Designation: E2984/E2984M − 14

Standard Practice for Acoustic Emission Examination of High Pressure, Low Carbon, Forged Piping using Controlled Hydrostatic Pressurization[1]

This standard is issued under the fixed designation E2984/E2984M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 In the preferred embodiment, this practice examines immersed low carbon, forged piping being immersed in a water tank with the acoustic sensors permanently mounted on the tank walls rather than temporarily on the part itself. The pipes are monitored while being internally loaded (stressed) by hydrostatic means up to 1000 bar.

1.2 This practice examines either an immersed pipe, or non-immersed pipe being stressed by internal hydrostatic means to create acoustic emissions when cracks are present. However, the non-immersed method is time consuming, requiring placement and removal of sensors for each pipe inspected, while the immersed method has sensors permanently mounted, providing consistent sensor coupling to the tank-eliminating reinstallation. The non-immersed method is not recommended for the specified reasons and only the immersed method will be discussed throughout the remainder of the standard. This is similar to pressure vessel testing described in Practice E569, but uses hydrostatic means not included in that standard.

1.3 This Acoustic Emission (AE) method addresses examination for monitoring low carbon, forged piping systems being internally loaded (stressed) by hydrostatic means up to 1000 bar [15,000 psi] while being immersed in a water bath to facilitate sensor coupling.

1.4 The basic functions of an AE monitoring system are to detect, locate, and classify emission sources. Other methods of nondestructive testing (NDT) may be used to further evaluate the significance of acoustic emission sources.

1.5 This practice can be used to replace visual methods, which are unreliable and have significant safety risks.

1.6 This practice describes procedures to install and monitor acoustic emission resulting from local anomalies stimulated by controlled hydrostatic pressure.

1.7 Other methods of nondestructive testing (NDT) may be used to further evaluate the significance of acoustic emission sources.

1.8 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E543 Specification for Agencies Performing Nondestructive Testing

E569 Practice for Acoustic Emission Monitoring of Structures During Controlled Stimulation

E650 Guide for Mounting Piezoelectric Acoustic Emission Sensors

E750 Practice for Characterizing Acoustic Emission Instrumentation

E976 Guide for Determining the Reproducibility of Acoustic Emission Sensor Response

E1316 Terminology for Nondestructive Examinations

E2374 Guide for Acoustic Emission System Performance Verification

2.2 *Other Referenced Documents*

ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel[3]

[1] This test method is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.04 on Acoustic Emission Method.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

NAS-410 NDT Certification[4]
SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing[5]

3. Terminology

3.1 *Definitions*—Definitions of terms relating to acoustic emission may be found in Section B of Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *AE activity*—the presence of acoustic emission during an examination.

3.2.2 *active source*—one which exhibits increasing cumulative AE activity with increasing or constant stimulus.

3.2.3 *critical source*—is where the event energy rate exceeds a baseline established from known good parts.

3.2.4 *critically intense source*—one in which the AE source intensity consistently increases with increasing stimulus or with time under constant stimulus.

3.2.5 *hydrostatic stimulation*—applies stress internally to a pressure vessel stimulating any incipient defects to be in motion yielding stress or strain waves.

4. Summary of Practice

4.1 Acoustic emission examination of a structure usually requires application of a mechanical or thermal stimulus to produce changes in the stresses in the structure. In this application, the use of internal hydrostatic pressure, over an appropriate range, stimulates changes in the stresses in the structure. During this stimulation, AE from discontinuities (such as cracks, corrosion and inclusions), or from other acoustic sources (such as leaks or structural motion) can be detected by an AE instrument, using sensors which, when stimulated by stress waves, generate electrical signals.

4.2 In addition to immediate, real time, evaluation of the emissions detected during the application of the stimulus, a permanent record of the number and location of emitting sources and the relative amount of AE detected from each source provides a basis for comparison with sources detected during the examination and during subsequent stimulation. This may be used to discriminate between AE events emitting from corrosion and those from the more serious cracks.

5. Significance and Use

5.1 High pressure fluids being pumped in all oil field applications often stress iron pipes where subsequent failure can lead to injury to personnel or equipment. These forgings are typically constructed from 4700 series low carbon steel with a wall thickness in excess of 1.25 cm [0.5 in.], dependent on the manufacturers' specification. The standard method to certify that these iron segments can withstand operational pressures is to perform dye penetrant (PT) or magnetic particle penetrant (MT) tests, or both, to reveal defects (cracks and corrosion). As these methods are subject to interpretation by the human eye, it is desirable to employ a technique whereby a sensor based system can provide a signal to either pass or fail the test object. To that end, the acoustic emission (AE) method provides the requisite data from which acceptance/rejection can be made by a computer, taking the human out of the loop, providing that a human has correctly programmed the acceptance criteria. Most of these pipe segments are not linear, thus a 3D defect location method is desirable. The 3D source indication represents the spatial location of the defect without regard to its orientation, recognizing the source location is only approximate due to sound propagation through the part and water bath.

5.2 The immersed 3D approach is found to be preferable due to the large number of parts to be examined. The 3D system is easily replicated and standardized in that all sensor locations are fixed to the exterior of the fluid bath. Multiple parts may be easily placed into an assembly, allowing all to be examined in a single test, thus accelerating throughput. Attaching a minimum of eight AE sensors to the tank enhances the probability that a sufficient number of AE hits in an event will occur, allowing for an approximate location determination. When an indication of a defect is observed, the subject part is identified by the spatial location allowing it to be removed for further examination, or rejected for service. An immersed test configuration is shown in Fig. 1a and b.

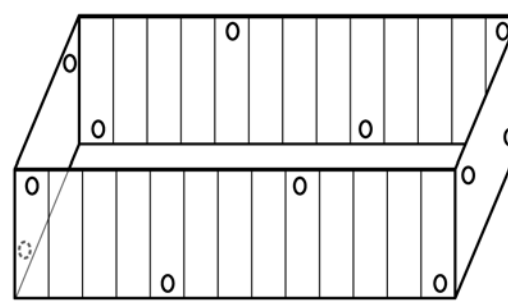

FIG. 1 (a) Immersion bath with permanently attached AE sensors on exterior (circles)

FIG. 1 (b) photo of part under test *(continued)*

5.3 The non-immersed examination is equally effective in detecting defects, but requires more time to assemble in that sensors must be attached to the part for each examination. Moreover, the fluid fill and air purge times are much longer than in the immersed bath immersion. The non-immersed test

[4] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.

[5] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

layout and photo are shown in Fig. 2a and b. Note the sensors

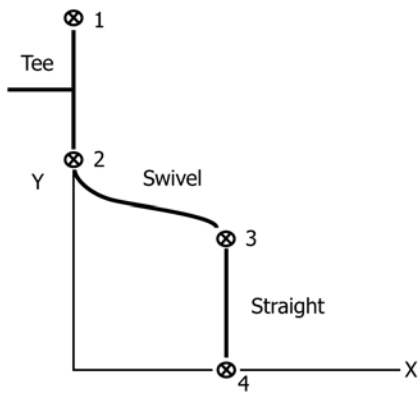

FIG. 2 (a) is the layout, with sensors 1–4, of a typical non-immersed test as is shown in the photo (b)

are indicated with the symbol *x*.

FIG. 2 (b) Sensors 1–4, of a typical non-immersed test *(continued)*

6. Basis of Application

6.1 The following items are subject to contractual agreement between the parties using or referencing this practice.

6.2 *Personnel Qualification*

6.2.1 If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally and internationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT CP-189, SNT-TC-1A, NAS-410, or similar as applicable. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

6.3 *Qualification of Nondestructive Testing Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E543. The applicable edition of Practice E543 shall be specified in the contractual agreement.

6.4 *Timing of Examination*—The timing of the examination shall be in accordance with a contractual agreement or with an established internal procedure.

6.5 *Extent of Examination*—This application requires sensor(s) placement such that the location where an AE event occurs can be reliably detected.

6.6 *Reporting Criteria/Acceptance*—Reporting criteria for the examination results shall be in accordance with Sections 11, 12, and 13.

6.7 *Reexamination of Repaired/Reworked Items*—Reexamination of repaired or reworked items is not addressed in this standard and if required shall be specified in a contractual agreement.

7. Examination Preparation

7.1 Before the examination begins, make the following preparations for AE monitoring:

7.1.1 *Sensor requirements*—Consideration should be given to the fact that multiple pieces of treating iron will be tested simultaneously. The type, number, and placement of sensors is critical in that source location will be used to determine which pieces are emitting during a hydrotest. Three dimensional source location is ideal for this application if used properly.

7.1.1.1 This requires knowledge of materials and physical characteristics of the structure being tested as well as the liquid-filled container in which they are tested. It also requires knowledge of wave propagation through a liquid as well as the instrumentation used to collect and process these waves. Knowledge of overdetermined source location is also helpful.

7.1.1.2 This determination is also dependent upon the required precision and the accuracy of examination. It is important to use an appropriate number of sensors to provide sufficiently accurate 3D source location to distinguish which piece of iron is generating significant AE.

7.1.1.3 No fewer than eight sensors are desirable for an immersion tank that is 10 ft. long by 5 ft. wide by 5 ft. deep.

7.1.1.4 Tanks with dimensions greater than these (for accommodating multiple pieces of treating iron) will require more sensors to instrument.

7.1.2 The immersion tank shell (walls) shall be constructed from stainless steel to avoid corrosion. This allows for a permanent attachment of all AE sensors defining a stable 3D location geometry. The water holding tank shall be no smaller than 400 cm [13 ft.] long by 150 cm [5 ft.] wide by 90 cm [3 ft.] tall, with 25 cm [10 in.] legs and levelers to raise the height to be a comfortable working height and accommodate a roll under crane for loading and unloading pipes. These dimensions allow the loading of multiple components for a simultaneous examination. The water bath is specified to be distilled with a corrosion inhibitor added.

7.1.3 An appropriate AE sensor with a frequency range from 150 to 450 kHz shall be employed to avoid ambient noise sources.

7.1.4 Establish communications between the control point for the application of the stimulus and the AE examination control center.

7.1.5 Provide a means for continuously recording a measure of the stimulus.

7.1.6 Identify potential sources of extraneous acoustic noise, such as vibration, friction, and fluid flow. Such sources may require acoustic isolation or control, in order not to mask valid acoustic emissions.

7.1.7 Attach the sensors; both the couplant and sensing device must be compatible with the surface conditions and the composition of the structural material being examined (see Guide E650).

7.1.8 Verify the AE monitoring system in accordance with Section 9 and Guide E2374.

7.1.9 A training set of multiple known "good" and "defective" pieces as previously determined by Magnetic Particle Inspection (MT) or Fluorescent Penetrant Inspection (PT) are examined by this method. These data establish a baseline for future comparisons to define acceptable/reject parts, as this method is applicable to the repetitive examination of large sets of parts on a periodic basis, and not for one time testing of unique structures.

7.1.10 AE methods can be applied to detect potential critical defects in high pressure piping, however 3D has an intrinsic advantage in that cracks can be separated from other AE sources using location detection algorithms.

8. Safety Precautions

8.1 Hydrostatic pressurization should occur in defined steps and holds, to minimize the chance of a sudden rupture. AE responses above a threshold established from known good parts, at relatively low pressure set points will signal the operator to terminate the examination. Further, when the vessel under test is submerged in a fluid-filled tank, the tank fluid will further mitigate the likelihood of personnel injury due to a rupture. During pressurization stages, test personnel should maintain a safe distance from the vessel under pressurization.

9. Calibration and Verification

9.1 Annual calibration and verification of AE systems, including; preamplifiers, signal processors (particularly the signal processor time reference), and AE waveform generators should be performed regularly, in accordance with the manufacturer's recommendations. Equipment should be adjusted so that it conforms to equipment manufacturer's specifications. Instruments used for calibrations must have current accuracy certification that is traceable to the National Institute for Standards and Technology (NIST). Likewise, AE sensors should be verified regularly and consistently, in accordance with the manufacturer's recommendations.

9.2 Routine electronic evaluations (verification) must be performed any time there is concern about signal processor performance. A waveform generator should be used in making evaluations. Each signal processor channel must respond with peak amplitude reading within 2 dB of the electronic waveform generator output.

9.3 A system performance verification (see Guide E2374) shall be conducted immediately before, and immediately after, each examination. Performance verifications can also be conducted during the examination if there is any suspicion that the system performance may have changed. A performance verification uses a mechanical device to induce stress waves into the structure at a specified distance from each sensor. Induced stress waves stimulate a sensor in a manner similar to acoustic emission. Performance verifications verify performance of the entire system (including couplant).

9.3.1 The preferred technique for conducting a performance verification is a pencil lead break. Lead should be broken in accordance with section 4.3.3 of Guide E976.

9.3.2 *Location Accuracy Check*—A simulated AE source is created on the surface of the tank wall in order to check location accuracy.

9.3.2.1 *Source Location Algorithm Accuracy Check*—Each channel shall have the same system examination threshold. A minimum of two sensors define a linear location, while a minimum of four hit sensors defines a 3D location verification.

10. Examination Procedure

10.1 Acoustic emission data shall be accumulated during the stimulation of the structure, as specified in the written procedure.

10.1.1 The part to be examined shall be immersed in the fluid-filled tank, with all specified pressure fittings and gauges. All air must be purged from the assembly prior to testing to eliminate this known interference with extraneous noise.

10.1.2 An appropriate pump shall be attached to the assembly and pressurization shall commence to produce predetermined values, depending on the rating of the vessel under examination.

10.1.3 A loading profile shall be defined for the objects under test. For example, on a 700 bar [10,000 psi.] rated segment, the hydrostatic pressure was set at 350 bar [5,000 psi], 600 bar [8,500 psi], 700 bar [10,000 psi] and 750 bar [11,000 psi] with two minute wait states at each level, while observing the AE activity.

10.1.4 During application of the stimulus, the locations of acoustic sources are determined through analysis of the times of arrival of AE signals at multiple sensors, by knowing the wave propagation velocity. Such analysis may be performed through the use of an AE computerized instrument. The computer accumulates and analyzes data over a specified parametric range. These parameters are pressure, time, and stress. Each channel shall have the same system examination threshold. As the stimulus is applied, record the number and location of emitting sources and the AE hits detected, by all sensors, from each source. The AE rate at all sensors should be monitored and displayed in real time during stimulation. If the acoustic emission activity indicates a critically intense source, or if the part under examination fails to maintain pressure, the AE operator shall stop the examination and notify the owner of the structure or his designee immediately.

10.1.5 Continuous emission from any leak in a structure (the inability to maintain pressure at any of the predefined values) shall be immediate grounds to reject the part, unless the leak is determined to originate from improper assembly.

10.1.6 Following the examination, repeat the performance verification in accordance with 9.3.

11. Examination Records

11.1 All system performance verification data and instrument adjustments, including equipment description and performance data, shall be included in the records of the examination with all pertinent qualification/certification records and be signed by the responsible AE examiner. The information recorded should be sufficient to permit complete reanalysis of the results. This information should include, but not be limited to:

11.1.1 Material, physical characteristics of the structure, and manufacturer's data sheet or tag data,

11.1.2 Sensor specifications, including size, frequency response, method of attachment, type of couplant, type and length of connecting cables,

11.1.3 Sensor locations,

11.1.4 Immersion tank specifications including materials, dimensions, fluid material and fluid fill level,

11.1.5 Functional descriptions of signal conditioners, processors, and display equipment,

11.1.6 Stimulation schedule, AE monitoring procedures, and results of all sensitivity checks,

11.1.7 Permanent data record of the measured AE signal parameters, in analog or digital form,

11.1.8 Stimulation medium temperature, ambient air temperature, and

11.1.9 Records of the training set used to establish "good" versus "defective" parts.

12. Interpretation of Results

12.1 All results shall be summarized on an appropriate layout map, displayed or tabulated, or both, for ready reference and interpretation. This layout or tabulation shall display the location and classification of each source with pertinent comments.

12.1.1 *Source Location*—All location data resulting from analysis shall be presented in a manner consistent with the previously established calibration accuracy. In location determinations, the propagation velocities for the materials under evaluation must be included in the calculations.

12.1.2 *Source Classification*—Sources shall be classified with respect to their acoustic activity, location, and intensity.

12.1.2.1 A source's acoustic activity is measured by event AE energy above a defined threshold. A source is considered to be active if its AE activity continues to increase with increasing or constant stimulus. This phenomenon is observed when pressure is increased in prescribed stages (see Fig. 3).

12.1.2.2 Preferred intensity measures of a source are its: average detected energy per event, average emission count per hit, or average peak amplitude per hit. A source is considered to be a critical source if it is active and its intensity measure consistently exceeds threshold established by examining known good parts.

12.1.2.3 When using source location algorithms, in addition to activity and intensity, another characteristic of each detected AE source that should be considered for source classification is the size of the "region" of the located source. The clustering of the located events from a sharp discontinuity, such as a crack, is usually dense, while regions of plastic deformation associated with corrosion pits result in source areas that show more uncertainty in the definition of their size, the events being contained rather sparsely distributed in the region. Note that plastic deformation is not detectable, but rather the associated corrosion particles that move in the region results in an AE source. In most cases, a growing crack is considered to be the more serious defect (see Fig. 4b). However, activity and intensity may not suffice for distinguishing between the two. Normally, there is subjective judgment on what size of observed cluster constitutes an isolated source. The 3D source location plot is extremely useful in the determination of a critical defect.

12.1.3 *Source Evaluation*—Sources are usually evaluated by their activity or intensity. The procedure shall specify definitions for critically active and critically intense.

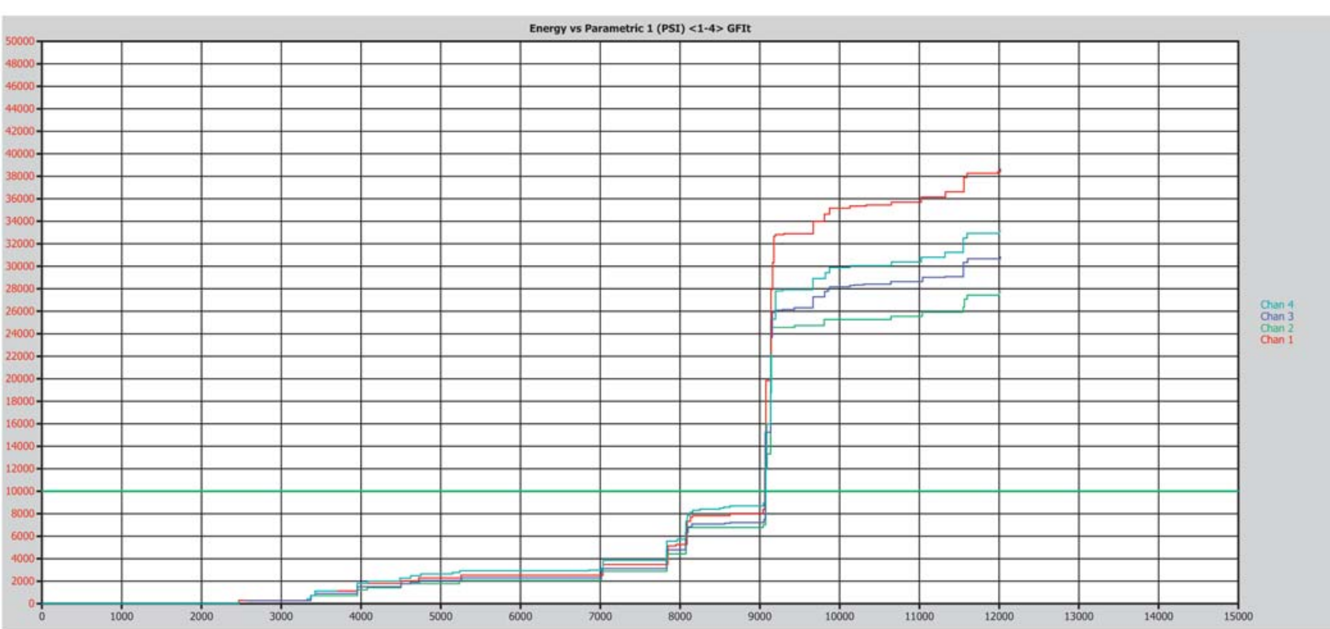

FIG. 3 Schematic representation of a critically active AE source in a submersed test by monitoring the cumulative AE energy for eight channels, although only four are shown here. Note the dramatic activity increase in all channels when the hydrostatic pressure reaches 620 bar [9,000 psi].

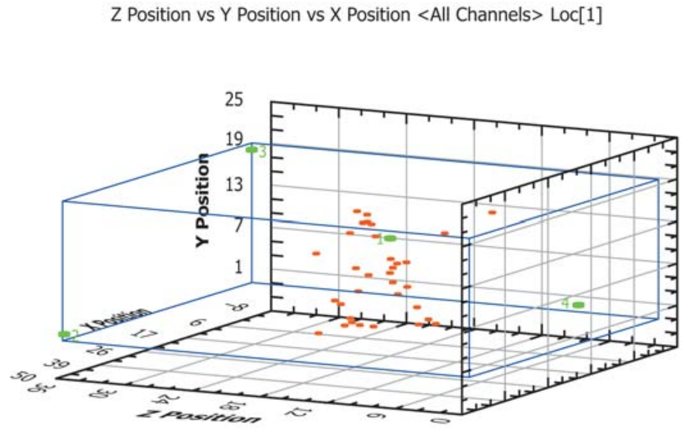

FIG. 4 (a) good part in a submersed test. 3D representation of random signals above a threshold

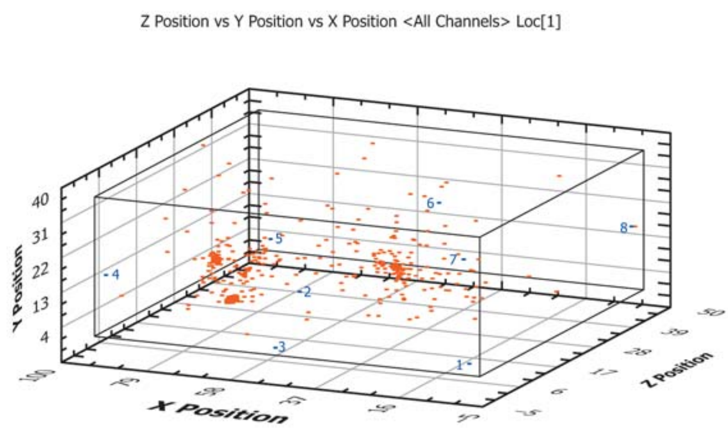

FIG. 4 (b) A known defective part. 3D space representation of clusters associated with likely cracks, plus plastic deformation associated with corrosion. The dimensions in all three axes are about 50 cm [20 in.] x 50 cm [20 in.] x 90 cm [35 in.]. *(continued)*

12.1.4 Indications located with AE should be examined by other techniques; for example, visual, ultrasonics, dye penetrants, etc., for corroboration.

13. Report

13.1 A report should contain at least the examination record, the interpretation of results and a diagram of the piping showing the sensor location(s). The creation of intensity as well as source location plots provides the examiner the requisite data from which determinations of acceptable parts, versus rejects can be made.

14. Keywords

14.1 acoustic emission examinations; controlled simulation; hydrostatic; sensor locations