Steam vs. Electric Heating — The Basics

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Consider process requirements and plant operating goals to determine the optimal heating source for your facility.

Most facilities in the chemical process industries (CPI) require some form of heat. The amount of heat required and the necessary level of consistency can vary from process to process. Regardless of the details, engineers must decide on a heating source that works best for a particular process. Choosing the wrong type of heating source can have a variety of negative consequences. On the benign end, an inefficient heating source increases operating expenses. Inefficient heating could also increase waste or reject rates by not achieving a temperature setpoint, which can impair quality. At the other end of the spectrum, frozen pipes and feedstock lines could trigger a plant shutdown.

Facilities commonly generate heat using electricity or steam. To decide which is better, the goals of the plant and the nature of the process must be determined. The process requirements will help guide the optimal heating approach. In some cases, the optimal approach may be a combination of steam and electric heating.

Steam heating systems

Steam is an efficient heating source that is also very cost effective. Much of the cost depends on the amount of heat required. If the plant's heat load is more than 1 MW (3.4 million Btu), a steam system is a realistic option; some steam boilers have a capacity exceeding 50 million Btu.

A steam system has four basic parts: a boiler, a steam distribution system, a heat exchange system, and a condensate return system (Figure 1). The heart of the steam system is the boiler — a pressurized chamber heated by a system of (typically gas-fueled) burners. Boiler design and construction is governed by the ASME Boiler and Pressure Vessel Code (BPVC), an American Society of Mechanical Engineers (ASME) standard. Many different types of boilers are available; see the Sept. 2017 *CEP* article "Boiler Project Fundamentals" *(1)*.

Water enters the boiler and is heated to generate steam, which is categorized by its pressure. Steam is classified as low pressure when it is below 50 psi. Medium-pressure steam falls between 50 psi and 250 psi. Steam above 250 psi is considered high-pressure steam. At 250 psi, the temperature of steam is approximately 406°F. High-pressure systems are expensive to build and maintain; therefore, steam is not an ideal solution for heating processes above 406°F. As the temperature in the boiler increases, so does the steam's pressure and enthalpy.

After exiting the boiler, the steam travels throughout the plant in a piping network. Higher pressure ratings translate into higher capital costs — higher-pressure steam requires piping with a higher pressure rating, which comes at a higher cost.

A heat exchanger is another component of a steam heating system. Hot steam flows through one side of the exchanger and the process fluid to be heated flows through the other side. As the steam gives up heat to the process fluid, the temperature of the steam decreases and the steam condenses. The condensate is normally routed back into the boiler feed line.

Steam heating is typically less expensive than electric heating. Thus, steam is generally the heating method of choice for CPI plants.

Challenges and considerations for steam systems. Steam typically has lower operating costs than electric heat — electric heat costs roughly four to five times as much per kWh than steam. That can be a bit misleading, however, because other factors should also be considered when weighing the total cost of steam vs. electric heating. Geography and location, for example, influence the cost of electric power. If the plant is located in an area where hydroelectric energy is abundant, the cost of electricity is lower. Many plants in the northwest U.S. use electric heating for this reason.

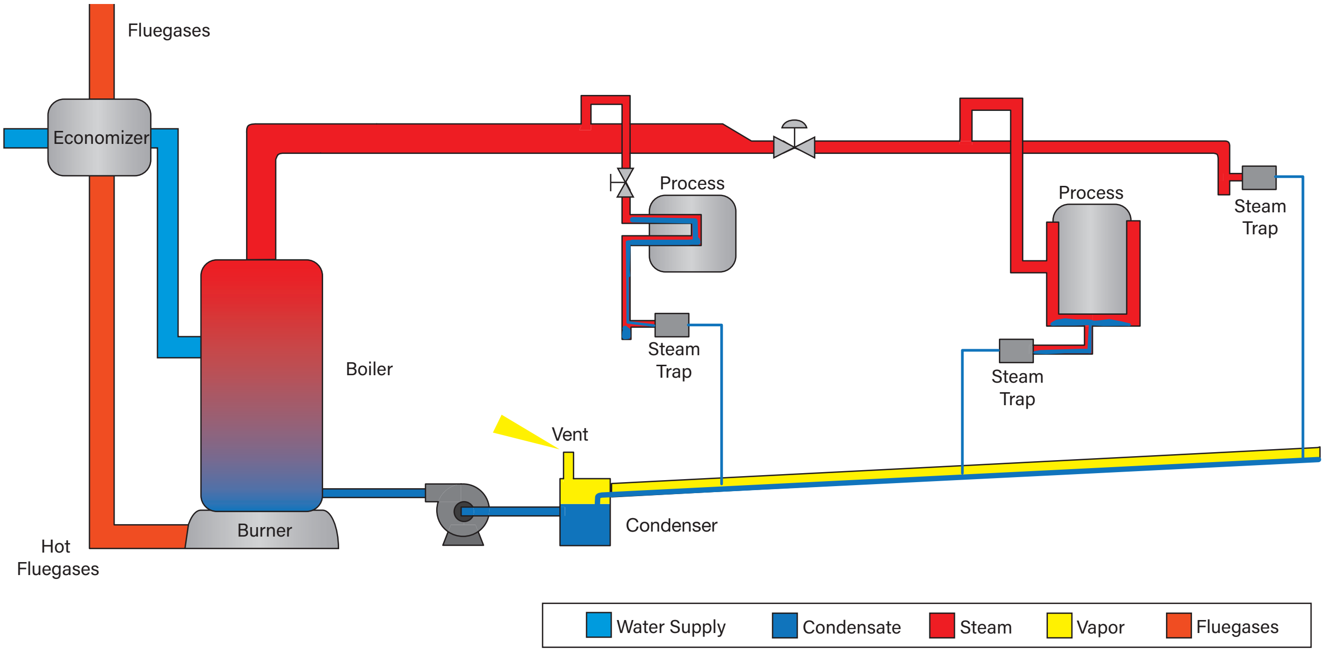
Maintenance costs should also be considered. Electric heaters typically have much lower maintenance costs than steam heaters. A significant amount of money must be allocated to steam system maintenance for a variety of reasons. Boilers alone require significant maintenance. First, boilers have burners that are prone to clogging, which ultimately affects performance. Additionally, the temperature of the water entering the boiler must be monitored. Water should flow in at a constant temperature so that the boiler uses a consistent amount of work to heat the water to the required temperature. A shift in the feedwater temperature can affect boiler performance and efficiency.

Scaling can also be a big concern with boilers. If the boiler is heating hard water, particulates can precipitate out of the water and scaling can occur on the boiler surfaces, lowering efficiency and reducing heat-transfer rates. Corrosion can also present problems. Pinhole leaks in heat exchangers allow steam to leak into the process fluid. Since the steam system is under pressure, leaking of additional steam into the process fluid can be a safety concern. A proper mechanical integrity program specifies intervals for inspecting for corrosion and scaling, as well as repair tasks such as replacing seals before they fail. In addition, steam traps must be regularly inspected and tested.

Finally, there is the matter of efficiency. Electric heaters are roughly 99% efficient because they are in direct contact with the process fluid. On the other hand, steam systems are typically less than 85% efficient, depending on the type of fuel used.

Steam is best viewed as baseload heat. Many plants have a large industrial boiler that generates a certain amount of steam, usually measured in lb/hr at a particular pressure rating. This is the base load of heat for a plant that is distributed across the various heating components. Steam is typically distributed in two ways: through steam tracing or through a heat exchanger.

Steam tracing, which circulates steam around process pipes (Figure 2), is an effective solution if the goal is simply to keep pipes warm (*e.g.,* above 100°F). A heat exchanger may be a better approach if the goal is to keep a tank warm. In both of these applications, a high level of precision is not required. However, if pipes must remain at an exact



▲ **Figure 1.** A steam generation and distribution system consists of a boiler, a steam distribution system, a heat exchange system, and a condensate return system.

temperature, steam is not a good choice because the typical steam system does not have the level of precision needed to accomplish this, and an electric heater may be a more prudent choice. If the goal is to heat certain processes just to keep them moving and prevent unexpected freezing of certain lines, steam systems are usually a good choice.

Consider asphalt plants, for example. Steam exchangers for storage tanks and steam tracing for piping enable the plant to maintain a pumpable product that does not solidify, and very little precision is required. Likewise, many chemical plants use steam tracing on their process lines because the goal is typically not to maintain a precise temperature, but rather keep a liquid in liquid form as it moves through the plant.

Many CPI processes generate waste heat in the form of hot fluegases. Boilers offer a way to capture waste heat and convert it to steam. For example, in combined-cycle power plants, heat-recovery steam generators (HRSGs) can recover heat from a gas turbine that is producing electricity (Figure 3).

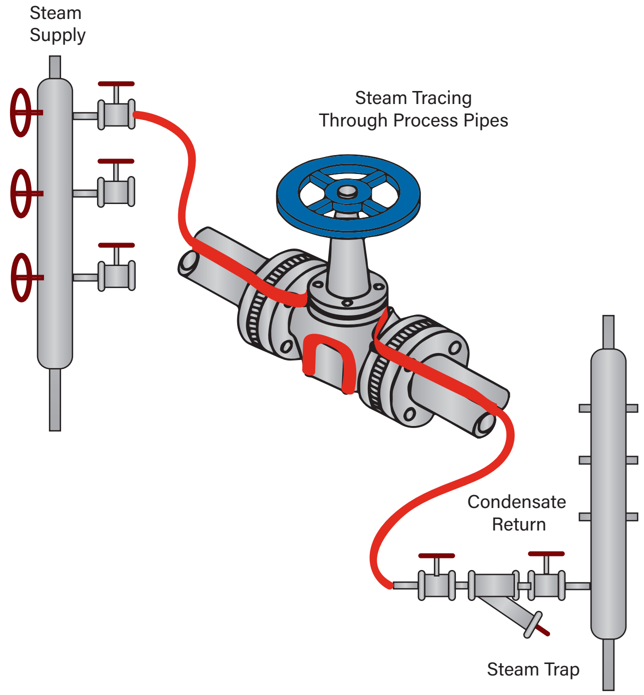
However, if complex temperature requirements inherent to a specific process must be met, a steam system leaves much to be desired. In such cases, electric heating is recommended.

When to go electric

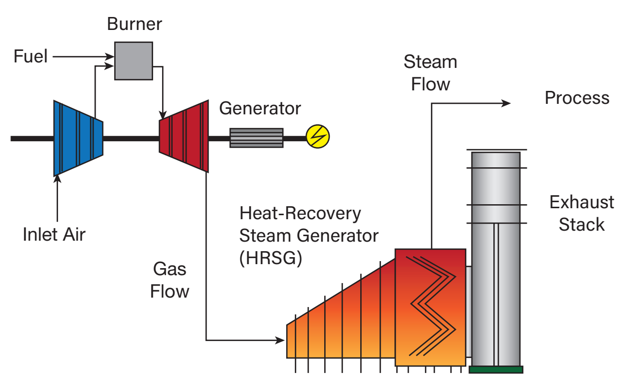
Electric heaters typically come in two forms: inline heaters and immersion heaters (Figure 4). Inline heaters, also referred to as circulation heaters, consist of a flange heater in a pipe body (pressure vessel). The process fluid is heated as it flows through the pipe . Immersion heaters, alternatively, are tubular or flat blade elements that are immersed in a vessel (*e.g.,* storage tank, process line, etc.).

Depending on the specific process, heat must be delivered under very precise circumstances and stay within a very narrow range. This can be difficult to achieve as flowrates change and incoming temperatures vary, forcing a fast response time and wide turndown ratio. Furthermore, some processes require the temperature to be such that it can be adjusted meticulously. In these cases, an electric heater is ideal. It is very difficult to achieve meticulous temperature control with steam systems, especially when the process experiences variable flowrates.

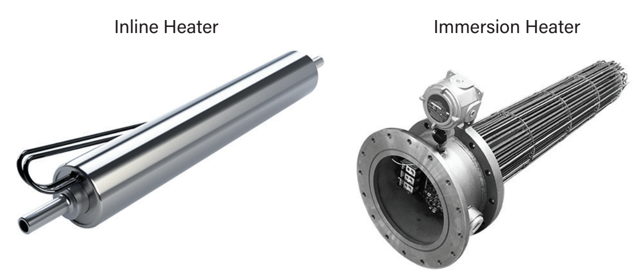
Challenges and considerations for electric systems. Electric heaters are more common than steam systems in certain industries, such as the food and beverage industry. Chocolate, for instance, must be cooked and maintained at a very specific temperature because if it is overheated, it will burn and its flavor will be ruined. The most important part of chocolate is the taste, and if the heat in the plant is not controlled at a very precise temperature, the product is easily ruined. Furthermore, consistency is critical, because if a



▲ **Figure 2.** Steam can be distributed throughout a plant via stream tracing, which circulates steam around process pipes to keep their contents warm.



▲ **Figure 3.** Heat-recovery steam generators (HRSGs) are one form of waste heat recovery. They use a gas turbine to recover heat from exhaust gases and generate steam.



▲ **Figure 4.** Inline heaters (left) are used to heat fluids flowing through process lines. Immersion heaters (right), on the other hand, are used to heat fluids in vessels. Images courtesy of Watlow.

plant does not produce chocolate that tastes the same every time, the customer experience is highly variable. On the other hand, plant operators must be careful to not undercook the chocolate. Chocolate can solidify in the pipes, preventing proper flow and reducing throughput. Chocolate can be effectively produced only when the process heating in the plant has high precision — thus, an electric heater is the recommended approach.

Some chemical plants heat processes to a particular temperature to activate a catalyst or start a reaction. These processes require maintaining very specific temperatures, which can be difficult for a steam system. Additionally, chemical plants can require extremely high temperatures. Because it is difficult to heat steam to extremely high temperatures without incurring significant expense, electric heating may be the best approach.

The ability for electric heat to achieve a 1:100 turndown ratio (*i.e.,* a heater rated for 100 kW can be adjusted from 1–100 kW of power) is also highly desirable, especially in processes with variable flowrates. Such turndown is not possible with steam systems. In many inline applications, the final process temperature must be constant in order to achieve a desired result. But, if the flowrate varies by 30–40%, the heating technology must be highly responsive in order to compensate quickly. Failure to do so can increase scrap rates and directly impact the bottom line.

Electric heaters are 99% efficient. Because the heating elements are directly immersed in the process, the thermal energy flows directly into the process fluid stream. This allows for fine-tuning of the process temperature and rapid response.

However, electric heaters do have some challenges — primarily, cost. Steam is most likely the first choice if high precision is not required, mainly because of cost. Furthermore, in order to utilize electric heat for some processes, sufficient power must be available. Determining the total heat required for a particular process and understanding the power requirements will help guide whether or not electric heat is possible.

For applications in a humid environment, wet heaters can also pose a challenge, especially if the heater is used intermittently. Heaters can absorb moisture out of the air like a sponge (the moisture is absorbed through the terminal housing), which can cause the heater to short to ground when it is energized. This is known as a wet heater because the insulation has become saturated. A current test should be performed prior to energizing an electric heater.

Combining steam and electric heating

Refineries are one type of facility that uses both steam and electric heating systems. Because steam temperature is directly related to the steam's pressure, and steam can only be safely distributed up to a certain pressure, there is a limit on the temperature it can reach. If the temperature requirements exceed the pressure ratings of either the pipes or the instrumentation, an electric heater may be required. If temperatures in excess of 450°F are required, steam is not a feasible process heating solution. Many refineries use steam as a baseload heating system and supplement it with electric heaters in specific processes to reach high temperatures.

Asphalt production and distribution facilities also use steam and electric heating in combination. For example, an asphalt plant used steam as baseload power. The plant's feedstocks typically arrived via rail at a temperature at which the material could not be pumped. The railcars were equipped with heat exchangers ready to accept high-pressure steam to warm the material, enabling it to be pumped into the facility and processed. This plant had a schedule that impacted heat generation. The plant would operate at full capacity for nine months of the year and as a peaker plant (*i.e.,* plant that runs only during peak demand) for the other three months. This schedule led to a dilemma: During those three months, keeping the boiler on idle would be prohibitively expensive, but it would take a long time to start the boiler back up if it was shut down between shipments.

After an economic analysis, the plant determined that keeping the plant on idle was not economically feasible. However, the fixed cost associated with firing up the boiler from a shutdown was greater than installing a small electric boiler to be used three months out of the year.

Therefore, they chose to install a small electric boiler, sized to heat a trainload of 12 cars up to temperature within 48 hr, allowing the plant to offload the product and move it through the transfer lines. Additionally, this approach would maintain temperature in the raw material storage tanks. This turned out to be a good decision by the plant — the economic benefits were realized quickly and the electric boiler paid for itself by the second year of operation.

Although steam is the logical choice for manufacturing asphalt, electric is the better choice for asphalt application — *i.e.,* spreading asphalt on the roads and filling in potholes. Since the spreader trucks are mobile, steam is not readily available. In addition, the heat profile across the machine is critical, requiring specialized heaters and an integrated control system that optimizes heating and ensures consistent asphalt quality.

In other situations, a plant may have a boiler in place, but an upgrade is required. For instance, an existing steam system can heat a process to 450°F to activate a catalyst, but if the plant expands and needs to tap into the steam line, the system would no longer be suitable for that temperature. In such a situation, electric heaters could be installed as a booster to reach the original heating requirements.

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The carbon footprint of the heating method of choice should also be considered. Environmental regulations can make it difficult to obtain permits for a new boiler. Adding electric booster heaters may preclude the need for a new boiler.

Steam loses pressure as it travels throughout the plant, which translates to a loss of thermal energy. Rather than investing in a new boiler system to supply heat to the periphery of the plant, the facility could install an electric booster or superheater to heat wet, low-pressure steam back up to its original high-pressure state. This technique is commonly employed when a plant has outgrown its original footprint and is experiencing less-than-optimal steam at the edges of the plant. Another option is to pair a small electric boiler with the existing steam infrastructure in the plant (heat exchangers or line tracing) rather than relying solely on the main boiler. Both options provide additional heat without increasing the carbon footprint of the plant or altering the base thermal scheme.

One way or the other

For some processes, the choice of steam or electric heating is fairly straightforward. However, for some applications, the choice may not be obvious. In those situations, carefully analyze the process and determine the needs that must be met. Most importantly, be aware of the options that are available, weigh the options, and fully understand the ramifications of your decision. CPI facilities can make an optimal decision by determining which outcomes are desired and what absolutely needs to be avoided. Going through this exercise is imperative before deciding which heating method works best for your process. CEP

Literature Cited

1. **Bell, J. L.,** "Boiler Project Fundamentals," *Chemical Engineering Progress,* **113** (9), pp. 53–59 (Sept. 2017).

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