QUANTIFYING VALVE LEAKAGE RATES WITH ULTRASONIC EMISSIONS TESTING

WITH INCREASING PRESSURE TO DRIVE EFFICIENCY IMPROVEMENT, MANY PLANTS AND FACILITIES ARE TAKING A CLOSER LOOK AT HOW TO ACHIEVE MORE EFFECTIVE PROCESS AND CYCLE ISOLATION.

BY MICHAEL FLAHERTY, TONY GLEMBOCKI AND MARC HAIN

Fluid losses and consequent energy losses across leaking valves have been considered acceptable, at least to a certain degree. In fact, codes and standards allow for certain rates of leakage on new valves, which increase over time and with wear and tear. In the past, detecting cycle or system losses due to valve leakage was challenging and time consuming, and the rate of leakage was nearly impossible to quantify. However, with continually increasing pressure to drive efficiency improvement, many plants and facilities are starting to take a closer look at more effective process and cycle isolation. Ultrasonic emissions testing (UET) is enabling plants to achieve this with minimal effort and improved accuracy.

THEORY AND APPLICATION

The basic principle underlying ultrasonic emissions testing is simple. A tightly seated valve will not produce any ultrasonic emissions or noise relative to the background. A valve passing liquid or gas will produce increased noise levels in the area of the valve seating surface. Additionally, the amplitude or volume of noise will generally increase with more severe leakage rates.

Accurately quantifying or measuring the rate of leakage, however, is far more challenging and largely dependent on many additional parameters or variables, including the type, size and class of the valve, physical properties of the fluid in the system, and operating conditions around the valve.

In practice, the ultrasonic emission, or acoustic signal level, is measured against background noise in order to isolate the sound energy associated directly with the leakage. Additionally, the valve specifications, fluid properties and operating conditions are recorded and all the data is input into a knowledge-based software program. The software program is based on both fluid dynamic principles for orifice flow and empirical results compiled over a decade using valves with known leakage rates. The software returns a leakage rate for the subject test valve in pounds per hour.

Finally, the software uses the cost of the liquid or gas, the unit cost of energy added to the liquid or gas, and the determined leakage rate to quantify the economic impact of each individual valve on plant operations.

The method utilizes portable instrumentation, and is intrinsically safe and entirely non-intrusive to online plant operations.

ACCURACY OF RESULTS

Fluid dynamic theory predicts the relationships and the empirical data verifies the correlation. To further validate the consistency of the results, third-party testing was

executed under conditions analogous to actual plant installations and the UET results were compared against controlled laboratory measurements.

The tests show conclusive evidence of the correlation and the accuracy of the results. Particularly with large populations of valves, plant operations personnel can use UET to easily identify "poor performers" and prioritize specific valves for repair or replacement.

THE THERMOGRAPHIC TESTING APPROACH

Thermography is the use of infrared imaging to measure thermal energy emitted from an object. Analogous to "night vision" cameras, thermographic imaging detects even small surface temperature variations on the plant process piping. In testing for cycle isolation, several measurements upstream of the valves, downstream of the valves and across the valve bodies are required.

Given the known upstream conditions inside the pipe, the surface temperature gradient is used as a model to predict the heat flux or the temperature gradient. Using computational heat transfer programs, the heat flux is directly correlated to energy losses or leakage across the valve.

Thermographic testing, i.e. using heat guns or thermal imaging cameras, is far more common than ultrasonic emissions testing. Although this technology has been successful, there is a potential to produce inaccurate or even false results if the user is not careful:

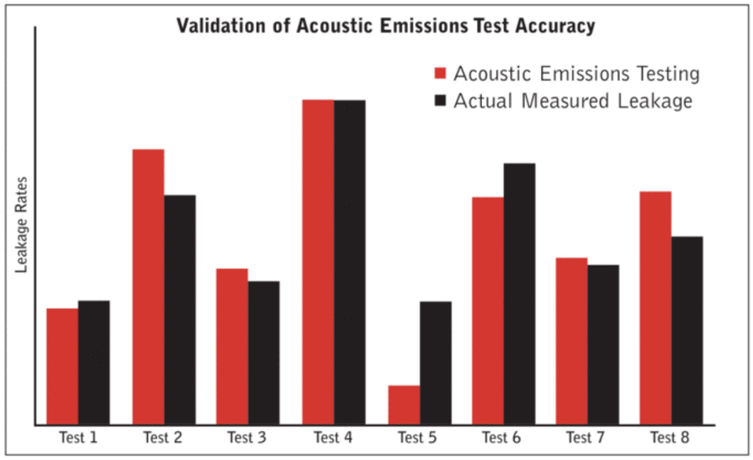

Figure 1. Third-party testing was used to verify results.

- Unlike UET, which is measuring the conditions at the very instant of the test, in thermographic testing, an elevated downstream temperature could be the result of residual heat from a recent cycling of the valve.
- UET identifies the leakage at the source and measures it against immediate background noise. With thermography, it is more difficult to delineate the valve leakage from all the other potential heat sources that may be affecting the results.
- A leaking valve will always emit an ultrasonic signature but will not always result in increases in downstream piping temperatures. If the valve is leaking to saturated conditions, the additional energy will increase the "dryness" of the saturated steam and not show a temperature increase that is indicative of the actual leakage rate. Additionally, if a high-pressure liquid is leaking to a lower pressure system, flash steam or a flash evaporation process may result, which will cause cooling in the downstream piping as in the expansion process of a refrigeration cycle.
- Considered to be a nondestructive test method, to improve the likelihood of a positive diagnosis and accurate result, significant sections of insulation must be removed in multiple locations along the process piping. This is a more invasive and time-consuming process compared to UET, which requires only a few, easily pluggable half-inch drill holes in aluminum jacket. (Ultrasonic emissions measurement is accomplished with a 3/8-inch diameter transducer placed against the valve and the adjacent pipe surfaces.)
- In contrast to the instantaneous results associated with ultrasonic emissions testing, thermographic test readings must be subsequently interpreted and mathematically or computationally modeled under a set of engineering assumptions.

In summary, the results of thermographic testing are user-dependent, and false readings may occur. Although good results have been achieved using thermographic testing, the ability to eliminate or mitigate the effects of the above is contingent upon the system specific knowledge, the amount of effort and the

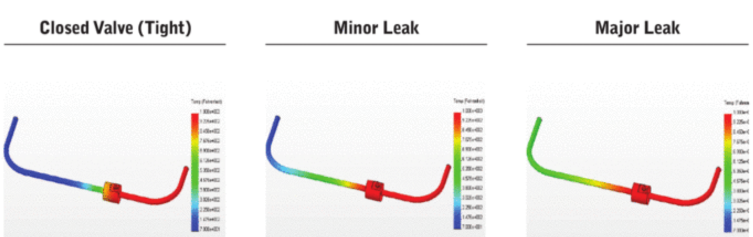

Figure 2. Thermographic testing results

assiduousness of the person executing the test. Conversely, by following simple procedure, UET produces user-independent, consistently repeatable results with less effort.

CASE STUDY: AES Red Oak

AES Red Oak is an 832 MW natural gas-fired combined cycle electric generating facility located in Sayreville, NJ. Commercial operations began in September 2002. A buyer for an energy trading company purchases power from the facility under a 20-year tolling agreement, which includes incentives for improved heat rate (i.e. electrical power generating efficiency).

The plant was constructed under fixed-price contract terms and operators were aware that many of the installed isolation valves were poor performers. There were visual indications and plant personnel were fearful that the steam turbine wasn't properly protected against water induction.

Marc Hain, a team leader at AES Red Oak, wanted to improve the decision-making process, so he targeted 50 valves for testing and performed ultrasonic emissions testing over the course of a half day. "During the test, we were opening and closing the subject valves as well as adjacent block valves. By comparing the readings, we could tell immediately we were getting meaningful results," recalls Hain.

Time and budget constraints didn't allow for mass valve replacements. The test results made it easy for plant personnel to identify which valves should be replaced or repaired immediately, and helped avoid unnecessary repairs or replacements on valves that were providing a tight shut-off.

After the valves were replaced, the final results were evident in the control room. "We saw an overall improvement in heat rate of 20 to 40 BTU per kilowatt-hour," Hain noted. The results also were noticed by the tolling agreement buyer. Because of the incentives built into the agreement, the buyer subsequently sent engineers to verify the efficiency improvement. "The cost of verifying the heat rate improvement far exceeded the cost of the actual test," Hain concluded.

Total Program Approach

AES Red Oak now uses ultrasonic emissions testing as an ingredient in a comprehensive heat rate (or plant efficiency) betterment program. The benefits include:

- Recovery of lost plant efficiency and ability to maintain peak cycle efficiency
- Cost avoidance of unnecessary repairs or replacements
- Confirmation that in situ equipment is performing to manufacturer specifications and warranties
- Protection of other (downstream) plant equipment from unnecessary heat loads or water induction
- Reduction of cycle make-up requirements
- The ability to make more informed decisions.

These benefits translated into enhanced revenue and both immediate and long-term reductions in the costs associated with valve maintenance and repair.

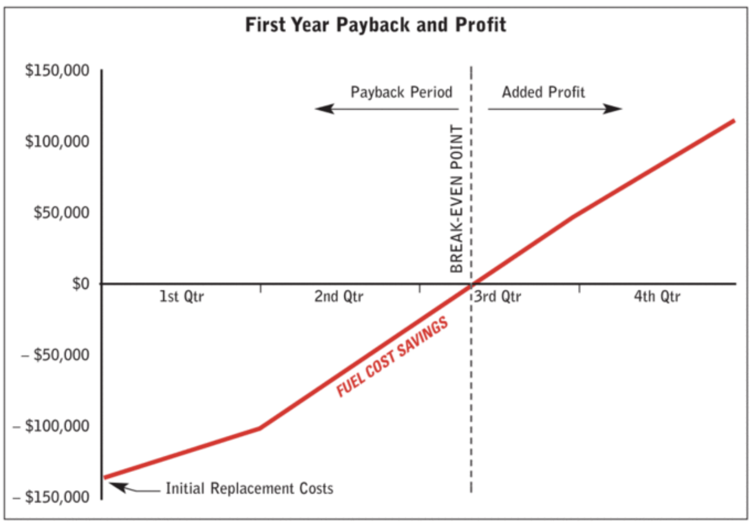

Figure 3. The initial cost to replace problem valves paid off during the third quarter of the first year as a result of fuel cost savings.

Conclusion

Ultrasonic emissions testing for cycle isolation is a very low-cost initiative, and potential returns are enormous. With energy losses across many valves exceeding 1,250 BTU/lb and fuel costs ranging from $1 to $10 per MMBTU, a single valve with a modest leak can be responsible for $10,000 to $100,000 in lost fuel costs during just one year of operation. For a valve that costs as little $3,000 to replace, that equates to internal rates of return on replacement in the hundreds and thousands of percent over a conservative four-year lifecycle.

The numbers add up quickly: With hundreds of valves in service, total loss recovery can total as much as 3% or higher in terms of overall plant efficiency, not to mention reductions in the working fluid make-up cost requirements for valves with fugitive leaks (i.e. leakage to atmosphere or effluent).

With modern industry's ever-increasing emphasis on cutting costs and improving plant efficiency, the effects of leaking valves or poor cycle isolation should be on every plant manager's and operator's radar screen. **VM**

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