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MINIMIZING STEAM LOSS THROUGH STEAM DISTRIBUTION NETWORK USING AN INTEGRATED METHODOLOGY –A CASE STUDY OF A CRUDE OIL REFINERY

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Abstract: *Steam comprises approximately 30% of the energy consumed in a typical petroleum Refinery. The results of the various steam trap performance assessment programs reveal that approximately 20% of the steam leaving a main boiler plant is lost via leaking traps in distribution network. In Petroleum Refineries the cost of steam loss through steam distribution network is insignificant as compared to production loss still the energy consumption leads to new awareness because of considerable environmental impact. Steam network performance is vital for process plant reliability, safety and product yield. Therefore, process plants need effective ways to reduce the amount of energy consumed by their steam network. Regular industry practice is to replace faulty traps by similar ones based on survey reports. However, this can induce further failures in case of insufficient preventive maintenance of steam network. In such cases, simple repairs and maintenance or one to one replacement of traps will not be the suitable choice because of severe pipeline corrosion and/or previous water and steam hammer effects on the traps and pipelines. Also, it malfunctions new technology traps which otherwise might be able to perform better. This paper presents performance improvement method in a Crude Oil Refinery, through a case study of steam network having 12,0000 steam traps. The method consists of an integrated approach of replacement of correct technology steam traps along with preventive maintenance schedule in place. The Root cause failure analysis (RCFA) performed using fishbone diagram for steam network elements and existing defective steam traps replaced with improved technology traps. Finally steam distribution network performance evaluation as per UNFCCC guidelines.*

Key words: Steam, Steam Traps, RCFA, Preventive Maintenance, Shutdown, UNFCCC.

1. INTRODUCTION

The Refining processes take place at elevated temperatures and heat transfer is the most used transport phenomenon. Refineries are designed to use steam, because steam is an important energy recovery mechanism as when process streams need to be cooled and recover waste heat so that a process should be much more energy efficient. Steam uses include turbines for running pumps and compressors, steam tracing and steam jacketing to keep viscous processes fluid in pipelines and soot blowing. Steam is used as source of heat for reboilers, stripper column to aid in stripping of different processes streams. In fuel oil fired furnaces steam is required to atomize the fuel oil to burn properly and in flares to aid in complete combustion of residual processes gases. The regular industrial practice is to adapt break down maintenance for failed traps based on plant shutdown availability and no active steam trap maintenance schedules are followed. Average quality traps may have just a 4-year life expectancy i.e. around 25% failure rate, while higher quality steam traps may have an 8-year life expectancy i.e. around 12.5% average failure rate. It is more likely that the underlying failure rate of steam traps is closer to a generally acceptable range of 15% - 20% per year [1]. Steam trap failures or design issues can quickly escalate into production problems. At the very least, they can be a significant source of energy loss, as past inspection results show that, on average, approximately 6.6 metric TPH of steam leakage due to trap failure can be expected from a medium-sized refinery with a trap population of 10,000[2]. In a steam plant if no trap preventive maintenance activities are done, up to 30% of the traps may fail within 3 to 5 years and that any one time, up to 50% may be blowing live steam [3]. In a report on adoption of trap maintenance in Textile industries in India [4], suggested that "Lack of Steam Trap Knowledge Is the Weakest Link". It is true, when considering the steam distribution systems in the process; the steam trap is the least understood equipment. In a nutshell, if a company with a steam trap capacity of 100 is adapting proper maintenance plan for the steam traps means they could save approximately 8-10 lakhs of rupees and further 400 tonnes of fuel per annum. Steam traps use a minimal amount of energy. Losses only become significant when traps are defective. The important thing therefore is to combine selection, checking and maintenance to achieve reliability. [5].

This paper illuminate's potential of energy saving through regular active maintenance of faulty traps in steam network. The significant steam losses justify the implementation of a program for traps reliability improvement through sustainable maintenance for the steam distribution network in its totality, increasing plant efficiency. It gives preference to establish a preventive maintenance plan over only third party audits. Study focuses on repair or replacement on the basis of root cause analysis of critical traps against only periodic replacement of faulty traps based on recommendation of third party audit results.

Examples: Steam leak problem in Industry

2. FUNDAMENTALS OF STEAM NETWORK:

Steam traps are automatic valves used in every steam system to remove condensate, air, and other non-condensable gases while preventing or minimizing the passing of steam. If condensate is allowed to collect, it reduces the flow capacity of steam lines and the thermal capacity of heat transfer equipment. In addition, excess condensate can lead to water hammer, with potentially destructive and dangerous results. Air that remains after system start-up reduces steam pressure and temperature and may also reduce the thermal capacity of heat transfer equipment. Non-condensable gases, such as oxygen and carbon dioxide, cause corrosion.

2.1. Types of steam traps

a) Mechanical traps

Mechanical traps have a float that rises and falls in relation to condensate level and this usually has a mechanical linkage attached that opens and closes the valve. Mechanical traps operate in direct relationship to condensate levels present in the body of the steam trap. Inverted bucket and float traps are examples of mechanical traps.

b) Temperature traps

Thermostatic Steam Traps work on the temperature difference between steam and condensate. Condensate is at a temperature lower than the steam being used. Thermostatic type of steam trap has a port which is opened or closed based on the temperature of the inlet fluid. If the temperature is above the specified range, the port is closed. The port open when the temperature of the fluid falls down below the previously specified value. Bi-Thermostatic traps, Liquid expansion and balance pressure traps are examples of thermostatic traps.

c) Thermodynamic (TD) traps

Thermodynamic traps work on the difference in dynamic response to velocity change in flow of compressible and incompressible fluids. As steam enters, static pressure above the disk forces the disk against the valve seat. The static pressure over a large area overcomes the high inlet pressure of the steam. As the steam starts to condense, the pressure against the disk lessens and the trap cycles. This essentially makes a TD trap a "time cycle" device.

2.2. TESTING METHODS OF STEAM TRAP

a) Visual Testing

Visual observation is an important first step in determining whether a trap is operating properly or not. For example, certain visual signs such as the lack of any condensate discharge or extremely large quantities of steam leaking out of a trap may indicate the need for trap repair. Traps can also be externally inspected for pinhole, connection joint, and gasket leaks.

b) Sound Testing

Condensate flowing through a trap produces sound and vibration, and so does the opening and closing valve mechanism of most traps. When a trap is no longer operating as intended (from wear, blockage or some other reason) these sounds will often change. Recognizing this difference can be one method of assessing a steam trap's condition. Sound testing includes ultrasonic leak detectors, mechanics stethoscopes, screwdriver or metal rod with a human ear against it.

c) Temperature Testing

Temperature testing includes infrared guns, surface pyrometers, temperature tapes, and temperature crayons. Typically, they are used to gauge the discharge temperature on the outlet side of the trap. The low reading generally indicates an undersized trap, incorrect pressure orifice for the trap, a blocked trap/strainer discharge failure. Blocked or turned off traps can easily be detected by infrared guns and surface pyrometers, as they will show low or cold temperatures. They could also pick up traps which may be undersized or backing up large amounts of condensate by detecting low temperature readings.

2.3. PERFORMANCE TESTING OF STEAM TRAPS

Along with selecting the correct trap for the application, the trap design must insure efficient operating performance and be tested by approved methods accepted throughout the industry.

Performance testing of steam traps done as per "International Standard ISO 7841" "Automatic steam traps – Determination of steam loss – Test methods". This test determines the amount of live steam / functional steam if any, that is lost through the steam trap when steam trap is functional and acceptable conditions.

2.4. Steam network design and operating parameters:

Table gives the basic data regarding the Utility Steam used in Refinery:

Table: 1

Service	Operating Pressure (kg/cm2)	Operating Tempt. (deg. C)	Design Pressure (kg/cm2)	Design Tempt. (deg. C)
LP Steam	4.5	155	6	163
MP Steam	10	260	12.5	273
HP Steam	15	280	18.8	293
VHP Steam	45.5	365	51.4	402

3. ROOT CAUSE FAILURE ANALYSIS OF STEAM NETWORK ELEMENTS: Important take away from the fishbone diagram:

Root cause failure analysis of "steam distribution network" the causes and their effects observed are given below:

i. **Steam Traps:**
  a. Incorrect selection of steam traps according to service application wise.
  b. Wrong selection of steam traps according to steam pressure & temperature wise.
  c. Non-functioning traps i.e. plugged, chocked traps which leads excess load on other functioning traps.

ii. **Maintenance method:**
  a. Lack of regular monitoring and preventive maintenance schedule of Steam Traps.
  b. Accumulated condensate carryover through steam lines due to unavailability of trap or chocked condition of existing traps.
  c. Lack of analysis of regular survey results and poor database management.

iii. **Pipeline elements:**
  a. Thinned down and corroded pipe lines are susceptible and easily start leaking.
  b. Improper support to steam lines leads leaking in lines & weld joints.
  c. Condensate discharge with high velocity through leak prone locations such as pipe elbow joints, flange joints, fitting joints, valve glands.

iv. **Insulation:**
  a. Lose & dislodged insulation leads heat loss, excess condensate generation, also dangerous from safety point of view.
  b. Lack of regular replacement of damaged or ineffective insulation.
  c. Improper insulation leads to surplus condensate discharge with high velocity causes water hammer, excess wear & tear of Steam lines.

v. **Technicians:**
  a. Less equipment knowledge specially steam traps.
  b. Lack of portable testing tools.
  c. Poor workmanship.

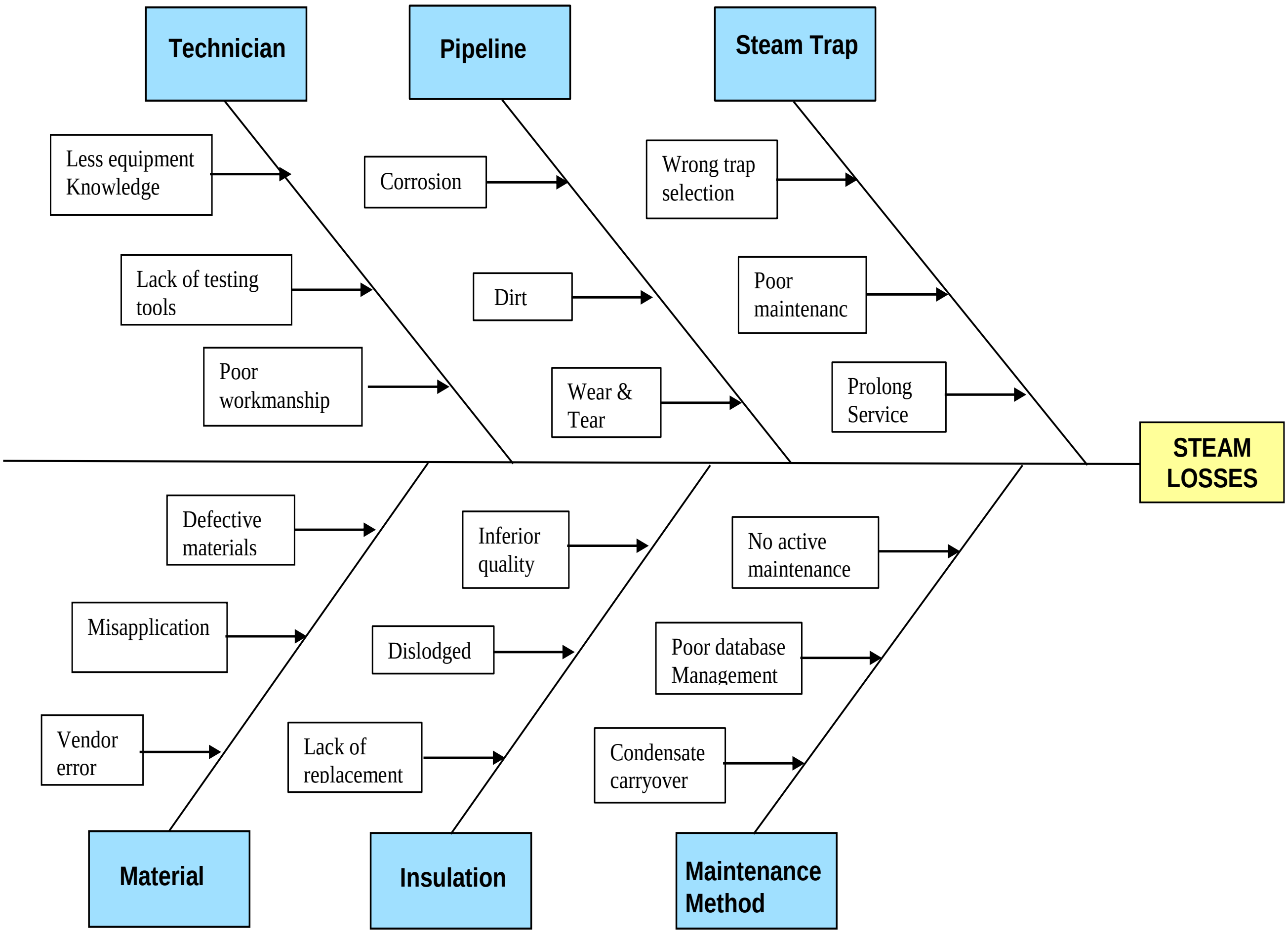


Figure 1: Fishbone diagram for steam distribution network elements.

vi. **Material:**

a. Misapplication, improper selection of material according to service.
b. Vendor error on account of performance testing and in transit damage.
c. Defective materials on account of improper raw material selection.

4. RESEARCH METHODOLOGY:

Minimizing steam loss – through an integrated approach:

The conventional steam trap survey and annual steam trap audits may not be able to identify all the problem areas. To achieve the visible performance improvement and safe operating conditions, a comprehensive & sustainable approach to steam network performance optimization is required. The various phases of such an integrated approach are as follows:

Phase 1: Steam network survey, traps inspection and generation of database:

- To identify entire steam trap population health status
- Calculating the steam losses according to steam trap failure mode.
- Coding and tagging each steam trap with unique identification number.
- Preparation of database with recommendation of correct steam trap.
- Estimation of direct steam leaks if any from header lines.
- Practical & cost effective solutions for improving performance of the steam traps.

Phase 2: Root cause failure analysis and correct technology trap selection for replacement of defective steam traps

- Identifying root causes of failure of steam traps.
- Thickness gauging of pipeline & components at corrosion prone locations like elbow, bend and weld joints.

- Replacement of all the identified defective traps with correct technology trap.
- Replacement of thinned down, corroded pipe lines, loose & dislodged insulation.
- Repairing of plugged, chocked traps with spare kit.
- Implementation of survey & inspection results for effective maintenance actions.

Phase 3: Standardizing the steam trap system to the best industry standard with system improvement

- Improving the system performance with selection based on pressure level and the applications to avoid improper assortment.
- Benchmarking the steam trap installation.
- Maintaining the Inventory details with standardized selection & lead times.
- Proper selection & management of steam traps based on the parameters like pressure, temperatures, application, and condensate load etc.

Phase 4: Sustenance of steam traps failure rate to agreed percentage

- Rectification of all irregularities in the steam trap system to its optimum operational level to ensure energy losses due to steam leaks are within acceptable range.
- Selection and implementation of comprehensive contracting philosophy considering non-interchangeability of traps & spares of different manufacturers.
- Frequent monitoring & testing of all critical steam traps.
- Training and awareness programs for team members.
- Quarterly random audit of identified performance of seam traps.
- Maintaining the history of steam trap failure, repair and replacement activities for future reference.

5. STEAM LOSS CALCULATIONS (THROUGH TRAPS) – UNFCCC METHODOLOGY

TERMS	DESCRIPTION	DEFINITION
OK	Good trap	Trap in normal operating mode.
BT	Blow thru	Trap has failed in an open mode with maximum steam loss. Trap should be repaired or replaced.
LK	Leaking	Trap has failed in a partially open mode with a steam loss of approximately 25% of maximum. Trap should be repaired or replaced.
RC	Rapid cycling	Disc trap going into failure mode.
PL	Plugged	Trap has failed in a closed position and is backing up condensate. Trap should be repaired or replaced.
FL	Flooded	Trap is assumed to be undersized and unable to handle the condensate load. Trap should be replaced by one of proper size.
OS	Out of service	The steam supply line is off and the trap is not in service.
NT	Not tested	Trap in service but not tested due to inaccessibility, unable to reach, too high, etc.

Table 2: Definitions in identifying failed steam traps:

Steam losses due to failed steam traps are calculated for each steam trap individually, based on the results of the steam trap survey. The loss of a steam trap is calculated with the following formula, which is derived from the Masoneilan approach, but has been adjusted to estimate steam losses in a more conservative manner:

$$L_{t,y} = (1kg/2.2046) FT_{t,y} * FS_{t,y} * CV_{t,y} * h_{t,y} * \sqrt{(P_{in,t} - P_{out,t})*(P_{in,t} + P_{out,t})} \quad (1)$$

Where,
t : steam trap and
y : is the period.
$L_{t,y}$: Loss of steam (in kg)
$FT_{t,y}$: failure type factor of 't' during 'y'.
$FS_{t,y}$: service factor
$CV_{t,y}$: flow coefficient.
$h_{t,y}$: hours for which trap 't' is operating.
$P_{in,t}$: pressure of steam at inlet of trap in Psia.
$P_{out,t}$:outlet pressure of condensate at outlet of trap in Psia.

Table 3: Failure Type Factor FT

Type of failure	FT
Blow-thru (BT)	1
Leaking (LK)	0.25
Rapid cycling (RC)	0.2

$$FS = 2.1*(s-1)/s \quad (2)$$

Where, FS – is the service factor and 's' is the capacity factor.

Table 4: Service Factor FS

Application	Capacity safety factor S	Service Factor FS
Process steam traps	1.75	0.9
Drip and tracer steam traps	3.0	1.4
Steam flow (no condensate)	Very large	2.1

Finally, steam losses depend on the actual size of the orifice. The flow coefficient CV is a function of the orifice size:

$CV=22.1*D^2$ ---------------------- (3)

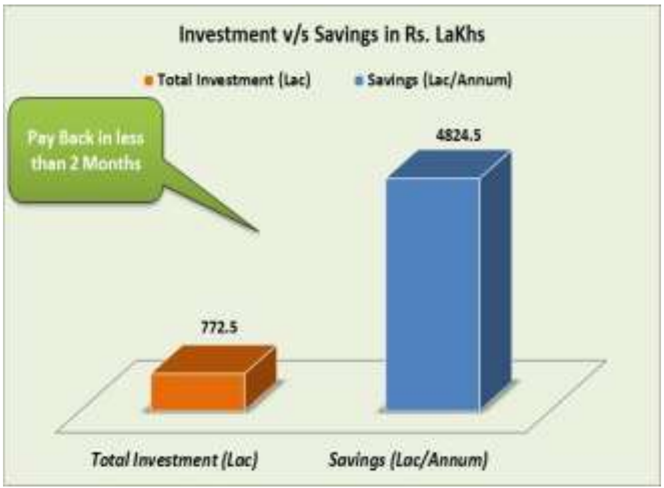
Where, CV - is the floe Coefficient & 'D' is the diameter of orifice of steam trap in meters.

With table 2, table 3 and equations 1 and 3 the loss of each failing steam trap can be calculated. The total steam savings due to the repair and/or replacement of steam traps are calculated as the difference between losses in the absence of the project (baseline) and losses identified in the plant during monitoring.

6. RESULTS AND DISCUSSIONS:

In most process plants, maintenance of steam traps is not a routine job and is neglected unless it leads to some definite trouble in the plant. In view of their importance as steam savers and to monitor plant efficiency, the steam traps require considerably more care than is given. One may consider a periodic maintenance schedule to repair and replace defective traps in the shortest possible time, preferable during regular maintenance shut downs in preference to break down repairs. The prime objective here is to ensure optimum operational efficiency and economy of steam distribution network through selection of correct technology traps along with established preventive maintenance plan:

i. The correct selection of steam traps according to service application wise will improve the efficiency of the steam network.
ii. By selection of correct technology steam traps according to steam pressure & temperature wise will increase the service life of the trap.
iii. Through implementation of regular monitoring and preventive maintenance schedule of Steam traps, associated pipelines & insulation will improve the overall reliability of steam network.
iv. By implementation of integrated methodology of proper technology steam trap selection with preventive maintenance in place will minimize the steam loss and serve multipurpose of energy saving, input cost reduction & minimizing the environmental impacts.
v. Through implementation of integrated methodology, steam distribution network overall performance found in the range of 90% to 95%.
vi. Steam Saving calculation:
Total steam loss Kg/ Hr – 25424
Cost replacement of all defective steam traps (6129 Nos.) – Rs. 772.5 Lakhs
Saving Per annum – Rs. 4824.5 Lakhs



7. CONCLUSION:

Steam distribution system are containing steam traps to remove condensation from the piping to protect plant equipment and allow the efficient operation of plant equipment and processes. When they fail, there is a significant monetary and environmental impact. The traditional method of annual audits and breakdown maintenance has drawbacks that it only looks at periodic assessment of the performance. In addition, annual audits leave the distribution network vulnerable to long periods of failed steam traps.
In case study done in crude oil Refinery having 12000 steam traps in steam distribution network, to reduce steam losses, and improve efficiency, the following observation found:

i. In first survey of steam distribution network, overall performance rate found 47% and defective steam traps in the system were 53%.
ii. Out of 53% defective steam traps, 30% traps were plugged and 12% found leaking.
iii. Application wise, steam traps correct installation found 63%. There were no trap locations 21% and 16% incorrect steam traps installation.

Based on results obtained, the following points concluded from study that "to minimize steam loss in distribution network" with the implementation of integrated methodology of regular preventive maintenance accompanied with RCFA and correct technology trap selection gives better results. It improves the plant operational efficiency by maintaining the steam quality at the end use point and reduces the steam losses which results in cost saving as well as minimizing the environmental impacts.

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