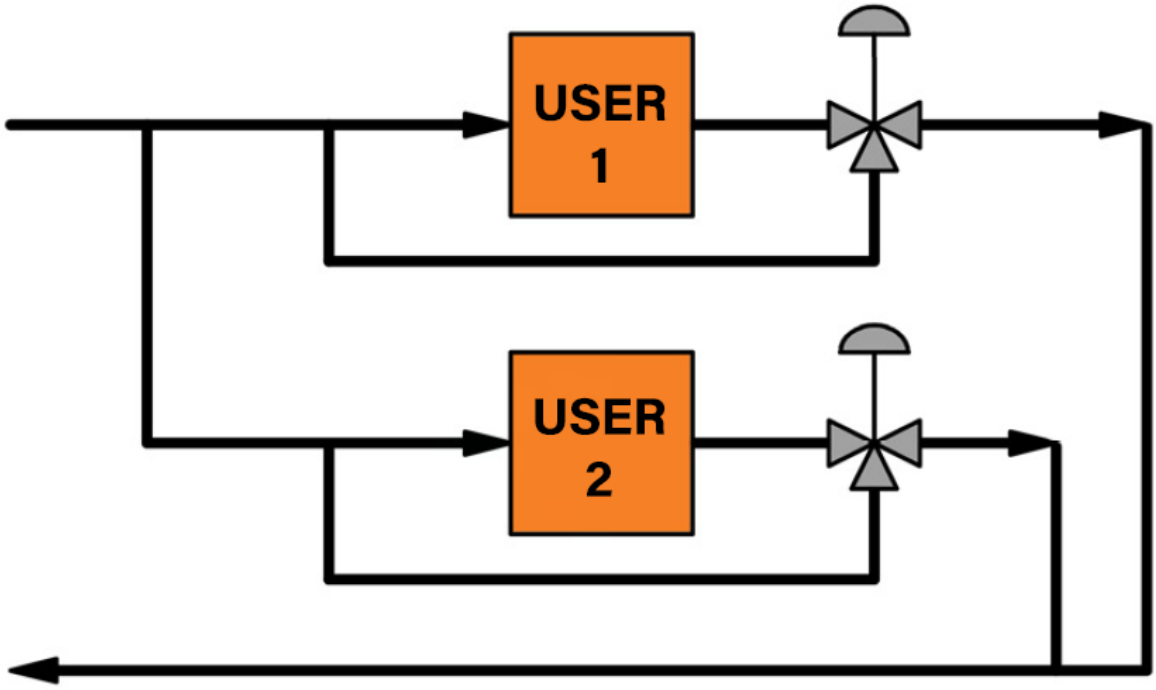
Whether you are controlling flow to a high-temperature user directly off the primary loop or using a secondary loop to control to a lower temperature, you will need to use thermal fluid control valves. That also means you will have to choose whether to use two-way or three-way control valves. Both valve configurations will work, but they have distinct advantages and disadvantages that need to be considered.

Two-way valves are most frequently used when energy might not be required in a secondary loop or a user at all times, and the energy is then available for other secondary loops. Batch loading in chemical reactors is a good example of a user type that doesn't have a consistent heat demand. If you have multiple reactors that only run periodically, the heater only needs to be sized to accommodate the maximum number of reactors running at one time. By using two-way valves at each reactor, flow is only being diverted to reactors that are actively being heated. Using two-way valves to control flow to the users necessitates an additional two-way valve as an automated system bypass to maintain constant flow in the heater regardless of the state of the user control valves.



Two users in parallel with two-way valve configuration

Three-way valves are most frequently used when it is permissible to have a fixed flow through the valve regardless of whether or not energy is being consumed by a secondary loop. Using the batch chemical reactor example again, the use of three-way valves would necessitate that the heater is sized to accommodate every reactor in the system and not just the ones operating. It is also a good selection for single-user systems or multi-user systems where systems must be sized for all users operating together.



Two users in parallel with three-way valve configuration

A three-way valve can be installed as a mixing valve or a diverting valve. A mixing valve is a valve with two inlets and one outlet. In the illustration below, the inlets are A and B, and the outlet is AB. A diverting valve is a valve with one inlet (AB) and two outlets (A and B). Diverting valves typically are placed upstream and converging valves are placed downstream of the user.

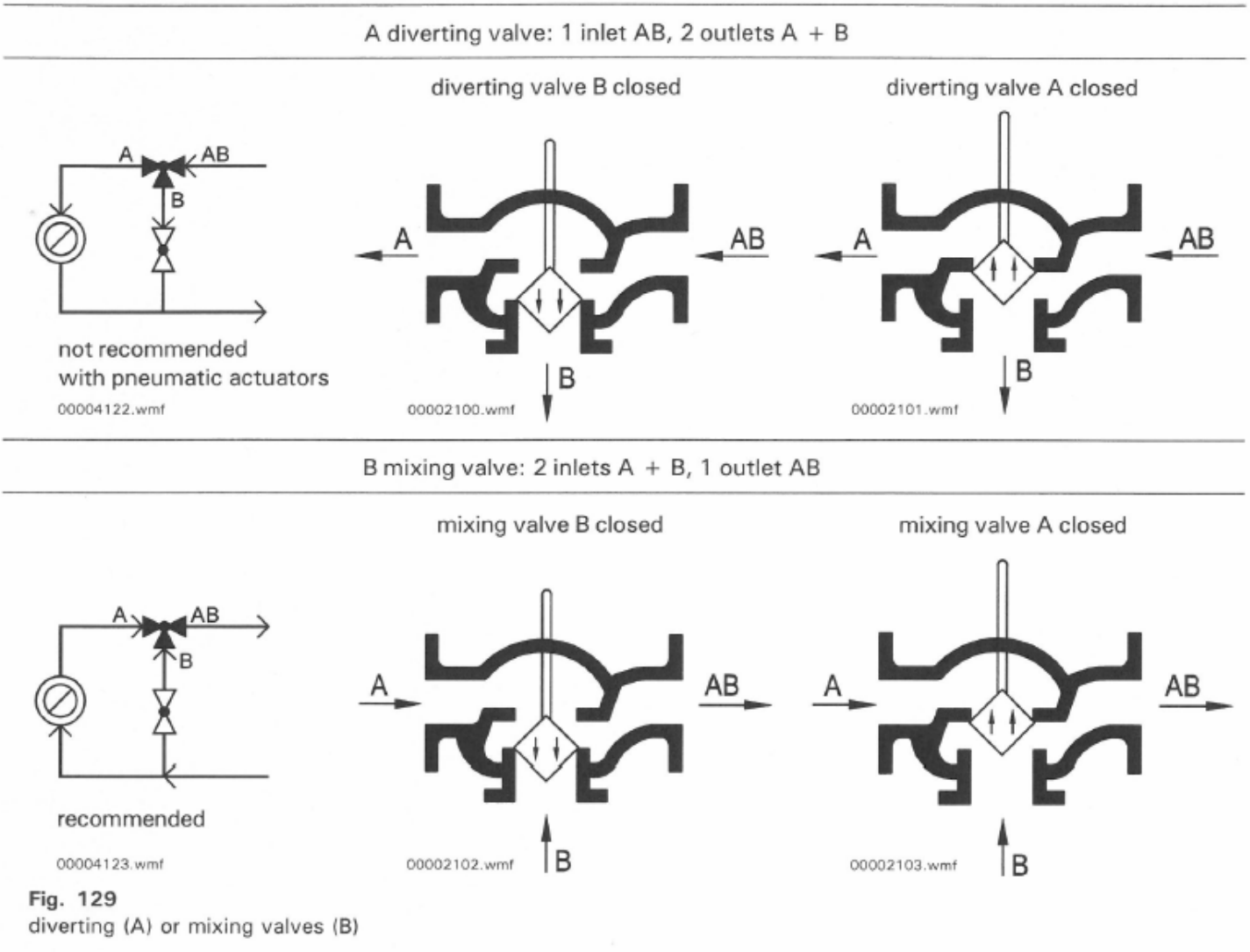


Fig. 129
diverting (A) or mixing valves (B)

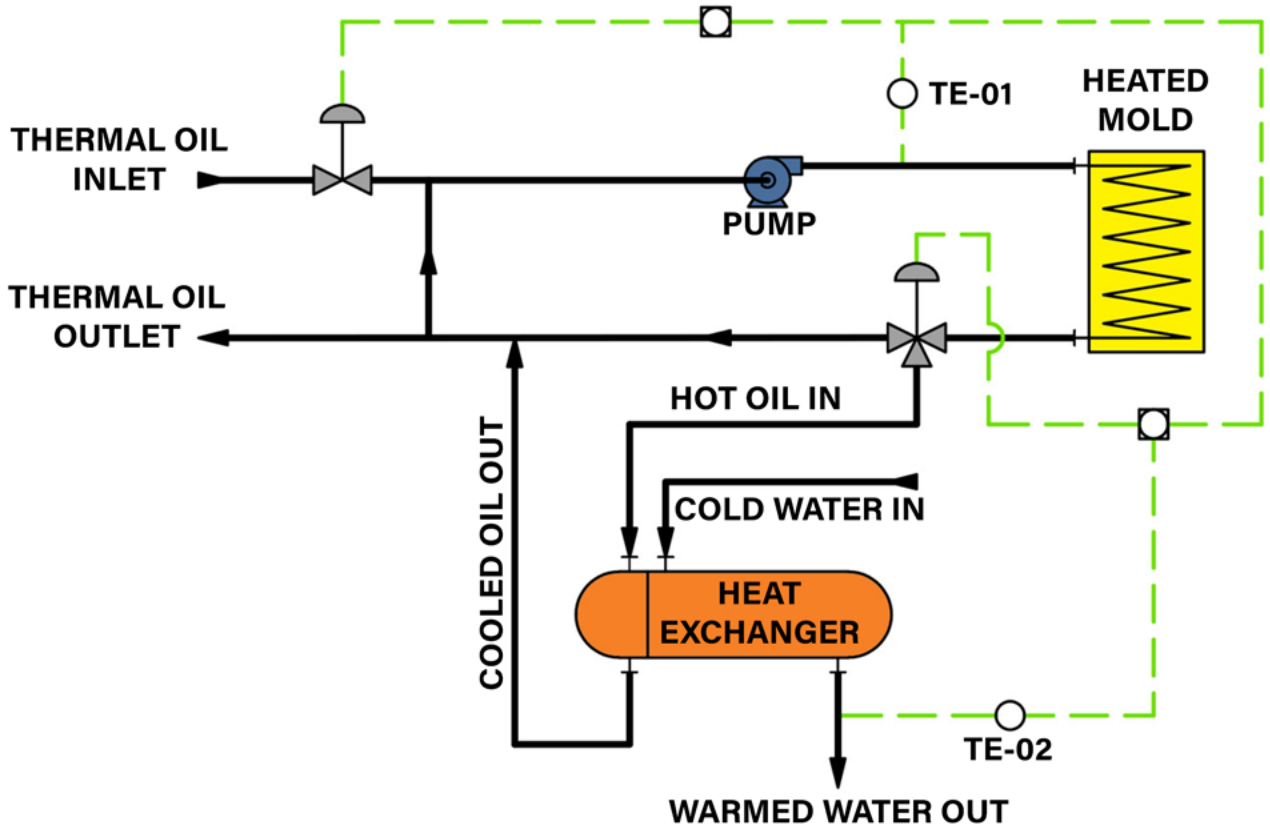
Diverting (A) and Mixing (B) valve diagrams
Courtesy of Baelz North America

COOLING LOOPS

It seems counterintuitive to intentionally use energy to cool something that you just used energy to heat. However, there are many processes that require that exact functionality, and a closed loop thermal fluid system with a cooling loop offers an excellent way to achieve that.

One example of this type of production process is a batch chemical reaction that starts as an endothermic reaction and later becomes exothermic. The cooler is used to remove heat from the reactor so that the reaction temperature stays stable.

Another example is in various types of molding applications. If a mold or die is heated to shape a plastic or other synthetic material, then that mold or die needs to be cooled so the shape will solidify. In principle, you could achieve cooling in either of these examples by installing a separate and stand-alone cooling system. The challenge with that approach is that each mold or reactor would require a separate set of cooling channels or coils.



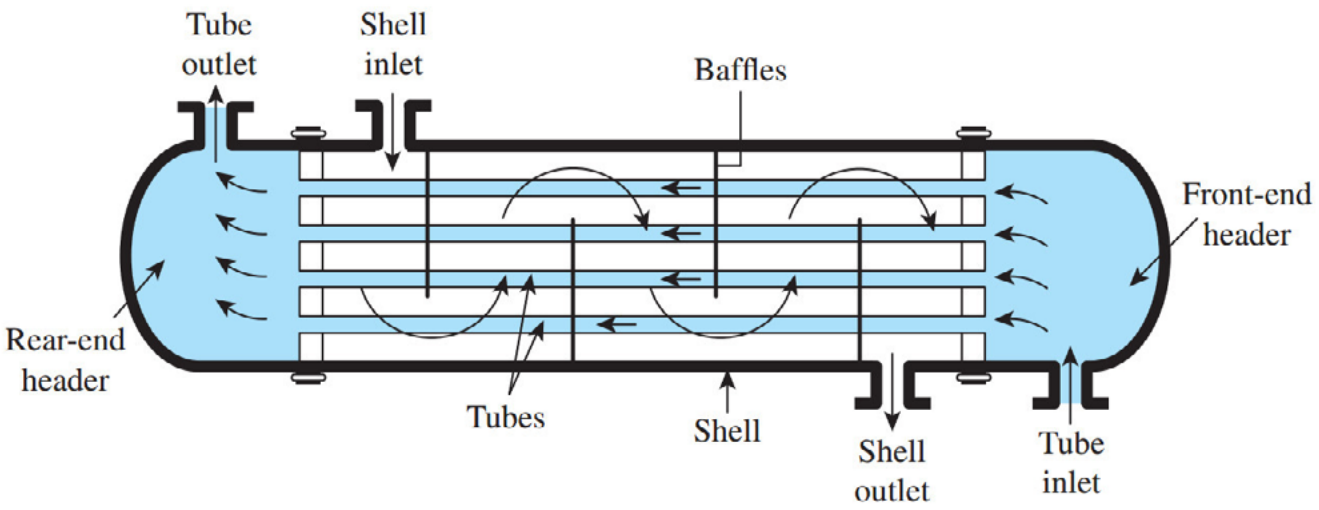
Secondary loop with cooling

A simpler and less costly solution is to use the same heating fluid to cool the hot oil in a secondary cooling loop. “Coolers” are simply heat exchangers that reduce the temperature of the hot oil. Typically, that is done with either water or air as the cooling media. If heat is required to the user, the primary loop control valve is modulating to keep the loop at the desired heating temperature. When the operator or controlling PLC decides cooling is required, it will send a new cooling setpoint to the loop temperature controller. That will drive the secondary control valves to different positions, simultaneously blocking hot fluid from the primary loop and opening a pathway to the cooler within the secondary circulation loop.

If water is chosen as the cooling medium, the control variable in the cooling loop is limited by the outlet temp of the water in the heat exchanger. The amount of hot oil routed through the cooler has to be limited at first to prevent overheating the cool water in the heat exchanger. When the valve is open again, the flow bypasses the cooling loop. This type of consideration is not required for air cooled heat exchangers where the overtemperature of water is not a concern.

COMMON HEAT EXCHANGERS

Shell-and-Tube: A shell-and-tube heat exchanger is one of the most common heat exchanger types used in secondary loops. They work well with a wide range of fluids, gases, pressures, and temperatures. A shell-and-tube heat exchanger is comprised of a number of tubes held within a shell that is typically cylindrical. In this arrangement, there are two fluids: one fluid within the tubes and one fluid in the shell. The two fluids have different temperatures, which drives the heat exchange.



Secondary loop with cooling

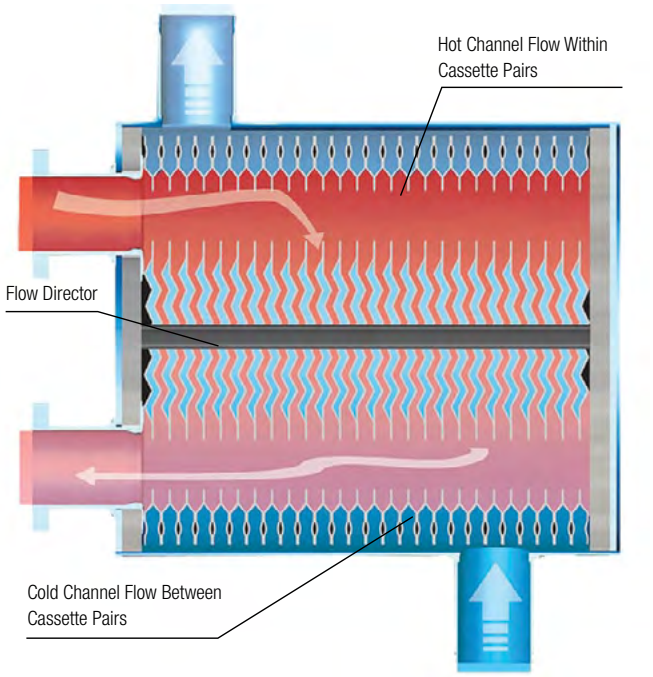
Image credit: Çengel, Yunus A, and Afshin J. Ghajar. Heat and Mass Transfer: Fundamentals & Applications. New York: McGraw-Hill, 2011. Print.
https://www.thomasnet.com/articles/process-equipment/shell-and-tube-heat-exchangers/

Shell-and-Plate: Shell-and-plate heat exchangers have also become popular for high temperature and high-pressure applications. They are commonly considered to be a combination of the designs from shell-and-tube and plate-and-frame heat exchangers. Shell-and-plate heat exchangers are particularly effective if one of the process fluids is a liquid and the other is a gas. In a shell-and-plate heat exchanger, a welded plate pack consists of round plates made to fit in the shell. The plates are welded together on the outside while leaving space inside for one of the fluids to flow. The other fluid enters the shell and flows on the outside of the plate pack.



Shell-and-plate heat exchanger

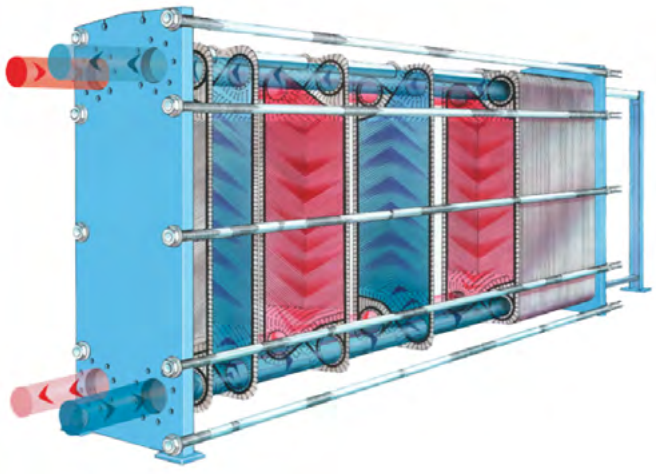
Courtesy of Tranter Heat Exchangers - www.tranter.com



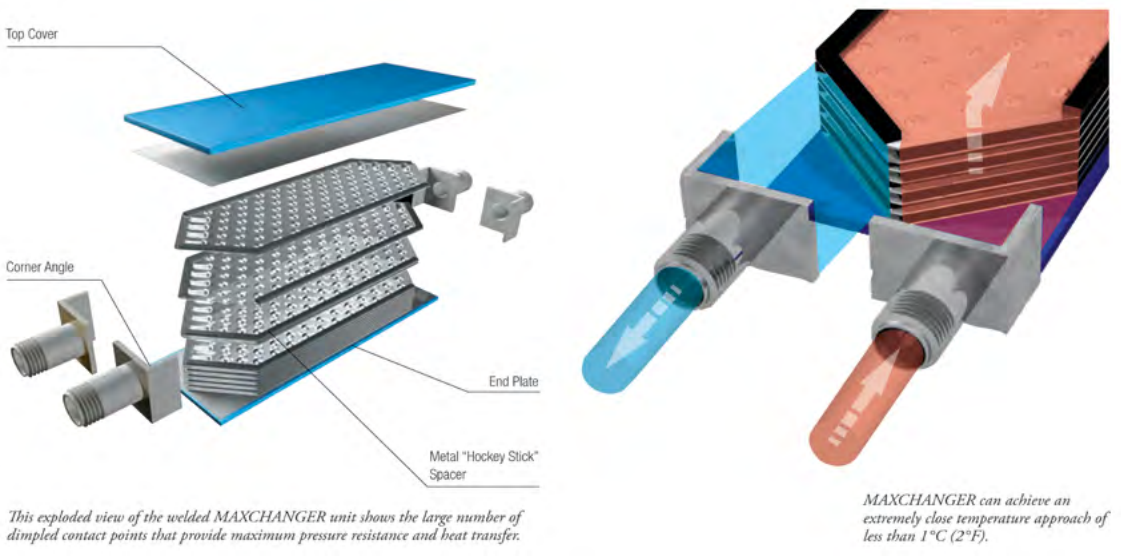
SUPERMAX countercurrent flow pattern can have hot channel on shell or plate side.

Shell-and-plate heat exchanger
Courtesy of Tranter Heat Exchangers - www.tranter.com

Plate-and-Frame: In a plate-and-frame heat exchanger, the metal plates separate channels of hot fluid and cold fluid. These plates are held within two end plates, supported by bolts. Gaskets seal the fluids in and don't allow mixing of hot and cold fluids. This type of design allows for a large amount of heat transfer surface area in a relatively small footprint. Plate-and-frame heat exchangers are useful when the demand of a process might increase over time. The construction of the exchanger allows for easy expansion through the addition of more plates. Gasketed plate-and-frame heat exchangers are limited to lower temperature operations due to the limitations of the gaskets. All welded plate-and-frame heat exchangers are available for higher temperature applications.



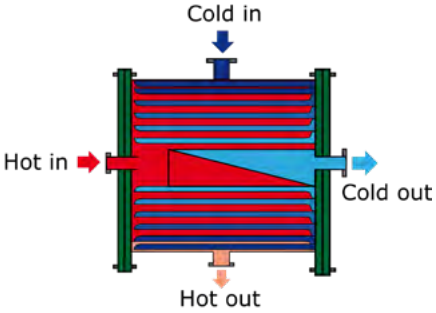
Exploded view of a gasketed plate-and-frame heat exchanger
Courtesy of Tranter Heat Exchangers - www.tranter.com



Exploded view of a welded plate-and-frame heat exchanger

Courtesy of Tranter Heat Exchangers - www.tranter.com

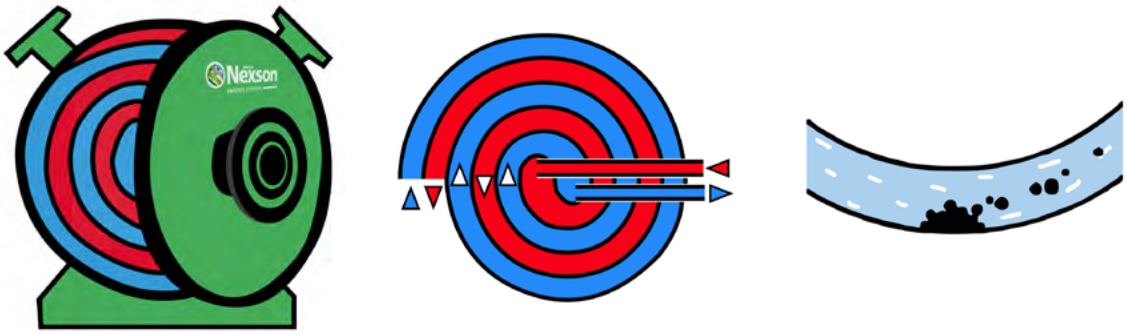
Spiral: In a spiral heat exchanger, two plates are formed into spirals and placed together to create separate flow paths for a hot fluid and a cold fluid. The channels are welded on opposite sides and covers are placed on the ends. This type of heat exchanger is useful when fouling might be an issue, because the design encourages turbulent flow and is often self-cleaning. Encouraging turbulent flow reduces fouling, which is common when using viscous or heavy particulate fluids. The spiral design is easier to take apart and clean.





Spiral heat exchanger

Courtesy of Nexson Group – www.nexson-group.com



Spiral heat exchanger

Courtesy of Nexson Group – www.nexson-group.com

Serpentine Finned-Tube: Finned-tube heat exchangers are often used in cases where one of the substances is a gas with low density. Because low density gases are less efficient at heat transfer, the addition of fins to the tubes in this type of heat exchanger is necessary. The fins are added to the side of the tube that contains the air, increasing the surface area of the tube and enabling faster air heating or cooling. Typically, a substance with higher thermal efficiency will be used within the tubes.



Example of a finned-tube heat exchanger

Courtesy of Super Radiator Coils – www.superradiatorcoils.com

About Us

Sigma Thermal designs, engineers, supplies, and services process heating systems for industry. Our products include thermal oil and thermal fluid heating systems, indirect process bath heaters, electric process heaters, biomass fired energy systems, direct fired process heaters, system automation, parts, retrofits/upgrades, and supporting services. Our staff is comprised of dedicated and experienced industry veterans who are prepared to learn about your application and provide solutions specific to your project needs. Whether you need a standard package heater, a highly engineered process heating system, or just a tuneup on your current system, our engineers and technicians have the knowledge and experience to make your project a success.

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