INTERNATIONAL

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Standard Test Method for Examination of Liquid-Filled Atmospheric and Low-Pressure Metal Storage Tanks Using Acoustic Emission[1]

This standard is issued under the fixed designation E 1930; 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 This test method covers guidelines for acoustic emission (AE) examinations of new and in-service aboveground storage tanks of the type used for storage of liquids.

1.2 This test method will detect acoustic emission in areas of sensor coverage that are stressed during the course of the ~~test.~~ examination. For flat-bottom tanks these areas will generally include the sidewalls (and roof if pressure is applied above the liquid level). The ~~test~~ examination may not detect ~~defects~~ flaws on the bottom of flat-bottom tanks unless sensors are located on the bottom.

1.3 This test method may require that the tank experience a load that is greater than that encountered in normal use. The normal contents of the tank can usually be used for applying this load.

1.4 This test method is not valid for tanks that will be operated at a pressure greater than the examination pressure.

1.5 It is not necessary to drain or clean the tank before performing this examination.

1.6 This test method applies to tanks made of carbon steel, stainless steel, aluminum and other metals.

1.7 This test method may also detect defects in tank linings (for example, high-bulke, phenolics and other brittle materials).

1.8 AE measurements are used to detect and localize emission sources. Other NDT methods may be used to confirm the nature and significance of the AE indications (s). Procedures for other NDT techniques are beyond the scope of this test method.

1.9 Examination liquid must be above its freezing temperature and below its boiling temperature.

1.10 Superimposed internal or external pressures must not exceed design pressure.

1.11 Leaks may be found during the course of this examination but their detection is not the intention of this test method.

1.12 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

1.13 *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.* Specific precautionary statements are given in Section 8.

2. Referenced Documents

2.1 *ASTM Standards:*

[1] This test method is under the jurisdiction of ASTM Committee E-07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.04 on Acoustic Emission Method.

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E 543 Practice for Evaluating Agencies that Perform Nondestructive Evaluation[2]
E 650 Guide to Mounting Piezoelectric AE Sensors[2]
E 976 Guide for Determining Reproducibility of AE Sensor Response[2]
E 1316 Terminology for Nondestructive Examinations[2]

2.2 *ANSI/ASNT Standard:*

ASNT SNT-TC-1A Recommended
Recommended Practice (ASNT SNT-TC-1A for Qualification and Certification of Nondestructive Testing Personnel)[3]
ANSI/ASNT CP-189 Standard for Qualification and Certification of NDT Personnel[3]

2.3 *ASME Standard:*

Section V, Article 12, Boiler & Pressure Vessel Code[4]

2.4 *AIA Document:*

NAS-410 Certification and Qualification of Nondestructive Testing Personnel[5]

3. Terminology

3.1 *Definitions:*

3.1.1 This test method makes use of definitions provided in Terminology E 1316. Definitions for terms that do not appear in Terminology E 1316 are given below.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *AE activity*—the presence of acoustic emission during a test. an examination. It is normally measured by one or more AE parameters such as number of hits, events, signal strength or AE counts. A source is considered active if its AE activity consistently increases with increasing load.

3.2.2 *maximum operating pressure*—largest pressure within the tank during the six-month period prior to AE examination. This pressure involves the maximum liquid contents level, the range of temperature experienced during operation, superimposed hydrostatic or pneumatic pressure, or both, and any overload or upset conditions which may have occurred.

3.2.3 *signal strength*—the measured area of the rectified AE signal.

4. Summary of Test Method

4.1 *General*—This test method consists of subjecting storage tanks to increasing stress while monitoring with sensors that are sensitive to acoustic emission (transient stress waves) caused by growing defects. flaws. The instrumentation and techniques for sensing and analyzing AE are described herein.

4.2 *Loading*—The test method requires stressing the tank. Stressing can be accomplished by filling the tank with its normal contents or with an alternative liquid and in some cases applying a superimposed hydrostatic or pneumatic pressure, or both.

4.3 *Report*—The report documents results of the AE examination and other important information. The report also provides recommendations for follow-up examinations at specific locations.

5. Significance and Use

5.1 *General*—This procedure is used for evaluation of the structural integrity of atmospheric storage tanks. The AE method can detect flaws which are in locations that are stressed during pressurization. Such locations include the tank wall, welds attaching pads to the tank, nozzle attachments, and welds attaching circumferential stiffeners to the tank. Among the potential sources of acoustic emission are:

5.1.1 In both parent metal and weld associated regions:
5.1.1.1 Cracks,
5.1.1.2 The effect of corrosion, including cracking of corrosion products or local yielding,
5.1.1.3 Stress corrosion cracking,
5.1.1.4 Certain physical changes, including yielding and dislocations,
5.1.1.5 Embrittlement, and
5.1.1.6 Pits and gouges.
5.1.2 In weld associated regions:
5.1.2.1 Incomplete fusion,
5.1.2.2 Lack of penetration,
5.1.2.3 Undercuts, and
5.1.2.4 Voids and porosity.
5.1.2.5 Inclusions:

[2] *Annual Book of ASTM Standards*, Vol 03.03.
[3] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.
[4] Available from American Society of Mechanical Engineers, 345 E. 47th Street, New York, NY 10017.
[5] Available from Aerospace Industries Association of America, Inc., 1250 Eye St., NW, Washington, DC 20005.

5.1.2.6 Contamination.
5.1.3 In parent metal:
5.1.3.1 Laminations.
5.1.4 In brittle linings:
5.1.4.1 Cracks,
5.1.4.2 Chips, and
5.1.4.3 Inclusions.

NOTE 1—Not all of these sources are typically encountered in field testing, examination, some are detected under laboratory conditions.

5.2 *Unstressed Areas*— Flaws in unstressed areas and passive flaws (those that are structurally insignificant under the applied load) will not generate AE. Such locations can include the roof and certain welds associated with platforms, ladders, and stairways.

5.3 *Passive Flaws (in Stressed Areas)*—Some flaws in stressed areas might not generate acoustic emission during stressing. This usually means that the flaw has a higher stress tolerance than the test examination stress.

5.4 *Filling*—Filling proceeds at rates which minimize AE activity caused by fluid flow and which allow vessel deformation to be in equilibrium with applied load. Hold periods are used throughout the filling schedule to evaluate AE activity produced by the loaded structure in the absence of fill noise.

5.5 *Follow-up*—Sources detected by AE should be examined using other NDT methods.

5.6 *Background Noise*— Excess background noise may distort AE data or render them useless. Users must be aware of common sources of background noise: high fill rate (measurable flow noise), mechanical contact (impact, friction, fretting) with the tank by objects, electromagnetic interference (EMI) (motors, welders, overhead cranes) and radio frequency interference (RFI) (broadcasting facilities, walkie talkies), leaks at pipe or hose connections, leaks in the tank bottom or walls, airborne particles, insects, or rain drops, heaters, spargers, agitators, level detectors and other components inside the tank, chemical reactions occurring inside the tank, and hydrodynamic movement of gas bubbles. This test method should not be used if background noise cannot be eliminated or controlled.

6. Basis of Application

6.1 *Personnel Qualification*—Nondestuctive testing (NDT)

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

6.2 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E 543. The applicable edition of Practice E 543 shall be specified in the contractual agreement.

6.3

6.1.2 *Training and Examination—In addition*, it is required that personnel performing acoustic emission examination of storage tanks attend a dedicated training course on the subject and pass a written examination. The training course shall include the following topics:

6.31.2.1 Storage tank construction and terminology,
6.31.2.2 Failure mechanisms of metal and metal fabricated systems,
6.31.2.3 Case histories of metal vessels examined with acoustic emission,
6.31.2.4 Storage tank examination procedures, including loading requirements,
6.31.2.5 Data collection and interpretation, and
6.31.2.6 Examination report and permanent record requirements.

6.2 *Qualification of Nondestructive Agencies*

6.2.1 If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E 543. The applicable edition of Practice E 543 shall be specified in the contractual agreement.

6.3 *Timing of Examination*

6.3.1 This test method may be used on new tanks, erected, in place or tanks which have been in service.

6.4 *Extent of Examination*

6.4.1 The extent of examination shall be in accordance with 1.2, 1.6, 1.7 and 1.11 unless otherwise specified.

6.5 *Reporting Criteria/Acceptance Criteria*

6.5.1 Reporting criteria for the examination results shall be in accordance with 10.11 unless otherwise specified.

6.5.2 Non-mandatory acceptance criteria are described in Appendix Appendix X2.

6.6 *Reexamination of Repaired/Reworked Items*

6.6.1 Reexamination of repaired/reworked items is not addressed in this standard and if required shall be specified in the contractual agreement.

7. Apparatus

7.1 Essential features of the apparatus required for this examination method are provided in Fig. 1. Full specifications are in Annex A1.

7.2 AE sensors are used to detect stress waves produced by flaws. Sensors must be held in contact with the vessel wall to ensure adequate acoustic coupling. Sensors may be held in place with magnets, adhesive tape, or other mechanical means.

7.3 A preamplifier may be enclosed in the sensor housing or in a separate enclosure. If a separate preamplifier is used, cable length between sensor and preamplifier should not exceed 6 ft (1.83 m). Longer cables may cause unacceptable signal attenuation and increase the likelihood of EMI and RFI.

7.4 Signal cable length (that is, cable between preamplifier and signal processor) should not exceed 500 ft (152.4 m). For longer cable lengths signal repeaters may be required to minimize signal attenuation.

7.5 Signals shall be processed with computerized systems with independent channels that filter, measure, and convert analog information into digital form for display and permanent storage. A signal processor must have sufficient speed and capacity to process data independently from all sensors simultaneously. A printer should be used to provide hard copies of examination results.

7.6 A video monitor should display processed data in various formats. Display format may be selected by the equipment operator.

7.7 A data storage device, such as a floppy disc, may be used to provide data for replay or for archives.

7.8 Hard copy capability should be available from a graphics/line printer or equivalent device.

8. Safety Precautions

8.1 Ambient temperature should not be below the ductile-brittle transition temperature of the pressure vessel construction material.

9. ~~Calibration~~Standardization and Performance Verification

9.1 Annual ~~calibration~~ standardization and verification of AE sensors, preamplifiers (if applicable), signal processor and AE electronic waveform generator shall be performed. Equipment should be adjusted so that it conforms to equipment manufacturer's specifications. Instruments used for ~~calibrations~~ standardizations must have current accuracy certification that is traceable to the National Institute for Standards Technology.

9.2 Routine electronic evaluations must be performed at any time there is concern about signal processor performance. An AE signal generator should be used in making evaluations. Each signal processor channel must respond with peak amplitude reading within ±2 dB of the AE signal generator output.

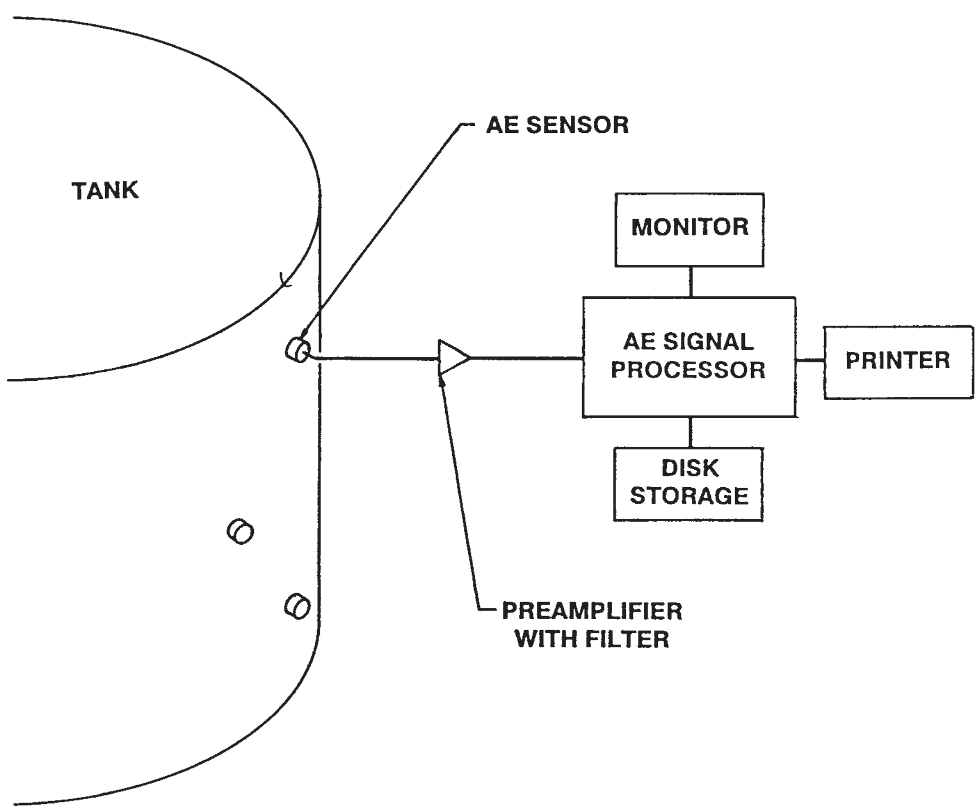

FIG. 1 Features of the Apparatus

9.3 System performance verification must be conducted immediately before each examination and should be repeated afterward.

9.3.1 A performance verification uses a mechanical device to induce stress waves into the vessel wall at a specified distance from each sensor. Induced stress waves stimulate a sensor in a manner similar to emission from a flaw. Performance verification checks the performance of the entire system (including couplant).

9.3.2 Pencil lead breaks, in accordance with Guide E 976, shall be used to verify system performance. Lead breaks will be ~~no farther than 1.5~~ at least 4 in. ~~(3.8~~ (10.16 cm) from the sensor. The average peak amplitude shall not vary more than ± 4 dB from the average of all sensors.

9.3.3 When computed location (See 10.8.7.3) is used, adjacent sensors shall detect lead break signals at amplitudes exceeding the examination threshold. The location accuracy shall be verified to be within 5 % of the sensor spacing.

9.4 *Functional Verification*—A simple functional verification used to insure that all channels are operational, makes use of a spring-loaded center punch before and after examination. To avoid damage to the tank wall, the center punch shall be made on a stiffener ring, or with a ~~1/8~~⅛ in. (3.2 mm) minimum thickness backup plate between the center punch and tank wall. Multiple center punch sites might be needed to cover the entire examination range. Center-punch impacts shall be made at a distance from sensors such that the peak amplitude measured by the sensor/channel combination does not exceed 90 dB (0 dB = one μv at preamplifier input). Before or during the examination, repair or replace channels that do not respond. After the examination, report channels that do not respond to the punch or have low sensitivity.

10. Procedure

10.1 *Examination Preliminary*—Prior to setting up the examination instruments, the examiner shall be furnished with the following information:

10.1.1 A ~~material~~ specification of materials in the tank under examination, including information on linings or internal coatings.

10.1.2 A tank drawing with sufficient detail to establish the dimensions, nozzle locations and material thickness.

10.1.3 Information on operating conditions for the 6 month period prior to AE examination. This information should include the type of liquid contained, maximum liquid contents level, the operating range of temperature, superimposed hydrostatic or pneumatic pressure, or both, and any overload or upset conditions that may have occurred.

10.2 *AE Examination Pressure*—The AE examination pressure depends on whether the AE examination is being performed in conjunction with the hydrostatic proof ~~test~~ examination of a new tank, or whether the AE examination is performed on an in-service storage tank. Table 1 describes AE examination pressure to meet the requirements of this examination procedure.

10.3 *Tank Stressing*— Make arrangements to expedite the stressing of the tank at a rate consistent with the requirements of 10.9.4 and Table 1. Tanks will normally be stressed by hydrostatic head pressure plus superimposed hydrostatic or pneumatic pressure, or both. For some in-service tanks it may be appropriate to stress using a combination of hydrostatic head pressure plus superimposed hydrostatic or pneumatic pressure, or both, plus elevated temperature. For such situations, the examiner and user must be in agreement on the thermal changes that will result in the desired stress change. During tank stressing, it is particularly important to fill through a submerged nozzle to minimize noise from liquid splashing, etc., that could invalidate data taken during filling. Additionally, the following should be considered in planning for an AE examination.

10.3.1 *Fill Time Required*—When scheduling AE examination of large storage tanks it is important that the tank owner provide the examiner with an estimate of the time interval necessary to fill the tank as required by the appropriate sequence described in either 10.9.4.1 or 10.9.4.2. This estimate should be based on the availability of fluid to fill the tank and flow rate of the filling fluid during examination.

TABLE 1 Storage Tank AE Examination Pressure

NOTE 1—If an alternative fluid with a specific gravity lower than the operating fluid is used, the required AE examination load may be achieved by filling to the maximum level and applying an additional superimposed hydrostatic or pneumatic pressure, or both, to achieve the 5 % overload.

NOTE 2—If an alternative fluid with a specific gravity higher than the operating fluid is used, the maximum fill level shall achieve the 5 % overload at the bottom of the tank, and must be at least equal to the maximum operating pressure.

NOTE 3—In some cases, due to physical limitations, it may not be possible to fill 5 % above the maximum operating level. In such cases a 2 % overload is acceptable. An overload less than 2 % is not acceptable per this procedure.

NOTE 4—Repaired tanks are examined with the same examination pressure as described above.

	Examination Performed	AE Examination Pressure
A.	New tank hydrostatic proof tested as specified by governing codes, Standards, or other regulations.	Fill to maximum design level and apply superimposed hydrostatic and/or pneumatic pressure above the liquid level as required by governing Code, test methods or other regulations.
~~B.~~	~~New tank with no hydrostatic test required.~~	~~Fill to maximum design level and apply superimposed hydrostatic or pneumatic pressure, or both, to achieve maximumesign pressure. If design pressure is not available, apply maximum operating pressure.~~
B.	New tank with no hydrostatic test required.	Fill to maximum design level and apply superimposed hydrostatic or pneumatic pressure, or both, to achieve maximum design pressure. If design pressure is not available, apply maximum operating pressure.
C.	In-service tank with operating and superimposed pressure < 0.22 psig	Fill to maximum operating level plus 5 %. Apply normal superimposed hydrostatic or pneumatic pressure, or both.
D.	In-service tank with operating and superimposed pressure 0.22 to 5.0 psig	Fill to maximum operating level plus 5 %. Apply maximum operating superimposed hydrostatic or pneumatic pressure, or both, that the tank has seen during the previous six months.
E.	In-service tank with operating and superimposed pressure > 5.0 psig	Fill to maximum operating level plus 5 %. Apply maximum operating superimposed hydrostatic or pneumatic pressure, or both, that the tank has seen during the previous six months plus 0.5 psig.

10.3.2 *Level Measurement*—Make arrangements to monitor the fill level throughout the AE examination. In most instances existing measuring systems can be used. If a fluid with a specific gravity different from that of the normal process fluid is used during AE examination, ~~recalibration~~ restandardization of the level instrumentation may be required for accurate level measurement.

10.3.3 *Start and Stop Filling*—Make provisions to start and stop filling as required for load hold periods. The tank owner shall review these provisions with the AE examiner, making him aware of unavoidable circumstances such as line flushing which may be required when flow stops.

10.3.4 *Hold Time Tolerance*—Shall be ~~–~~ -0, +2 min.

10.3.5 *On-Line Examination*—When existing storage tanks are examined on-line, the tank owner shall make the AE examiner aware of circumstances that could affect AE data acquisition. Such circumstances may include existence of steam or gas spargers inside the tank, agitators or submerged pumps, motion of solids suspended in the liquid, chemical reactions, or the inability to ~~arrange for~~ accomplish submerged filling.

10.3.6 *New Atmospheric Tanks*—A new tank will normally be AE examined during hydrostatic proof ~~testing~~ examination as specified by governing codes or standards. Examine a new tank in its operating position and supported in a manner consistent with good installation practice.

10.3.7 *In-Service Tanks*— In-service tanks will normally be AE examined over the pressure range of 75 or less to 100 % of AE examination pressure. The pressure range shall include both the liquid contents and any superimposed pressure.

10.4 *Safety*—All safety requirements unique to the examination location shall be met.

10.4.1 ~~W~~Examiners shall wear protective clothing and equipment that is normally required in the area in which the examination is being conducted.

10.4.2 A fire permit may be needed to allow use of the electronic instrumentation.

10.4.3 Take precautions to prevent overflowing of tanks. Consideration shall be given to the consequences of fluid spillage.

10.4.4 Take special safety precautions during gas or pneumatic ~~testing,~~ examinations, and the examiner shall determine that it is safe to conduct the examination. Such precautions may include the use of safety valves, a rapid-release valve, and supplemental acoustic emission monitoring during pressurization. Such monitoring shall be separate from the acoustic emission monitoring defined under this procedure and shall provide a real time warning of impending failure. Terminate pressurization and unload the vessel if the acoustic emission characteristics described in paragraph T-1244.3.3 of Article 12, Section V, of the ASME Boiler and Pressure Vessel Code are observed.

10.4.4.1 ~~*Test*~~*Examination Termination*~~—That is, departure~~—Departure from a linear count or signal strength vs. load relationship should signal caution. If the AE count or signal strength rate increases rapidly with load, the vessel shall be unloaded and either the ~~test~~ examination terminated or the source of the emission determined and the safety of continued ~~testing~~ examination evaluated. A rapidly (exponentially) increasing count rate or signal strength may indicate uncontrolled, continuing damage indicative of impending failure.)

10.4.4.2 Bolted and screwed connections such as manway covers, valves, and blind flanges are a particular concern. These shall be inspected prior to examination to ensure that bolts and other attachment components are in place, adequate for the examination pressure, properly torqued, not seriously corroded, or otherwise deteriorated.

10.4.5 Provide proper venting when draining tanks after completing AE examination. This is necessary to prevent excessive vacuum loading.

10.4.6 Exercise care to avoid the consequence of sudden and unexpected premature release of relief valves and safety vents. This is particularly important when examining tanks containing potentially hazardous fluids.

10.5 *Environmental*— For ambient temperatures below 32°F (0°C) take care to eliminate ice buildup that can cause emissions during vessel loading.

10.6 *Background Noise*— It is important to capture ~~real~~ valid emissions during monitoring periods. To accomplish this, background noise must be at a minimum. Sources of background noise are discussed in 5.6

10.6.1 The examiner shall review the stressing techniques ~~to~~ and identify all potential sources of extraneous acoustic noises due to loading.

10.6.2 Field experience has shown that care should be exercised in dealing with electrical background noise sources, for example, electromagnetic interference (EMI) is usually due to motors, switch gear, solenoids, and the like. EMI can also be caused by a bad power supply, particularly an inadequate ground. Radio frequency interference (RFI) can be distinguished from EMI with an oscilloscope or correlation plot. Control both RFI and EMI by using shielded sensors and narrow band filters. Power source EMI can be controlled with a constant voltage supply unit.

10.7 *Power Supply*— A stable grounded power supply meeting the specifications of the AE system is required at the examination site.

10.8 *Sensor Mounting*:

10.8.1 *General*—Guide E 650 gives guidance on sensor mounting. The location and spacing of sensors are discussed in 10.8.3. Place the sensors in the designated location with a couplant between the sensor face and metal surface of the tank. Exercise care to ensure that adequate couplant is applied. All signal cables must be constrained to prevent ~~stressing the sensor or~~ loss of coupling and to avoid extraneous noise from wind-induced movement of the cables.

10.8.1.1 *Attachment*—Attach sensors against the tank with a suitable couplant applied between the sensor face and metal tank surface. In order to examine a jacketed (insulated) tank from the outside, it is necessary either to use waveguides or cut a hole through the jacket and insulation so that the sensor face can be mounted against the tank surface. The preferred methods of securing sensors in place are with magnetic hold-downs and a suitable acoustic couplant or hot melt glue. When using hot melt glue, the glue serves as an acoustic couplant, making it important that the glue layer be thin to minimize signal losses, and that couplant losses be checked per procedures described in 9.3. A third method attaches sensors with a combination of duct tape and a suitable couplant applied between the sensor face and tank surface. This method, however, is less reliable, particularly when sensors must remain in place for long periods of time. After completion of an insulated tank examination, arrangements will be made for all insulation and jacket holes to be refilled with insulation and sealed to prevent water or other foreign materials from getting beneath the insulation.

10.8.2 *Surface Contact*— Mount the sensor with the center of the sensor face directly coupled to the surface of the tank. Reliable coupling between the sensor and metal surface must be ensured, and the surface in contact with the sensor face must be clean and free of particulate matter. Signal loss can be caused by certain types of paint or coatings, geometric discontinuities, and surface roughness. The magnitude of this type of signal loss can be determined using the procedures ~~defined~~ described in 9.3. In certain cases, it may be necessary to reduce signal loss by locally removing corrosion, paint, etc. from the surface of the metal.

10.8.3 *Sensor Locations*— A primary consideration in choosing sensor locations is the need to detect structural defects at critical sections, for example, high-stress areas, geometric discontinuities, nozzles, manways, reinforcement pads, and attachment welds. Take particular care to avoid shielding by large openings and to compensate for attenuation through fillet welds. It is also important to provide coverage of plate areas and not to exceed the maximum sensor spacing described in 10.8.4. Sensor location guidelines and recommended sensor arrangements for various tank configurations are found in Appendix X1.

10.8.4 *Sensor Spacing*— Locate sensors so that they provide complete coverage of the tank.

10.8.4.1 Zone location requires determination of the zone radius according to the procedure defined in 10.8.5. It is not necessary to measure the zone radius on every tank. However, this distance must be determined for at least two representative tanks having the same type of paint, lining (if any), and of the same size, design, and pressure rating. If severe internal or external corrosion or pitting is suspected, determine the zone radius for the specific tank to be examined. In many cases, the suspected condition of the tank will be provided by the owner prior to the examination.

10.8.4.2 Computed location requires determination of the maximum allowable sensor spacing according to the procedure defined in 10.8.5. It is not necessary to measure the maximum spacing on every tank. However, this distance must be determined for at least two representative tanks having the same type of paint, lining (if any), and of the same size, design, and pressure rating. If severe internal or external corrosion or pitting is suspected, determine the maximum spacing for the specific tank to be examined. In many cases, the suspected condition of the tank will be provided by the owner prior to the examination.

10.8.5 *Attenuation Characterization* —In order to determine sensor spacing an attenuation characterization of representative tanks must be performed. Perform the characterization on a representative cylindrical portion of the tank away from the heads, manways, nozzles, heater coils, etc., and below the fluid level. Mount sensors in the same fashion as when the AE examination is performed.

10.8.5.1 *Un-Insulated Tanks*—Mount a sensor and strike a line out from the sensor. Break 0.3 mm (2H) pencil leads (refer to Guide E 976) next to the sensor and then at 2 ft (61 cm) intervals along this line. The breaks shall be done with the lead at an angle of approximately 30° to the surface and with a 0.1 in. (2.5 mm) lead extension. Record the amplitude as the average from five lead breaks at each point. Plot amplitude versus distance from the sensor for each breakpoint and find the zone radius. The zone radius is the distance at which the lead breaks can no longer be detected. For zone location, maximum sensor spacing is ~~1½~~ 1.5 times the zone radius. For computed location, the maximum sensor spacing is one zone radius. These data shall be retained as part of the examination record.

10.8.5.2 *Insulated Tanks*— To determine zone radius or maximum sensor spacing on insulated tanks it may be necessary to remove insulation or cut additional access holes.

10.8.6 *Source Location*— As a minimum, base source location on the zone location method. This method uses sensor activity from each area of interest as an indication of the approximate location of the source.

10.8.7 *Location Refinement*—An improved approximation of the location of a source can be obtained by three different methods.

10.8.7.1 *Comparative Signal Strength* —This method is based on a comparison of the relative signal strength at adjacent sensors responding to the same source. Large emission bursts on multiple channels are recognized as being from a common source when responding channels show a sharp increase in signal strength at the same time. Such occurrences can be seen on the cumulative signal strength per channel versus time plots. When this is observed, the relative distance of the source from each sensor can be estimated from the relative magnitude of the signal strengths at the time of the emission bursts.

10.8.7.2 *Reduced Zone Sizes*—If an AE examination indicates a source in a particular zone, the zone can be subdivided into smaller zones by adding channels in the zone of interest. The emission source is then stimulated to emit by a small increase in load. Typically, a pressure increase of the smaller of 5 % or 2 psi will stimulate emissions. If the load cannot be increased, it may be possible to stimulate the emission source by reducing the level by 15 to 20 %, then reapplying the stress by refilling to achieve the previous maximum stress level. For the follow-up examination, channels that had originally covered zones away from the region of interest can be used to provide the additional zone coverage within the region of interest.

10.8.7.3 *Computed Location*—This method involves the use of additional sensors that cover the area to be monitored such that the exact position of the source can be calculated.

10.9 *Data Acquisition*:

10.9.1 *General*—Each storage tank is subjected to programmed increases in pressure up to a predetermined maximum and monitored with sensors detecting acoustic emission (stress waves) caused by stressed structural defects.

10.9.2 *Data*:

10.9.2.1 *Examination Log*— The examiner shall maintain an examination log recording: setup and data file names, times of various phases of the examination such as the start and end of hold periods, manual parameter settings (if available) as the tank fills, occurrences impacting data acquisition such as leaks or other significant observations, pre/post examination system performance verification files, setup files and examination data files.

10.9.3 *Background Noise*— Extraneous noise must be identified and minimized. If the examiner judges background noise to be excessive the examination must be terminated.

10.9.3.1 *Leaks*—Background noise due to a leak may be of sufficient quantity and magnitude to require the examination to be stopped until the leak can be sealed. Leaks can occur in the shell of a tank, but more commonly occur across improperly sealed valves, or at gaskets.

10.9.3.2 *Movement*—False emissions can be caused by movement between tank components such as the tank wall and insulation. Such emissions are generally sporadic and can be identified and filtered out in post-examination analysis.

10.9.3.3 *Wind and Vibration*—Visually examine the sensors, cables, and other hardware to verify the equipment is securely mounted and will not be subject to wind or vibration-induced movement. Isolate the tank and AE hardware from uncontrollable sources of noise.

10.9.3.4 *External Noise*— Evaluate uncontrolled noise caused by conditions such as rain, sleet, hail, snow, wind-blown particles, air hoses, leaks, blasting, etc., as they occur. Minimize the effects of such sources by acoustic isolation where practical. In extreme cases it may be necessary to delay examination until uncontrolled sources can be eliminated.

10.9.3.5 *Internal Corrosion*—Emission can be generated by internal rust ~~formation~~ during hydrotesting of carbon steel tanks. This problem is particularly severe with new or recently blasted metal surfaces. Emission will show as a steady stream of hits during the entire background noise period. Use of corrosion inhibitors may be required to control this problem.

10.9.3.6 *Thermal Expansion of the Jacket* —It has been found that certain types of jackets, particularly those with sliding expansion joints of the type used on tanks with exterior heating coils, will generate emission when exposed to changes in temperature. Direct sunlight has been found to be particularly troublesome. This type of emission will show as discrete bursts which include long duration hits. To overcome this type of problem it may be necessary to ~~test~~ examine in a temperature-controlled atmosphere, or ~~in a shady location~~ during periods when the temperature is relatively constant, such as early morning.

10.9.3.7 *Filling Rate*— Flow noise from fluid entering the tank can be a source of high background noise. Filling rate must be adjusted to eliminate this noise.

10.9.4 *Examination Procedure*—The tank is stressed by filling with liquid. To determine the AE examination pressure refer to 10.2.

10.9.4.1 *New Tanks*—Fig. 2 shows the filling schedule for new tanks. AE monitor an initial 10-min period for background noise. After acceptably low levels of background noise have been confirmed, monitor the tank during filling, with hold periods at 50, 80, 90, and 100 % of the AE examination pressure. If the examination includes superimposed pressure, apply this pressure before the start of the hold at the 100 % AE examination pressure. During examination, increases in pressure levels shall not exceed 10 % of the AE examination pressure in 2 min. Hold periods at 50, 80, 90, and 100 % are 10 min each. The final hold at the 100 % AE

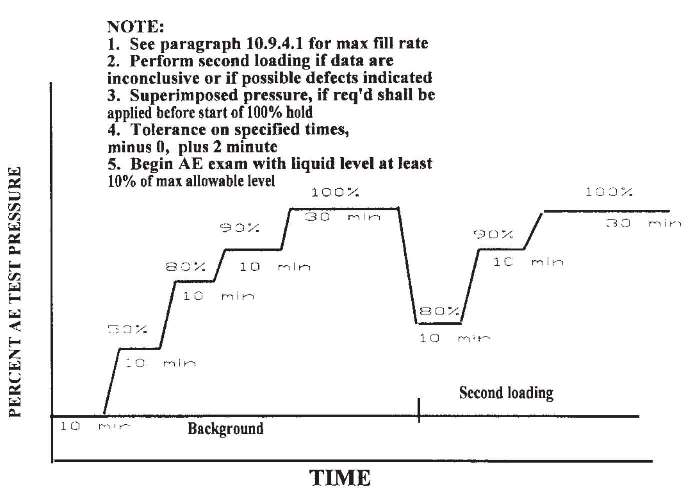

FIG. 2 New Tank Fill Schedule

examination pressure is 30 min. If emission data indicates a flaw, or are inconclusive, a second loading may be performed from 80 to 100 % of the AE examination pressure, with holds the same as during the initial examination.

10.9.4.2 *In-Service Tanks*—Fig. 3 shows the filling sequence for in-service storage tanks. Monitor an initial 10-min period for background noise. After acceptably low levels of background noise have been confirmed, monitor the tank during filling. The fill range shall be 85 to 100 % of the AE examination pressure. During examination, increases in pressure shall not excee~~e~~d 10 % of the AE examination pressure in 2 min. Holds at 85 and 95 % are 10 min each. The final hold at the 100 % AE examination pressure is 30 min. If the purpose of the AE examination is to evaluate repairs, and emissions indicate a flaw in the repaired area, or are inconclusive in the repaired area, a second examination may be performed from 75 to 100 % of AE examination pressure, with load holds the same as during the initial filling.

10.10 *Description of Evaluation Criteria* —Evaluate the tank based on the following criteria. If these criteria are exceeded, additional nondestructive evaluation may be required.

10.10.1 *Emission During Hold*—This is a very important criterion. Emission that continue during a hold period may indicate continuing yielding or damage caused by creep, or a flaw which is continuing to grow under a constant stress level.

10.10.2 *Cumulative Duration*—This criterion measures total activity. It is particularly important as an indicator of widespread damage. Emission that continually exceed this criterion may be an indication of a tank in a deteriorated condition.

10.10.3 *Number of Hits*— This criterion is particularly important in the evaluation of in-service tanks. Hits at stress levels below normal operation may indicate the presence of significant defects.

10.10.4 *Large-Amplitude Hits*—Large amplitudes often signal a growing crack. An observed trend of increasing amplitudes with increasing stress may indicate severe defect growth.

10.10.5 *Signal Strength*— Increasing signal strength may indicate that a defect area is responding to increasing stress.

10.11 *Examination Report*—Issue, a report for each tank examined. Appendix X3 shows a report form that can be used to document examination results. An examination report should include this form, plus a sensor layout sketch. The following information shall be included with each examination report:

10.11.1 A complete identification of the tank, including:

10.11.1.1 Tank item number,

10.11.1.2 Material of construction,

10.11.1.3 Manufacturer,

10.11.1.4 Serial number, and

10.11.1.5 Applicable codes or standards.

10.11.2 Examination date and location,

10.11.3 Sketch or drawing showing overall dimensions and sensor locations and corresponding channel numbers,

10.11.4 Examination fluid and fluid temperature,

10.11.5 Stressing sequence including fill level(s), hold levels, starting and ending times of hold periods, and examination loads relative to normal operating conditions,

10.11.6 A comparison of the data with the appropriate evaluation criteria,

10.11.7 Results of analysis,

10.11.8 Recommended follow-up examination including areas of concern and complementary NDT methods,

10.11.9 Any unusual effects or observations during the examination,

10.11.10 Name(s) of examiner(s) and qualification level, and

10.11.11 Examination instrumentation, including serial number, type of sensor and ~~calibration~~ standardization dates.

11. Precision and Bias

11.1 Precision of the results from this test method will be influenced by many external factors such as background noise,

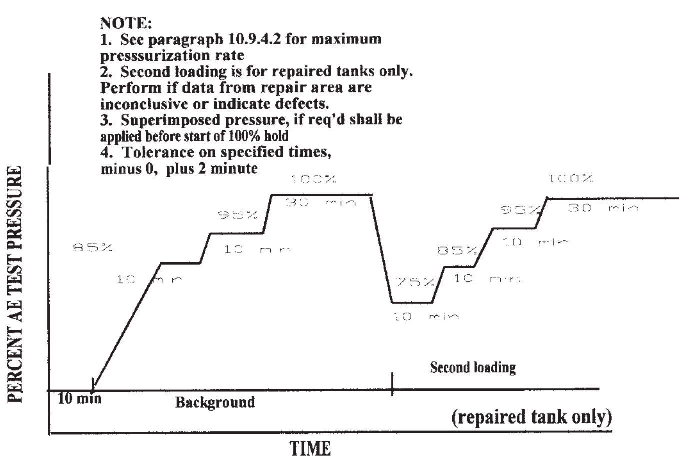

FIG. 3 In Service Tank Fill Schedule

material variations, previous stress history, calibration standardization of instrumentation, contents of tank, and tank wall surface protection.

11.2 The outcome of this test method is to determine if the tank is structurally sound in its present condition or requires follow-up NDT to make that determination. Bias of this test method generally leads to follow-up examination of more areas than those that actually have significant flaws.

12. Keywords flaws.

ANNEX

(Mandatory Information)

A1. SPECIFICATIONS FOR APPARATUS

A1.1 Instrumentation Specifications

A1.1.1 AE sensors shall be resonant in a 100 to 200 kHz frequency band.

A1.1.2 Sensors shall have a peak sensitivity greater than -77 dB (referred to 1 volt per microbar, determined by face-to-face ultrasonic test) examination) within the frequency range 100 to 200 kHz. Sensitivity within the 100 - 200 kHz range shall not vary more than 3 dB within the temperature range of intended use.

A1.1.3 Sensors shall be shielded against electromagnetic interference through proper design practice or differential (anti-coincidence) element design, or both.

A1.1.4 Sensors shall be electrically isolated from conductive surfaces.

A1.1.5 Sensors shall have omni-directional response, with variations not exceeding 2 dB from the peak response.

A1.2 Sensor-Preamplifier Cable

A1.2.1 Cable connecting sensor to preamplifier shall not attenuate the sensor peak voltage in the 100 to 200 kHz frequency range more than 3 dB (6 ft (1.83 m) is a typical length). Integral preamplifier sensors meet this requirement. They have inherently short, internal, signal cables.

A1.2.2 Sensor-preamplifier cable shall be shielded against electromagnetic interference. Standard low-noise coaxial cable is generally adequate.

A1.3 Couplant

A1.3.1 Commercially available couplants for ultrasonic flaw detection may be used. Silicone-based stopcock grease has been found to be particularly suitable. Quick-setting adhesives may be used, provided the reduced couplant sensitivity is accounted for by closer sensor spacing. Couplant selection should be made to minimize changes in coupling sensitivity during an examination. Consideration should be given to the time duration of the examination and to the surface temperature of the tank.

A1.4 Preamplifier

A1.4.1 Preamplifier shall have noise level no greater than 5 microvolts rms (referred to a shorted input) within the 100 to 200 kHz frequency range.

A1.4.2 Preamplifier gain shall vary no more than ± 1 dB within the 100 to 200 kHz frequency band and temperature range of use.

A1.4.3 Preamplifier shall be shielded from electromagnetic interference.

A1.4.4 Preamplifiers of differential design shall have a minimum of 40 dB common-mode rejection.

A1.4.5 Preamplifier shall include a bandpass filter with a minimum of 18 dB/octave signal attenuation below the 100 kHz and 18 dB/octave above 200 kHz. Note that the crystal resonant characteristics provide additional filtering as does the band pass filter in the signal conditioner.

A1.4.6 It is preferred that the preamplifier be mounted inside the sensor housing.

A1.5 Power-Signal Cable

A1.5.1 Cable and connectors that provide power to preamplifiers, and that conduct amplified signals to the main processor, shall be shielded against electromagnetic interference. Signal loss shall be less than 3 dB over the length of the cable. (When standard coaxial cable is used, 1000 ft is the maximum recommended cable length to avoid excessive signal attenuation).

A1.6 Power Supply

A1.6.1 A stable, grounded, power supply that meets signal processor manufacturer's specification shall be used.

A1.7 Signal Processor

A1.7.1 Electronic circuitry gain shall be stable within ±1 dB in the temperature range 40 to 100°F (4.4 to 37.8°C).

A1.7.2 Threshold shall be accurate within ± 1 dB.

A1.7.3 Signal strength shall be measured on a per channel basis and shall have a resolution of 1 % of the value obtained from a one millisecond duration, 150 kHz sine burst having an amplitude 25 dB above the data analysis threshold. Useeable dynamic range shall be a minimum of 35 dB.

A1.7.4 Peak amplitude shall have a usable dynamic range of a minimum of 60 dB with 1 dB resolution over the frequency band of 100 kHz to 200 kHz, and the temperature range of 40 to 100°F (4 to 52°C). Not more than ±2 dB variation in peak detection accuracy shall be allowed over the stated temperature range. Amplitude values shall be stated in dB, and must be referenced to a fixed gain output of the system (sensor or preamplifier).

A1.7.5 Hit duration shall be accurate to ±10 µs and is measured from the first threshold crossing to the last threshold crossing of the signal or envelope of the rectified linear voltage time signal. It shall not include the hit definition time that defines the end of an event.

A1.7.6 *Arrival Time*— Hit arrival time shall be recorded globally, for each channel accurate to within one millisecond when a zone location technique is used.

A1.7.7 *Rearm Time*— The rearm time of each channel of the system shall be no greater than 200 µs.

A1.7.8 *Hit Definition Time*—The hit definition time shall be 400 µs.

APPENDIXES

(Nonmandatory Information)

X1. SENSOR LOCATION GUIDELINES

X1.1 *General* —A common approach is used to select sensor locations regardless of the size or shape of the tanks examined. The first step is to determine the maximum distance between sensors using the techniques described in 10.8.5. Once the maximum spacing has been determined, sensors can be spaced accordingly in rings around the circumference of the tank shell. The first ring will generally start at or near the bottom of the shell. Additional rings will be added up the sidewall. The vertical distance between rings should also be determined on the basis of 10.8.5. The following guidelines should also be considered:

X1.1.1 Sensor positions in alternate rings should be staggered. A staggered arrangement provides maximum coverage of the shell plate sections and is particularly helpful in minimizing the number of AE channels necessary to cover very large tanks.

X1.1.2 When possible, additional sensors should be placed near large diameter openings such as manways. When reinforcing pads are present and a zone location technique is used, it is advisable to tee at least two sensors together, placing one on the pad and one on the opposite side of the manway on the tank shell.

X1.1.3 For vented storage tanks which cannot fill up into the roof and are not otherwise pressurized above the liquid, it may not be necessary to place sensors on the roof. AE will not detect defects in locations which are not stressed during the course of the examination. Flat roofs on non-pressurized storage tanks normally will not be stressed during AE examination.

X2. EXAMPLE INSTRUMENT SETTINGS AND REJECTION CRITERIA

X2.1 *Acceptance Criteria*:

X2.1.1 Signal strengths (that is, of signals from AE sources) shall not increase with increasing load.

X2.1.2 Activity shall not increase with increasing load.

X2.1.3 Evaluation Threshold shall be 50 dB (where 0 dB equals one microvolt at the preamplifier input).

X2.1.4 Any flaw which is detected must be precisely located; and, flaw dimensions must be determined using secondary NDT method (for example, ultrasonic inspection).

X2.1.5 Flaws that are large enough to be "fracture critical flaws", or that are large enough to grow to fracture critical size before another re-test re-examination is performed, shall cause a tank to be repaired or removed from service.

X2.1.5.1 "Fracture critical" flaw dimensions are based upon fracture mechanics analysis of a vessel using strength properties which correspond to materials of construction.

X2.2 *Material of Construction*—This example is based on tanks made from carbon steel.

X2.3 *Instrumentation, Characteristics and Settings*:

Sensor sensitivity	-77 dB ref. 1 volt/microbar at approximately 150 kHz
Couplant	silicone grease
Preamplifier gain	40 dB

Preamplifier filter	100 to 300 kHz bandpass
Power/signal cable length	less than 500 ft (152 m)
Signal processor threshold	40 dB (0 dB = 1 µv, preamplifier input)
Signal processor filter	100 to 300 kHz bandpass
Hit definition time	400 µs
Background noise	less than 27 dB (0 dB = 1 µv, at the preamplifier input)
Functional check	amplitude greater than 80 dB (0 dB = 1 µv, preamp input)

X3. EXAMINATION REPORT

1. Tank Identification:

A. Item No. ______________________________

____

B. Material ______________________________

____

C. Manufacturer ______________________________

s/n ______________________________

D. Design Code/Standard ______________________________

____

2. Examination Date: ____________**Examination Location:**__________

____

3. Examination Fluid: ____________ **Fluid Temp:** ______________

____

4. Stressing Sequence: New Tank ________ **In-service Tank** __________

5. Maximum Stress Relative to Maximum Operating Load: __________

____

6. Examiner(s): Examiner Company ______________________________

____

Examiner(s) ______________________________

____

7. Examination Threshold: ______________________________

____

8. Examination Instrumentation: ______________________________

s/n ______________________________

9. Sensor Model: ______________________________

____

10. Date of most recent calibration of instrumentation: ____________

____

11. NOTES: ______________________________

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____

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FIG. X3.1 Sample Examination Report