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Valve Leak Quantification with Acoustic Emission

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Valve leaks are a common problem for refineries, processing plants and power generation plants. Studies conducted by several companies in the late 1980s found that 5 to 10 percent of the valves in their plants had leaks. More importantly, it was determined that just 1 to 2 percent of the valves accounted for approximately 70 percent of the losses from leakage.[1] The studies also found that as many as 20 percent of flare valves had leaks (Fig. 1). A single leaking flare system can account for several hundred thousands of dollars in losses in a year. There are thousands of valves in refineries or power generation plants. The effort to find those that leak presents an ongoing challenge.

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How Does Acoustic Emission Leak Detection Work?

Acoustic Emission (AE) leak detection works by detecting the "noise" produced as the medium, gas or liquid, flows through the leak orifice. When product leaks through a small orifice in a valve, the flow is turbulent or chaotic (Fig. 2).

Figure 1. Primarily safety devices, flare systems collect and route waste gases (released through pressure relief valves or leaked from plant equipment) through piping runs called *flare headers* to elevated flare stacks, where they can be burned under controlled conditions.

Turbulent flow creates a signal with frequency components well over 100 KHz. This allows the use of high frequency acoustic emission sensors with frequencies above the vibration and background noise level of the plant, a characteristic that makes reliable detection and quantification of leaks possible. As a valve is opened, the flow orifice becomes larger causing the medium flowing through it to go from a turbulent flow state to one that is laminar. Laboratory and field tests have shown that a flow stream converts from turbulent to laminar when a valve is approximately 15 percent open. With no fluctuating pressure fields, the signal level of laminar flow is decreased, especially higher frequency components. Thus, the signal for a small leak in a valve can be much higher than that of an open valve.

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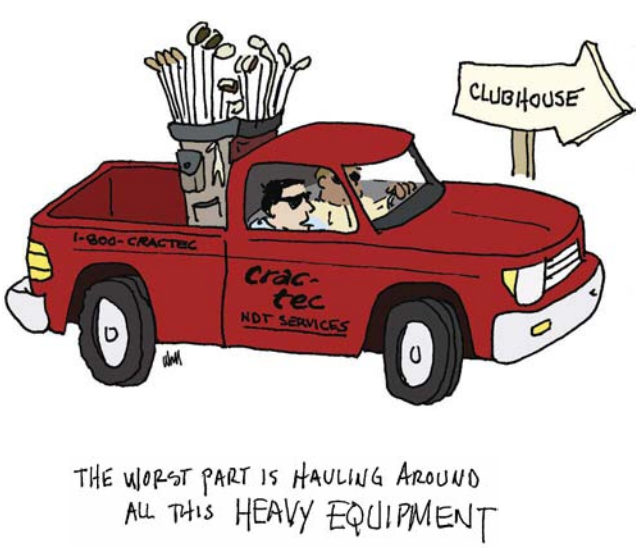

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The magnitude and frequency content of a signal from a leaking valve are affected by several parameters. These include: (1) valve type, (2) size of the valve or leak orifice, (3) differential pressure across the leak orifice and (4) viscosity of the medium inside the valve.[2] A small gas leak across a valve with a differential pressure of 2000 psig (pounds per square inch gage) can produce higher signals than a large fluid leak with a differential pressure of 50 psig. For this reason, it is important to consider all of the variables when developing leak quantification procedures.

Conducting Tests

To conduct a test, the acoustic emission sensor is placed on the valve with couplant, much like a UT transducer.[3] The operator monitors the signal level for a few seconds and if the measured signal is above a reference level, additional readings are taken upstream and downstream on the pipe flange. If the highest signal is measured on the valve, the valve leaks. There is turbulent flow producing a sound in the valve. If the initial reading is at or below the reference level, no additional testing is conducted and the operator moves on to the next valve. In most cases, a valve leak can be determined in about 20 seconds.

Should a leak be indicated, the data collected can be used to quantify the through valve leak rate. Most instruments designed for this application are supplied with software that takes the data from the data logger and enters it into a spreadsheet for the affected valve (Figs. 3 and 4).[2] Valve type, product and differential pressure across the valve are pre-loaded. The quantification software then calculates the leak rate and the annual losses attributed to each leaking valve. This information allows plant operators to easily prioritize valve repairs. The data can also be reviewed to determine which valves perform best in a particular application. Focusing on the valves in greatest

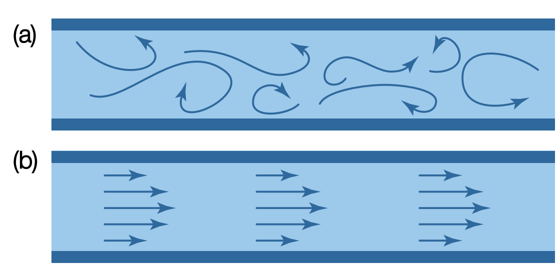

Figure 2. Flow of medium in (a) turbulent or chaotic state and (b) smooth or laminar state.

need of repair allows maximum return on valve maintenance dollars.[3]

If the acoustic emission instrument being used does not have quantification software, the relationship of the acoustic emission signal level and leak rate must be empirically developed. This can be done by setting up a calibration standard simulating worst case testing situations. Several measurements are made at different leak rates. A best fit line of the data provides the leak rate for a given set of variables. It may be necessary to develop several calibration references depending on the types of valves and systems to be tested.

Testing Procedure

Many AE instruments use sensors with piezoelectric elements that can generate large voltage spikes if not properly designed. Before using an AE instrument in a plant or other hazardous area (Fig. 5), it is important to verify that the instrument is certified intrinsically safe for operation.[4,5]

Before going out to test valves, the following preparations should be made. A spreadsheet with the test route should be prepared. The spreadsheet should include valve identification numbers, valve types, inlet sizes, test medium and differential pressures across the valves. Test personnel should review the locations of the valves to be tested and be thoroughly familiar with all safety requirements to access the valves. Instrument batteries should be checked to confirm they are fully charged and able to power the instrument during the complete test schedule. All cables and connections should be checked to ensure they are in good condition and properly secured. All required personnel protection equipment should be in use by the personnel involved with the data collection. Other accessories that may be of use include a wire brush, paint scraper and paint marker.

Prior to taking any measurement, it is important to confirm that the valve to be tested is closed and has a differential pressure across it. A partially closed valve will result in an erroneous reading and false indication of a leak.

Figure 6 shows various measurement points for different types of valves. The first measurement point should be made on the valve body. Any rust or loose paint that may be on the surface of the valves should be removed before measurements are made. Apply acoustic coupling grease to the surface of the transducer. Press the transducer to the valve body and hold it in place for several seconds. If the reading is below the reference level for no leakage, the valve is considered tight and after

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Leak Quantifcation

N.B. The signal level to be entered is the reading on the LCD display.
Fluid density is used only in the calculation of tonnes/year loss.
Leak rate is volume at downstream pressure

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Test Point	Valve I.D.	Signal Level (dB)	Pressure Difference PSI	Inlet Size (ins NB)	Cubic Feet/ Hour	Gallons Per Hour	Loss (Tonnes/yr)	Cost per Tonne	Total Loss In dollars for Valve/yr
e.g									
1	BDV401	28	497	3	67.8	507.3	19.0	15.00	$285.09
2	SDV101B	28	497	3	4.2	31.7	1.2	15.00	$18.61
3	SDV400B	18	1800	6	8.5	63.4	2.5	15.00	$37.21
4	FIC100A	62	245	6	10.6	79.3	3.1	15.00	$46.52
5	FIC200A	82	1050	3	726.7	5437.2	212.7	15.00	$3,190.97
6	FIC300A	89	1800	2	680.1	5088.5	199.1	15.00	$2,986.30
7	FIC100D	71	245	6	26930.8	201504.6	7883.8	15.00	$118,257.71
8	FIC200D	88	880	3	1129.2	8449.1	330.6	15.00	$4,958.56

Figure 3. Spreadsheet showing collected data. Quantification software calculates leak rate and annual losses for each valve tested.

Figure 4. Leak detection systems: (a) handheld, high frequency, nonquantification system for spotting leaks, (b) system with quantification capabilities and (c) handheld system with quantification capabilities.

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recording the reading on the spreadsheet, the operator may proceed to the next valve. If the reading is above the no leak reference, then additional measurements are made on the upstream and downstream pipe flanges. If either of the readings on the pipe flanges is equal to or greater than the reading on the valve body, the valve is not leaking and the operator can proceed to the next valve. If the readings on the pipe flanges are lower than the reading on the valve body, the valve is leaking and the values for all three locations should be recorded in appropriate locations on the spreadsheet. After completing the survey of all the valves, the operator should enter the acoustic emission readings into the software to quantify the leak rate for the valves that are leaking.

Precautions

The accuracy of the detection and quantification will vary depending on test conditions. Most instrument manufacturers provide guidelines as to minimum conditions required for testing. Typically, this may be a minimum differential pressure across the valve or leak rate. Consult the user manual for the instrument to make sure it is capable of providing accurate information for the conditions in which it will be used. Also check the maximum temperature rating for the sensor to make sure it will not be damaged by exposure to a temperature above its rated value.

When making measurements on large valves, it should be noted that there may be differences in the readings at different locations on the valve. This is because the acoustic emission signal attenuates as it travels away from the source to the different sensor locations. When testing large valves, the highest reading on the valve body is the one that should be used to determine if a leak is occurring and to quantify the leak rate.

Acoustic emission leak testing technology can also be used on

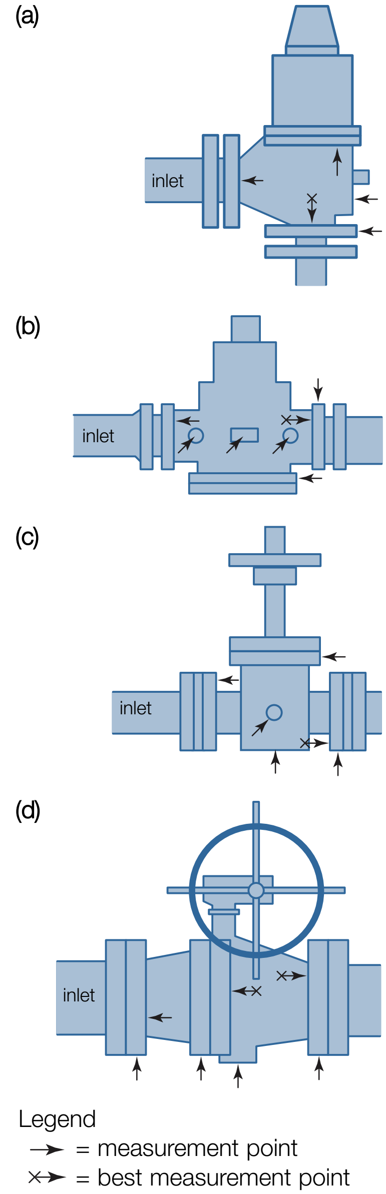

Figure 6. Measurement points for: (a) relief or pressure safety valve, (b) plug valve, (c) gate valve, (d) ball valve.

Figure 5. Piezoelectric elements used in many AE instruments are capable of generating large voltage spikes. AE instruments should be verified intrinsically safe before use in a plant or hazardous area.

Figure 7. Acoustic emission sensor and waveguide for high temperature valves.

steam valves such as those used in power generation. Steam is extremely erosive and valve seats can be worn away quickly should a leak exist. Because steam valves operate at high temperatures, they are typically insulated. A special waveguide must be used to penetrate the insulation and conduct the acoustic emission signal from the valve body to the sensor (Fig. 7). Tests of steam valves require additional training and skills. Steam contains a great deal of energy and steam valves produce a great deal of background noise. Excessive background noise can cause an operator to misinterpret a properly functioning valve as one that is leaking. Two precautions are necessary when testing steam valves. The acoustic emission system being used must have a high frequency sensor greater than 200 kHz. In addition, upstream and downstream measurements are required.

References

1. Cole, P. and M. Hunter. "An Acoustic Emission Technique for Detection and Quantification of Gas Leakage to Reduce Losses from Process Plant." Fourth Oil Loss Control Conference [London, United Kingdom]. London, United Kingdom: Institute of Petroleum (October 1991).
2. Nondestructive Testing Handbook, third edition: Vol. 6, Acoustic Emission Testing. Ch. 6, "Acoustic Leak Testing." Columbus, OH: American Society for Nondestructive Testing (2005): p 220-221
3. Husain, C. and P. Cole. "Quantification of Through Valve Gas Losses Using Acoustic Emission — Field Experience in Refineries and Offshore Platforms." Paper presented at European Working Group for Acoustic Emission [Robert Gordon University, Aberdeen, United Kingdom] (May 1996).
4. UL 913 [formerly FMRC 3610], *Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II and III, Division 1 Hazardous (Classified) Locations.* Northbrook, IL: Underwriters Laboratory (2002).
5. EN 50020, *Electrical Apparatus for Potentially Explosive Atmospheres — Intrinsic Safety "i."* Brussels, Belgium: European Committee for Electrotechnical Standardization [CENELEC] (2002).