U.S. DEPARTMENT OF ENERGY

SAVANNAH RIVER SITE, SC

CONDENSATE REMOVAL DEVICE EFFICIENCY STUDY: VENTURI VERSUS THERMODYNAMIC TYPE STEAM TRAPS

PERFORMED BY:

Proficient Technologies

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PRIMESOUTH (SCE&G)

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EXECUTIVE SUMMARY

The purpose of this collaboration between Proficient Technologies and PrimeSouth was to compare the efficiency of the Proficient Technologies venturi type steam trap replacement device to that of the various thermodynamic steam traps currently in use throughout the 385 psig steam distribution system at the U.S. Department of Energy's Savannah River Site location. Four testing locations were chosen for the study. At each location the efficiency of the existing, properly operating, thermodynamic steam trap was tested. It was then replaced by a properly sized Proficient Technologies steam trap replacement device that was tested as well. The average steam loss of the thermodynamic traps was 27.5 lbs/hr. The average steam loss of the Proficient Technologies devices was 9 lbs/hr. The difference, 18.5 lbs/hr, represents an average savings of $1,620/yr (steam cost = $10/1,000lbs & 8,760 hrs/yr) associated with replacing a thermodynamic steam trap with a Proficient Technologies venturi type steam trap replacement device.

STUDY OVERVIEW

OBJECTIVE

The objective of this study was to compare the condensate removal efficiency of the existing steam traps on the steam distribution header to that of the Proficient Technologies steam trap replacement devices. In other words, we wanted to determine which device removed the condensate from the steam distribution header with minimum steam loss.

TESTING APPARATUS

The test apparatus is referred to as a *calorimeter*. The calorimeter consists of an insulated twenty-gallon carbon steel tank. The tank is on wheels for mobility purposes. This tank has an inlet for the steam trap's discharge to enter, vent to maintain it at atmospheric pressure and a temperature probe. A separate scale is used to measure the calorimeter and its content's mass.

ANSI/ASME PTC 39.1 1980 (REAFFIRMED 1991)

The ANSI/ASME PTC 39.1 is the Performance Test Code for Condensate Removal Devices for Steam Systems. Our test procedures and steam loss calculations follow those in this specification. The calorimeter we used is also used by Proficient Technologies to determine the capacities of different nozzle designs and arrangements. For this purpose, we had already experimentally determined the equivalent water thermal mass of our calorimeter. The ANSI/ASME specification uses the c_p value for the calorimeter material at the average temperature. In either case, this figure is a constant in the calculations. It will be the same for both devices being tested, therefore, irrelevant when comparing the steam losses.

TEST LOCATIONS

The study was conducted on June 10^{th} and 11^{th}, 1999. A ten-inch diameter distribution header was chosen for the testing. This header has approximately fifteen trap stations between the powerhouse and the processing facility where the steam is utilized. Steam flow is recorded at the powerhouse and the entrance to the processing facility, therefore, energy losses in the distribution header are known. If one technology proves to be a more efficient manner of condensate removal, all fifteen trap stations could be converted and the subsequent data collected from the steam flow meters will confirm this study's findings. Four test locations were chosen on this header; one at the beginning, one at the end and the other two in-between. All the drip stations discharge to the ground, therefore, the existing traps were confirmed to be operating properly by a visual inspection.

TESTING PROCEDURE

1) The calorimeter was initially weighed empty to determine its mass.

2) The calorimeter was then filled halfway with tap water. This was to insure that all of the discharge from the device being tested would be condensed and collected.

   a) The calorimeter and water were weighed.

   b) The temperature was noted.

3) Location, make and model of the condensate removal device were recorded.

4) Steam pressure was noted.

5) The calorimeter was connected to the condensate removal device. The discharge at this time was bypassing the calorimeter and going to the ground.

6) The system was allowed to return to steady state operation.

   a) The calorimeter and water temperature was confirmed.

   b) Instantaneously, a stopwatch was started and the discharge was valved into the calorimeter.

7) Instantaneously, the elapsed time was recorded and the discharge into the calorimeter was discontinued.

   a) The calorimeter and water were weighed.

   b) The temperature was noted.

8) The procedure was then repeated for the alternate device.

DEFINITION OF VARIABLES

M_c – mass of the calorimeter empty = 77.5 lbs

M_i – initial mass of tap water in the calorimeter

M_f – final mass of water (tap & discharge collected) in the calorimeter

M_d – discharge collected from trap = $M_f - M_i = M_s + M_w$

M_s – mass of steam in trap discharge

M_w – mass of condensate in trap discharge

T_i – initial temperature of tap water and the calorimeter

T_f – final temperature of water (tap & discharge collected) and the calorimeter

c_p – specific heat of water from 40 to 212 degrees F = 1.0

M_e – equivalent water thermal mass (c_p = 1.0) of calorimeter = 32 lbs

h_f – enthalpy of condensate at steam trap inlet pressure

h_g – enthalpy of steam at steam trap inlet pressure

h_{fg} – enthalpy of evaporation at steam trap inlet pressure = $h_g - h_f$

t – length of time trap discharge collected

P_i – pressure at steam trap inlet

EQUATION DERIVATION

(1) $Q = M*c_p*dT$

Therefore,
(2) $Q_{initial} = (M_e+M_i)*c_p*(T_i - 32)$
(3) $Q_{final} = (M_e+M_i+M_d)*c_p*(T_f - 32)$

Substituting $c_p = 1.0$, equations (2) & (3) become:
(4) $Q_{initial} = (M_e+M_i)(T_i - 32)$
(5) $Q_{final} = (M_e+M_i+M_d)(T_f - 32)$

Heat added by the discharge collected is the difference between equations (4) & (5):
(6) $dQ = (M_e+M_i+M_d)(T_f - 32) - (M_e+M_i)(T_i - 32)$

Which simplifies to:
(7) $dQ = (M_e+M_i)(T_f - T_i) + M_d(T_f - 32)$

Heat added by the discharge collected is *also* equivalent to:
(8) $dQ = M_w*h_f + M_s*h_g$

Since we need to solve for M_s, substitute $M_w = M_d - M_s$ into equation (8):
(9) $dQ = (M_d - M_s)*h_f + M_s*h_g$

Which simplifies to:
(10) $dQ = M_d*h_f + M_s*h_{fg}$

Solving equation (10) for M_s:
(11) $M_s = (dQ - M_d*h_f)/h_{fg}$

Substituting equation (7) into equation (11):
(12) $\mathbf{M_s = ((M_e+M_i)(T_f - T_i) + M_d(T_f - 32) - M_d*h_f)/h_{fg}}$

TEST #1

Test location: Station 2-11
Application: Steam distribution system drip leg
P_i – pressure at steam trap inlet = 385 psig
h_f – enthalpy of condensate at steam trap inlet pressure = 424 Btu/lb
h_{fg} – enthalpy of evaporation at steam trap inlet pressure = $h_g - h_f$ = 780 Btu/lb

Device tested: [redacted]-[redacted]

M_i – initial mass of tap water in the calorimeter = 79.5 lbs
T_i – initial temperature of tap water and the calorimeter = 79.5 degrees F

t – length of time trap discharge collected = 9 minutes

M_f – final mass of water (tap & discharge collected) in the calorimeter = 95.5 lbs
M_d – discharge collected from trap = $M_f - M_i = M_s + M_w$ = 16 lbs
T_f – final temperature of water (tap & discharge collected) and the calorimeter = 151.5 degrees F

Substituting into equation (12), ***the rate of steam loss is:***

$\mathbf{M_s} = ((M_e+M_i)(T_f - T_i) + M_d(T_f - 32) - M_d{*}h_f)/h_{fg}$ **= 27 lbs/hr**

Device tested: Proficient Technologies – TGETB7

M_i – initial mass of tap water in the calorimeter = 76.5 lbs
T_i – initial temperature of tap water and the calorimeter = 79 degrees F

t – length of time trap discharge collected = 9 minutes

M_f – final mass of water (tap & discharge collected) in the calorimeter = 93 lbs
M_d – discharge collected from trap = $M_f - M_i = M_s + M_w$ = 16.5 lbs
T_f – final temperature of water (tap & discharge collected) and the calorimeter = 134 degrees F

Substituting into equation (12), ***the rate of steam loss is:***

$\mathbf{M_s} = ((M_e+M_i)(T_f - T_i) + M_d(T_f - 32) - M_d{*}h_f)/h_{fg}$ **= 5.5 lbs/hr**

TEST #2

Test location: Station 3-10
Application: Steam distribution system drip leg
P_i – pressure at steam trap inlet = 385 psig
h_f – enthalpy of condensate at steam trap inlet pressure = 424 Btu/lb
h_{fg} – enthalpy of evaporation at steam trap inlet pressure = h_g – h_f = 780 Btu/lb

Device tested: [redacted]

M_i – initial mass of tap water in the calorimeter = 82.5 lbs
T_i – initial temperature of tap water and the calorimeter = 74 degrees F

t – length of time trap discharge collected = 13 minutes & 4 seconds

M_f – final mass of water (tap & discharge collected) in the calorimeter = 100 lbs
M_d – discharge collected from trap = M_f – M_i = M_s + M_w = 17.5 lbs
T_f – final temperature of water (tap & discharge collected) and the calorimeter = 174 degrees F

Substituting into equation (12), ***the rate of steam loss is:***

$\mathbf{M_s} = ((M_e+M_i)(T_f - T_i) + M_d(T_f - 32) - M_d*h_f)/h_{fg}$ **= 38.5 lbs/hr**

Device tested: Proficient Technologies – TGEBB2

M_i – initial mass of tap water in the calorimeter = 84 lbs
T_i – initial temperature of tap water and the calorimeter = 79 degrees F

t – length of time trap discharge collected = 13 minutes & 4 seconds

M_f – final mass of water (tap & discharge collected) in the calorimeter = 93 lbs
M_d – discharge collected from trap = M_f – M_i = M_s + M_w = 9 lbs
T_f – final temperature of water (tap & discharge collected) and the calorimeter = 116 degrees F

Substituting into equation (12), ***the rate of steam loss is:***

$\mathbf{M_s} = ((M_e+M_i)(T_f - T_i) + M_d(T_f - 32) - M_d*h_f)/h_{fg}$ **= 7.5 lbs/hr**

TEST #3

Test location: Station 8-20
Application: Steam distribution system drip leg
P_i – pressure at steam trap inlet = 385 psig
h_f – enthalpy of condensate at steam trap inlet pressure = 424 Btu/lb
h_{fg} – enthalpy of evaporation at steam trap inlet pressure = $h_g - h_f$ = 780 Btu/lb

Device tested: [redacted] [redacted]-[redacted]

M_i – initial mass of tap water in the calorimeter = 83 lbs
T_i – initial temperature of tap water and the calorimeter = 80 degrees F

t – length of time trap discharge collected = 8 minutes & 5 seconds

M_f – final mass of water (tap & discharge collected) in the calorimeter = 105.5 lbs
M_d – discharge collected from trap = $M_f - M_i = M_s + M_w$ = 22.5 lbs
T_f – final temperature of water (tap & discharge collected) and the calorimeter = 162 degrees F

Substituting into equation (12), ***the rate of steam loss is:***

$\mathbf{M_s} = ((M_e+M_i)(T_f - T_i) + M_d(T_f - 32) - M_d*h_f)/h_{fg}$ **= 27 lbs/hr**

Device tested: Proficient Technologies – TGETC4

M_i – initial mass of tap water in the calorimeter = 82.5 lbs
T_i – initial temperature of tap water and the calorimeter = 78 degrees F

t – length of time trap discharge collected = 8 minutes & 5 seconds

M_f – final mass of water (tap & discharge collected) in the calorimeter = 102 lbs
M_d – discharge collected from trap = $M_f - M_i = M_s + M_w$ = 19.5 lbs
T_f – final temperature of water (tap & discharge collected) and the calorimeter = 143 degrees F

Substituting into equation (12), ***the rate of steam loss is:***

$\mathbf{M_s} = ((M_e+M_i)(T_f - T_i) + M_d(T_f - 32) - M_d*h_f)/h_{fg}$ **= 12.5 lbs/hr**

TEST #4

Test location: Station 6-25
Application: Steam distribution system drip leg
P_i – pressure at steam trap inlet = 385 psig
h_f – enthalpy of condensate at steam trap inlet pressure = 424 Btu/lb
h_{fg} – enthalpy of evaporation at steam trap inlet pressure = h_g – h_f = 780 Btu/lb

Device tested: [redacted]-[redacted]

M_i – initial mass of tap water in the calorimeter = 82 lbs
T_i – initial temperature of tap water and the calorimeter = 80 degrees F

t – length of time trap discharge collected = 8 minutes & 25 seconds

M_f – final mass of water (tap & discharge collected) in the calorimeter = 109 lbs
M_d – discharge collected from trap = $M_f - M_i = M_s + M_w$ = 27 lbs
T_f – final temperature of water (tap & discharge collected) and the calorimeter = 165.5 degrees F

Substituting into equation (12), ***the rate of steam loss is:***

$\mathbf{M_s} = ((M_e+M_i)(T_f - T_i) + M_d(T_f - 32) - M_d{*}h_f)/h_{fg}$ **= 17.5 lbs/hr**

Device tested: Proficient Technologies – TGETC4

M_i – initial mass of tap water in the calorimeter = 82.5 lbs
T_i – initial temperature of tap water and the calorimeter = 84 degrees F

t – length of time trap discharge collected = 9 minutes

M_f – final mass of water (tap & discharge collected) in the calorimeter = 104 lbs
M_d – discharge collected from trap = $M_f - M_i = M_s + M_w$ = 21.5 lbs
T_f – final temperature of water (tap & discharge collected) and the calorimeter = 152 degrees F

Substituting into equation (12), ***the rate of steam loss is:***

$\mathbf{M_s} = ((M_e+M_i)(T_f - T_i) + M_d(T_f - 32) - M_d{*}h_f)/h_{fg}$ **= 10.5 lbs/hr**