Heating Water by Direct Steam Injection

Producing hot water by direct steam injection provides a solution where large volumes of hot water at precise temperatures are required, and where energy and space savings are factors in system design.

A viable alternative to indirect heating is the use of direct steam injection. Direct steam injection is recommended for those facilities that have process steam, where large volumes of process hot water are required, or when accurate temperature control is needed. In these applications it is far more energy efficient than traditional indirect (heat exchanger) systems.

Indirect water heating systems are used primarily where hot water demand is intermittent and close temperature control is not important. These systems have certain shortcomings that make them unsuitable for many large applications such as for plant processes in industry where large volumes of hot water are needed, and where the hot water must be held at precise temperature.

Because most indirect storage type heating systems cannot heat water on an instant, straight-through basis, they are used to heat stored water. As hot water is drawn off to meet demand, cold water enters the storage tank. The incoming cold water lowers the average temperature of the stored water. This typically presents problems if close temperature control of the water is critical to a process.

Furthermore, if hot water demand exceeds the recovery rate of the storage heating system, the hot water supply could be totally exhausted. In most industrial processes, when the hot water supply is exhausted, the operation must shut down until more water is heated.

Indirect storage tank systems also require extended start-up time at the beginning of the work day. Unless they are insulated, they radiate and waste enormous amounts of heat energy. Close temperature control is not possible under intermittent start/stop and variable flow conditions, even with the tankless (instantaneous) indirect water heaters. Finally, indirect systems are relatively inefficient because they use only about 75% of the Btu’s in the steam.

What is direct steam injection?

With direct steam injection cold water is heated by injecting steam directly into it. Indirect heating systems on the other hand transfer heat by conduction through a metal wall.

The four major advantages of direct steam injection systems are:

- It is energy efficient.
- It provides an unlimited supply of hot water.
- It is compact.
- It provides accurate temperature control.

Energy efficiency

Because steam is injected directly into the water, direct steam injection systems can be up to 28% more energy efficient than indirect systems. With direct steam injection, all of the Btu's in the steam are used to heat the water. Steam coils or heat exchangers are about 75% efficient at best, because only about 75% of the Btu's in the steam are actually used to heat the water. Saturated steam at 100 psig, for example, contains 1,189 Btu's per pound. As steam condenses in a heat exchanger, only the latent heat (about 880 Btu's) is released to heat the water. The condensate, which still contains at least 309 Btu's is at 338°F. This condensate must be removed from the system. It may be discharged to drain and wasted completely, or it may be returned to the boiler.

As the condensate returns to the boiler, Btu's may be lost through faulty steam traps and ancillary equipment. Leaking steam traps, a major cause of energy waste, have high maintenance costs. Additional Btu's are lost by radiation from condensate return lines. At the receiver tank Btu's are lost when the condensate flashes as it is reduced to atmospheric pressure before being returned to the boiler. Overall efficiency falls too, as mineral deposits accumulate on the wetted side of the metal conductor and creates an insulating barrier.

With direct steam injection, because 100% of the steam is condensed in the water as it is heated there is no need for condensate return lines with their attendant energy losses and steam trap maintenance problems.

Speed of operation

Many indirect systems heat stored water. Direct steam injection heats the water instantly on a continuous straight-through basis as it is used. A direct injection system properly sized to the available steam supply, cold water supply, and hot water demand, can deliver a continuous supply of hot water as required. The user does not run out of hot water, and does not need to store large quantities of hot water.

Compactness

Even the most sophisticated direct steam injection water heating systems are so compact that they can be suspended from a wall, ceiling or mounted on a compact skid on the floor. Thus, the system is desirable where space does not allow for a storage tank. When a large storage tank must be replaced, it is much easier to install a steam injection system than it is to bring a new large storage tank into an existing building.

The more sophisticated direct injection systems provide very close temperature control at Constant and Variable Flow rates and in start/stop applications. This control is possible because heat transfers immediately from the steam to the liquid when heating starts. When demand and steam flow stop, heating ceases at once unlike a heat exchanger which continues to release residual energy.

Types of Steam Injection Systems available:

Many methods can be used to inject steam directly into cold water. These differ primarily in their ability to adjust to variations in steam pressure, incoming water pressure, and hot water demand. The most sophisticated injection systems adjust automatically for these variations. Others have more limited capabilities, but are adequate in some situations. The following is a discussion of each of these systems-how they work and where they may be used effectively.

Sparger - The simplest system is the steam sparger, which "bubbles" steam into a tank of cold water (see Figure 1). The sparger does not have the advantages of other direct injection systems. Sparging systems can be simple and relatively inexpensive to install, but the disadvantages can outweigh the benefits. A sparger is perforated pipe or other fixture through which steam is introduced directly into the water in a vented storage tank.

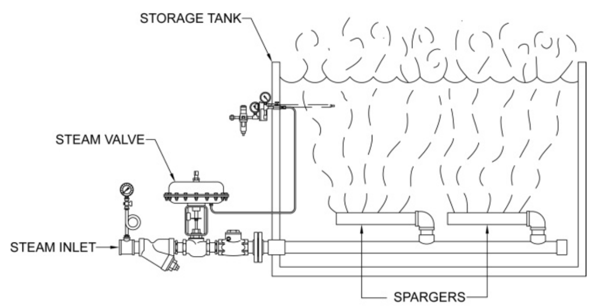

Figure 1. Spargers heat water in an open tank by bubbling steam up through it.

Spargers have been used for many years because they are a simple and inexpensive way to heat liquids. They are often used for boiler feed water tanks, storage tanks and silos, and heating cryogenic fluids.

Spargers have four major disadvantages. First, it is difficult to arrive at and hold a set temperature with spargers. Second, spargers are the least efficient method of heating water. This is so because, as a sparger injects steam into the bottom of a tank, some of the steam “channels” upward to the surface and flashes to the atmosphere resulting in a total waste of energy. Sparging is usually less than 50% energy efficient.

Third, spargers often cause very severe water hammer and vibration because there is no way to balance the pressure of the steam in excess of the surrounding water pressure. Storage tanks are frequently damaged by this water hammer and vibration.

Fourth, extra time will need to be allowed to heat large volumes of water.

Mixing tees - As their name implies, mixing tees (see Figure 2) are individual single-use devices which blend steam with cold water in a “tee” arrangement. Three types of mixing tees are used: manual, semi-automatic, and systems in which the temperature is automatically controlled.

With manual systems, the operator first turns on the cold water, and then opens the steam valve to admit enough steam to bring the cold water up to temperature. With this system it is impossible to achieve more than an approximate temperature.

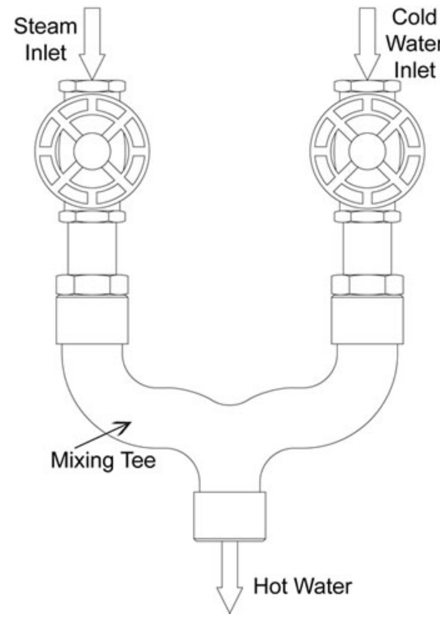

Figure 2. Manual Mixing Tee

Semi-automatic mixing tees require manual adjustment of steam and water, but contain the added feature of an automatic steam shutoff in the event that the water supply is interrupted.

With automatic mixing tees, the temperature is preset with a controller and then the steam and water supplies are turned on. Neither the manual nor the semi-automatic systems can adjust for variations in steam pressure, water pressure, or hot water demand. For this reason they are not recommended for use in plant sanitizing situations requiring 180°F hot water. They are, however, adequate for general plant washdown, and for this reason are often used as wash stations. Unless correctly operated and properly maintained, manual or semi-automatic systems can be potentially hazardous in that live steam maybe ejected if the cold water supply is abruptly stopped. This could be a dangerous situation for personnel using the equipment.

When specifying systems for multiple wash stations, it may be worthwhile to compare the cost of several individual mixing tees with the cost of a central Variable Flow steam injection system-especially if the temperature requirement at all wash stations is the same. Generally, if three or more wash stations are called for, the installed cost of a central steam injection system may be lower. In addition, a central system will prevent workers from misadjusting individual wash station mixing tees.

Venturi injection systems - With the venturi or eductor injection method steam is drawn directly into the cold water through a venturi or constriction in the water line (see Figure 3). By passing through the venturi, steam enters the water at a high (sonic) velocity. This creates a pressure differential and generates a turbulence that promotes rapid mixing of the steam with the cold water.

There are two types of venturi systems-fixed orifice and variable orifice. As their name implies, fixed orifice venturi systems cannot be adjusted for variations in steam pressure, water pressure or hot water demand. They are satisfactory only where these conditions remain constant.

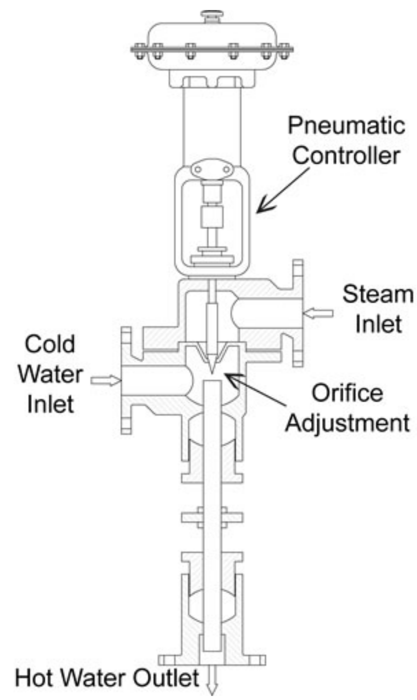

***Figure 3.* Venturi Steam Injector**

With variable orifice venturi systems, depending upon the type, the flow of steam or water may be adjusted to deliver water at varying degrees of temperature. The adjustment may be manual or it may be pneumatically regulated. Where steam pressure, incoming water pressure and hot water demand remain fairly constant, they are satisfactory. They cannot, however, prevent water hammer if steam and cold water pressure are near equilibrium. And because they have very limited turndown capabilities, they cannot accommodate variable flows, low-flow conditions, wide variations in steam or water pressure, and hot water temperature demand without the aid of a storage tank. The liquid pressure drop though this type of system may exceed 30 PSI, whereas with the dual-modulating systems the pressure drop seldom exceeds 2 psi. Also the sound level generated from the venturi system will be higher due to the high sonic velocities developed.

Dual modulating steam injection system - The most effective steam injection heating system is the Dual modulating steam injection control system (see Figure 4)-In actual practice, steam pressure, water pressure and hot water demand seldom, if ever, remain the same. While steam pressure may remain constant, incoming cold water may vary in pressure and temperature. Demand for hot water may vary from maximum flow to no flow. Where a flow of hot water at a precise temperature is required, regardless of these varying conditions, a dual-modulating steam injection system is recommended. With this system, the steam flow is modulated at two points: an external modulating control valve, and at the point of actual injection.

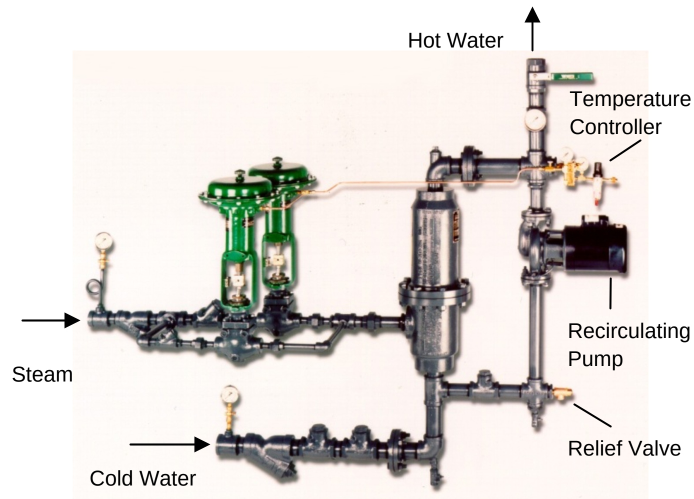

*Figure 4. **Dual Modulating Steam Injection Control System***

The steam control valve is activated by a temperature controller located immediately at the hot water outlet. This controller may be manually set to any desired outlet water temperature or it may be regulated remotely by a pneumatic or electronic temperature controller. The controller signals the modulating steam control valve to admit more or less steam as required to hold the outflow temperature to any desired preset temperature automatically-regardless of outflow demand.

With this system, a single modulating steam control valve provides approximately than a 10:1 turndown capability. (Turndown is the ratio of maximum to minimum steam flow rates.) Additional turndown capability (approaching 100:1) can be obtained with the use of dual steam control valves.

In addition to controlling the incoming steam flow with a modulating steam control valve, this system also controls the steam injection pressure at the point where steam enters the cold water. At this point of steam injection steam enters the cold water through hundreds of very small orifices in an injection tube. By breaking the steam up into multiple small streams and by maintaining a positive pressure differential all the steam is instantly and quietly injected into the flow of water.

As the modulating steam valve varies the steam flow in order to maintain the outflow water temperature, the steam pressure works against a spring-loaded piston in the injection assembly (see Figure 5). As the steam flow varies, it forces the piston to rise or fall exposing more or fewer steam injection orifices.

By applying pressure against the incoming steam, the spring-loaded piston constantly maintains steam pressure in excess of incoming water pressure. This eliminates the “water hammer” which occurs when steam and water pressures are at or near equilibrium, such as with the steam sparging method.

Because of its capabilities, the dual-modulating system can deliver hot water quietly within very precise temperature tolerances under an unlimited range of flow conditions. This close temperature control is essential in many processes because it prevents overheating. This is a very important energy-saving feature when one considers that overheating 100 gallons of water per minute a mere 10° F wastes approximately 500,000 Btu’s per hour.

The dual-modulating steam injection system is available in two basic configurations. One is designed to deliver a Constant Flow of hot water. The other accommodates Variable Flows, where the demand for hot water fluctuates from intermittent or very low flow rates to a high flow at peak demands.

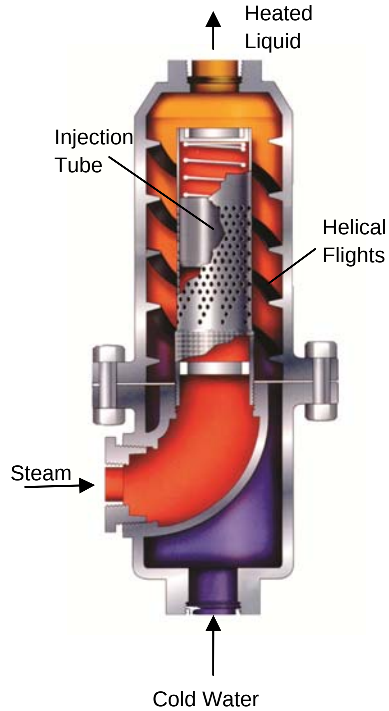

Figure 5. Dual Modulating Steam Injection Control System

In addition to Variable Flow applications, this system is widely used in industry where hot water must be delivered in a sequence of varying temperatures to meet process requirements. It is used in these applications because it can change the temperature of the hot water instantly.

How to specify

- Provide a description of the application – What is the hot water to be used for?
- Provide process conditions. Examples:
    - Water flow (min & max)
    - GPM/LPM
    - Cold water inlet temperature (°F/°C)
    - Hot water outlet temperature (°F/°C)
    - Steam pressure (PSIG/BARG)
    - Water pressure (PSIG/BARG)
- Material of construction for piping, valves, and components.
- What type of temperature controls are required. Examples:
    - Local pneumatic
    - Electronic – remote
    - PLC
    - DCS
- Electrical area classification and power required.
- Space considerations for locating equipment.

With direct steam injection, all the Btu’s in the steam are injected directly into the cold water – resulting in significant energy savings. Direct steam injection systems furthermore, can supply hot water on a continuous straight-through basis. They occupy much less space than indirect storage system, and provide much more accurate hot water temperature control.

Common Applications in the Chemical Industry

- Heating Jacketed Reactor Vessels
- CIP - Cleaning/ Sanitizing
- Filter Washing
- Tank Car Washing
- Adding Process Batch Water
- General Plant Clean-up
- Tank Car Heating
- Line Tracing
- Brackish Water Heating
- Closed Loop Jacketed Dryers, Blenders and other devices

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