LIMITATIONS OF ULTRASOUND IN PREDICTIVE MAINTENANCE

ERRORS ON STEAM LEAKS DETECTION IN STEAM TRAPS

By Vicente Blázquez (Aeronautical Engineer)

1. GAS LEAK DETECTION BY ULTRASOUND

Ultrasonic measurement is the method currently used to locate internal gas leaks through valves.

Passage of a gas through an orifice generates an ultrasound whose frequency and intensity are related to several parameters, such as differential pressure at both sides of the orifice, gas temperature, gas density, gas velocity through the orifice and geometry of the hole.

Regardless of the gas flow through the orifice, if the differential pressure is greater than 1 bar, passage of gas through orifices generates sound waves over a wide range of frequencies. The wave of higher intensity occurs around 39 kHz, with multiple harmonics at higher frequencies. Now, experimentally it is verified that the intensity or peak of the frequency wave does not depend on the flow amount of gas through the orifice.

Therefore, the presence of ultrasound in a valve in closed position clearly means the existence of a fissure through which an internal or external gas leak occurs. However, it is practically impossible to determine the magnitude of the leak from the ultrasound measurement since this depends on the geometry of the valve, the geometry of the crack and thermodynamic variables of gas. In any case, the correlation between ultrasound and leakage flow rate would have to be established for each valve and in each case. There are approximate calculation methods, which are accepted internationally; among them, one of the most recognized methods is the Masoneilan formula, which provides quite conservative results.

2. STEAM LEAK DETECTION. LIMITATIONS OF ULTRASOUNDS

The application of the ultrasonic measurement method has experienced a great increase in the predictive maintenance of traps. However, the research carried out by BITHERM during the development of the SmartWatchWeb™ system for predictive maintenance of traps has shown that the traditional method of measuring ultrasound does not offer enough reliability when applied in large installations with thousands of traps in service (oil refineries, large chemical plants, etc.), since the problem becomes more complex when it is not about detecting gas leaks but steam leaks in steam traps, which handle a fluid that may be in the liquid or vapor phase.

In effect, the trap normally discharges at a temperature close to boiling. During this process the condensate undergoes an expansion that produces a phase change from liquid to vapor (re-vaporization). The gas phase (flash steam) flows at high speed generating ultrasound. However, the percentage of flash steam generated in such expansion depends on two parameters: the pressure jump through the steam trap (differential pressure) and the degree of cooling that the condensate suffers before being evacuated by the steam trap. However, the presence of ultrasound in this case does not mean the existence of leakage of live steam through the steam trap. In this case, to make a reliable diagnosis it is necessary to determine the cause of ultrasound and its origin. For that it is useful measuring attenuation of ultrasound downstream steam traps, or analyzes other variables such as inlet and outlet temperature on

steam traps to verify if there is enough differential temperature between inlet and outlet of the steam trap.

A serious additional problem occurs in low pressure lines, which are very typical in steam applications accompanying in refineries and petrochemicals such as steam tracing at 3.5 bar. In this application thousands of vapor traps discharge to a general condensate return header. In this case, the formation of flash steam pressurizes the return line locally decreasing the differential pressure through the steam trap. This effect is very intense and typical of installations that use steam traps that do not allow adjusting their discharge temperature (thermodynamics, float, inverted bucket, impulse, calibrated orifice, etc). The effect is even more intense when there are steam leaks through traps and traps, which is usually very frequent since the rate of leakage in these elements usually ranges between 10% and 15%.

It must be borne in mind that although the average pressure in the condensate collector is acceptable, a localized increase of backpressure in the pipeline occurs just at the discharge of the steam trap. Under conditions of strong local backpressure, differential pressure may be less than 1 bar (≈15 psi) in the vicinity of the steam trap; this significantly reduces the speed of steam passage through the steam trap, even in the case of internal leakage, and may not be sufficient to generate ultrasound to identify the leak.

In summary, the reliability of the ultrasound measurement method on predictive maintenance of steam traps decreases as the number of steam traps increases and the rate of internal steam leakage increases.

The main failures of the ultrasound leak detection method are:

- Apparent steam leakage, masked by flash steam.
- Real steam leakage undetectable due to high back pressure.

Research carried out by BiTherm for years have allowed the method to be perfected to achieve a high degree of reliability achieved by the intelligent bithermostatic steam trap BiTherm SmartWatchWeb™ (international patents).

3. EXPERIMENTAL RESULTS

During the development of the intelligent Bitherm SmartWatchWeb™, multiple tests were carried out in order to find correlations between frequency and intensity of ultrasound with thermodynamic parameters of tested steam traps.

When trying to reproduce the results in large petrochemical facilities it was observed that the conclusions reached in the laboratory did not correspond at all with reality.

For example, steam facilities with a seemingly correct preventive-corrective maintenance, whose leak rate on steam traps did not exceed 2%, presented an unacceptable operation with strong thermal water hammer and large amount of steam (apparently flash steam) in condensate return collectors. By carrying out a thermodynamic study of these facilities, a strong degree of coupling was found between the steam distribution lines and the condensate return lines, a coupling that demonstrates the improper functioning of the steam traps.

It was proved that the intelligent bithermostatic steam trap, unlike steam traps that discharge condensate at saturation temperature, behaves like an energy control valve, which constantly

regulates the level of energy degradation of the fluid, before being evacuated to the return line. In this way the intelligent steam trap is able to control the amount of flash steam in condensate headers to achieve optimal operation of the installation.

As an example, during the inspection of low pressure purifiers in a refinery the ultrasonic method detected 3% of failures due to vapor leakage. Due to the doubtful validity of the result, an exhaustive inspection of steam traps was carried out applying several alternative methods, obtaining 27% as real failure rate of steam leakage. Finally it was found that the ultrasonic method did not detect steam leaks in those areas where the differential pressure on both sides of the steam trap was less than 1 bar.

4. RELIABILITY OF INTELLIGENT STEAM TRAPS *BiTherm SmartWatchWeb™*

The intelligent steam trap BiTherm SmartWatchWeb™ achieves its high reliability by analyzing fundamental aspects of its operation, such as:

- Continuous monitoring of several parameters: It allows analyzing the evolution of ultrasound, temperature and backpressure, generating its reliable diagnosis
- Trend analysis: Premature fault detection
- Continuous self-inspection of the monitoring system
- Evaluation of energy efficiency of the steam trap
- Differential alarm of steam trap failures
- Historical record of steam trap operation

Therefore, the reliability of the intelligent BiTherm SmartWatchWeb ™ trap is extraordinarily high since it allows detecting small variations of the monitored parameters, even before the failure occurs, which makes it possible to evaluate the energy efficiency of the trap.

Finally the Bitherm steam trap is repairable online without the need for spare parts. This operation is carried out in a couple of minutes without interrupting the normal operation of the steam trap.