Process Heating

FOR MANUFACTURING ENGINEERS WHO USE HEAT PROCESSING EQUIPMENT AND SUPPLIES.

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SENSORS SCENE

Seen throughout process applications, temperature sensors capture essential data.

Taking the DIRECT APPROACH

Direct steam injection for heating water provides many benefits.

By David Degelau, Hydro-Thermal Corp.

Heating water is the most common industrial need in manufacturing today. Whether the water is used for processing food, metals, pulp or paper or any other commodity consumed, water needs to be heated. Often, it must be heated to a very specific temperature that will make the process run best and preserve product quality.

Manufacturers have several options when heating water. Indirect methods of heating such as heat exchangers heat water though a heat transfer barrier such as a wall. Typically, they have a specific rate of heat conduction. Another method, direct contact steam, transfers heat right into the water and provides instant heat transfer.

Most manufacturing engineers are familiar with heat exchangers and how to size them for their processes, but they may not know as much about direct steam injection heating. So, this article will examine direct contact steam injection heat transfer, explain its theory of operation, demonstrate a typical installation and describe how to size a water-only direct steam injection heater.

What Is It?

Unlike indirect methods of heating, direct steam injection (DSI) does not have a "heat transfer barrier" such as the wall separating the steam and the fluid in a heat exchanger. While necessary in some applications, heat transfer barriers have a specific rate of heat conduction that can lengthen the device's response time to process changes. Direct steam injection heaters do not have a barrier and can respond instantly to a signal from the temperature controller. In effect, because there is no barrier, there is little lag time with a direct steam injection heater. The fluid temperature will change immediately with changes in the regulated steam flow. Direct steam injection heaters can be regulated as fast and precisely as the control loop is capable of measuring and responding to changes in temperature.

This instant transfer of heat provides two main advantages of direct steam injection: precise temperature control and energy efficiency. More than 20 percent of steam's energy can be present as sensible heat. Because it utilizes both the latent and sensible heat of the steam, a direct steam injection heater requires less steam flow for a given process than indirect heating methods. Condensate return is not needed because all the steam's energy is transferred to the process. In effect, 100 percent of the condensate energy is recovered.

Different direct steam injection control valves make use of various physical principals for their operation. The various control schemes each provide different levels of temperature control accuracy as well as different maintenance requirements.

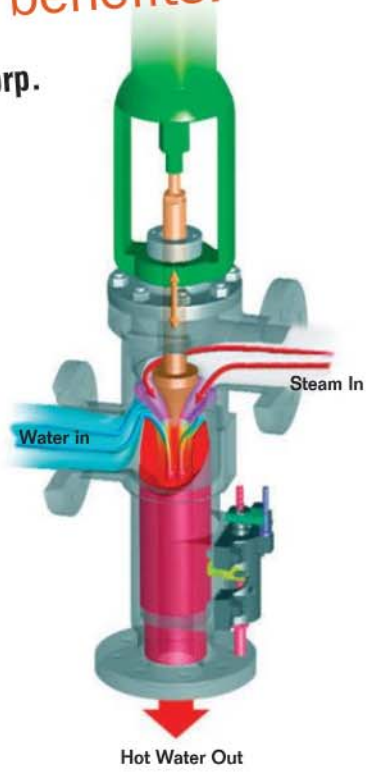


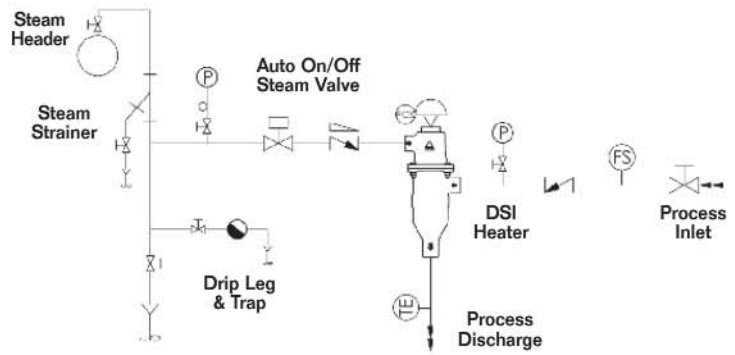
Figure 1. With the internally modulated direct steam injection heater, steam flow is controlled by varying the nozzle throat area to maintain optimal steam velocity.

Table 1. Process Information Required for Direct Steam Injection Heaters

Fluid Specific Heat	Fluid Density
Fluids Solids Content	Fluid Viscosity
Presence of Abrasive or Corrosive Products	Flow Rates
Automatic/Manual Temperature Control	Pipe Size
Type of Operation:	
• Continuous	Inlet Temperature
• Intermittent	Outlet Temperature
• Variable	Steam Pressure

Table 1. To specify a heater properly, examine the process criteria carefully.

External Steam Control. Some direct steam injection heaters have an external steam control valve. They control steam flow by throttling the steam en route to multiple orifices in the heater. When properly instrumented, this type of device provides temperature control and good turndown capabilities. As with other externally modulated devices, steam pressure at the point of injection can vary widely, resulting in inconsistent steam/fluid mixing. This style of heater often requires regular monitoring



The simplest direct steam heater systems need a minimum of components and should follow the basic principles of steam usage, piping and safety procedures.

and maintenance. In applications where hard water is present, routine disassembly to clean plugged orifices may be required. Hard water tends to scale and foul these heaters because steam is at less than sonic velocity.

Internal Modulation. More advanced and more easily controlled is the internally modulated direct steam injection heater. These devices eliminate the need for an external steam control valve. Steam flow is controlled by varying the nozzle throat area (figure 1), maintaining optimal steam velocity. Internally modulated direct steam injection heaters introduce metered amounts of steam into the process fluid through a nozzle with variable area, or by opening fewer or more orifices in the diffuser.

With this method of control, constant nozzle exit velocity is ensured at the point where the steam contacts the water, eliminating the potential for pressure upsets and ensuring smooth heater operation. If heaters are not sized correctly, vibration and noise can occur.

Specifying Direct Steam Injection for Water Heating

Specifying direct steam injection heating and properly sizing the equipment for an application entails an examination of process requirements, general process information and fluid characteristics (table 1) Properties such as specific heat, density and viscosity as well as solids content and whether any abrasive or corrosive materials are present need to be identified.

Application conditions such as flow rate (normal, minimum and maximum), inlet and discharge temperatures, process pressure and steam pressure, and pipe sizes must be considered. Users should determine whether manual or automatic temperature control is desired and whether continuous, intermittent or variable operation will be the norm.

The specifying process engineer may also want to discuss the application requirements with a specialist familiar with direct steam injection technology.

The simplest of direct steam heater systems needs a minimum of components and should follow the basic principles of steam usage, piping and safety procedures. Conformance to all applicable local, state and federal laws, codes and standards should be followed strictly. Designing the system to meet the heater's specified temperature, pressure and flow rating is important.

Often, manufacturing engineers order complete systems from the direct steam injection heater manufacturer to be sure the proper controls, fittings, gauges, steam traps, pipe sizes and other components are in place (figure 2). These plug-and-play complete systems only need to be plumbed into the piping at the processing plant.

When to Consider Direct Steam Injection

Direct steam injection can be used for many process and utility heating applications. Hot water is used in the production of food, chemicals, pharmaceuticals, pulp and paper, metals refining, grain milling, fermentation, water treatment and many other processes for which the precise control of flow rate, output temperature and other factors is critical. For example, in the food industry, a few degrees difference in water temperature can mean the difference between adequate sterilization and a potential food safety problem.

The energy savings associated with replacing a heat exchanger with direct steam injec-

Data Input		
Process Flow Rate		150 gal/min
Temperature of Incoming Water		60°F
Required Output Temperature		180°F
Header Steam Pressure		110 psig
Percent of Heat Exchanger Capacity		80%
Boiler Efficiency		78%
Percent of Condensate Reclaimed to Boiler		0%
Percent of Condensate Heat Lost During Return		100%
Condensate Return Line Pressure		0 psig
Boiler Makeup Water Temperature		60°F
Boiler Fuel Cost	Calculate Fuel Cost	4.00 $/MBTU
Water Treatment Expense per 1,000 lb of Steam	Calculate Water Cost	0.30 $/1,000 lb
Average Hours Per Day in Use		24 Hours

Fuel Cost Savings Results	Heat Exchanger	Direct Steam Heater		
Required Energy Load	150,210	150,210	BTU/min	
Steam Flow Required	164.9	129.1	lb/min	
Energy Required at Boiler	246,047	192,597	BTU/min	Estimated Annual Savings: $117,697.78
Water Treatment Cost	$2.97	$2.32	$/hr	
Cost Per Hour of Use	$62.02	$48.55	$/hr	
Cost Per Day	$1,488.46	$1,165.11	$/day	
Cost Per Week	$10,419.20	$$8,155.78	$/week	
Cost Per Year	$541,798.30	$424,100.52	$/year	

Table 2. An example of water heating shows the possible energy savings with direct steam injection heating would be $117,697 per year.

WEB EXCLUSIVE

Typical Applications Suited to Direct Steam Injection

If a plant has a steam boiler and the need to heat water for any reason, direct steam injection often is a good option.

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tion heating can be estimated by using standard thermodynamic analysis and calculating the required energy from known process conditions (flow rate, incoming process fluid temperatures, required output temperature, and steam pressure). The specifying engineer should compare the amount of energy needed for direct steam injection heating with that needed for a heat exchanger.

An example of water heating — for instance, in an annealing operation — shows the possible energy savings with direct steam injection heating would be $117,697 per year (table 2). In some cases, the estimated savings are dramatic, and these units can show a return on investment in less than a year.

Direct steam heating often provides a reduction in energy usage. Typical savings can be up to 30 percent over systems without condensate recovery and 12 to 15 percent over a well-designed heat exchanger system.

Direct steam injection heating offers other advantages as well. Maintenance for cleaning is reduced or eliminated. The small size of direct steam injection heaters reduces floor-space requirements. These space savings also can lead to a more efficient overall plant layout. Precise temperature control saves energy by heating fluids to exact temperatures, allowing setpoints to be reduced. This reduces energy demand and can result in improved product quality.

While direct contact steam injection cannot be used for every process heating application, it is a smart choice in many cases. Because of its inherent properties, small footprint and low maintenance requirements, direct steam injection fits into many sustainability and energy saving initiatives. Water heating is an easy application for direct steam injection, yet some of these applications can be complicated enough to require the assistance of a steam system specialist. For best results, when specifying DSI, be sure the entire process is understood and completely communicated to the heater manufacturer. **PH**

Figure 2. Manufacturing engineers can order complete systems from the direct steam injection heater manufacturer.

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Inner Workings

Dismantling and erection should be completed by the end of December, and includes inspection services, material supplies, training and startup assistance. The project is valued at $37.4 million.

Arauco is one of the largest forestry businesses in Latin America in terms of forest ownership and plantation performance. The company manufactures market pulp, panels and sawn timber.

Calculate Heat Process Energy Use

Industrial hot water heating can be a major energy and cost outlay for food processors and manufacturers. Reducing that energy use is good for a company's bottom line, the environment and the public. Smart processors look for alternative technologies to heating water for cooking, cleaning-in-place, hose stations and sanitation that can save money and energy while achieving precise temperatures.

According to Hydro-Thermal Corp., Waukesha, Wis., direct steam injection is an alternative that saves energy by replacing a heat exchanger. To help demonstrate this, the company has added an energy calculator to its website for free use. To try it, visit www.hydro-thermal.com, then register for the company's the Knowledge Center (link in the upper left of the page).

Developed by Hydro-Thermal, the calculator uses standard thermodynamic assumptions and formulas to estimate the energy used for specific process conditions such as flow rate, incoming process fluid temperatures, required output temperature and steam pressure. Then, the calculator compares the required energy of a heat exchanger with that of a direct steam injection three-way valve. Users also can input their process conditions, fuel costs and other data directly into the calculator. A comparison of energy use is shown side-by-side for each heating technology. Because the calculator can provide an estimate of energy use based on a company's exact process conditions, engineers and operators can use it to plan process improvements.

The calculator has been vetted by representatives from Wisconsin Focus on Energy and the U.S. Department of Energy. Also, several engineering professors at the University of Wisconsin and the Milwaukee School of Engineering have vetted the calculator, according to Hydro-Thermal.

Body Heat Supplants Boilers

Never mind using boilers to heat buildings in Paris. The city has found a novel way to keep a public housing project warm — body heat. The housing complex, now undergoing renovation, connects to the Metro subway system — and therein lies the source of the heat: Metro passengers.