SELECTION, SIZING, AND TESTING OF STEAM TRAPS IN COMMERCIAL BUILDINGS

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ABSTRACT

For maximum effectiveness in steam systems, steam traps should have operating characteristics which closely match the requirements of the applications for which they are used. A trap which holds back condensate until it is subcooled and some of the sensible heat has been utilized is unsuitable where the need is to get maximum output from an exchanger by discharging condensate as soon as it forms. Equally, a trap discharging condensate at steam temperature can exacerbate flash steam problems in cases where surplus heat exchange area exists and a subcooling trap might be more suitable.

In all cases, undersized traps simply cannot drain condensate from the steam equipment at the required rate, while oversized traps which cost more will usually wear faster and begin leaking expensive steam.

This emphasizes the need for carefully selecting trap sizes that are properly engineered for maximum system efficiency. And, of course, the ability of a trap to cope with varying loads and to discharge noncondensible gases is often important. The recommended procedure is to first select the trap type which has performance capabilities that satisfy specific application needs, and then to choose a size which handles the condensate load without any unnecessary excess capacity. The Selection Guide, Table 1, is not comprehensive but helps in many applications where no unusual operating conditions or severe corrosion problems exist. Choosing the correct trap size then implies estimating the steam consumption rate, which of course equals the condensate load. Sometimes the load has already been measured, or the rated output of the steam equipment is known or can be obtained from the original manufacturer. In other cases, an estimate must be made and a Table of Load Formulas will help although it, too, cannot be comprehensive. After making the best possible estimate of the load, a safety factor is applied. This allows for any inaccuracies in the estimating, for increased condensation rates at start-up, and for lower than anticipated pressure differentials across the trap.

It is possible to use any make, or type or even size of steam trap on any given application, and the trap will usually work. The equipment being drained will also "work", but very often it will be working at much less than 100% effectiveness!

Maximizing equipment efficiency and output, energy conservation, and other facets which add up to the proper use of steam call for the use not only of correctly sized steam traps, but also of types having characteristics which closely match the needs of each individual application. The first of these application requirements is the necessity of choosing a trap to remove the varying amounts of air and other noncondensibles which will collect in the system. The second consideration is to select a trap type which discharges with the degree of condensate subcooling which is desirable. Obviously, using a trap which holds back condensate until it has cooled well below saturation temperature may be acceptable when draining an oversized coil such as in heating a storage tank. Here, it is beneficial to use both latent heat from steam and sensible heat from condensate thereby minimizing the heat content of condensate discharged without the lowered LMTD adversely affecting total heat transfer. However, the same trap will lead to nothing but trouble if used on a shell & tube heat exchanger where 100% or even 110% of the design output is required. In this case the condensate backing up in front of the trap and flooding the heat exchanger surfaces lowers the LMTD just when the highest values are needed, and will reduce the output of the equipment while causing waterhammer and corrosion. It follows that some guidelines on estimating condensate loads and pressures, as well as the characteristics of different steam trap types, need to be kept in mind when choosing the best trap for the job.

Some people, having their own axes to grind, have built up a fog of myths about steam traps. For example, it is easy for a manufacturer who is having a sales drive on type "X" traps to advertise that competitive type "Y" traps waste steam, but this is only a half truth. Of course, this manufacturer's intent is to lock us into choosing one type of trap by instilling the fear that other manufacturer's trap types will have excessive steam loss.

What is the truth regarding leakage? Conclusive, independent tests have shown that all steam traps, regardless of type, will lose a small amount of steam when tested on extremely light loads. This loss amounts to less than the steam condensed in an exposed section of 2" pipe about one foot long. Further, this extremely light load condition is unusual, and as normal condensate loads are generated, steam leakage becomes negligible. These tests provide the strongest justification for selecting quality steam traps that satisfy particular application needs without the ungrounded fear of suffering excessive steam leakage. As a general rule, the Selection Guide shown in Table 1 indicates trap types which are suitable for many applications where no unusual operating conditions or severe corrosion problem exist. An examination of how the different steam trap types operate will clarify the reasoning behind these choices.

The float thermostatic trap is designed to discharge condensate continuously, as soon as it forms, and at steam temperature, as well as to discharge air reaching the trap. Therefore, it will help achieve full output on air heating coils, hot water heaters and shell and tube heat exchangers where immediate condensate removal and air venting are required. However, where waterhammer exists, and until it is eradicated, the use of the float and thermostatic trap is to be avoided because the ball float can be damaged by waterhammer.

Inverted bucket traps can also discharge condensate at steam temperature, almost continuously, and will not permanently air bind. Although they continuously discharge air at the temperature of the air/steam mixture, this discharge is at a very slow rate due to the limited size of the bucket's vent hole. This orifice, usually about 1/16 inch diameter and located in the top of the bucket, allows the air to be pushed through it by the difference in water level between the inside and outside of the bucket. Even in the largest traps this is only a matter of about 2 inches or so. Because of its limited air handling capabilities, an inverted bucket trap that deals happily with the small amount of air and condensate in 2-feet of 1-inch diameter pipe may take half an hour or more to clear a larger volume of air from 100-feet of 4-inch pipe. Therefore, supplementary thermostatic air vents are often required with inverted bucket traps to help the whole system work more effectively.

Thermodynamic disc traps, at least the Spirax Sarco patterns, discharge condensate at some 2°-4°F below steam temperature. They shut off when the condensate is hot enough to release sufficient flash steam for the thermodynamic effect to operate, and they don't need live steam to make them work. Of course, if no condensate at all is reaching them, they, and other types, will use a very small amount of steam, rather less than one pound per hour according to the test report referenced earlier. Their rugged reliability, small size, and near-to-steam operation makes them an ideal choice for mains drip applications and laundry ironers. They are also successfully used on some jacketed vessels, though usually here as a second choice.

Thermostatic traps are of three basic types: expansion, balanced pressure or bimetallic. Generally speaking, they discern between steam and water by measuring temperature differences. Since freshly condensed water is at steam temperature, the use of a thermostatic trap requires that the condensate is held back within the steam space until it has cooled down below saturation to the trap's operating temperature. This backup is referred to as "subcooling" and can be either large or small depending on the type of thermostatic trap chosen. With small amounts of subcooling, condensate backup is fine provided that sufficient heat transfer surface exists to accommodate the subsequent waterlogging without adversely affecting output. In other cases where traps are used that have of subcooling, long collecting legs are needed upstream of the traps for the purpose of radiating heat and these models tend to be limited in their versatility.

Liquid expansion thermostatic traps operate at a constant temperature below 212°F. They can be used where substantial waterlogging is acceptable, and encourage using the steam's sensible heat as well as the latent heat. Typical uses are some storage coils, but they also can be used to drain condensate from dead ends in systems to prevent freezing when steam is shut down, or waterhammer on start-up.

Bimetallic type thermostatic traps more or less approximately follow the steam saturation curve, depending on the design of the element. They are usually built to discharge condensate at 50°F or more below steam temperature, to make sure that at differing pressures they don't discharge live steam. This substantial degree of waterlogging makes them suitable for oversized tank coil or instrument tracing applications. On shell and tube exchangers or heater coils, very great care is needed with their positioning and adjustment if waterlogging is not to reduce output by an unacceptable amount. However, bimetal traps are usually contained in steel bodies and their design enables them to withstand high pressures and temperatures, and also waterhammer.

Balanced pressure thermostatic traps operate much closer to the steam saturation curve, and follow it much more accurately, so they don't need adjustment at differing pressures. Many current traps of this type discharge condensate within 12-15°F or even less below steam temperature. Early models were very susceptible to damage by corrosion or waterhammer, but the introduction of stainless steel elements has greatly improved their performance. Latest, third generation, stainless steel capsules closely follow the steam curve, withstand corrosive conditions and waterhammer, and can even tolerate 90°F of superheat without damage. Applications for balanced pressure traps include steam radiators, many types of steam jacketed pans used in kitchens and main drips.

Because air mixed with steam will substantially lower the steam's temperature, these traps cannot air bind. Their free air venting characteristics mean that they serve double duty by being a first choice air vent for steam systems. This air venting requirement is one that is all too often overlooked, and the lowered heat transfer rates and corrosion problems that subsequently result are then wrongly accepted as inevitable concomitants of steam service.

Once the best type of trap to be used on a given application has been chosen, the appropriate size must be selected. This means that an estimate must be made of the condensate load to be handled, and Table II may be helpful in this context. It is usual to apply a safety factor to the calculated condensate load, to allow for start-up conditions when pressures may be lowered but condensing rates are highest, and also for any inaccuracies in the assumptions made in the initial estimates. This table also lists some safety factors commonly used.

Additionally, we need to know the differential pressure which will be available to push this condensate through the trap, and the maximum pressure at which it will be required to work. Remember that where temperature controls modulate the supply of steam to heat exchangers, the steam pressure in the tubes and at the inlet to the trap is often greatly reduced, down to or even below atmospheric pressure. In such cases, vacuum preventer valves are fitted at the inlet side of the exchanger and the trap is located below the condensate outlet. Gravity head, between 12-18 inches, provides approximately 1/2 psi and then pushes the water through the trap.

Even where supply pressures are maintained, back pressures caused by lifts in condensate lines reduce differentials across traps. Equally, pressurized return lines mean that differentials are lowered, so the effects of total back pressure resulting from lifts, friction, and existing pressures must be considered as shown in Table II.

When using the estimated loads and differential pressures to size traps in the manufacturers capacity tables or charts, make sure that the capacities are quoted for hot condensate rather than for cold water, which is sometimes used so that inflated figures can be listed. Read the small print! Published capacity ratings should be actual test ratings, with hot condensate discharging from various pressures to atmosphere.

When the best choice of trap type has been made, and a suitable size chosen and fitted, there remains the problem of knowing when a trap has become worn, or affected by the presence of pipe scale or debris, and has started to leak steam. We realize that all traps not under inspection and maintenance will eventually fail in this manner, and waste considerable amounts of energy dollars. Actually, the key to achieving the best energy conservation lies in establishing testing and repair programs. Because of this fact, it is important to know if a trap is still functioning correctly after it has been in service for some time, or if it is leaking expensive steam and requires attention. The only way to know for sure is to individually test each trap, an often difficult task.

Until recently, available methods of checking steam traps have been optimistic rather than realistic, ignoring the laws of nature which govern the way traps, steam and condensate all behave. It is certain that in the past many good traps have been condemned as faulty, and many faulty traps have been allowed to remain in steam systems. Fortunately, a device known as SPIRA-TEC is now available which is highly proficient in detecting leaking steam traps and it performs unambigously.

A special chamber (Table III) is built into the condensate line at the inlet side of the steam trap. The chamber contains a baffle plate under which condensate can pass, and a conductivity electrode. A small hole in the baffle equalizes the pressures at each side, when the trap is working normally. If the trap, which can be of any manufacturer or type, begins to leak steam, this leaking steam will begin to pass beneath the baffle with the help of a pressure differential between the upstream and downstream sides. When this differential reaches 1 or 2 inches water gauge, it depresses the water level on the upstream side of the baffle enough to expose the conductivity electrode to steam instead of water.

Checking the trap is then simply a matter of plugging onto the electrode a portable meter, and switching on. A green light shows if the electrode detects water, a normal condition; but if a red light shows, then the electrode is surrounded by steam indicating leakage. In cases where the trap and sensor chamber are located at an inaccessible position, perhaps behind a ceiling panel, the sensor can be permanently wired to either a single or a 12-way remote checking point. Alternatively, up to 12 sensors can be wired to an RI2E electronic continuous monitor. Of course, any number of these can then be connected in a cascade system to a master indicator or to a building management system, so that faulty steam traps can be serviced or replaced before the cost of steam losses becomes a problem.

In summary, overall benefits will be maximized when properly sized traps are selected with performance capabilities that match application needs; and when these traps are part of an overall energy management program that quickly identifies and corrects maintenance problems as they occur, thereby eliminating excessive energy losses.

TABLE I
STEAM TRAP SELECTION GUIDE

APPLICATION	FIRST CHOICE	SECOND CHOICE
Air Heating Coils		
Low and Medium Pressure	Float-and-Thermostatic	
High Pressure	Float-and-Thermostatic	
Hot Water Heaters (Instantaneous)	Float-and-Thermostatic	
Hot Water Heaters (Storage)	Float-and-Thermostatic	
Shell-and-Tube Exchangers		
Small—High Pressure	Thermo-Matic Thermostatic	Float-and-Thermostatic
Large—Low and Medium Pressure	Float-and-Thermostatic	
Reboilers	Float-and-Thermostatic Thermo-Matic Thermostatic	
Steam Humidifiers	Float-and-Thermostatic	Inverted Bucket
Steam-Jacketed Vessels		
High Pressure	Thermo-Matic Thermostatic Thermo-Dynamic	Float-and-Thermostatic
Low Pressure	Float-and-Thermostatic	Thermo-Dynamic
Steam Line Drip Traps		
0- 15 PSIG	Float-and-Thermostatic	
16-125 PSIG	Thermo-Dynamic	Float-and-Thermostatic
126-600 PSIG	Thermo-Dynamic	Inverted Bucket
High Pressure—Superheat	Bimetallic	Thermo-Dynamic
Steam Pipe Coils (Air Heating)	Balanced Pressure Thermostatic	Thermo-Dynamic
Steam Radiators	Balanced-Pressure Thermostatic	Thermo-Dynamic
Steam Separators		
0- 15 PSIG	Float-and-Thermostatic	
16-125 PSIG	Thermo-Dynamic	Float-and-Thermostatic
126-600 PSIG	Thermo-Dynamic	Inverted Bucket
Steam Tracer Lines	Thermo-Dynamic Bimetallic	Liquid Expansion
Storage Tank Coils	Liquid Expansion Bimetallic	Thermo-Dynamic
Submerged Heating Coils		
High Pressure	Thermo-Matic Thermostatic Thermo-Dynamic	Inverted Bucket Balanced-Pressure Thermostatic
Low and Medium Pressure	Float-and-Thermostatic	Balanced-Pressure Thermostatic
Unit Heaters	Float-and-Thermostatic	Balanced-Pressure Thermostatic
Sterilizers	Balanced-Pressure Thermostatic	
Autoclaves	Thermo-Dynamic	Inverted Bucket
Dryers	Thermo-Dynamic	Float-and-Thermostatic
Platen Presses	Thermo-Dynamic	

NOTE: Unusual operating conditions, or severe corrosion may influence the choice of a steam trap for a particular application.

TABLE II

CALCULATING CONDENSATE LOADS

When the normal condensate load is not known the load can be approximately determined by calculations using the following formulae.

GENERAL USAGE FORMULAE

Heating water with steam

$$\text{lbs Condensate/hr} = \frac{GPM}{2} \times \text{Temperature Rise °F}$$

Heating air with steam coils

$$\text{lbs Condensate/hr} = \frac{CFM}{900} \times \text{Temperature Rise °F}$$

Heating fuel oil with steam

$$\text{lbs Condensate/hr} = \frac{GPM}{4} \times \text{Temperature Rise °F}$$

Steam Radiation

$$\text{lbs Condensate/hr} = \frac{\text{Sq. Ft. E.D.R.}}{4}$$

SPECIALIZED APPLICATIONS

STERILIZERS, AUTOCLAVES, RETORTS HEATING SOLID MATERIAL

$$\text{lbs Condensate/hr} = \frac{W \times Cp \times \Delta T}{L \times t}$$

W = Weight of material — lbs.
Cp = Specific heat of the material (see page III-55)
ΔT = Temperature rise of material °F.
L = Latent heat of steam BTU/lb
t = Time in hours

Note: The condensate load to heat the equipment must be added to the condensate load for heating the material. Use same formula.

HEATING LIQUIDS IN STEAM JACKETED KETTLES

$$\text{lbs Condensate/hr} = \frac{G \times s.g. \times Cp \times \Delta T \times 8.3}{L \times t}$$

G = Gallons of liquid to be heated
s.g. = Specific gravity of the liquid
Cp = Specific heat of the liquid (see page III-56)
ΔT = Temperature rise of the liquid °F
L = Latent heat of the steam BTU/lb
t = Time in hours

STEAM JACKETED DRYERS

$$\text{lbs Condensate/hr} = \frac{1000\,(Wi - Wf) + (Wi \times \Delta T)}{L}$$

Wi = Initial weight of the material — pounds per hour
Wf = Final weight of the material — pounds per hour
ΔT = Temperature rise of the material °F
L = Latent heat of the steam BTU/lb

HEATING AIR WITH STEAM; PIPE COILS AND RADIATION

$$\text{lbs Condensate/hr} = \frac{A \times U \times \Delta T}{L}$$

A = Area of the heating surface in square feet
U = Heat transfer coefficient (2 for free convection)
ΔT = Steam temperature minus the air temperature °F
L = Latent heat of steam BTU/lb

EFFECT OF BACK PRESSURE ON STEAM TRAP CAPACITY % REDUCTION IN CAPACITY

% Back Pressure	Inlet Pressure PSIG 5	25	100	200
25	6	3	0	0
50	20	12	10	5
75	38	30	28	23

RECOMMENDED SAFETY FACTOR FOR STEAM TRAPS

TYPE OF TRAP	SAFETY FACTOR
Thermostatic Traps	2 to 4
Liquid Expansion Traps	2 to 4
Float-and-Thermostatic Traps	1.5 to 2.5
Thermodynamic Traps	1.2 to 2
Bucket Traps	2 to 3
Thermo-Matic	1.5 to 2.5

Note: The actual safety factor to use for any particular application will depend upon accuracy of:

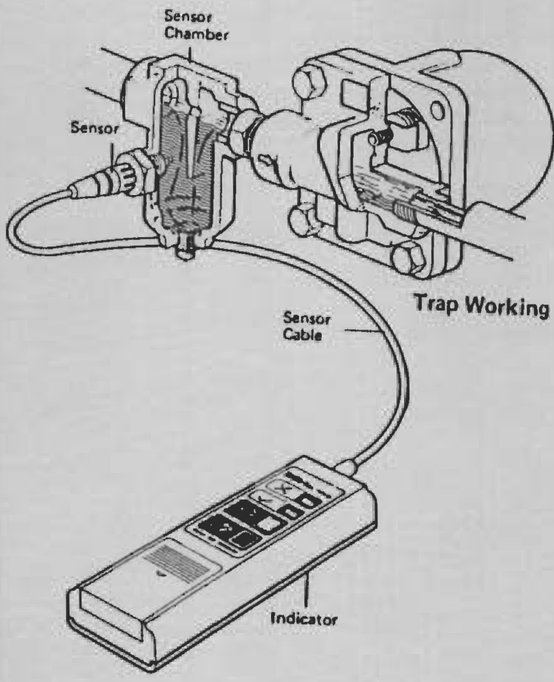
1. Estimated load
2. Estimated pressure at trap
3. Estimated back pressure

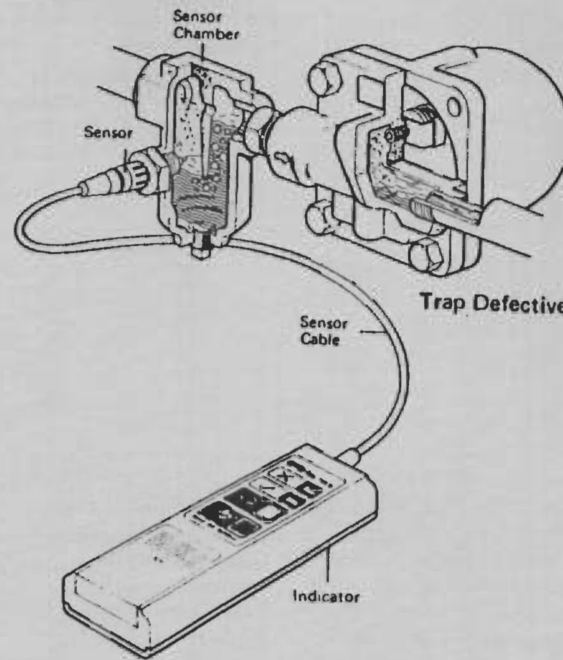
Any unusual or abnormal conditions must be taken into consideration.

TABLE III

spira-tec Trap Leak Indicator System

For Checking Steam Traps





Remote Test Point

Automatic Remote Test Point