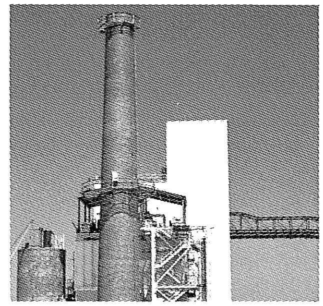
Steam traps can snare users with high energy losses



High steam costs require careful selection of steam traps. Here's how different types of traps compared in industrial tests

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☐ It has not been too many years ago that the cost of steam production was only 50 cents to $1 per thousand pounds. Energy was so inexpensive that steam costs were not significant when considering the total cost of operating buildings and institutions or producing a product in industrial plants. As a result, the selection of accessory equipment and the maintenance necessary to minimize steam loss were not of paramount concern to designers and operators.

Today's high cost of fuel has changed all that. At $4 to $8 a thousand pounds, the cost of steam production is a significant expense to all users. The selection of accessory equipment must be based on its impact on the energy consumption of the entire system and on the amount of maintenance necessary to minimize energy consumption of that equipment over a prolonged service life.

Steam traps must be selected with energy conservation in mind. According to Jerry Roy, Staff Engineer, Union Carbide Corporation, South Charleston, West Virginia, "The significant point is that the criteria, such as ease of repair, size, and parts standardization that were attractive in pre-oil embargo days are no longer paramount. Energy costs have escalated efficiency as a primary factor in trap selection." These comments were made in a Union Carbide report entitled, "Study of Energy Consumption in Process Steam Traps."

TABLE 1—TEMPERATURE REDUCTION CAUSED BY AIR

Pressure, psig	Steam temperature, no air present	Steam temperature, F, with various percentages of air (by volume) 10%	20%	30%
10.3	240.1	234.3	228.0	220.9
25.3	267.3	261.0	254.1	246.4
50.3	298.0	291.0	283.5	275.1
75.3	320.3	312.9	304.8	295.9
100.3	338.1	330.3	321.8	312.4

Heating and process traps

Steam traps which drain heat exchangers handle large amounts of condensate which flows continuously into the trap. These are ideal conditions for long life of the condensate handling valve in any steam trap. The primary consideration here is the effect of the steam trap on the efficient use of steam within the heat exchanger.

The study cited above covered steam usage of the same heat exchanger while being drained by each of three different types of steam traps. Two kinds of float and thermostatic traps, a high capacity impulse, and an inverted bucket of appropriate capacity were used to drain the steam coil of a vacuum still. The study involved measuring the amount of steam consumed by the vacuum still while operating for three hours at the same production rate with each of these steam traps. The amount of steam consumed by the heat exchanger while being drained by the high capacity impulse traps was used as the base (100 percent consumption) with which to compare the other types of traps. The results were:

High capacity impulse—100 percent
Float and thermostatic—108 percent at high load or 93 percent low load range.
Inverted bucket—92 percent

With steam costing up to $8.00/1,000 lbs, even small steam losses can become very expensive

Based on these results, all process traps at Union Carbide's South Charleston plant are being changed to the inverted bucket type. It is estimated that the savings in one plant alone will be $1.1 million annually.

The use of sub-cooling thermostatic types of traps was not considered in the study because another plant reported vapor binding of heat exchangers by non-condensible gases.

Insulating effects of air

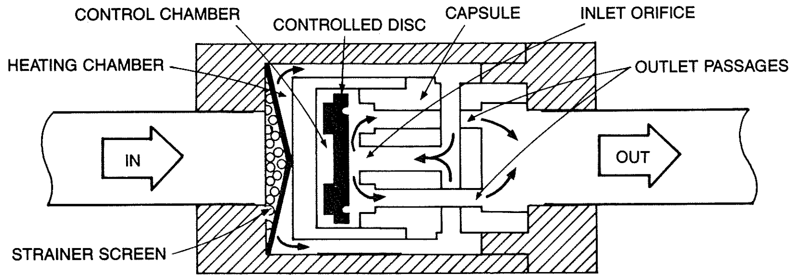
Water contains dissolved oxygen and compounds which volatilize when steam is generated. The result is non-condensible gases including oxygen and carbon dioxide. These gases are carried over into the heat exchanger with the steam. When the steam condenses, these non-condensible gases remain in the heat exchanger. If not removed, these gases can accumulate with those in the incoming steam and build concentrations which can affect heat exchange efficiencies.

Mixing air with steam lowers the saturation temperature. The greater the percentage of air that is mixed with steam, the greater the temperature drop at a given pressure (see Table 1).

If not removed, concentrations of 30 percent air or more can be present. With a 30/70 air/steam mixture in the heat exchanger, a steam pressure of nearly 100 psig will be required to maintain the temperature and heat exchange rate that could be realized with only 50 psig pure steam. Less latent heat is available in each pound of steam so more steam is consumed at the higher pressure. Also, more heat is needed to generate the steam initially.

Air is an excellent insulator. As steam condenses, air migrates to the heat transfer surface where it plates out as an insulating film. Only 0.01 in. of air has the same insulating effect as 11 ft of copper. In order to drive heat through this insulating barrier, steam temperature must be raised by increasing steam pressure. Again, less latent heat is available per pound of steam and more steam must be used. More Btu's per pound are required to generate steam at the higher pressure. In fact, it is estimated that the combined temperature reduction and insulating effect of as little as one half of one percent by volume of air in steam can reduce heat transfer efficiency by as much as 50 percent. In most institutions and industrial plants producing steam under 300 psig, water treatment methods do not remove the air-producing element. A steam trap must remove air (see Figure 1).

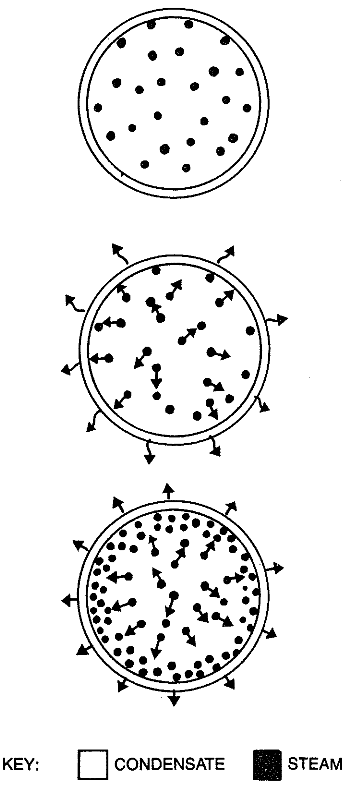
FIGURE 2—DISC TRAP



Steam traps and air removal

All traps differ in the method and efficiency with which they remove air. The thermodynamic trap is designed to close on the presence of vapor—flash steam vapor. This means that they close before all condensate is exhausted except on extremely light loads, such as tracers. There is always a barrier of hot water between the steam (and/or air/steam mixture) and the trap valve; thus limited air can be removed. If the air/steam mixture should get to the trap, the vapor will close the valve before all the air is expelled.

FIGURE 1—AIR "INSULATION"



Air moves to the heat transfer surface where it collects or "plates out" to act as insulation.

All float and thermostatic traps have separate thermostatically operated valves for removal of air. The trap cannot differentiate between air and steam at saturation temperature. Therefore, it must be set to open at the depressed temperature of an air/steam mixture. This temperature depression can be as little as 10 F or as much as 200 F, depending on the type of sensing element. This means that at 100 psig, an air/steam mixture of 15 to 75 percent exists in the system immediately ahead of the trap at all times—diminishing in various degrees into the coil. This promotes inefficiency in the heat exchanger.

Additionally, since the air removal valve opens only on depressed temperature, it cannot separate air from steam. When it opens, both steam and air are discharged. If set to open at 10 F below saturation, the trap discharges 85 percent steam and 15 percent air. How much steam is wasted depends on how often the $\frac{3}{8}$ to $\frac{3}{16}$ in. valve opens. This depends on how much air is in the steam.

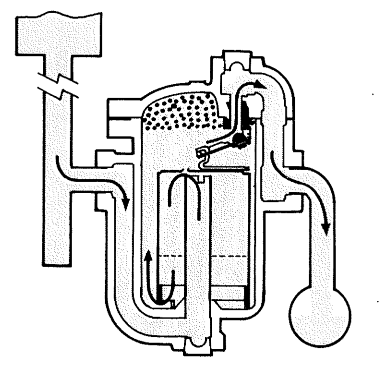
Thermostatic traps cannot discriminate between steam and condensate at saturation temperature. They must be set to open at some temperature below that of steam. On start-up with cold condensate, the valves are wide open and all air in the system ahead of the steam and condensate will pass through easily. When the condensate reaches 10 to 108 F below saturation temperature, the valve will close. The air in the steam cannot reach the trap until the air/steam mixture temperature and the condensate temperature drop to 10 to 108 F below saturation. At 100 psig, the air/steam mixture must reach 15 to 80 percent air before it can get to the steam trap to be discharged. There is a 15 to 80 percent air/steam mixture in the system immediately ahead of the trap at all times. At 15 psig, a 10 to 75 percent mixture can exist—a highly inefficient situation.

The inverted bucket trap removes air by letting it bubble by displacement through an air vent at the top of the bucket. As this mixture of steam and air in boiler proportions at saturation temperature passes through the air vent and through the water seal, the small amount of steam is condensed. Therefore, only air passes to the top of the trap where it collects to be discharged when the condensate valve opens. No matter what the pressure, the flow through the vent is small because flow is produced by a head of only a few inches of water. Since the air is discharged at or close to saturation temperature, only minute air/steam ratios exist in the system and best effeciency is maintained.

Where the savings are

The large amounts of steam involved and the potential for wasting energy by reducing heat exchanger efficiency makes the selection and sizing of heating and process traps very important. While steam and condensate loads are much smaller, the larger number of drip and tracer traps gives them a great potential for affecting energy consumption also. These applications are low capacity. Therefore, service conditions promote rapid wear of the valves, and the steam loss of worn trap valves becomes the primary source of energy waste. The effects on system efficiency and the small

FIGURE 3—INVERTED BUCKET TRAP



live steam losses associated with every type of new trap in these applications are minimal considerations compared to the amount a trap wastes when failed open or during the rapid cycling which precedes the ultimate failure.

The primary criteria for selecting drip and tracer traps are:

- Extent of steam loss when failed.
- Length of service life before excessive loss can be expected.

The amount of steam loss to be expected from a failed open trap is proportional to its rated capacity. For steam loses from various types of traps, see Table 2. The figures are based on total failure. However, losses can be excessively long before complete failure.

How long the trap valve can be expected to last determines how soon it will begin to waste steam and, thus, how often it must be checked, repaired, or replaced to minimize steam loss. All this depends on its operating characteristics. The manner in which the valve is closed and the ability of the sensor to close the valve before steam passes determines how much wear occurs and how long the trap lasts. Disc type thermodynamic and inverted bucket traps are the types predominantly used for these applications.

Disc type traps were popular because of their small size, ease of installation, and relative low initial cost. Their mode of operation requires two-phase flow of condensate and steam or flash steam passing through the valve. Vapor flow at high velocities causes the trap to close, and the combination of high velocity water and vapor flowing across the disc and seat causes rapid wear.

On the other hand, the combination of a valve at the top of the body of an inverted bucket trap and a water seal between steam vapor and the valve ensures that only water passes through the valve. Velocities are low so that wear is slight and long valve life is natural consequence.

Disc and inverted bucket types (see Figures 2 and 3) from all manufacturers were taken from drip and tracer service after varying periods of service in a multitude of industrial plants in all parts of the United States and Canada. They were tested for energy loss. Information from thousands of tests on hundreds of traps was gathered and the service life vs. steam loss curves for both types are shown in Figure 4.

Traps other than inverted buckets for this type of application have short lives, waste energy, and cause maintenance problems due to increased corrosion probabilities. Their operating characteristics cause

- Lags in response: prevents valve closure before steam passes.
- A poor valve seal when closed: permits steam loss at low condensate loads.
- Severe sub-cooling of condensate: promotes corrosion with resultant steam losses and high equipment replacement costs.

Conclusions

It is true that all types of traps have limitations which make some better than others for given applications. But, if avoiding unnecessary energy consumption caused by heat exchanger inefficiency is important, the inverted bucket type of trap should be used on all types of heat exchangers within its limits.

The primary limitation to be considered is capacity. Where normal operating conditions, or modulating steam pressure control, require removing large quantities of condensate with low pressure differentials across the trap, multiple installations of inverted bucket traps would be necessary. If space or piping complexity prohibit, high capacity float and thermostatic traps should be used despite the loss in system efficiency.

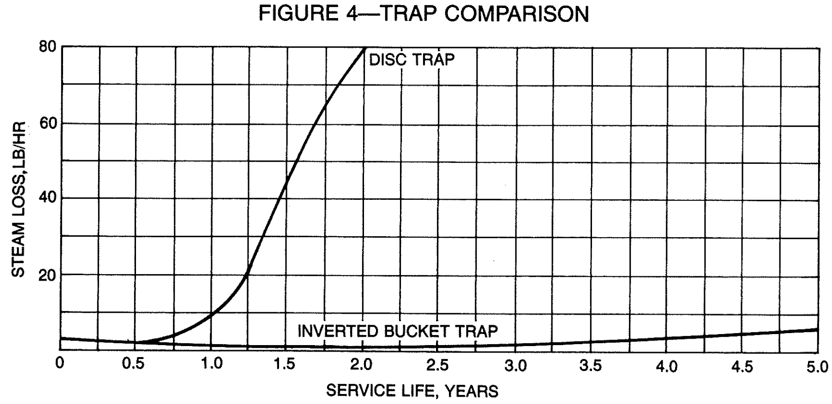
Although the air handling capabilities of inverted bucket traps are adequate for normal operating conditons, larger amounts of air must be discharged during the start-up of equipment requiring fast heatup. In these instances, a thermostatic bellows air vent can be piped in parallel from trap inlet to outlet above the trap. This vent would open to discharge air on start-up, but the inverted bucket would remove air during normal operation, maintaining steam temperature at saturation and keeping the thermostatic air vent closed.

The combination of low capacity, small orifices and long life make inverted bucket type steam traps the best choice for drip and tracer applications. The small orifices will waste less steam when the trap valve wears, and the long life expectancy will mean less frequent field checking and replacement. The net result—lower steam loss. □

TABLE 2—STEAM LOSSES

Type of trap	*Condensate capacity, lb/hr*	*Steam loss, lb/hr*
Disc	300-900	55-170
Float and thermostatic	350-650	65-110
Bi-metal	600-1,900	110-350
Bellows	350-2,800	65-500
Diaphragm (water)	300-1,000	55-180
Inverted bucket		
w/5/65 in. orifice	350	35
w/restricted orifice	100	10

FIGURE 4—TRAP COMPARISON



Steam losses over the service life of disc and inverted bucket traps are compared. Test conditions were: Inlet pressure, 150 psig; outlet pressure, 0 psig; ambient temperature, 50 F.

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