TECHNICAL REPORT

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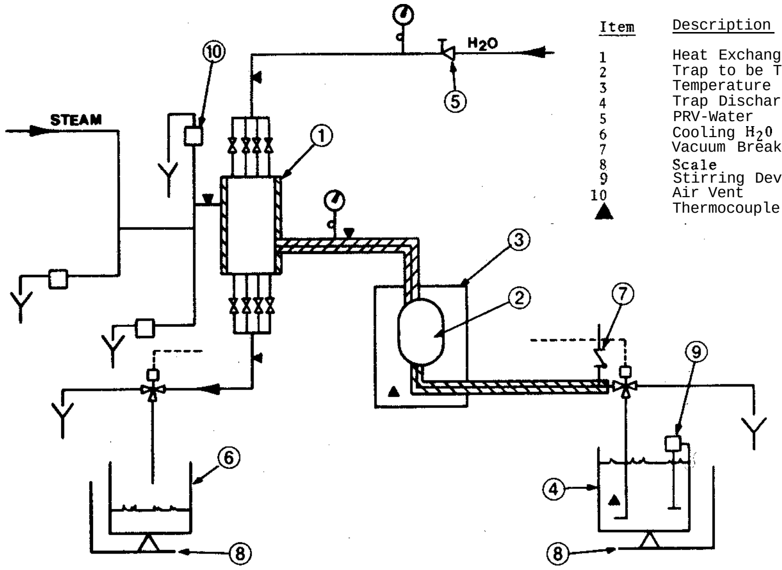
ENERGY LOSS CHARACTERISTICS OF DRIP AND TRACER STEAM TRAPS

TEST TO ESTABLISH THE ENERGY CONSUMPTION OF A STEAM TRAP

Figure No. 1



Item	Description
1	Heat Exchanger
2	Trap to be Tested
3	Temperature Controlled Chamber
4	Trap Discharge Collection Tank
5	PRV-Water
6	Cooling H_2O Collection Tank
7	Vacuum Breaker
8	Scale
9	Stirring Device
10	Air Vent
▲	Thermocouple Location

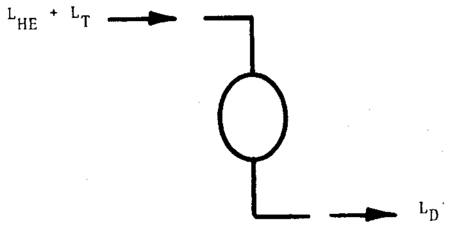
Procedure for Conducting Test

Saturated steam is introduced into the system. The test conditions are established by setting the temperature in the controlled temperature chamber, the cooling water flow rate and the number of open tubes through the heat exchanger. The initial weights of the trap discharge and cooling water collection tanks are set by partially filling them with water. The trap discharge collection tank is filled with a sufficient amount of water to condense any flash steam the trap may discharge. The system is allowed to stablilize with the trap discharge and the cooling water flowing to drain. The steam pressure, ambient temperature, the initial weight and temperature of the trap collection discharge tank and the weight of the cooling water collection tank are recorded. The test is started by simultaneously diverting the trap discharge and the cooling water discharge into their respective collection tanks and starting the timer. A multi-point temperature recorder continuously monitors steam temperature, cooling water temperature at the inlet and outlet of the heat exchanger, and the temperature in the test chamber. The temperature of the water in the trap discharge collection tank is monitored on an extremely accurate digital readout device. The test is terminated when the temperature in the trap discharge collection tank is the same amount above room temperature as it was below room temperature at the start of the test.

This minimizes the resultant heat transfer between the tank and its surroundings. Simultaneously, the timer is stopped and the trap discharge and cooling water discharge are again diverted to drain. The final weight and temperature of the trap discharge collection tank and the final weight of the cooling water collection tank are recorded. The temperature plots on the multipoint recorder are averaged for each of the points monitored and recorded.

The data collected during this test is reduced to meaningful results by performing a number of calculations.

Figure No. 2



The basis for the calculation of the total steam loss of the trap is a mass balance across the trap. The condensate load generated in the heat exchanger plus a quantity of steam (total steam loss of the trap) flow to the trap. This equals the load discharged by the trap into the collection tank.

$LHE + LT = LD$ (Law of Conservation of Mass)

Or

$L_T = LD - LHE$ (LB/HR)

Where:

LT = Total Steam Loss of Trap (LB/HR)

L_D = Load Discharged by Trap (LB/HR)

L_{HE} = Condensate Load Generated in Heat Exchanger (LB/HR)

The load discharged is calculated as follows:

$L_D = (WE - W_S)(60/t)$ (LB/HR)

Where:

L_D - Load Discharged (LB/HR)

W_S - Initial Weight H_2O & Container (LB)

W_E - Final Weight H_2O & Container (LB)

t - Length of Test (MIN)

The condensate load generated in the heat exchanger is calculated using the equations that follow:

$L_{HE} = qH/hfg$ (LB/HR) (Saturated Steam Supplied to Heat Exchanger)

But:

$qH = \dot{m} \cdot Cp \cdot \Delta T$ (BTU/HR)

And:

$\dot{m} = \Delta W (60/t)$ (LB/HR)

Therefore:

$L_{HE} = (60 \cdot \Delta W . cp \cdot \Delta T) / hfg . t$ (LB/HR)

Where:

L_{HE} - Load Generated in Heat Exchanger (LB/HR)

qH - Heat Transferred in Heat Exchanger (BTU/HR)

$\dot{m}$ - Mass Flow Rate Cooling H_2O (LB/HR)

CP - Specific Heat Cooling H_2O at Temp. Average (BTU/LB .°F)

AT - Temp. H_2O Out - Temp. H_2O In (°F) (Temp. Out $\ll$ 212°F)

ΔW - Cooling H_2O Collected (LB)

hfg - Latent Heat at Steam Temp. (BTU/LB)

The condensate load to the trap equals the load generated in the heat exchanger plus the load generated by piping losses between the heat exchanger and the trap. The magnitude of this loss is extremely small because this pipe is short in length and is well insulated. Since this loss is nearly identical for every trap tested, it cancels when comparing the results.

After the total trap steam loss has been determined, the total trap heat loss is calculated as follows:

$$Q_{TL} = L_T \cdot hg \text{ (BTU/HR)}$$

Where:

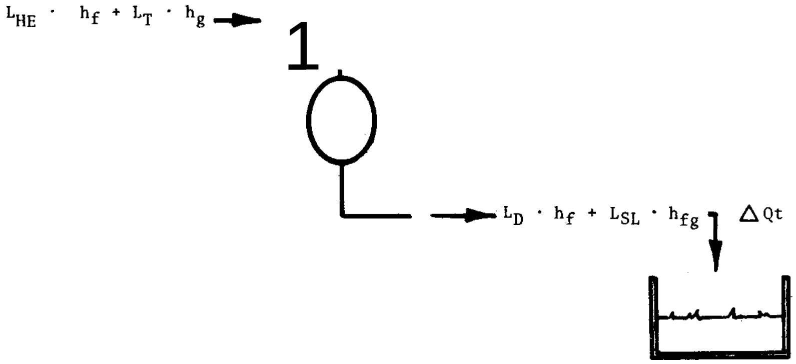
Q_{TL} - Total Heat Loss of Trap (BTU/HR)

LT - Total Steam Loss of Trap (LB/HR)

hg - Specific Enthalpy of Saturated Steam (BTU/LB)

The total trap losses which have been determined, represent the quantity of steam that passed through the heat exchanger without performing any useful work. These total losses are composed of two parts. The first part is attributed to the condensate generated within the trap as a result of convection and radiation losses from the trap body. The second part is live steam which has passed through the trap's orifice. To further evaluate the performance of the trap, the magnitude of this live steam loss is determined. The basis for this calculation is a heat balance between the trap and the trap discharge collection tank.

Figure No. 3



(Assuming the trap discharges saturated condensate plus possibly some live steam)

$\Delta Qt = L_D \cdot hf + L_{SL} \cdot hfg$ (BTU/HR) (Law of Conservation of Energy)

Where:

ΔQt - Heat Collected in Trap Discharge Tank (BTU/HR)

L_{SL} - Live Steam Loss of the Trap (LB/HR)

L_D - Load Discharged by Trap (LB/HR)

hf - Enthalpy of Condensate at Steam Temp. (BTU/LB)

hfg - Latent Heat Saturated Steam (BTU/LB)

The heat collected in the tank equals the change in total enthalpy of the tank and water during the time period of the test.

$Q_t = (E_F - EI)\ 60/t$

Where:

E_F - Total Enthalpy at the End of Test (BTU)

EI - Total Enthalpy at the Beginning of Test (BTU)

t - Length of Test (MIN)

To calculate the total enthalpy or heat of the tank-water system the water equivalent weight of the tank is first calculated. This is necessary because it obviously requires fewer BTU's to raise the temperature of the metal tank 1°F than to raise the temperature of the water 1°F.

$We = Wc \cdot C_{PC} / C_{PW}$ (LB)

Where:

We - Water Equivalent Weight of Tank (LB)

Wc - Weight of Tank (LB)

C_{PC} - Specific Heat Container (BTU/LB °F)

C_{PW} - Specific Heat Water (BTU/LB °F)

$We = .117\ Wc$

(Container is stainless steel; water in 50°F to 130°F range; container temp. $\approx H_2O$ Temp.)

And:

$WI = W_S - Wc + We$

$= W_S - WC + .117\ WC$

$= W_S - .883\ Wc$ (LB)

$W_F = WE - Wc + We$

$= WE - .883\ Wc$ (LB)

Where:

WI - Initial Weight H_2O + H_2O Equiv. Container (LB)

W_F - Final Weight H_2O + H_2O Equiv. Container (LB)

W_S - Initial Weight H_2O + Container (LB)

W_E - Final Weight H_2O + Container (LB)

The initial and final total enthalpys of the tank-water system are the following

$EI = W_I \cdot h_{fI}$ (BTU)

Where: h_{fI} - Specific Enthalpy of H_2O at Initial Temp. (BTU/LB)

$EF = W_F \cdot h_{fF}$ (BTU)

Where: h_{fF} - Specific Enthalpy of H_2O at Final Temp. (BTU/LB)

Again, the heat added to the trap discharge collection tank is the following:

$\Delta Q_t = (E_F - E_I)\ 60/t$

Or

$\Delta Q_t = (W_F \cdot h_{fF} - W_I \cdot h_{fI})\ 60/t$

But it was previously stated that:

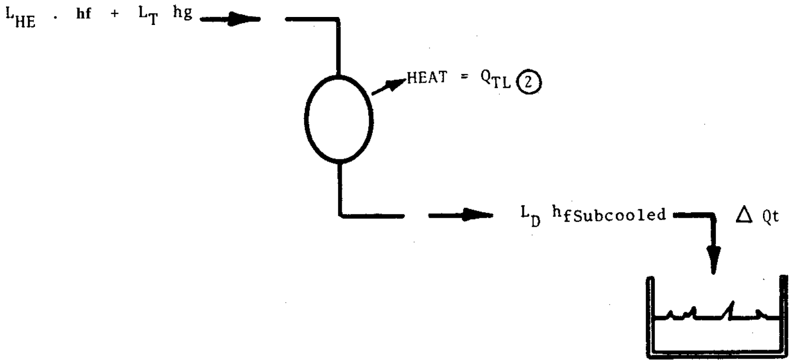
$$\Delta Q_t = L_D \cdot h_f + L_{SL} \cdot h_{fg}$$

Therefore, the live steam loss is determined:

$$L_{SL} = (\Delta Q_t - L_D\ h_f) / h_{fg}$$

Some traps back up condensate allowing it to cool below saturation temperature before it is discharged. When this condition exists, the assumption that the trap discharges saturated condensate plus possibly some live steam which was made in the above calculation of live steam loss, is invalid. As a result, the calculated live steam loss will appear negative. Obviously, the magnitude of the trap's live steam loss cannot be less than 0. When a trap discharges subcooled condensate only, the total trap heat loss can be evaluated as follows:

Figure No. 4



$$L_{HE} \cdot h_f + L_T \cdot h_g = Q_{TL\textcircled{2}} + L_D \cdot h_{fSubcooled}$$

(Law of Conservation of Energy)

But:

$$L_D \cdot h_{fSubcooled} = \Delta Q_t$$

So:

$$L_{HE} \cdot h_f + L_T \cdot h_g = Q_{TL\textcircled{2}} + \Delta Q_t$$

Or:

$$Q_{TL_{\textcircled{2}}} = L_{HE} \cdot hf + L_T \cdot h_g - \Delta Q_t$$

Where:

$Q_{TL_{\textcircled{2}}}$ - Total Trap Heat Loss (Subcooling) (BTU/HR)

L_{HE} - Condensate Load Generated in Heat Exchanger as Previously Calculated (LB/HR)

L_T - Total Steam Loss of Trap as Previously Calculated (LB/HR)

L_D - Load Discharged by Trap as Previously Calculated (LB/HR)

ΔQt - Heat Collected in Trap Discharge Tank (BTU/HR)

$h_{f\,Subcooled}$ - Specific Enthalpy of Subcooled Condensate (BTU/LB)

hf - Specific Enthalpy of Saturated Condensate (BTU/LB)

h_g - Specific Enthalpy of Saturated Steam (BTU/LB)

Two problems occasionally occur when testing steam traps which subcool the condensate before it is discharged. The first is caused by a trap which subcools the condensate to a temperature far below saturation resulting in a back-up of condensate into the heat exchanger. This adversely affects the accuracy in determining the condensate load generated in the heat exchanger. Therefore, the test must be considered invalid. The second is encountered when testing a trap which has a poor response to the system. These traps back-up a leg of condensate allowing it to subcool, then discharge all the condensate plus a quantity of live steam. In this case, the calculated live steam loss is in error. However, the total steam and total heat losses are still correct.

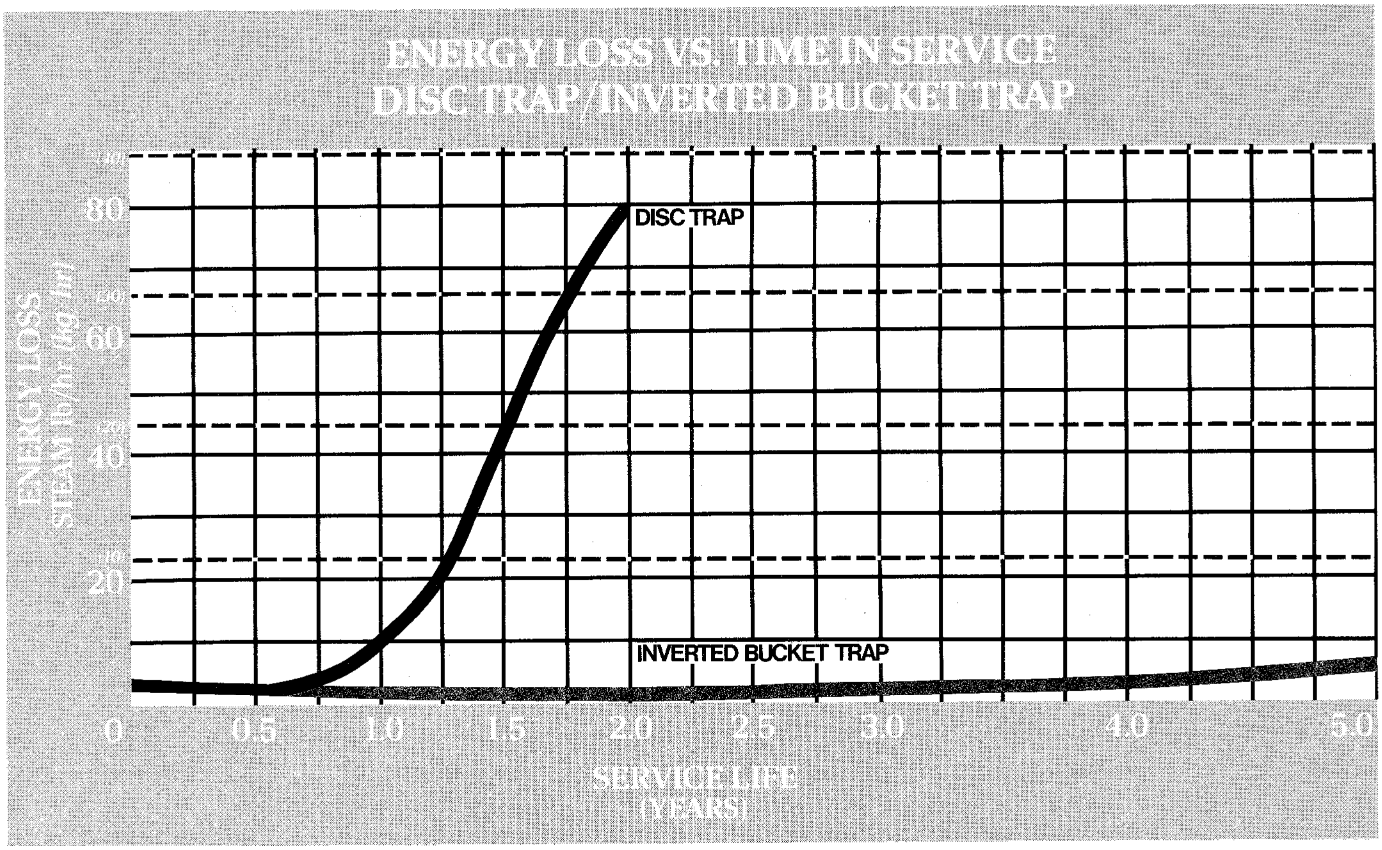
TEST RESULTS

With the information generated from the test just described, the energy loss characteristics of steam traps commonly used on drip and tracers can be evaluated and substantiated. Thousands of individual tests have been conducted on hundreds of traps. These traps were selected from operating mainline drip applications or tracer lines. The traps were operating traps supplied by chemical plants, refineries and petrochemical complexes. No "scrap heap" traps were used. Each trap regardless of manufacturer, type, make or design, was tested under identical conditions. All traps were tested under tracer line load characteristics: 2 to 50 lbs/hr. All traps were tested with an inlet pressure of 150 psig and an outlet pressure of 0 psig (no back pressure). Each test was conducted under an ambient temperature of -50°F. Similar tests were conducted under a higher ambient temperature with no substantial difference in the results. Although many types of traps were tested, the results from the testing of the thermodynamic type principle and the inverted bucket type principle have been completed and substantiated. Refer to the inverted bucket trap curve on the chart - last page.

This is the curve illustrating the results of the inverted bucket type principle. As the inverted bucket trap is placed in service, the trap action laps the surface of the valve actually showing a slight decrease in energy loss. The inverted bucket principle did not show substantial energy loss for five years. The curve is a composit of many traps, tested many times. It is not necessarily a curve of an Armstrong inverted bucket type steam trap, but of inverted bucket type steam traps used on drips and tracers in general. Refer to the disc trap curve on the chart - last page.

This is the curve of thermodynamic type drip and tracer steam traps. It is again a composite of many different traps tested many different times. For the first six months, the energy loss characteristic of these traps is quite similar to the inverted bucket principle. However, as the thermodynamic type trap wears, the disc or piston has a very predictable wear characteristic. The longer it is in service, the greater the probability it will increase its cycle rate and then eventually start "machine gunning." This characteristic shows up in steam loss from six months service life on. By the end of the first year, it may be losing over 10 lbs/hr or an average over the first year time period of 5 lbs/hr. During the two year life span, it very likely will be losing over 70 lbs/hr with an average of 23 lbs/hr per year. This is not a curve of an Armstrong thermodynamic trap, but a characteristic curve of thermodynamic or disc traps used on drips and tracers service in general.

Energy loss tests are being conducted on all types of traps. Based on the results of extensive laboratory testing, we conclude -- where energy conservation is a major criterion in selecting steam traps for drip or tracer line service, the inverted bucket type steam trap is more efficient than the thermo namic



ENERGY LOSS CHARACTERISTICS OF DRIP AND TRACER STEAM TRAPS

Chemical plants and refineries today are demonstrating an increasing interest in energy conservation. Fuel costs are rising and the availability of energy over the next ten to twenty years is the subject of much discussion. Any petrochemical producer who is concerned about the energy situation will not overlook the steam system in his plant. 3.7 million barrels of oil per day in the U.S. are used to produce steam. This is 17% of all U.S. energy usage; 47% of all industrial energy used. As energy costs continue to soar, steam becomes more valuable. The ability of a steam trap to provide maximum thermal efficiency in the steam system while not wasting steam itself is more important than ever.

The purpose of any steam trap is twofold: To retain the steam in the heat exchanger until it releases its very valuable latent heat of vaporization; then to release the condensate from steam space. If the steam trap is sluggish or backs up condensate into the heat exchanger, it increases the amount of time required to perform an operation. Efficiency in a steam trap includes more than the obvious aspect; preventing the loss of live steam. Efficiency is the ability to transfer a maximum quantity of heat at the heat transfer surface while using a minimum amount of steam.

A very important and measurable factor of any steam trap is the quantity of heat consumed by the trap. An effective new trap consumes a small amount of steam (from 1 to 2 lbs/hr). As trap parts wear and dirt accumulates, there can be a substantial rise in the amount of energy wasted by a steam trap. This amount of energy or steam consumed can and has been, accurately determined by laboratory controlled testing. It's the purpose of this technical paper to describe in detail this steam trap evaluation test.

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