Assess high-energy piping on line—before it’s too late

Acoustic emissions monitoring—relatively new to the power industry, but used for over 20 years elsewhere—can help in the quest to protect plant assets and avert catastrophic loss

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For the past 20 years, acoustic emissions (AE) monitoring has been extensively applied in the petrochemical, nuclear, and aerospace industries. A variety of professional and testing societies, including the American Society of Mechanical Engineers (ASME), and the American Society for Testing & Materials (ASTM) incorporate AE methods into inspection codes and practices. Transmission and distribution (T&D) personnel have used AE in aerial man-lift vehicle inspections since the early 1980s via ASTM F914-85.

AE, a passive monitoring technique, can inexpensively locate areas of potential damage in seam-welded piping. It has key advantages, compared to ultrasonic testing (UT). It is an on-line technique, which for aging fossil-fired units struggling to be profitable (box, next page), can be critical.

Listen for failures

An AE device listens for the high-frequency sounds of material failures. Before a failure occurs, energy from sound waves emanates from growing flaws in the steel. It detects and locates any defect growing in the metal path including hard-to-reach areas—such as seams, closures, hanger welds, drains, and vents. Emissions can be “source-located” within a few inches on linear lengths of piping by time-of-arrival techniques, similar to seismology.

Direct inspection costs are typically 70-90% less than with UT, which has to be performed with the equipment out of service. Because of this, AE can be used more frequently, increasing the safety margin for early detection of problems.

Instrumentation is minimal. Only 1 ft² of insulation is removed every 15-20 ft along the length of the line to install AE waveguides. The guides are 0.25-in-dia stainless steel rods welded to the pipe surface, with a platform to mount the AE sensor at the opposite end (Fig 1). Welding is allowed by ASME B31.1 off-line or during operation.

A typical UT inspection of 500 ft of hot reheat (HRH) piping might require extensive scaffolding, complete insulation removal and reapplication, and two to three weeks of plant downtime—easily costing $300,000. Many times, material conditions, such as original welding flaws and plate lamination, are evaluated that do not represent active defect sources.

A comparable AE test program can cost less than $60,000 and be completed in two weeks or so. AE detects active and growing flaws, focuses the priorities for follow-on inspection, and leads to findings that are otherwise ignored or not aggressively pursued. After initial setup and calibration, monitoring can be conducted remotely via modem.

Early work lays foundation

During the early 1990s, the Electric Power Research Institute (EPRI), Palo Alto, Calif. investigated AE testing for a quick screen of on-line piping. Later, it began to compare AE results with conventional UT exams. The R&D program began with partner Pacific Gas & Electric Co (PG&E), San Francisco, Calif., and produced a reliable field procedure through tests at the utility’s Potrero Unit 3 HRH line. Comprehensive guidelines for seam-welded HRH line inspection were published in November 1995. Corroboration between AE and UT was deemed successful.

Between 1995 and 1998, extensive field tests were collected into a data base. Methodology and evaluation criteria were verified, refined, and compared with other techniques. Thirty inspection programs were conducted on both HRH and superheat (SH) seam-welded piping systems for 12 weeks or so. AE detects active and growing flaws, focuses the priorities for follow-on inspection, and leads to findings that are otherwise ignored or not aggressively pursued. After initial setup and calibration, monitoring can be conducted remotely via modem.

1. Field test engineer installs an acoustic emission sensor in a welded waveguide assembly on a HRH line (left)
2. KU Brown Unit 3 SH link piping segment (seam weld cross section) shows no evidence of creep cracking. Sensitive cryo-cracking examination of the weld centerline reveals evidence of early stage creep cavitation around grain boundary (right)
utilities. At least five other utilities started their own programs.

**Sound examples**

Many recent examples prove the technique's value. Several are described here.

Early tests at PG&E’s Potrero Unit 3 HRH line established AE’s sensitivity, and uncovered several defect conditions, including a cracked saddle weld in a hanger support, cracks in a cast elbow, and inner-diameter (ID)-connected thermal fatigue cracking in the parent material adjacent to a spool closure weld.

During an April 1997 inspection of Carolina Power & Light Co.’s (Raleigh, NC) Joslin Unit 1 HRH line, a problem at a mechanical hanger on the bottom of the line was detected when line loading increased. As station employees watched the AE system’s graphics displays, a special 400-kHz sensor output provided audible proof of the problem in the form of “pops and cracks,” clearly heard above the background flow noise. Both manual and automated, multi-angle pulse-echo and time-of-flight (TOF) UT inspections verified problems in the seam weld. The hanger strap was removed during the next outage.

Wes Hull, manager, Central & South West Services Corp, Dallas, Tex, leads a group that evaluates high-energy piping for the utilities in the holding company. Based on the Joslin test and five others at various units, his group determined that AE was a reliable method for use on the remainder of the utility’s 43 fossil-fuel units.

Two tests were conducted on American Electric Power Co.’s (Columbus, Ohio) Gavin Units 1 and 2. During the summer of 1996, Gavin-1 was subjected to a double blind test with UT inspection. The lower 50 ft of the dual 1200-ft HRH pipe was inspected with both manual and TOF UT during a planned outage. AE testing, applied for several weeks during peak load cycling, revealed two areas of activity on elbow closure welds, and two minor areas of activity on turbine leads. Closure weld indications correlated with outer diameter (OD)-connected shallow cracks, visually ground out during the outage.

Two areas on the turbine leads also matched UT indication, as predicted—the pattern of intermittent indications and length of line affected. None of these indications posed an immediate structural problem, but a spool piece with a high density of plate laminations in another turbine lead was flagged as a potential problem. For this problem, AE results showed no significant activity, so regular UT reinspection costs...

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**Aging and need to stay on line are worry points**

The general aging of fossil-fuel plants raises concerns about the safety of operating seams welded high-energy piping systems. The lack of set re-inspection intervals combined with high inspection costs and plant downtime compounds the problem. Many power producers are extending time between scheduled outages, and limit the time allowed for periodic off-line inspections.

Since the 1985 catastrophic failures of seam-welded hot reheat (HRH) piping at Southern California Edison Co.’s (Rosemead, Calif) Mohave plant and Detroit Edison Co.’s (Detroit, Mich) Monroe plant during 1986, power producers have carefully considered the need for periodic inspections of critical piping to guard against creep-induced failures. During the 1980s, several serious defects in seam piping were eliminated, and for a time, catastrophic failures ceased.

Five failures of seam-welded superheat (SH) link piping supplied with tangential-fired boilers have been documented since 1992. Two have been catastrophic—Virginia Power Co’s (Richmond, Va) Mt Storm Unit 1 in 1996, and Kansas City Power & Light Co’s (KCPL, Kansas City, Mo) Hawthorn Unit 5 in 1998. Thankfully, no loss of life occurred, but the cost of repairs and loss of power generation is a critical concern in this age of growing competition.

All failures of SH link piping have occurred on units with accumulated service between 125,000 and 200,000 hours. Inaccuracy of supplied documentation compounds the problem—many times true alloy content and method of fabrication are unknown. For example, Hawthorn’s SH link piping was not known to be seam-welded.

Note that seamless piping is not exempt—failures of circumferential welds and through-wall creep failure of improperly fabricated seamless SH pipe have occurred.

The normal inspection process is arduous: wait for a scheduled outage, remove pipe insulation from large areas, and conduct ultrasonic (UT) inspections inch by inch slowly. Predictable and reliable results are elusive. Certain areas, such as welds under hanger attachments and at floor penetrations, typically are not inspected because of access cost, and in some cases, unreliable results. To illustrate, the 1992 through-wall failure in the HRH elbow at Entergy Corp/Gulf States Utilities’ (New Orleans, La) Sabine station was preceded by UT inspections five and three years prior to failure. The Mt Storm SH link piping failure was preceded by UT inspection 14 months prior to failure.
for this area were averted.

Testing of the full 1200 ft of the Gavin Unit 2 HRH line during 1997 revealed no significant AE indications. Total estimated cost saving by using AE screening in lieu of conventional UT inspection was $500,000—not including potential lost power generation.

Two significant inspection programs were conducted at Kentucky Utilities' Ghent-1 and Brown-3 in 1997. Several exit elbows in the HRH link piping exhibited highly active AE sources during startup and on-line monitoring. Manual UT inspection confirmed all activity in five indicated areas. After most of the bad weld material was removed, AE monitoring indicated a 95% reduction in activity at the two elbows repaired by through-wall removal of weld material. The SH link piping was also monitored and showed no significant activity.

At Brown Unit 3, the seam-welded SH link piping leads, installed in 12-ft vertical segments, were monitored during a unit restart following the spring 1997 outage. Both leads were observed to have active AE sources in areas below the penthouse roof—similar to the location of a through-wall failure on a SH link at Alabama Power Co's Gaston plant discovered in 1992. Monitoring was performed on-line again in February 1998, prior to an outage when the links were scheduled for replacement.

One lead was analyzed by EPRI's NDE Center. A phased-array automated UT inspection performed on the seam weld, confirmed AE source location results in a 21-ft length. Further metallographic analysis showed no cracking in a 3-in. plug sample. This was confirmed by a cryo-cracking examination performed by Materials & Mechanical Engineering Inc, Austin, Tex. Evidence of early-stage creep cavitation in the weld centerline was uncovered (Fig 2).

These sophisticated UT and metallographic methods confirmed that AE identified a developing problem well ahead of the appearance of microcracking, which could coalesce into a major crack. Early detection, measured in years in this case, allowed the utility to remove a future hazard on a reasonably planned schedule.

A recent AE monitoring program at Illinois Power Co's Baldwin and Wood River plants identified potential creep problems in several seam-welded elbows and bends. Structural Integrity Associates (Silver Spring, Md) performed TOF and Focused Array Test (FATS) UT inspection on one of the clamshell elbows on Baldwin Unit 1. Evidence of early-stage creep cavitation was found in the midspan extra-dose weld of the elbow. This result matched the AE prediction, which identified this area as a low-activity source. With this level of knowledge, the utility can efficiently plan periodic inspections and institute a replace or repair schedule consistent with operating objectives.

Edited by Carol Ann Giovando

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Note: Joslin is Central Power & Light plant