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Understand the Basics of Steam Injection Heating

Lower energy requirements and better temperature control makes direct- contact steam injection attractive for heating many process fluids.

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Precise temperature control, reduced energy consumption, and lower maintenance costs are the key benefits of direct-contact steam injection heating in chemical processing applications. Unfortunately, direct-contact steam injection is often overlooked or not used to its full advantage by chemical engineers because they are unaware of its potential in chemical applications.

This article offers guidelines for the use of steam injection heating. It explains what steam injection heating is, describes the types of equipment used, outlines several common applications, and summarizes the information required for selecting and sizing a steam injection heater.

Categories of contact

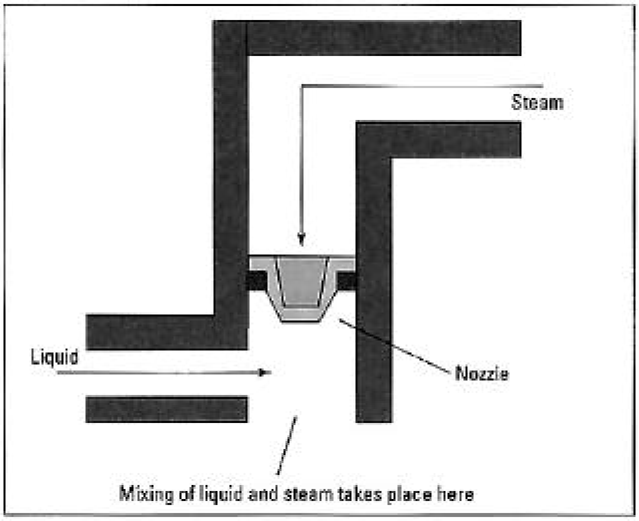
There are two basic types of exchangers used to transfer heat between process fluids — direct and indirect. Generally, indirect-contact heat exchangers, such as shell-and-tube, plate-and-frame, or scraped surface exchangers, have two or more fluid flow paths that do not allow for direct mixing of the fluids. They promote the transfer of heat from one fluid to another across a thermally conducting, but otherwise impermeable, barrier such as a tube wall or plate.

Direct-contact heat exchangers transfer heat by injecting precisely metered amounts of steam from a plant's steam supply into the process fluid (liquid or slurry) that needs to be heated (Figure 1). Injecting steam directly into the process fluid results in more rapid heat transfer and more efficient energy usage than indirect heat exchangers. Direct-contact steam heating can provide 100% thermal efficiency, because both the sensible and the latent heat of the steam are used. Energy savings can be considerable — reductions in the 20—25% range are not uncommon.

Additional benefits of direct-contact heating relate to plant layout and maintenance. Both equipment expense and space requirements can be trimmed: Direct-contact steam injection systems generally require less space than other methods of heat transfer, and they also eliminate the need for condensate return systems, which are often required for indirect heat exchangers. Additionally, maintenance costs may be significantly lower than those of other heating systems.

A potential limitation of direct steam injection heating is that the steam is injected directly into the process fluid. If the process fluid is sensitive and cannot tolerate this,

Figure 1. In direct contact steam heating, steam is injected directly into the liquid.



steam injection cannot be used. The addition of the condensate to the process must be considered when specifying steam injection equipment.

Steam heating methods

Several types of direct-contact steam injection heaters are used today, including tank spargers, in-line spargers, mixing tees, and internally modulated steam injection heaters. While each of these offers the basic time and space advantages of direct-contact steam heating, they have distinct differences, and some have limitations that make them suitable for certain applications yet unsuitable for others.

Direct-contact steam heaters can be classified as either externally modulated or internally modulated (Figure 2). This refers to how the amount of steam injected into the process fluid is controlled.

External modulation

This type of steam flow control varies the velocity at which the steam is injected into the liquid, as well as the pressure relationship between the steam and the liquid. Efficient and rapid transfer of the thermal energy is achieved. However, with some of these devices, accurate temperature control can be difficult to maintain under varying load conditions.

Various externally modulated devices are employed in the chemical process industries, including tank spargers, in-line spargers, and mixing tees. Piping from the steam header directs steam to an external valve, which controls the steam flow to the injection device (located downstream in line with the process fluid being heated).

Spargers and mixing tees are simple methods of direct-contact steam injection heating. The basic design of these units enables them to efficiently and quickly provide hot water, as well as offer an initial cost advantage. Yet, neither the tank sparger nor the mixing tee affords the user the full advantage that other, more-sophisticated direct-contact steam injection methods can.

The sparging nozzle has multiple holes that allow steam to enter the process fluid. The sparger may be places in a tank in the process or may be installed directly in the process piping. Steam is dispersed through the many holes located in the sparging nozzle. As a result, a sparger is not designed to confine the mixing process to a specific region. Also, because the sparger is valve located in the steam piping, steam hammer or unit vibration can occur as the steam mixes with the process fluid in the piping or tank. Over time, this can lead to equipment deterioration, adversely affecting performance and increasing maintenance costs.

Another externally modulated method of steam injection is the mixing tee. Manual, semi-automatic, and automated systems are available to mix steam and cold water, each with varying degrees of accuracy. With manual systems, where an operator controls the cold water flow rate and the steam valve, only approximate temperatures can be achieved. While semi-automatic

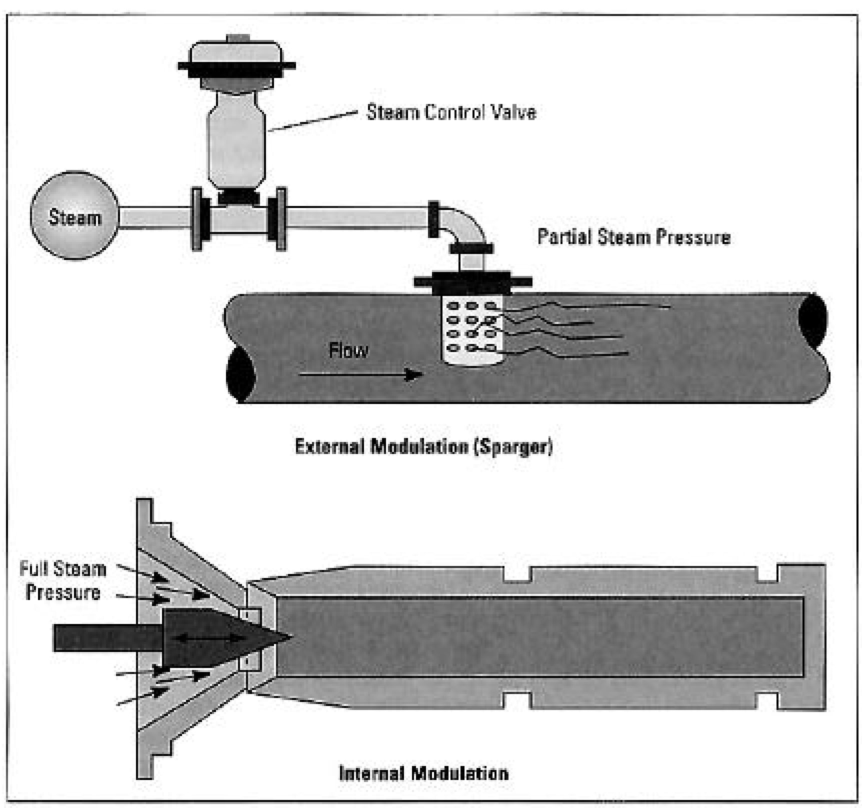


Figure 2. Steam injection may be externally or internally modulated.

mixing tees have preset temperatures, they (like manual systems) experience difficulty in compensating for changes in steam or water pressure or hot water demands. Proper operation guidelines and maintenance procedures must be closely followed to avoid unstable operation and poor temperature control.

Other more-sophisticated externally modulated systems control the steam flow rate from outside the injection device. Steam is injected downstream of the control valve through multiple orifices located inside the steam injection heater. A piston rises and falls with changes in the steam flow rate, compensating for changes in steam pressure, inlet water pressure, and hot water demand. When properly instrumented, this type of externally controlled steam injection device can provide improved temperature control and good turndown capabilities.

However, as with other externally modulated devices, because the steam is controlled outside of the injector, the steam pressure at the point of injection can vary and upsets in the system may occur. Another limitation of these heaters is that they require regular monitoring and maintenance. In applications where hard water, slurries, or high-viscosity liquids are heated, routine disassembly to clean plugged orifices is required.

Internal modulation

An internally modulated heater controls both steam flow and mixing by employing a stem/plug assembly inside the heater (Figure 3). Controlling the position of the stem/plug controls the steam discharge area of the nozzle. This, in turn, controls the amount of steam that is allowed to pass through the nozzle. Internal modulation eliminates the need for an external steam control valve.

Internally modulated direct-contact steam heaters inject metered amounts of steam into the process fluid through a variable-area steam nozzle. The nozzle design ensures constant steam pressure and velocity at the point where steam contacts the liquid or slurry, eliminating the potential for pressure upsets and ensuring smooth heater operation.

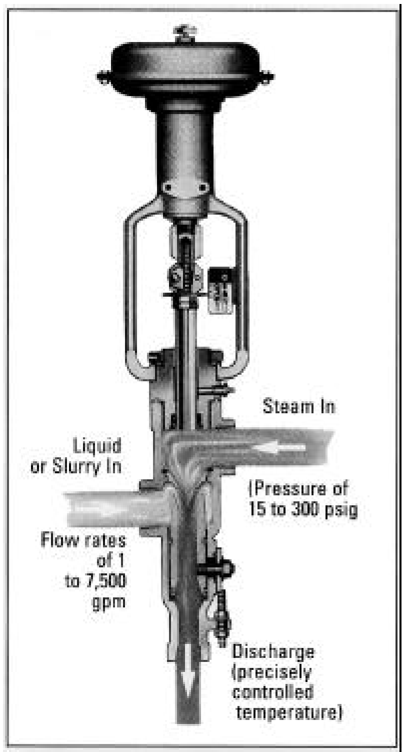


Figure 3. Internal modulation uses a stem/plug assembly inside the heater to adjust flow.

Internally modulated direct-contact steam heaters are cleaned by their own turbulent mixing action, so they do not encounter fouling or scale buildup. They also have the flexibility to heat slurries containing a high concentration of solids or non-Newtonian liquids.

A limitation of internally modulated injection systems is that the differential between the available steam pressure and backpressure at the discharge of the heater must be maintained to ensure proper operation of the unit. If the backpressure at the heater discharge is too high (relative to the available steam pressure), the user will not realize the maximum efficiencies of the equipment.

Automatic temperature control

Direct-contact steam injection effectively heats liquids via either manual or automatic control. Where the operating conditions do not vary, the steam injection unit can be set for the desired discharge conditions and automatic controls are not required. Under variable operating conditions, automatic control is desirable and can be readily provided.

Control can be achieved by a pneumatic reverse-acting actuator of the type used on automatic control valves. This actuator is mounted directly on the injection unit. The actuator positions the injector stem to inject precise amounts of steam based on the desired discharge temperature. In the event of an air failure, the actuator will automatically close the stem, shutting off the flow of steam.

Changes in output water temperature due to variations in steam supply pressure or in supply liquid flow rate or temperature are sensed by the controller. It in turn provides the control signal to the injector to reset the steam flow as needed to correct the temperature deviation.

Intermittent heating

Full delivery of heated liquid begins instantly — no warm-up time is needed. Similarly, heating terminates the instant process requirements are satisfied. There is no residual steam in the heater to cause a continuation of heating or overshooting of the desired temperature. Consequently, direct-contact steam injection is ideally suited for intermittent or “on-demand” operation, as well as for continuous service.

This type of system can also be designed to cool as well as heat a process. Once the steam flow is stopped, heating of the process is discontinued. Introducing cooling water will immediately begin the cooling cycle.

In a simple manual, pressurized hot water system, each time an outlet valve is opened, a flow switch on the liquid-supply line senses liquid discharge and opens a steam solenoid valve. For uniform supply conditions, the direct-contact steam injection unit will deliver heated water at the same flow rate and temperature each time an outlet valve is opened. Once the requirement has been satisfied, the system instantly shuts down.

The piping arrangement in Figure ***5*** is used where the unit is a part of an automated process. Each

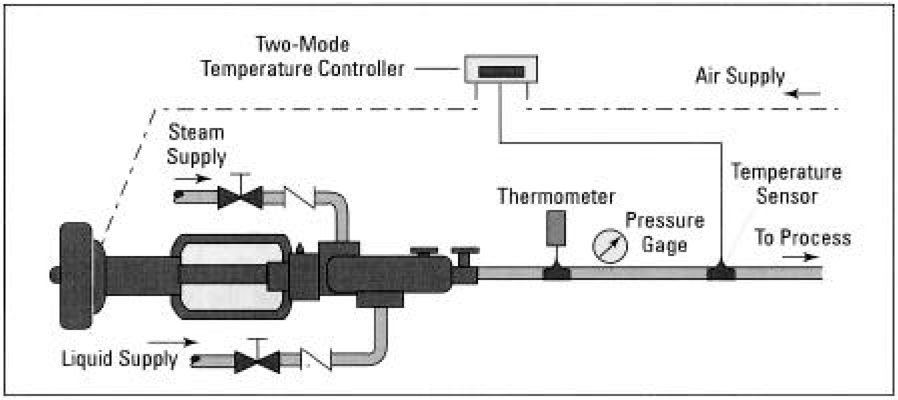


Figure 4. This piping arrangement is used where the steam injection heater is part of an automated process.

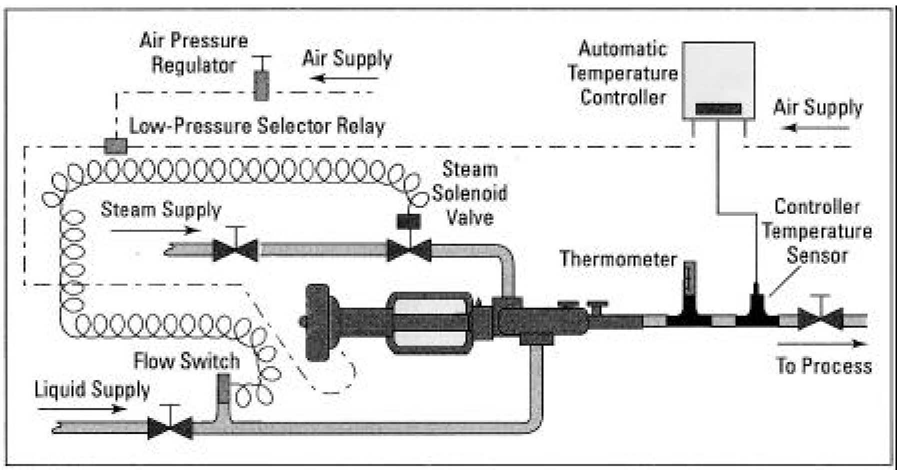


Figure 5. In this configuration, the steam solenoid valve automatically stops steam flow when the liquid flow stops.

time hot water is required, the master controller sends an air signal to the actuator, activating the heater. Heating continues until the process requirements are satisfied and the master controller terminates the air signal being sent to the actuator. The steam heater is then shut down until hot water is again required.

The direct-contact steam injection heater and its accessories are compact and can be installed as part of the piping, requiring less space than other types of heating equipment. for applications where the fluid being heated is hard water or chemical slurry, the liquid velocity through internally modulated direct-contact steam injection heaters is high enough that chemical deposits or scale will not form on internal surfaces. This eliminates the need for periodic acid cleanout, which may be necessary in applications where externally modulated devices are used.

Another automatic temperature control application includes an automatic direct-contact steam injection heater, a temperature controller, and a steam solenoid valve operated by a flow switch in the liquid supply line (Figure 5). The steam solenoid valve automatically stops the steam flow when the liquid flow stops, even though the temperature controller may be calling for more steam. If the liquid flow is controlled by a solenoid valve downstream of the heater, the steam solenoid valve can be wired in parallel with this valve to provide simultaneous steam and liquid flow shutoff. This system is used when the time between flow shutoff and startup is short. However, if the shutoff time is so long that the temperature sensor cools too much, the liquid temperature will overshoot the setpoint temperature during the controller settling time.

Jacketed vessel heating

In these applications, the advantages of direct-contact steam heating are exploited to gain accurate and precise temperature control of the water in the jacket surrounding a kettle or reactor. Using water in the jacket as the heating medium instead of steam provides better control of the process, which eliminates the violent steam and water shock often associated with conventional jacketed kettle and reactor heating systems.

Application specifications

Specifying direct steam injection heating and properly sizing the unit for an application requires an examination of process requirements.

General information about the process and the heating requirements is needed, along with data on the characteristics of the fluid to be heated. Fluid properties such as specific gravity, density, solids content, viscosity, and whether any abrasive or corrosive products are present must be taken into consideration.

Application conditions, such as flow rates under normal and maximum conditions, pipe sizes, and inlet and discharge temperatures and pressures, must be examined.

Users should also determine whether manual or automatic temperature control is desired, and whether continuous, intermittent, or variable operation will be the norm.

This information will help determine the heater that delivers maximum performance and benefit — both short-term and long-range.