Steam Management:

Don't Send Money Down the Drain

Driving energy savings through key solutions to condensate management

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Energy consciousness and environmental awareness have transformed condensate from an inexpensive byproduct of steam distribution to a valuable resource that can substantially reduce operating costs. For process systems that use steam as the heat transfer media, improved condensate management can enhance the overall system performance and longevity.

Condensate is a ready-made supply of recoverable energy. Typical chemical-process plants should be able to recover over 60% of the condensate produced in their steam systems. Unfortunately, traditional system design and installation practices are in many cases inadequate for insuring positive condensate drainage. As a result, the condensate is either drained to waste, or the performance of the heat exchanger is diminished.

Making simple changes in system design, along with following practical management steps, can offer significant financial returns while also increasing heat exchanger performance and integrity.

Condensate-recovery challenges

In any steam distribution system in a process plant, such as the one represented by Figure 1, the condensate requires some means of motive pressure to be returned to the boiler plant. The motive pressure either is a result of the supply-steam pressure, or is generated by a mechanical pump. In either case, the motive pressure must always be greater than the condensate return backpressure to guarantee continuous drainage.

The two most common piping designs for heat-exchanger condensate drainage consist of incorporating a level-actuated collection pot or utilizing a steam trap. In both cases, the equipment is directly piped to the condensate return system and, accordingly, is affected by the return line backpressure.

The level-actuated collection pot is a common choice for large, high-capacity, heat-exchange vessels such as reboilers (both positive pressure and vacuum) and shell-and-tube designs. The condensate level in the collection pot, controlled by an actuated drain valve, can be constant or variable. The constant-level version incorporates a modulating steam valve for process-side temperature control, whereas the variable-level system uses a constant-pressure steam valve and varies the exposed heat exchanger surface area by flooding the vessel with condensate. While both options provide process temperature control, neither is without potential performance and equipment integrity problems.

Constant-level pot: The constant-level design relies on varying the steam pressure and volume to maintain the desired process temperature requirements. The problems occur as the supply steam control valve throttles closed with the thermal requirements decrease from startup conditions This, in turn, decreases the steam pressure and volume, which leads to an even lower available condensate motive pressure. To make matters worse, if the steam valve throttles closed to the point that the pressure in the heat exchanger is less than the condensate backpressure, the heat exchanger will unintentionally flood. This decreases thermal performance and can lead to corrosion (carbonic acid from cooled condensate), surface pitting (accelerated by trapped non-condensable gases), and potentially compromising the structural integrity of the tubes and tube sheet through stress cracking and water-hammer.

Variable-level pot: To avoid low-pressure problems that can occur with a constant-level, modulated supply-steam control system, many heat exchanger systems are *designed* to flood for process temperature control. Instead of the process temperature actuating the supply steam control valve, a condensate drain valve is modulated to expose or flood the heat exchanger surface area while maintaining a constant supply-steam pressure to the vessel. As the thermal requirements decrease, the condensate drain valve throttles closed to back up condensate into the vessel, effectively decreasing the surface area for heat transfer. This is similar to the unintentional flooded condition occurring with a constant-level design, except that the constant steam pressure creates a positive motive pressure for condensate return. Nevertheless, the detriment to the system, corrosion, vessel life and structural integrity, still exist, just as in the constant-level installations.

Conventional steam traps: Steam traps are widely employed to drain condensate and vent noncondensable gases from heat exchangers. Because the internal mechanism performs as a discharge control valve, the steam trap inherently operates in a manner

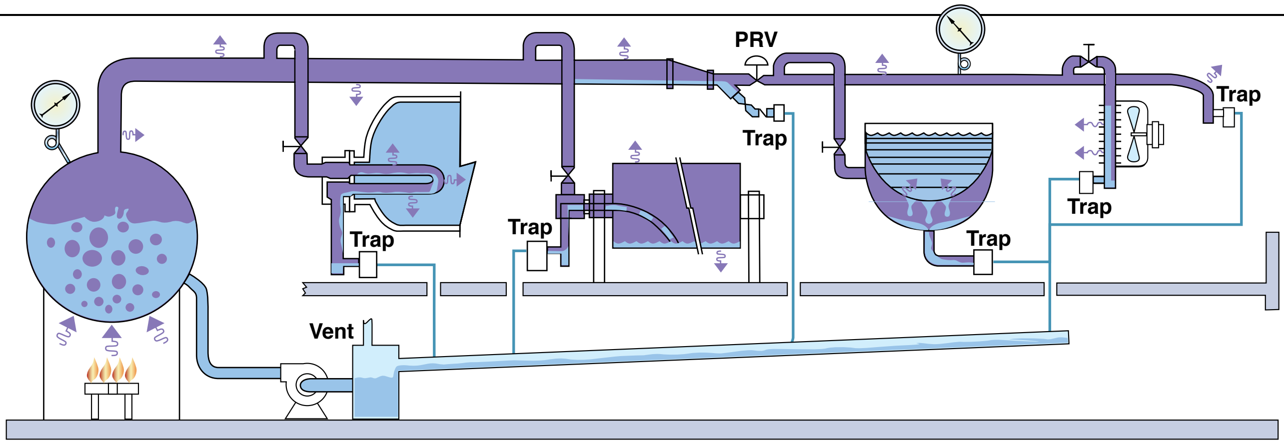

FIGURE 1. Illustration of distribution system with boiler, pipes, traps, etc.

FIGURE 2. Open valve discharging to atmosphere

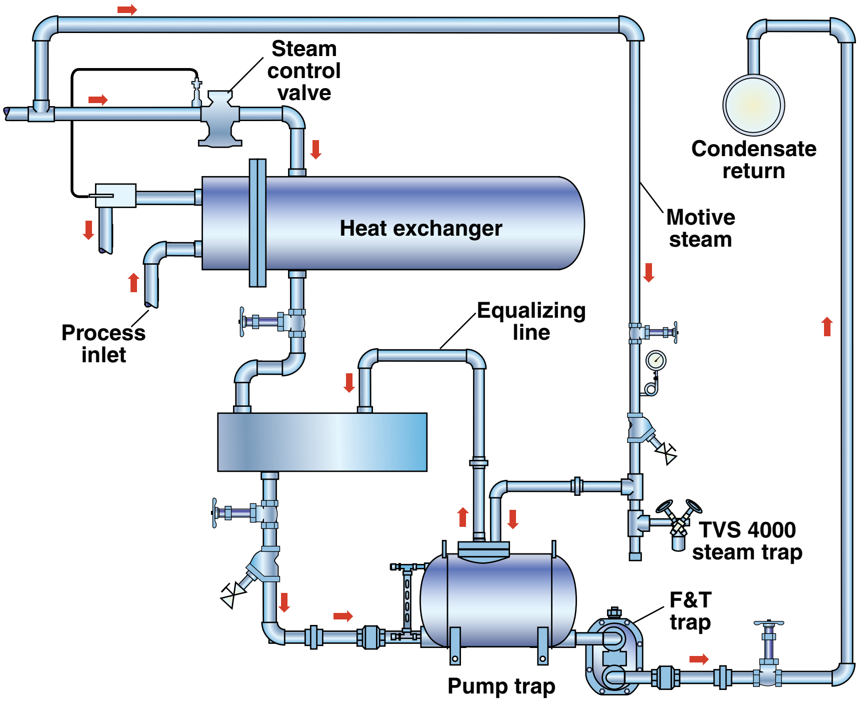

FIGURE 3. Picture of the Process heat exchanger with 100% turndown

comparable to that of a condensate system with a constant-level collection pot.

Thus, a system employing a conventional steam trap is subject to operating conditions similar to those described for exchangers that employ collection pots. With adequate steam pressure to overcome the condensate return backpressure, the heat exchanger will perform with optimal efficiency. But if the supply-steam control valve throttles closed due to a decrease in thermal requirements, the available condensate motive pressure decreases, and the condensate backs up and floods the vessel. As with the collection pot, the heat exchanger loses performance and is subject to corrosion and structural damage.

The recurring theme of the aforementioned operating scenarios is that adequate pressure is required for to overcome the condensate-return-line backpressure, ensuring complete drainage and noncondensable-gas venting from the heat exchanger. Admittedly, a quick remedy for a flooded vessel is to drain the condensate (and vent the gases) by opening valves to the atmosphere (Figure 2). Obviously, though, this remedy wastes thermal energy and creates a potential safety hazard.

Solving the problem

The preferable solution consists of incorporating a mechanically actuated pumping device driven by air, other gas, or steam, called a pump trap, into the system (Figure 3), to isolate the heat exchanger from flooding and to insure sufficient condensate pressure to overcome the return-line backpressure. This approach will keep the heat exchanger operating at optimal efficiency while assuring its structural integrity.

The installation of such a device in a closed-loop arrangement allows process unit to maintain a dry heat exchanger regardless of the chest pressure, condensate rate, or efficiency of the tube bundle. The main benefits of this system solution are the elimination of tube bundle corrosion and potential tube failure, both of which could cause an upset condition and production interruption. But furthermore, because complete condensate removal from the heat exchanger is assured, the plant can take advantage of all of the surface area in the bundle;

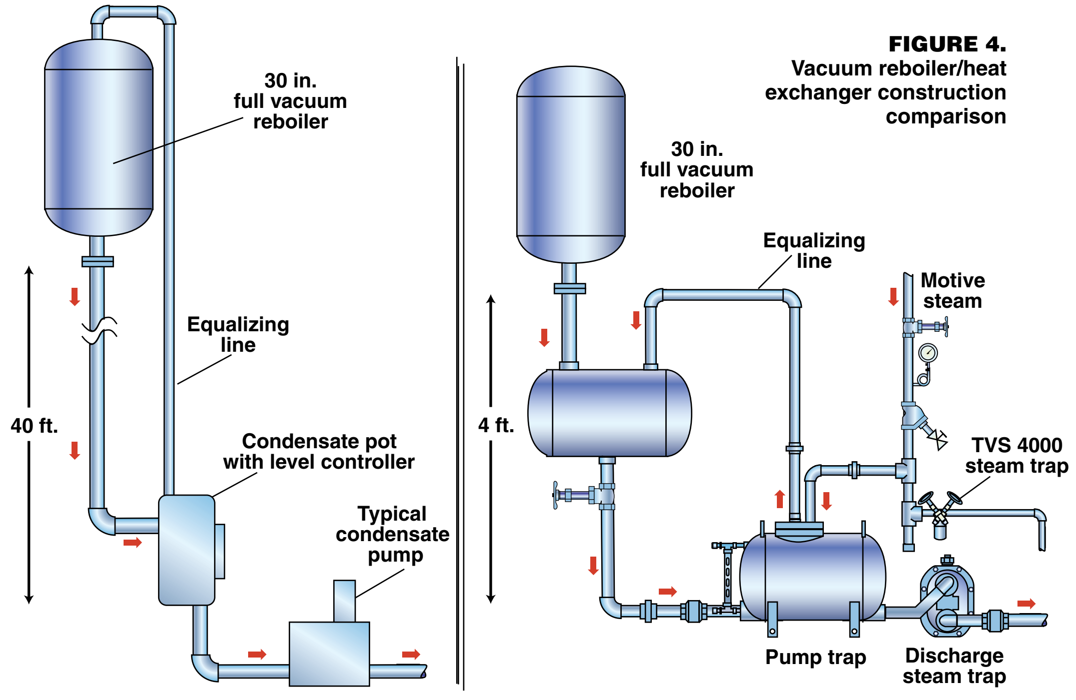

FIGURE 4. Vacuum reboiler/heat exchanger construction comparison

this capability may allow the heater to run at its lowest possible pressure, which minimizes energy consumption due to the latent heat content of lower-pressure steam.

In new process plants, the installation of a pump trap, rather than a conventional centrifugal or positive-displacement pump, on process heat exchangers can lead to savings on installation costs. For one thing, net positive suction head (NPSH) is critical for those heat exchanger systems that operate under vacuum and employ conventional pumps, because such pump are subject to cavitation. For that reason, heat exchangers that are to be outfitted with conventional pumps are often elevated to extreme heights to allow for proper drainage. Some systems may require a 40-foot elevation to drain a conventional condensate pot. But with pump traps employed instead, such heights are not necessary, because those traps are immune to the cavitation. Use of pumps traps thus can often lead to significant capital-cost savings, by reducing the skirt height required for exchangers or reboilers — sometimes to as little as 4 ft. (Figure 4).

Pump traps offer other benefits that collection pots or conventional steam traps do not. Complete, effective removal of condensate under all operating conditions allows a heat exchanger to operate at peak efficiency by reducing corrosion on the tube bundle, while also lessening the potential for destructive water hammer. Likewise, as noted above, allowing a heat exchanger to operate at its lowest possible chest pressure while maintaining a consistent outlet process temperature profile minimizes energy consumption.

Other aspects of condensate management

Condensate management requires a holistic, turnkey approach to realize significant energy savings. In addition to the recommendations discussed up to now, here are a few practical pointers:

Return-line sizing: The size of condensate return lines is a critical design factor. Because steam is a vapor, it requires more volume per unit of mass than does a liquid (such as condensate). Return lines must be adequately sized to account not only for the movement of liquid condensate, but also for the presence of live and flash steam. The receiver vent lines also need to be sized accordingly, to reduce the condensate return temperature to acceptable levels and avoid damage to condensate return pumps.

Steam traps: Aside from the condensate return issues discussed earlier in this article, every system also needs to have the right type of steam trap for the application, as well as a sufficient number of traps installed at proper intervals to remove condensate as quickly as possible. The general rule of thumb is that traps should be located at 100- to 300- foot intervals. Determining the right trap depends on a number of variables; but in general, the mechanical, inverted-bucket steam traps usually prove to be the best solution as they allow continuous drainage of condensate.

Condensate collection assemblies: These assemblies, which bring together multiple valves into one central location, may be advantageous; they help reduce the number of individual condensate collection points along the line. Additional benefits include reductions in installation costs and space requirements, as well as an increased accessibility to equipment for routine maintenance and repairs.

Thermal insulation: Insulating distribution and condensate return lines can pay big dividends; in fact, it can reduce energy losses by 90%. Any surface over 120°F should be insulated.

Smart management: Simple but intelligent management practices, such as establishing a routine steam trap inspection and maintenance program are also an essential part of maximizing condensate recovery and return. Fuel savings exceeding 10% can be achieved through an effective trap management program alone. ■

Edited by Nicholas P. Chopey

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