ESTIMATING THE COST OF STEAM LOSS THROUGH THE ORIFICE OF A STEAM TRAP

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Investigation of steam loss in a steam system, or routine or preventive maintenance procedures, may reveal that one or more steam traps are leaking. How does the cost of repairing or replacing the defective steam traps compare to the value of the lost steam?

When a steam trap malfunctions, steam in form of vapor escapes through the outlet valve or orifice. The steam that escapes is wasted energy that cannot be recovered. By determining the amount of steam that escapes, it is possible to determine the financial loss and whether or not a trap maintenance and repair program would be beneficial. Steam loss through an orifice can be estimated using a variant of the Napier formula:

\[
\text{Steam Flow (lb/hr)} = 24.24 \times Pa \times D^2
\]

where:

- \( Pa = P_{gage} + P_{atmospheric} \)
- \( P_a = \text{Absolute Pressure, psia} \)
- \( P_{gage} = \text{Gage Pressure, psig} \)
- \( P_{atmospheric} = \text{Atmospheric Pressure, psi} = 14.696 \) psi
- \( D = \text{Diameter of Orifice, in.} \)

Example

\[
\begin{align*}
P_{gage} &= 5 \text{ psig} \\
P_a &= 19.696 \text{ psia} \\
D &= 0.1875 \text{ in} \\
W &= 24.24 \times 19.696 \times 0.1875 \times 0.1875 = 16.78 \text{ lbs/hr}
\end{align*}
\]

ESTIMATING ANNUAL FUEL COST PER STEAM TRAP

For a trap that is leaking continuously throughout the entire heating season, the cost for the loss of steam in the trap can be determined using the following formulas:

**Formula for Annual Fuel Cost per Trap - Using Cost per MMBtu in Natural Gas in Commercial Heating Systems:**

\[
Q = L \times H \times E \times 10^6 \times C \times \frac{1}{BE}
\]

where:

- \( Q \) = Energy Lost ($)
- \( L \) = Lb/HR of steam lost = 16.78 lbs/hr (0.187” orifice, 5 psig)
- \( H \) = Hours in heating season = 5,808
- \( E \) = Latent heat of steam at 5 psig = 960.8 Btu/lb
- \( 10^6 \) = MMBtu/Btu
- \( C \) = Cost of gas per million Btu = $6.23
- \( BE \) = Boiler Efficiency = 80%

\[
Q = \frac{(16.78) (5,808) (960.8) (10^6) (6.23)}{0.80} = $729.20
\]
**Equipment Cost**

If a steam trap maintenance program were to be implemented and the cost to repair or replace each defective trap were known, the Equipment Cost for the project can be determined as follows:

\[
\text{Equipment Cost} = \text{Cost per Trap} \times \text{Number of Traps}
\]

The Cost per Trap is:
- 3/4” Float and Thermostatic Trap = $65
- 1 hour labor = $35
- Cost per Trap = $100

Calculating the Equipment Cost for one trap:

\[
\text{Equipment Cost} = 100 \times 1 = 100
\]

**Simple Payback (years)**

The Simple Payback in terms of years is beneficial in determining the financial return of the proposed trap maintenance program. The quicker the payback, the more a project can be justified.

\[
\text{Simple Payback} = \frac{\text{Equipment Cost}}{\text{Savings}}
\]

Using the Annual Fuel Cost per Trap ($/M-Lb) and the Equipment Cost from above, the Simple Payback can be determined:

\[
\text{Simple Payback} = \frac{100}{729.20} = 0.1371 \text{ years or (1.645 months)}
\]

Figuring a total annual energy savings of $729.20 and an equipment cost of $100 for a new trap, the savings acquired from the replacement of just one trap would be enough to pay for 7 new traps. Greater savings and quicker paybacks would occur by using less expensive repair kits rather than a new unit in specific instances.

This is an example of the cost effectiveness of implementing a steam trap preventive maintenance program where traps are inspected, maintained, repaired and replaced on a regular basis.

**References**

- Techniques for Testing Steam Trap Operation, by Milton Hilmer, Chief Engineer, Sarco Co., Inc.
  Technical Publishing Company – 1977
- Testing Traps to Keep Your System Operating Effectively and Efficiently, by Joe Radle October 10, 2000
  Employed by Spirax Sarco, Inc. for 28 years.
- Spirax Sarco Design Of Fluid Systems – Hook-Ups

**Note:** The attached charts and table illustrate the steam loss at a variety of orifice sizes and steam pressures.
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STEAM LOSS THROUGH ORIFICES DISCHARGING TO ATMOSPHERE
STEAM CAPACITY THROUGH AN ORIFICE
(0 - 200 psig)

Flow Rate, lb/hr

Orifice Diameter, in

Inlet Pressure, psig

0 25 50 75 100 125 150 175 200

0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400
STEAM CAPACITY THROUGH AN ORIFICE
(15 - 30 psig)
STEAM CAPACITY THROUGH AN ORIFICE
(30 - 75 psig)

Inlet Pressure, psig

Orifice Diameter, in

Flow Rate, lb/hr

0  50  100  150  200  250  300  350  400  450  500  550  600

30  35  40  45  50  55  60  65  70  75
STEAM CAPACITY THROUGH AN ORIFICE
(75 - 125 psig)
STEAM CAPACITY THROUGH AN ORIFICE
(125 - 150 psig)
STEAM CAPACITY THROUGH AN ORIFICE
(150 - 200 psig)

Inlet Pressure, psig

Flow Rate, lb/hr

Orifice Diameter, in

150 155 160 165 170 175 180 185 190 195 200