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Infrared Thermography in Steam Trap Inspection

1 Statements expressed in the paper are author's own opinions, they are not binding for the company/institution in which author is employed nor they necessarily coincide with the official company/institution's positions.

SUMMARY

Steam traps play a significant role in condensate evacuation from steam as well as in heating ventilation and cooling systems (HVAC), i.e., industrial climate chambers. Preventive maintenance and periodical audit of steam traps increase reliability and reduce the number of facility off hours. In some elements of the system, condensate can damage some parts, which means that monitoring their function is one of the basic preventive maintenance tasks. One way of checking steam traps is by using infrared thermography. The paper presents the simplicity of steam trap control by using an infrared thermography camera.

KEY WORDS

Key words: Infrared thermography, Steam trap, Maintenance

INTRODUCTION

As a contactless method for determining temperature distribution on the surface of the object under consideration by measuring radiation intensity in the infrared (IR) band of the electromagnetic spectrum, infrared thermography represents one of the ways of controlling the steam trap state. According to international standards, infrared thermography is classified as a non-destructive testing method (NDT), [1]. Every object heated to the temperature above absolute zero transmits EM radiation of a continuous spectrum of all wavelengths, and when the temperature exceeds 525°C, it emits visible light [2]. The application of an infrared thermographic camera is easier when the operator is educated in the field of thermography, but even then, there are possibilities of making a mistake. Mere knowledge of thermography is not sufficient but physical knowledge is necessary to understand the system in which thermographic analysis is performed. Steam traps are very important from a technical point of view, but from the energy aspect, they are imperative. Regular control of steam traps contributes to the overall maintenance of thermodynamic steam generating systems. It is estimated that 20% of generated steam is lost through defective steam traps, [3].

COMMON TECHNICAL SOLUTIONS

The basic function of steam traps is fast condensate evacuation, preventing the loss of working media (dry steam) and releasing accumulated air in the system, which is a thermal insulator. Steam traps are self-opening valves, which open in the presence of condensate and close in the presence of steam. They contribute to efficient transfer of heat energy, reduce corrosion in pipes and the occurrence of water hammer. Their task is to separate the condensate with reduced condensate cooling. Dimensioning is based on usage, differential pressure, working/starting capacity and steam temperature, [4]. The common application of steam traps in the thermotechnical system is represented in Figure 1, which also best illustrates a closed flow of condensate within the system [5].

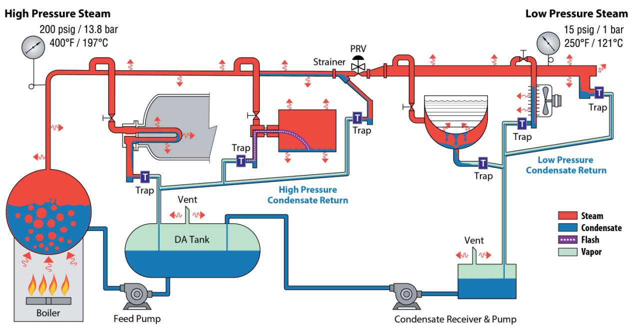

Figure 1. Steam trap in a thermotechnical system [5].

Steam traps requre periodic maintenance to ensure safety, quality of a production cycle and increased process efficiency. The experience of maintainers tells us that 20-25% of installed separators do not work properly.

Steam traps work well if the system is balanced, if there is enough steam at inlet and if the steam arrives at the steam trap. By their mode of operation, they are divided into continuous discharge steam traps and intermittent steam traps that work on the principle of collecting condensate leakage of content and closure of the valve.

The most common technical solutions are:

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Bimetallic steam traps, Figure 2. Their advantage are small dimensions, but they have high condensate discharge capacity. One of their characteristics is also large starting capacity due to an open valve when it is cold. In addition, they suit well water hammer, corrosion, high pressure, and superheated water steam. They work within a high operating pressure range and can be maintained while connected to the system. The shortcomings are a slow operation mode and the possibility of excessive condensate cooling of at increased output pressure.

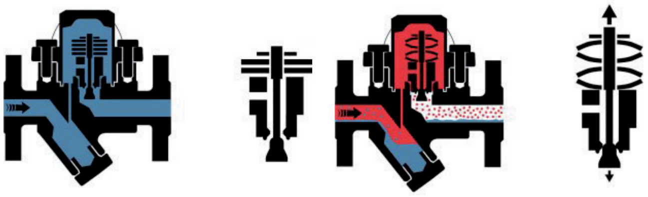

Figure 2. Bimetallic steam trap, cross section and principle of operation, [6]

Float type steam traps shown in Figure 3 are extremely reliable, but can lead to air accumulation. The advantages of a technical solution with thermostatic and floating type steam traps are as follows: continuous discharge of the condensate, which is at a steam temperature, at high and low loads it has good endurance, it is not affected by pressure changes, and it releases air. The shortcomings are as follows: constructive elements are susceptible to water hammer and they are not suitable for corrosive condensate and superheated water steam. Also, freezing can occur and the pressure determines the aperture.

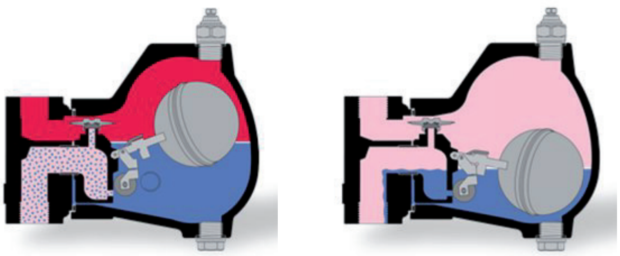

Figure 3. Condensate steam trap with float, cross section and the principle of operation, [6]

Inverted bucket steam traps, given in Figure 4, are one of the oldest solutions, their problem is the initial startup and steam release. The required force of operation ensures that steam enters the condensate bin until steam rises up and closes the valve. Steam passes through the hole in the canister, then condensates and ensures that the valve reopens and the condensate is discharged. This type of steam traps is used in high pressure systems and superheated water vapor, it is impact resistant, simply designed and easy to maintain. The disadvantage is that it has a slow discharge of steam that can lead to steam loss and sealing requires water in the body that is subject to freezing.

Figure 4. Inverted bucket steam trap cross section, [7]

Thermodynamic steam traps are small, Figure 5, (steam traps with disks). They work on a mechanical principle, using the pressure increasing and decreasing zones that raise and lower the disc. Thanks to the flow rate and the differential pressure, the steam and condensate flow stops. They are often used because they are cheap but may pose a problem in poorly regulated systems. The benefits are low cost and a wide range of high capacity utilization, plus they are compact and lightweight. They can be used in high-pressure superheated water vapor and are corrosion resistant. They are not affected by freezing and are easy to maintain because they have only one disk. The disadvantages are that a low pressure at the entrance or a high pressure at the outlet affects the operation. Cooling of the operating chamber due to a low outdoor temperature or rain results in faster condensation of an accelerated operation and premature wear. They are also noisy and lead to energy loss.

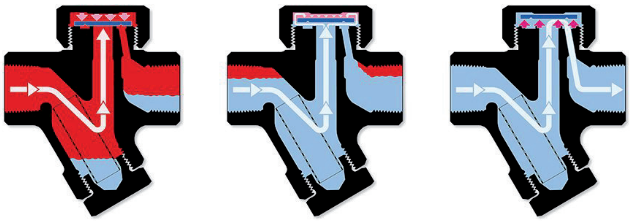

Figure 5. Thermodynamic steam traps, cross section and the operation principle, [6]

Thermostatic steam traps, Figure 6, allow easy separation of air, quickly and without loss. This type of steam trap uses a bimetallic delta loop that combines thermodynamic and thermostatic forces for larger amounts of condensate. They use pressure and temperature for operation and have a modulated output.

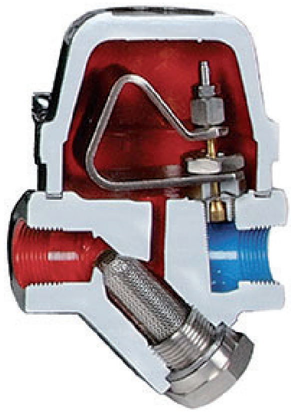

Figure 6. Thermostatic bimetallic delta element steam trap cross section [7]

STEAM TRAP STANDARDS

To the best of our knowledge, there are six European and six ISO standards defining the basic requirements placed on steam traps and these are: ISO 6552: 1980 Automatic Steam Traps - Definition of Technical Terms; This international standard gives definitions of the main technical terms and expressions used to describe automatic steam traps regarding dimensions, pressure, temperature and flow as well as their respective symbols and units. EN 26553: 1991 - Its purpose is to establish certain basic requirements for marking steamers and give recommendations for additional information marks. In general, consideration should be given to specific requirements that can be agreed upon by the respective partners. It sets mandatory and optional tags for steam traps. (ISO 6553: 1980 Automatic steam traps - Labeling - withdrawn). EN 26554: 1991, ISO 6554: 1980 -Automatic air steam traps with flanges - face-to-face dimensions. EN 26704: 1991, ISO 6704: 1982 - Classification of steam traps. EN 27841: 1991, ISO 7841: 1988 - Methods for determining vapor losses of automatic steam traps. ISO 7842: 1988 - Determination of the capacitance of discharge automatic steam traps. EN 26948: 1991 ISO 6948: 1981 - Performance tests for automatic steam traps.

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MAINTENANCE SAVINGS

Studies published in [3] indicate that 20% of the generated steam is lost through improper steam traps. Regular preventive maintenance of the system is necessary because the proportion of defective steam traps increases over the years. This is presented best in Figure 7. Potential savings of preventive maintenance can be derived from the statistics referring to the corrected malfunctions.

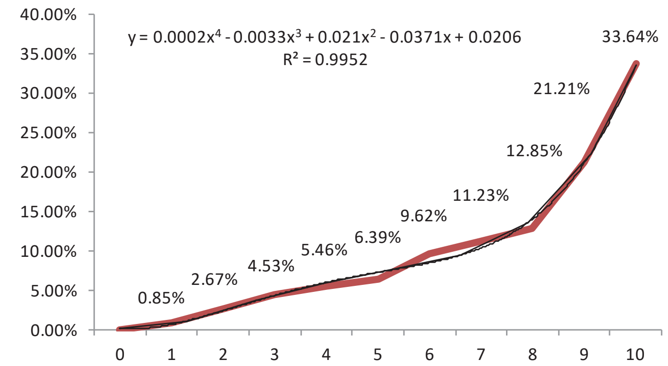


Figure 7. Percentage of steam trap breakdown over a period of 10 years, [8]

STEAM TRAP TEST METHODS

Steam traps are commonly tested in three ways: visually, by ultrasound and by infrared thermography. By applying all three testing methods we come to the best results [9]. Ultrasound testing is most commonly used because it is a fast simple and accurate method, which is the only disadvantage that requires education and experience [9]. The ultrasound frequency used for steam traps ranges from 20 to 25 kHz [10]. Steam traps is essentially a valve that automatically discharge condensate when it comes to its accumulation. In Figure 8, we can see the signal level in the ultrasonic valve test.

Figure 8. Ultrasonic valve testing and measured values

Apart from the level of signal, the shape of the signal is essential for interpretation. Figure 9 shows the shape of the signal taken from [11], where opening, discharge of condensate and closure are colored magenta, yellow and cyan, respectively. In the case of a defective open damper, the signal is continuous with the shape shown in yellow, and in the case of a defective enclosure, we have a slight noise. It may be concluded from the signal format [11] if the steam trap does not have sufficient capacity, if it is overloaded due to malfunctioning of other system elements or if it is corrupted.

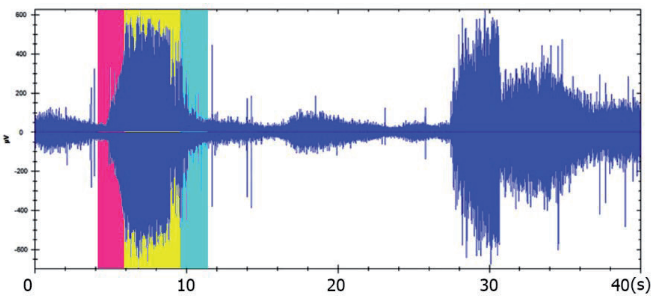


Figure 9. The steam trap signal shape in the correct operating mode

Ultrasonic analysis in practice is preceded by infrared thermography. A thermographic audit includes the analysis of the apparent temperature of the input and output openings, i.e., the determination of the temperature difference. IC thermography assists best in the analysis of thermodynamic steam traps, while in more complex structures it does not provide more information. It neither provides sufficient information for traps where the condensate passes continuously and in the case of a steam trap close to the condensate line. Delta T temperature measurement is a rough indicator of trap condition because small and moderate leaks cannot be detected [12]. Thermal analysis begins on the inlet pipe in the steam trap.

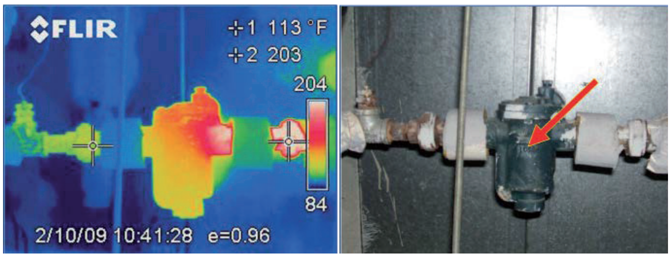


Figure 10. Thermogram of the clogged inverted bucket steam trap [13]

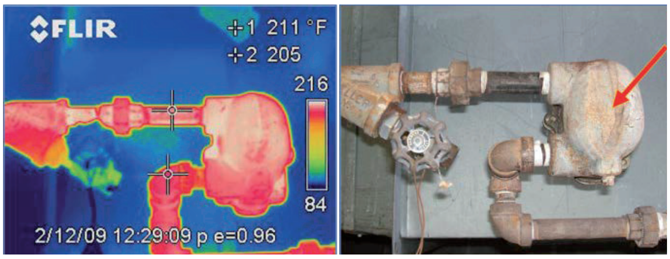


Figure 11. Thermogram of a leaking float ball steam trap with [13]

The inlet pipe temperature should be close to the steam temperature to the system, indicating that the steam comes in the steam trap and is not locked or defective in the closed position. If the temperature of the inlet pipe is considerably lower than the steam temperature, the steam does not reach the trap and it is necessary to investigate the cause. It occurs most often because of the closed valve before the steam trap, but the barriers within the pipeline can also prevent vapor flow. The condensation temperature should be monitored during the test. Figure 12 shows a typical temperature limit values for a given amount of condensation overpressure [14].

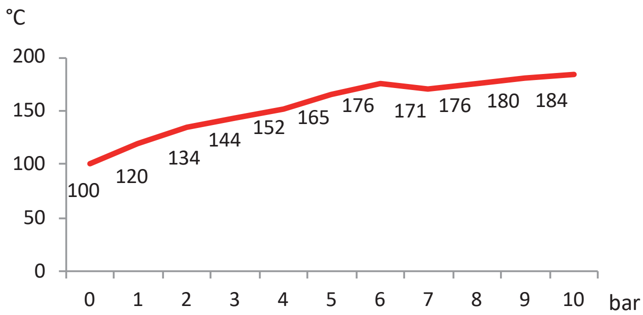


Figure 12. Temperature limit values

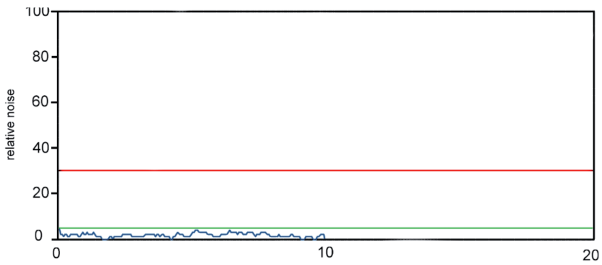
It can be concluded from a before mentioned that the pressure information within the analyzed part of the system is necessary for a successful thermographic analysis. The infrared thermal camera is especially useful for finding quickly closed valves or steam lines jamming, [12].

TESTING THE STEAM TRAP WITH GESTRA TRAPtest VKP 40

The GESTRA TRAPtest VKP 40 measuring device detects and analyzes the ultrasound produced by the steam trap and the connecting pipes. Measurements are made by selecting the type of the steam trap and by pushing the tip of the probe onto the trap. According to empirically established limit values, ultrasonic vibration are analyzed. Provided that the specified system pressures are known steam trap state can be analyzed and temperature information can be obtained, [15]. Figure 13 shows the test procedure.

Figure 13. Conduction of measurement

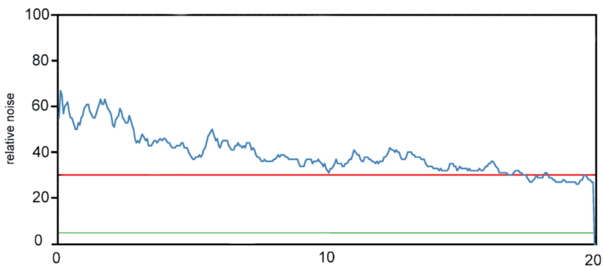
Measurement results are transferred to the computer and displayed as a report. Figures 14, 15 and 16 can be seen as typical records for particular situations inside the system. In the diagrams, we can see distinctive lines. The green line in the diagram represents the beginning of the active threshold line value TV measurement zone. If the measurement is this value it is possible to not have flow/load thru trap. Ideally, the measurement curve is below the TV, which is in practice, not a rare case. The red line represents the upper limit of the line value LV of measurement accuracy (not necessarily device malfunction).



Date	Test results	Tester	Mean value	Limit value	Threshold
15.3.2019.	Cold (Result)		1	30	5

Figure 14. Steam trap is off or without flow/load

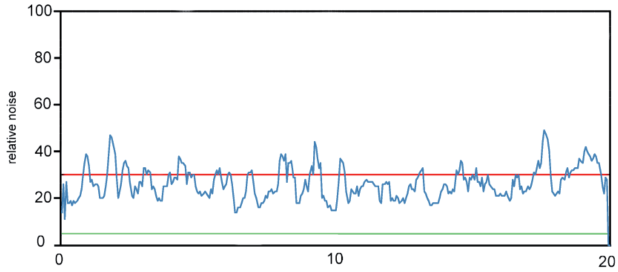
Figure 14 represents the stationary condition of the steam trap in which the steam supply is physically disabled (most often by the manual valve or an automatic valve operator). The device displays a blue vibration curve transmitted to the trap through the connecting pipes (or various brackets/ fixers) connected to the trap. Figure 15 shows the case when most curves are above the upper limit and the trap does not perform its function properly. A similar curve can be observed in the cases of noise transmission from the ˝foreign noise˝ system, in which the external factor affects the measurement. The problem can be resolved by experience or by using software that comes with the device.



Date	Test results	Tester	Mean value	Limit value	Threshold
15.3.2019.	Defective		39	30	5

Figure 15. Steam trap does not perform its function properly

Figure 16 illustrates the case of the normal functioning of the steam trap. Most curves are below the upper limit, which suggests that the trap performs its function properly, but there are indications of wear. The shape of the curve indicates possible noise pollution or potential wear due to the manufacturing date of the device.



Date	Test results	Tester	Mean value	Limit value	Threshold
15.3.2019.	OK		26	30	5

Figure 16. Steam trap performs the function properly

THERMOGRAPHIC ANALYSIS OF STEAM TRAP

For the paper, a practical test of the float ball steam trap was initially carried out with infrared camera Fluke Ti200. The basic characteristics of the camera are: resolution 200x150 pix, FOV 24 ° H x 17 ° V, IFOV 2.09 mRad, thermal sensitivity 75 m ° C, measuring ranges from -20 ° C to +650 ° C. The test results can be seen on the thermograms shown in Figure 17, Figure 18 and Figure 19.

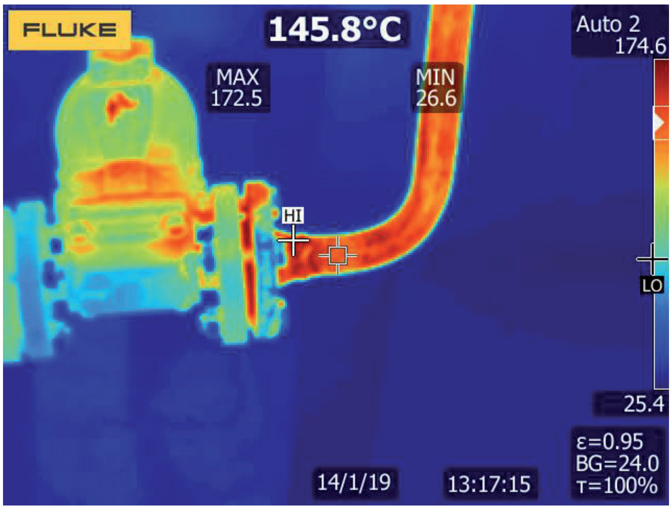


Figure 17. Apparent temperature at the inlet

Figure 17 shows the maximum amount of measured apparent temperature at the inlet of a separator of 146 °C. Figure 18 indicates that the outlet water temperature of 94 °C. At the time of recording the pressure in the system was 3 bars.

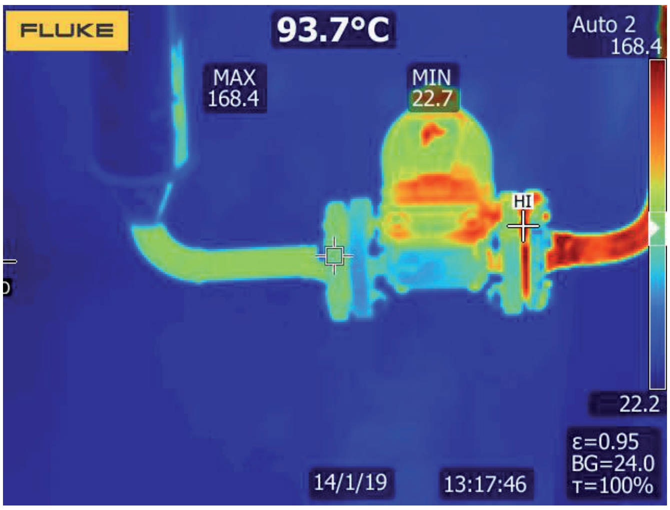


Figure 18. Apparent temperature at the outlet

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Based on the data from Figure 12, we can conclude that water vapor arrives at the inlet of the steam trap, and the temperature difference of 52 °C suggests the correct operation. The float ball steam trap represents a technical solution of the continuous flow. In the case of malfunction/jamming, the output temperature would be significantly smaller, and in the case of openness, it is significantly higher. In Figure 11 showing the aperture we have a temperature difference of 3 °C; at the inlet, it is 99 °C (211 ° F) and at the outlet, it is 96 °C (205 °F).

The temperature values displayed by an infrared thermocamera are called apparent temperatures because the camera measures the amount of infrared radiation that the temperature parameter assigns to the temperature value. The parameters that most influence the wrong reading in our case are the wrong choice of material emissivity and angle of recording. In Figure 17, the maximum recorded temperature is 173 °C, while in Figure 18, the maximum apparent temperature is 168 °C. This is a temperature difference of 27 °C between the measured point and the maximum value recorded by the camera. That is why it is very important to do multi-angle analysis to eliminate measurement errors because they can lead to wrong conclusions. This temperature difference corresponds to the equivalent difference of more than 2 bars within the pipeline and incorrect interpretation of the apparent temperature may misrepresent the steam condition in the inlet water.

Figure 19 represents additional control measurement, confirming of conducted testing. For a proper interpretation, it is necessary to analyze the thermal recordings in software, taking into account the camera's resolution and IFOV (Instantaneous Field of View), which determines the spatial angle of each IC sensor element. The area where the apparent temperature is measured must be greater than IFOV.

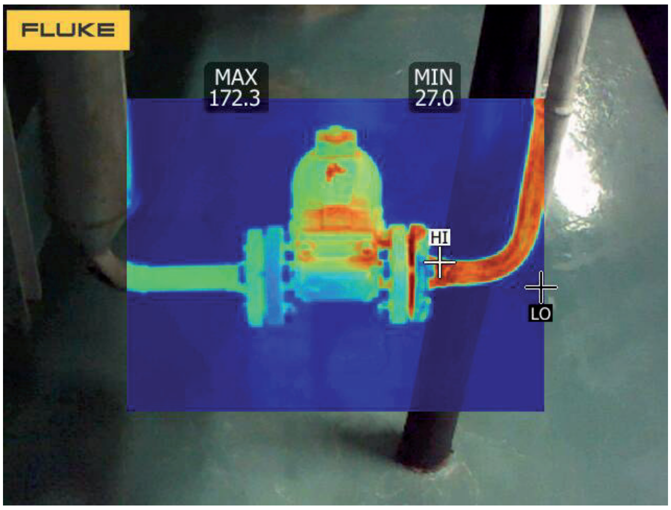

Figure 18. Steam trap analysis check

The biggest problem in thermographic testing are the metal parts upon which it is difficult to determine emissivity and apparent temperature values. This problem can be solved by placing reference points (tags) or painting measuring spots with the color of the known emissivity. From the displayed thermograms it is not possible to estimate the status of the operating trap, decay/wear of the trap that performs its function properly, that can be easily seen in Figure 16, by using the TRAPtest VKP 40.

CONCLUSION

Steam traps play a significant role in maintaining the reliability of the system's operation in which the condensate vapor separation is necessary. Steam is an invisible medium that transmits energy. When we can see steam, we talk about wet steam, i.e., condensate. The task of the steam trap is to separate the condensate and preserve the steam in the system and thereby contribute to overall efficiency, i.e. energy savings. Energy losses due to defective traps reach up to 20% of the energy invested in steam generation. Energy savings are the primary reason for preventive maintenance and trap testing, and the secondary increase of system reliability because it reduces the number of failures and prolongs life expectancy.

The steam trap test can be carried out by visual inspection, ultrasonic inspection and by a thermographic camera. The visual method is not reliable because by steaming it condenses, so it is difficult to estimate the amount of liquid phase in the condensate. The ultrasonic analysis is the most accurate form of testing that produces reliable results if the examiner has enough knowledge and experience. Despite the simplicity and the knowledge of system operation, Infrared thermographic analysis is not able to provide us information about the inside status of the steam trap. An exception is thermodynamic steam traps because they have a working member close to the casing surface. Another problem with the use of infrared thermography is the choice of emissivity, which is difficult to determine due to the presence of metal surfaces. This problem can be resolved by using reference tags and applying paint to metal parts, but this undermines the idea of the advantage of fast and contactless methods because reference markers and colorants have to be refreshed regularly due to a high working temperature of the system.

Regardless of whether infrared thermography is absolutely reliable in determining the condition of the steam trap, it is the first step of the trap testing because defective traps can be easily identified in order to reduce energy losses and it is the main reason why infrared thermography is irreplaceable test method.

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