**Tech Sheet #ST 106**

# Effective Drainage of Condensing Equipment

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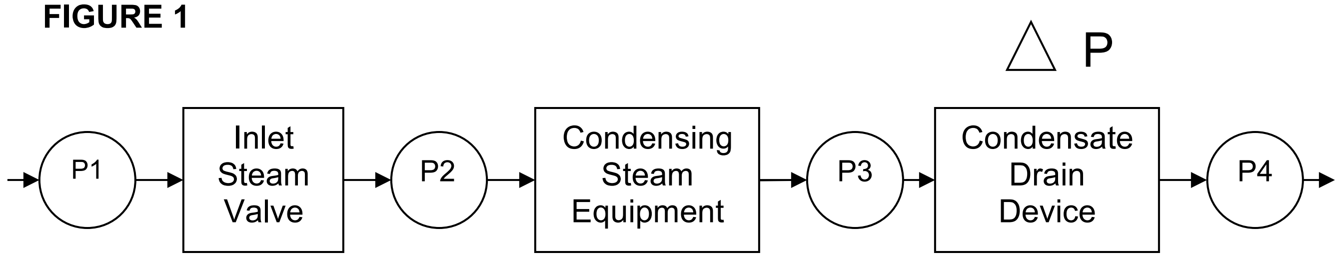
Condensing equipment is often a critical source of revenue in a process plant or a significant heating cost in an HVAC system. Therefore, one of the more challenging issues facing plant personnel or design engineers is how to properly drain such condensing equipment for maximum life and reliability.

Virtually everyone involved with steam condensing equipment has at least one story about a frozen coil, uneven heating process, or corroded heat exchanger. On the surface, it seems like a simple task to select a steam trap with proper capacity and safety factor to drain the steam equipment. Why then do so many installations of condensing equipment suffer from poor performance or unexpected and premature failure?

The core issue or difficulty can often be traced to an incomplete evaluation of the differential pressure (Δ P) across the drainage device employed. A step-by-step review of figure 1 demonstrates the typical differential pressure considerations necessary for effectively draining condensate from steam equipment.

**FIGURE 1**




Although the condensing equipment is supplied with steam at pressure P1, pressure drop across an inlet valve and the equipment itself will result in a reduced pressure of P3 just ahead of the Condensate Drain Device. That pressure, P3, must be evaluated for its relative driving force against the back pressure, P4; and it will determine the type of condensate drain device needed to discharge the condensate.

That driving force, otherwise known as the differential pressure, is calculated as the difference of P3 minus P4. When the differential pressure is positive, P3 pressure has enough energy to drive the condensate against the back pressure, P4. When the differential pressure is negative, P3 pressure can't drain the condensate against P4 and the system will waterlog. Understanding this basic information leads to basic selection decisions:

- In positive differential pressure conditions, the typical drainage solution is to select a steam trap.
- In negative differential pressure conditions, the typical drainage solution is to select a type II SPD (Secondary Pressure Drainer).

Additional selection and sizing considerations follow.

**Draining of Condensing Equipment with a Manual Supply Valve on the Steam Inlet**

On steam systems with a manual supply valve, it is usually relatively easy to determine the differential pressure P3 – P4. Then on positive differential pressure systems, the steam trap can be chosen with suitable valve and body pressure ratings. The trap must be capable to operate at the highest pressure, P1, but discharge the condensate load with the driving force of *ONLY* the differential pressure. Typically, manufacturers will recommend a safety factor of between 1.5 and 2.0 times the condensate load at the lowest differential pressure.

Some equipment with a manual valve steam supply can experience P3 pressure that is lower than the P4 back pressure. When P3 is lower than P4, there is a negative differential pressure, and a different drainage solution is needed to overcome the higher back pressure. There are a variety of drain alternatives in negative differential systems with manual valve supply, but all are relatively easy to design.

One possible alternative under manual valve supply steam and negative differential pressure is to try to remove the effect of P4 back pressure by gravity draining from the condensate drain device directly into an atmospheric flash tank. This is a suitable solution provided that gravity drainage can be accomplished and local flash steam venting can be permitted. Once the back pressure is removed, the differential pressure across the condensate drain device becomes positive, and the system can be drained into the flash receiver by a steam trap. Normally it is useful to install a vacuum breaker on the steam space of the condensing equipment to enable free drainage. The vacuum breaker is effective to enable drainage in instances where the equipment has sufficient surface area to reduce the steam pressure to vacuum conditions – or if the equipment goes into vacuum on shut-down.

Once condensate is discharged into the flash receiver, a Type I SPD or electric condensate pump can be used to discharge the atmospheric receiver condensate against the back pressure. This is usually a suitable alternative when multiple equipment condensate sources must be drained.

When gravity drainage is not possible, another negative differential pressure drainage alternative is to pump the condensate directly from the equipment into the higher back pressure system. Typically this solution will require a Type II Secondary Pressure Drainer (SPD) that uses a secondary motive source at higher pressure to push condensate into the return system.

Therefore, with manual valve steam supply systems, the selection of a steam trap for positive differential pressure, or Type II SPD for negative differential pressure is relatively easy.

**Draining of Condensing Equipment with Modulating Steam Inlet Control**

Condensing equipment often requires a modulating steam valve to maintain the desired temperature or pressure control point.

With modulating control, a dynamic process occurs in the condensing equipment. The Heat Output (or Supply) of the equipment seeks to equalize with the Heat Demand of the process. Equalization is necessary to avoid overheating or sub-cooling the process fluid. This effort to equalize causes the control valve or regulator to modulate its valve opening, thereby directly affecting the delivered P2 pressure.

Depending on the demand change relative to the equipment maximum heat capability, pressure P2 can reduce to its lowest point which is designated, $P2_{min}$.

When the differential pressure based on $P2_{min}$ is positive, a steam trap can be selected similarly as previously explained under the manual supply valve scenario. The main consideration is that the lowest positive differential pressure must be used to size the trap.

However, modulating control will often lead to a negative differential pressure. Although P1 can be a significantly high pressure, in many instances modulated $P2_{min}$ may be a low pressure or a vacuum condition. When P4 is higher than the reduced P3 which results from $P2_{min}$, then a negative differential pressure condition exists. This describes the situation that causes many if not most difficulties with condensing equipment.

Under negative differential pressure conditions, a steam trap would have insufficient $P3_{min}$ pressure to push condensate through the trap, and the system would “Stall”. Therefore, it is critical to evaluate the demand load profile of the equipment and determine whether or not a “Stall” condition will occur. A “Stall Chart”, available from a variety of manufacturers and other technical reference sources is one easy method to determine the resulting differential pressure in modulating control systems; and therefore whether or not a “stall” condition will exist in the evaluated equipment.

Another method to determine stall is to perform a mathematical calculation of the steam supply pressure profile by equalizing;

$$\text{“}Q_{demand} = M\ Cp \bigtriangleup T\text{”} \qquad \text{to} \qquad \text{“}Q_{supply} = U\ A \bigtriangleup T\ (LMTD)\text{”}$$

Mathematical calculation can determine the required steam temperature (and resultant pressure) to equalize the delivered heat to the demand for a given load condition. A “stall” condition is reached when the pressure of the delivered steam is equal to the back pressure. The ratio of the “stall” load relative to the maximum load determines the percentage of load for a stall condition to occur. Since other factors such as “U” value are estimates, it is often easier to perform a stall chart graphical analysis and visually track the estimated pressure profile of the steam supply under varying load conditions.

There are two potential solutions when it is determined that a “Stall” condition will exist. One possible solution is to remove the back pressure by gravity draining condensate into a vented flash receiver as previously explained in the manual valve section. In effect, this method removes the back pressure from the equipment, creating a positive pressure differential from the equipment into the flash receiver. However, the condensate from the flash receiver must still be pumped against the back pressure.

The preferred solution to prevent flashing high temperature condensate and recover higher energy value is to combine the pump and trapping stages by installing a Type II SPD (trapping function can be either internal or external). The Type II SPD includes a pumping capability and also can trap steam when the modulating pressure creates a positive pressure differential. This system allows for closed system condensate recovery by using a secondary motive pressure to overcome the back pressure. The manufacturer of the SPD can provide product sizing and selection for a given application.

**Draining of Condensing Equipment Summary**

- **Calculate the lowest differential pressure**, P3 – P4.
    - Simple calculation on manual valve steam supply.
    - Stall chart graphical analysis on modulating steam supply.

- **On positive differential pressure systems**, select a steam trap for drainage.
    - Trap must meet maximum steam pressure conditions
    - Size trap for condensate load with suitable safety factor at lowest differential pressure

- **On negative differential pressure systems**, select among two alternatives
    - *Gravity drain* the condensate into a vented flash receiver to remove back pressure (thereby converting to positive differential pressure)
        - Select steam trap to drain the system according to positive differential pressure guidelines above.
        - Install vacuum breaker on steam space to break vacuum and help drain the system on shutdown.
        - Select a Type I SPD to drain the flash receiver condensate into the pressurized condensate return header.

    - *Positive back pressure* in a negative pressure differential installation eliminates the possibility of gravity drainage
        - Type II SPD (internal or external trapping) is recommended.
        - Estimate "stall" load percentage.
        - Size pumping function of SPD for the maximum condensate load under stall (negative differential pressure) conditions.
        - Size trapping function of SPD for the maximum achievable INSTANTANEOUS discharge flow rate under positive differential pressure conditions.
            - Internal traps are sized by the manufacturer
            - External traps should also be sized by the manufacturer

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