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Steam trap performance and process plant efficiency

INTRODUCTION

Contrary to the image created by the demise of steam-powered locomotives in favour of diesel or electric trains, the use of steam as a heating medium for the process industry continues to grow.

There are several reasons for this, not the least of which is that any release of steam into the atmosphere will have little damaging effect upon the environment. However, we cannot escape the fact that the generation of steam involves some form of energy, usually the combustion of coal, oil, or wood. Such fuels are expensive and their very combustion raises questions about the release of increased quantities of greenhouse gases into the atmosphere.

It is not surprising, therefore, that companies engaged in manufacturing, which utilise steam as their prime heating medium focus their attention upon improving boiler efficiency as a means of controlling their energy costs. Whilst this is important, it is by no means the whole story. A simple analogy is to compare the boiler and the associated steam system with a car whose petrol engine has been tuned to its peak performance, but whose wheels are not round and whose tyres are completely flat. The overall efficiency is, as a result, extremely poor.

Similarly a great deal of effort and costs can be spent on the boiler plant, plus associated controls, but the high quality steam being delivered to the process plant can be needlessly squandered. Once again, several factors play a part in the eventual reduction of the overall plant efficiency, but none more so than the performance of the humble, low cost, steam trap.

THE FUNCTION OF A STEAM TRAP

When saturated steam flows into the tubes of some form of heat exchanger, a rapid transfer of heat occurs. The steam gives up its valuable latent heat, (the specific enthalpy of evaporation), with the result that condensate, (high temperature water), at the same pressure and temperature as that of the steam, forms on the walls of the tubes.

If this condensate is allowed to remain in the ‘steam space, it will inhibit the further flow of steam into the heat exchanger tubes and, hence, slow down the rate of heat transfer. What is required is a simple device that will allow the condensate to drain from the tubes into a return piping system, but prevent the escape of steam. Such a device is a ‘steam trap’ (see Figure 1). Various models, employing different principles of operation, are available from a wide range of manufacturers.

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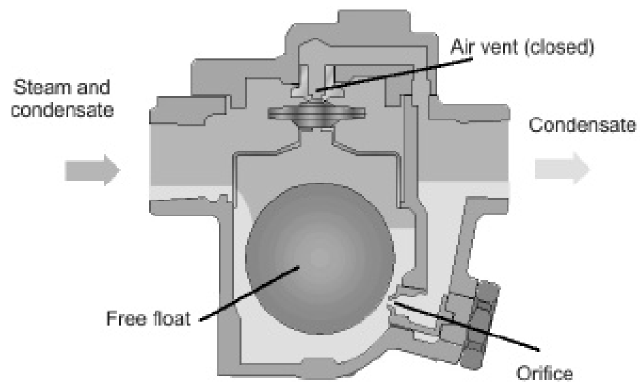

Figure 1: Free float steam trap

THE IMPORTANCE OF STEAM TRAPS

- Process efficiency
- Safety
- Energy saving

Steam traps have a hugely important role to play in maintaining the good health and operating efficiency of a steam system. A malfunctioning steam trap can bring about a number of problems, including the following.

A blocked trap

The trap may be blocked by debris such as pipe scale, or feed-water chemicals that have been carried over from the boiler entrained within the steam itself. Alternatively, the trap mechanism may have failed and the valve that controls the flow of condensate through the trap could be closed on the seating surface of the orifice.

The effect of the above is to hold back condensate in the 'steam space' of the equipment, which, as previously explained, slows down any heat transfer and can cause the heat exchanger to lose operating temperature completely.

While this is disastrous for process efficiency, what is even worse is the resultant safety hazard posed by the blocked trap. If this is a steam trap whose function is to drain the actual steam pipe supplying the process, then condensate will be held back and subsequently flood the bottom of the pipe until it is swept up by the steam which is flowing through the pipe at a velocity approaching 30 m/sec (108 km/h). The impact of even a few litres of condensate travelling at this velocity, when it meets up with a solid object like a control valve, can be disastrous. The resultant forces are such that large cast steel valves can be smashed apart and in such cases have actually caused fatalities of operators who were working close by.

A leaking trap

There are two major effects caused as a result of a trap allowing steam to leak, or blow, through the orifice of the trap.

The first effect is in many ways the most serious and is in fact the impact upon the process temperature and hence the efficiency. As steam leaks away, the pressure within the heat exchanger tubes close to the condensate outlet falls. Quite often this will cause a temperature differential across the heating surface, but in all cases there is an associated drop in output. In the worst situation, when a trap is operating intermittently, but allowing steam to escape, there are continual swings in the process temperature, much to the dismay of the Instrument Engineer, who tries desperately to fine-tune the temperature controller.

The second effect is the actual cost of the energy that is lost by the leaking steam. Typical losses of steam escaping are shown in Table 1.

Table 1: Steam loss through an orifice

Dia of hole (mm)	*Steam (kg/hr) 7.0 barg*	*Steam (kg/hr) 20.0 barg*
1.5	5.5	14.1
3.0	21.9	56.4
5.0	60.8	156.7
6.5	102.8	264.8

So for example, a small steam trap having a 3 mm orifice, draining a steam main and operating at 7 bars in a plant working for 10 hrs per day, for 6 days per week over an annual plan of 44 weeks, will lose some 57.8 tonnes of steam per year. That is 57.8 tonnes at an operating cost of R45 per tonne of steam, or a total loss of R2 601 per annum.

Typical costs of a replacement steam trap would result in a pay back of approximately 10 months.

STEAM TRAP POPULATION AND PERFORMANCE

The significant impact that steam traps can have on process plant efficiency, becomes apparent when analysing typical average populations of traps in a given industry.

Industry	*Population*
Chemical plant	3500
Paper mill	1200
Textile plant	650
Food processing	450
Brewery	200
Laundry	150

Clearly it is evident that the number of steam traps acting as important control devices in a steam system is large in comparison with the size of factory/plant and with controls within the same plant. Therefore, for a steam heating process to perform efficiently, it is crucial that all the steam traps are functioning correctly.

The question we need to ask is, what percentage of the installed traps are working as they should be in any given plant? As an example, in a recent survey of a chemical plant with a steam trap population of 2 650, testing revealed that only 52.9% of the installed traps were operating correctly. (See Figure 2.)

The results from the testing of steam traps in a wide range of industries over a period greater than one year reveal the following average of trap functionality.

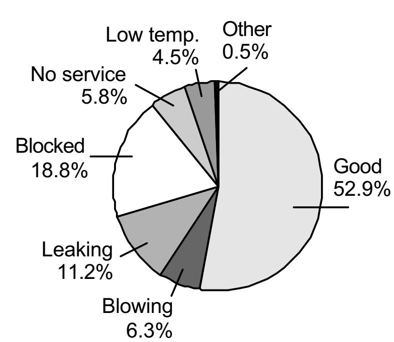

Figure 2: Chemical plant survey result

Average performance of all testing
The implication of these results is that, in any industry that utilises steam for processing the product it is manufacturing, most probably the process is operating at a much lower efficiency than is achievable, with increased costs for energy used per product produced. It also means that there is a greater than necessary emission into the atmosphere of gases produced as a result of fuel combustion. (See Figure 3.)

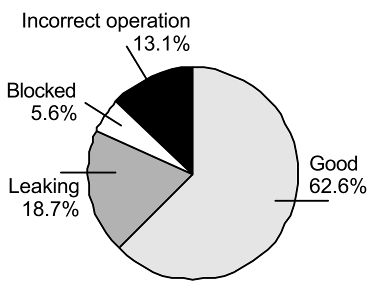

Figure 3: Average result of all trap testing

THE CREDIBILITY OF THE TRAP TESTING

Of course the information available above is only valid if the methods used for testing steam traps are credible. Therefore, it is important to spend some time evaluating the technical background for the measurement of energy losses through steam traps and the most common techniques used for testing.

The measurement of energy losses through steam traps

Manufacturers of steam traps who wish to provide data on the performance of their steam traps are required to make use of an existing standard, ISO 7841-1988, which determines methods for the measurement of steam losses through a steam trap.

In this standard two methods of measuring steam losses through steam traps have been approved by the International Standards Organisation. A manufacturer may choose either one to evaluate the performance of their products. The steam losses so measured only take into account the losses of steam used in a steam trap as a function of its operation and not any energy losses associated with convection or radiation. (See Figure 4.)

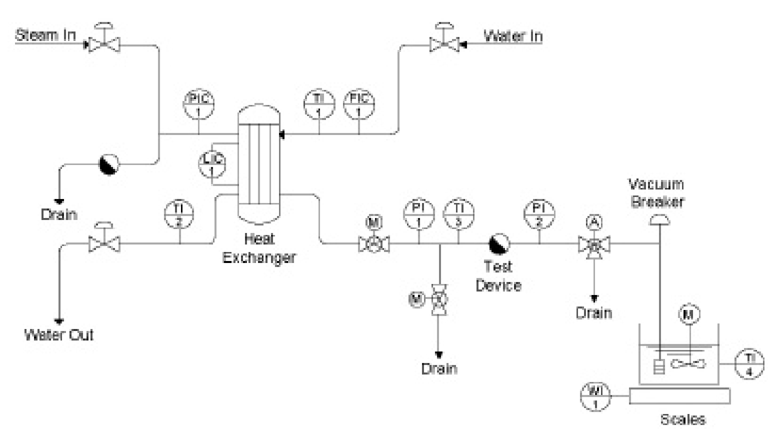

Figure 4: Schematic of ISO 7841 test method

One such Manufacturer is TLV Co Ltd, based in Kakogawa Japan, and Figure 5 illustrates the test rig they have constructed in their Engineering Centre. Note that this test rig has been independently verified and a Statement of Compliance issued by Lloyd's Register – Certificate No. KOB 0140032/1.

Typical results of tests carried out in accordance with the ISO Standard are as given in Table 2.

Data obtained from such testing may now be used by a trap manufacturer in a number of ways.

- To improve the performance and efficiency of the trap.
- To determine which trap to use for any specific application.
- To analyse the likely loss of energy in a steam system due to malfunctioning steam traps.

The testing of steam traps on the plant

Over the last 50 years, many techniques have been used to determine if a steam trap in use on a steam system is operating correctly and if leaking steam, what is the likely waste of energy involved.

Some of these techniques have been primitive, to say the least, but over the last 10 years two major methods have been employed. One is based upon temperature measurement, the other on the use of an ultrasonic instrument.

Temperature measurement
Contact thermocouples are being used to measure the temperature of the surface of the pipe at both the inlet and outlet of the steam trap as shown in Figure 6.

The measurement of surface pipe temperature is not a true indication of the steam temperature inside the pipe. Normally the surface temperature is some 80% to 90% of the steam temperature inside the pipe, depending on the grade of pipe, the insulation and ambient conditions. Nevertheless, a measurement taken in such a way on a carefully filed flat spot will give a reli-

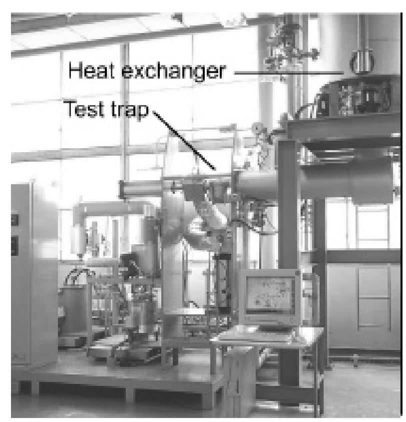

Figure 5: ISO 7841 test rig at TLV Co Ltd

Table 2: Average results of energy losses through steam traps

Test at 10-bar g with condensate flow 5 kg/hr

Type of trap	Steam loss (kg/hr)
½" free float (3 point seating)	Less than 0.1
½" inverted bucket	0.6 to 0.8
½" thermodynamic	0.5 to 1.5

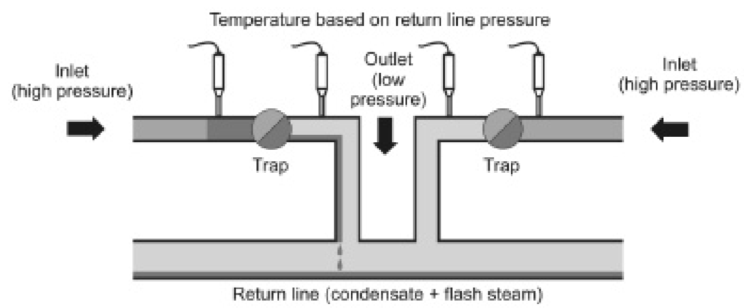

Figure 6: Checking inlet and outlet temperatures of a steam trap

able indication of the steam, or condensate, temperature within the pipe. However, contrary to what operatives who use such a technique believe, the information provided by such measurement cannot be used to accurately judge if a steam trap is leaking steam.

Contact thermometer on inlet

In this instance, all the measurement will tell you is that the steam trap is hot. It could, however, be leaking steam, or operating intermittently. If the temperature is low, then this could be because the plant it is connected too is 'off-line', or the trap is blocked by scale/dirt.

However, by taking a measurement close to the inlet of the steam trap and another say 1 metre upstream of the inlet, you can detect if there is a temperature difference. This is only useful when testing a thermostatic type of steam trap that is designed to hold back condensate and only release hot condensate when the temperature has fallen by at least 10°C below the saturated steam temperature. If such a differential exists, then it points to the thermostatic trap operating correctly, but is by no means totally foolproof.

Contact thermometer on the outlet

This method has been used by several organisations to check the temperature of the pipe after the trap, in the belief that if the outlet temperature is lower than that of the inlet, then the trap must be working correctly. This is totally incorrect as the following test data illustrates.

Test condition

Inlet pressure: 7 bar (saturated steam at 170°C)

Condensate load: Minimum of 5 kg/h

Ambient temperature: 35°C

Therefore, for example, in the case of the free float trap, an operator using this technique may judge that when the outlet temperature is 98°C, the trap was fine, yet in fact it could also be leaking a small amount of steam. Alternatively, when the operator makes a comparison with other traps under the same operating conditions, the judgement given is that the higher temperature of 105°C must mean that the trap is leaking steam. However, the truth is that the trap may be working well, but handling a reasonable amount of condensate.

Likewise in the case of the thermodynamic trap, a high outlet temperature could mean either that the trap is operating correctly, or it is blowing a large amount of steam.

The result of such testing is to incorrectly label many good steam traps as faulty and, therefore, add considerably to maintenance expenditure by ordering replacements.

Use of ultrasonic instruments

Manufacturers of ultrasonic test instruments have strongly promoted the use of such devices for testing steam traps. Basically the instrument consists of a hand held amplifier with an integrated meter display, to which is connected a contact probe. In addition headphones and microphones may be included at additional cost (see Figure 7).

When the contact probe is placed upon the inlet pipework adjacent to the steam trap it detects the vibrations caused by the flow of condensate, or steam, through the orifice of the steam trap. These vibrations are fed to an amplifier and electronic filter where they are processed into a signal within an ultrasonic frequency range of 35 to 45 kHz. In turn, this signal is processed

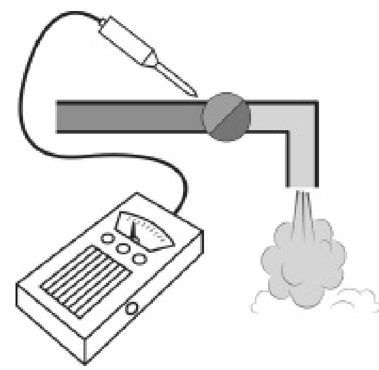

Figure 7: Ultrasonic leak detector

Table 3: Outlet temperatures of good and faulty steam traps

Inverted bucket trap				
Condition	Good 5 kg/h cond flow	Good 40% max capacity cond flow	Blowing	
Leak amount	-	-	Over 10 kg/h	
Surface temp of outlet C	99	105	104	
Thermodynamic trap				
Condition	Good	Leak	Blowing	
Leak amount	-	-	Over 10 kg/h	
Surface temp of outlet C	110	104	111	
Free float trap				
Condition	Good 5 kg/h cond flow	Good 20% max capacity cond flow	Leak	Blowing
Leak amount	-	-	4.2 kg/h	Over 10 kg/h
Surface temp of outlet °C	98	105	98	103

to produce an effective frequency of 5 to 15 kHz, making it now possible to be heard in headphones, or displayed on the meter.

By the use of this instrument, the operator watches the meter and listens on the headphones to the flow of the condensate or steam through the trap and then makes a judgement on the trap performance. Very often the adjustment knob is used to change the sensitivity of the signal, until it is to the operator's satisfaction!

While such Instruments are useful, they will not provide the accuracy required for consistent and repeatable diagnosis. The technique is subject to:

- variables introduced by the alteration in sensitivity of signal detection;
- experience of the operator to interpret the results;
- differences in interpretation by several operators;
- no benchmark of a standard to work from.

In addition, the capturing of the data and subsequent analysis of the results is laborious.

TLV Co Ltd 'TrapMan'

Fortunately, for the professional test and inspection organisation, there is an instrument available that will provide an accurate diagnosis of steam trap operation. This is 'TrapMan', manufactured by TLV Co Ltd (see Figure 8). The principle of operation of the TrapMan Instrument is based upon testing a steam trap in situ on a plant and comparing the 'ultrasonic signature' with that of data already stored in the TrapMan memory for that specific trap.

TLV Co Ltd has tested several thousand-steam traps from all the leading manufacturers, making use of their extensive test facilities and the Lloyd's Register approved ISO 7841 test rig. Data is captured for each model of trap under varying operating conditions of pressure and flow, and for good and leaking steam traps. This information is then stored in the memory of each TrapMan.

Figure 8: TLV Co Ltd TrapMan

Consequently, when an operator in the field uses the instrument he can select the model of trap being tested, confirm the operational conditions, place the probe on the inlet pipework to the trap and then allow TrapMan to make the diagnosis. TrapMan compares the trap under test with the stored data for that specific trap. This data is then captured and can be downloaded to a computer where it is processed using the TrapManager Software. The accuracy of this Instrument has again been validated by Lloyd's Register – Certificate KOB 0240042. This instrument is not subject to variations in the testing of traps by operators and importantly is 'benchmarking' the diagnosis of the performance of a trap, against the same correctly operating model of steam trap from that specific manufacturer.

SUMMARY OF THE BENEFITS FOR A PROGRAMME OF STEAM TRAP TESTING

It is obvious from the data presented above that with such high populations of installed steam traps in a process plant, considerable benefits are obtained through a regular programme of testing in order to ensure that steam traps are operating correctly. To summarise these benefits, they include the following:

- Safe operation of the steam plant.
- The operation of the heating process at maximum efficiency.
- The reduction of product spoilage and wastage.
- Good consistent product quality.
- Eliminating the wastage of energy.
- A reduction in maintenance costs through the identification of the best and most reliable steam traps, based upon facts and not subjective commercial judgements.
- The reduction of greenhouse gases caused by the unnecessary wastage of the combustion of fossil fuels within the steam boiler.

However, such benefits are only achievable when the testing is carried out utilising experienced personnel and accurate test instruments. Furthermore it is not driven by the desires of a manufacturer who wishes simply to sell more steam traps.

Examples of testing programmes

Names withheld due to client confidentiality. Where savings are quoted they include the cost of the survey and also the purchase, plus installation, of replacement traps.

1. Steel plant
Total traps tested = 2523
Replaced = 899
Saving = 3.5 tonnes/hr of steam
Payback = 6 months

2. Rubber manufacturing
Total traps tested = 142
Replaced = 16
Saving = R94 300
Payback = 7 months

3. Chemical plant
Total traps tested = 106
Replaced = 11
Saving = R68 400
Payback = 8 months

4. Power plant
Percentage of traps faulty = 69%
Replaced = 137
Saving = R1 382 000
Payback = 6 months

5. Chemical plant
Total traps tested = 3762 in 1996
Failure rate = 38.7%
In 2003 failure rate now = 6.1%
Effective saving if no action had been taken in 1996 and failure rate remained the same = R867 000 in 2003

6. Refinery
Total traps tested = 5676
Replaced = 642
Saving = R5 037 500
Payback = 6 months

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