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Standard Guide for Hydraulic Integrity of New, Repaired, or Reconstructed Aboveground Storage Tank Bottoms for Petroleum Service[1]

This standard is issued under the fixed designation E2256; 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 guide is intended to provide the reader with a knowledge of construction examination procedures and current technologies that can be used to give an owner or operator of an aboveground storage tank (AST) in petroleum service, relevant information on the hydraulic integrity of a new, repaired, or reconstructed tank bottom prior to return to service. This guide does not pertain to horizontal ASTs, manufacture of tanks using UL 142, or to tanks constructed of concrete or other non-ferrous materials.

1.2 The adoption of the mathods and technologies presented in this guide are not mandatory, rather they represent options that may be selected to identify the likelihood of product leaking through a new, repaired, or reconstructed tank bottom.

1.3 This guide is not intended to suggest or treat any technology in a preferential manner.

1.4 The person responsible for applying this guide should be a knowledgeable individual with experience in the design, inspection, construction, or combination thereof, of aboveground storage tanks for use in petroleum service, and should also be certified under the requirements of API 653 when use is related to tank bottom repair.

1.5 This guide is written in metric measure units (SI Units) in accordance with requirements of Practice E621. English measure equivalents are in parentheses.

1.6 The applicability of this guide to the proposed tank configuration and service conditions should be established prior to use.

1.7 This guide complies with ASTM policy for development and subsequent use of a standard.

1.8 This guide is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this guide or for additional standards and should be addressed to ASTM International, 100 Barr Harbor Drive, W. Conshohocken, PA 19428.

1.9 This guide is not intended for use as a model code, ordinance or regulation.

1.10 *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 requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A36/A36M Specification for Carbon Structural Steel

A53/A53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

A106/A106M Specification for Seamless Carbon Steel Pipe for High-Temperature Service

A333/A333M Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness

D3282 Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes

E165 Practice for Liquid Penetrant Examination for General Industry

E621 Practice for Use of Metric (SI) Units in Building Design and Construction(Committee E06 Supplement to E380) (Withdrawn 2008)[3]

E709 Guide for Magnetic Particle Testing

E1209 Practice for Fluorescent Liquid Penetrant Testing Using the Water-Washable Process

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[1] This guide is under the jurisdiction of ASTM Committee E50 on Environmental Assessment, Risk Management and Corrective Action and is the direct responsibility of Subcommittee E50.01 on Storage Tanks.

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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] The last approved version of this historical standard is referenced on www.astm.org.

E1219 Practice for Fluorescent Liquid Penetrant Testing Using the Solvent-Removable Process
E1220 Practice for Visible Penetrant Testing Using Solvent-Removable Process

2.2 *Other Documents:*
ASME Section V and IX Boiler and Pressure Vessel Code[4]
SNT TC-1A Society for Nondestructive Testing Recommended Practice[5]
AWS B1.10 Guide for the Nondestructive Inspection of Welds[6]
AWS QC1-96 Standard for AWS Certification of Welding Inspectors[6]
API Publication 322 An Engineering Evaluation of Acoustic Methods of Leak Detection in Aboveground Storage Tanks, Jan. 1994[7]
API Publication 334 A Guide to Leak Detection for Aboveground Storage Tanks, Mar. 1996[7]
API 571 Damage Mechanisms[7]
API 575 Inspection of Atmospheric and Low-Pressure Storage Tanks[7]
API 577 Welding, Inspection and Metallurgy[7]
API RP 479 Fitness for Service[7]
API RP 580 Risk Based Inspection[7]
API 581 Base Resource Document-Risk-Based Inspection[7]
API 650 Welded Steel Tanks for Oil Storage[7]
API 653 Tank Inspection, Alteration, and Reconstruction[7]
STI 1–SP001 Steel Tank Institute Standard[8]

3. Terminology

3.1 *The following terms as used in this guide may differ from the more commonly accepted definitions elsewhere.*

3.1.1 *aboveground storage tank (AST), n*— a vertically oriented tank (normally cylindrical), whose bottom is in contact with the soil or other solid material and whose shell to bottom joint is designed to be at the plane of grade. See Fig. 1.

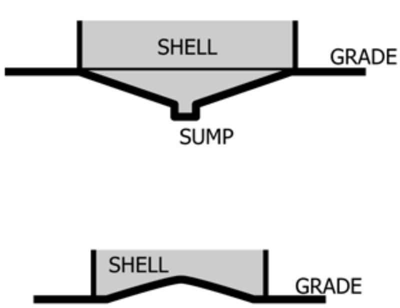

FIG. 1 Examples of ASTs per this Guide

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.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.

[6] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.

[7] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org.

[8] Available from Steel Tank Institute / Steel Plate Fabricators Association 944 Donata Ct. Lake Zurich, IL 60047, http://www.steeltank.com

Many tanks are supported on a gravel or concrete ring. Some tanks have a full concrete pad foundation.

3.1.2 *conditions and limitations, n*—the environmental and physical effects that restrict the collection of data.

3.1.3 *cut and cover or bunkered tank, n*— a field-constructed aboveground storage tank that has been cut into the soil and covered to protect it from damage either by accident or hostile intent of war.

3.1.4 *developing technology, n*—a procedure or testing method that may be used to provide additional information on a potential leak path.

3.1.5 *for petroleum service, n*—an AST that is designated for or expected to be used for petroleum product storage to include crude oil, residual, and refined petroleum products.

3.1.6 *hydraulic integrity, n*—the actual ability of a tank bottom to prevent passage of a stored product to the external environment.

3.1.7 *leak path, n*—the route or opening through which the tank contents are released through to the exterior environment.

3.1.8 *tank, n*—a field-erected steel structure constructed of welded or riveted steel and designed for petroleum service.

3.1.9 *tank bottom, n*—the floor of a vertically oriented tank, including the shell to bottom weld, connected piping supports, column base plates, sumps, floor plates, and floor welds, but not interior or exterior coatings or cathodic protection.

3.1.10 *tank owner or operator, n*—an individual or entity that owns or operates an aboveground storage tank in accordance with and definitions of The U.S. Environmental Protection Agency Regulation 40 CFR 112.

3.1.11 *technologies, n*—systems or services that provide information that can be used to evaluate the hydraulic integrity of a tank bottom.

3.2 *Abbreviations:*

3.2.1 *cm*—centimetre

3.2.2 *mm*—millimetre

3.3 *Acronyms:*

3.3.1 *ANSI*—American National Standards Institute

3.3.2 *API*—American Petroleum Institute

3.3.3 *ASM*—American Society for Metals

3.3.4 *ASME*—American Society of Mechanical Engineers

3.3.5 *ASNT*—Society for Nondestructive Testing

3.3.6 *AST*—aboveground storage tank

3.3.7 *AWS*—American Welding Society

3.3.8 *ERW*—electric resistance weld

3.3.9 *NDE*—non-destructive evaluation

3.3.10 *OSHA*—United States Occupational, Safety and Health Administration

3.3.11 *UL*—Underwriters Laboratory

3.3.12 *UST*—underground storage tank

3.4 *Measurement Units*—This guide is written in metric measure units (SI Units) in accordance with requirements of Practice E621. English measure equivalents are in parentheses.

4. Summary of Guide

4.1 This guide establishes a process and provides guidance about practices and procedures that are called for in API 650 and API 653, or available as optional selections and which will lead to a better understanding about the hydraulic integrity of an AST's bottom. The information contained in the guide is set out in three formats: a flowchart of the procedures and the appropriate point for employment in order to gather the most useful information; a table of the procedures briefly describing what and how they should be used in order to gather the most useful information; and an expanded listing of the procedures to provide the guide user with procedure background and expected results in order to determine the type and validity of the information gathered.

5. Significance and Use

5.1 Inspection, repair, and construction of ASTs in petroleum service should follow at a minimum the requirements of API 650 and API 653. These standards describe methods for testing the weld quality and structural and hydraulic integrity of new or repaired ASTs. With increasing emphasis on protecting the environment and with environmental issues related to the storing of petroleum materials in ASTs, owners and operators of such tanks may want or need a guide devoted to existing and enhanced methods for evaluating the hydraulic integrity of new or repaired tank bottoms.

5.2 The consequences of a tank bottom failure include the economic loss of product, cost of repair or replacing the tank bottom, and exposure to the cost of environmental remediation and potential damage or harm to adjacent lands that may give rise to adverse public relations or regulatory action. In addition, releases of petroleum products introduce potential fire or explosive conditions.

5.3 Owners and operators of ASTs or their agents can use this guide to help choose methods of evaluating the hydraulic integrity of their repaired or new tank bottoms. Selection of the methods should be based on regulatory and economic criteria that include operational and cost/benefit considerations.

5.4 This guide is intended for use by an individual experienced in repair and construction of ASTs in petroleum service.

5.5 This guide is intended for use when repairing or building ASTs. This guide does not address suitability for use or imply useful life of an AST bottom.

5.6 This guide is intended to be used in conjunction with and as a supplement to standards provided for hydraulic integrity in API 650 and API 653.

5.7 Procedures or methods included here may be supported by a previously completed and documented performance evaluation(s) that may lend itself as valuable results validation.

6. Procedures

6.1 This section provides information on established practices described in API 650 and API 653. This section provides information on other practices listed in this guide as optional during a hydrostatic test, and which may be used to assess the hydraulic integrity of the tank bottom. Also identified in this section are developing technologies that may be used in conjunction with a hydro-test, and may produce supplemental information about the hydraulic integrity of the completed tank bottom construction. Some of the procedures identified here are recognized to be voluntary when used for attaining an enhanced confidence in the hydraulic integrity for a repaired or newly constructed tank bottom. For those owners and operators that already have procedures for determining the suitability of the tank bottom, this guide may serve as a reference when policy warrants a change in their methods.

6.2 Table 1 identifies tests and procedures, and notes when application of those tests or procedures will provide the most useful information for assessing the hydraulic integrity of tank bottom.

6.3 Table 1 supplements the flow chart by listing the accepted tests and procedures from API 650 and API 653, as a readily available reference, and also the developing technologies. These API procedures, although established chiefly to assess tank structural soundness, are also useful for determining the hydraulic soundness of tank bottom construction when it has been repaired or newly constructed. Information relating to the developing technologies may be employed by an owner and operator in order to obtain hydraulic integrity and other supplementary information during a hydrostatic test.

6.4 When using information provided in this section, considerations for schedule, operational, economic, and environmental characterizations should be reviewed. An owner and operator or the owners' and operators' representative should be familiar with conditions under which the tests and procedures can be used and in the case of the developing technologies, API 334 should be consulted.

7. Evaluation Methods

7.1 *Procedures Prior to Filling and After Filling the Tank:*

7.1.1 The owner and operator of a tank, included by definition in this guide, will find that there are numerous procedures associated with the determination of the hydraulic integrity of a tank bottom. Of this total number of procedures there can be at least nine that are conducted prior to filling the tank and can be at least another four procedures that are applied with the tank either partially or completely filled to its safe fill height.

7.2 *Evaluation of Floor Plate, Weld Construction Practices:*

7.2.1 Factors or conditions that contribute to tank bottom failure are:

7.2.1.1 Imperfections that may be included in steel plate during manufacture.

7.2.1.2 Gouging and tearing in steel plate can occur during shipment and storage, and in moving the plates into final position for welding. Such damage can be the result of improper use of equipment for moving the plate or the dragging of the plates across one another or other construction materials and rocks. The gouges and tears can compromise the structural integrity and intended service life of the tank.

7.2.1.3 Irregular surface continuities or voids in the structural fill or concrete foundation can be a significant condition causing a bottom to fail and leak. The voids and projections

TABLE 1 Tests and Procedures

Procedure	General Description of Procedure	General Application	Thresholds, Results, and Limitations
7.2 Evaluation of Floor Plate, Weld Construction	Good practices, procedures, record keeping, and oversight of plate manufacturing process, shipment, and storage at site. Compliance with design requirements, welding procedures, certifications and plate preparation prior to completing welds. Experience requirements for construction personnel and inspectors. Performance of work in proposed hydrogen sulfide uses or other environments that may cause cracking. Review structural fill and concrete sub-floors for compliance with specification.	This procedure is performed on the steel floor plate, floor plate welds, floor plate to shell welds, internal piping supports connected to the floor plates, tank sumps, and gauging well wear plate. In addition, this procedure recognizes that improper preparation of the tank bottom substrate, by permitting hills and voids, contributes significantly to the potential for early tank bottom hydraulic integrity failure.	Impacts to tank bottom hydraulic integrity include: completion schedule, individual integrity, skill and experience in the plate manufacturing process, those individuals directing, performing, inspecting, and reviewing records. Reliance on subjective opinion. Plate Manufacture complies with Specification A6/A6M or Specification A20/A20M. Welding Complies with API 650, Section 7.2 and API 653, Section 11, ASME and AWS standards as applicable. Certification of Weld Inspectors complies with AWS QC1-96.
7.3 Evaluation of Connected Underfloor Piping	Accepted practice, procedures, and inspection of completed water draw offs, drain dry piping, and sump systems including the bedding.	This procedure is performed on the tank piping that passes beneath the sub-floor and floor plates of a tank bottom including the welds.	Impacts to piping installation include: completion schedule, individual integrity, skill and experience in the pipe manufacturing process, those individuals directing, performing, inspecting, and reviewing records. Reliance on subjective opinion. Prior to back filling these systems inspect completely.
7.4 Evaluation by Visual Examination of the Tank Floor	Visual inspection of the tank floor, including the plates, welds, shell to floor plate welds, and piping, sumps, and wastewater drains. The inspection may be performed using direct eye, mirrors, cameras, and other suitable instruments. The eye should be placed no more than 60.9 cm (24 in.) from the surface and at an angle of not less than 30°.	Plates, welds, shell to floor plate welds, and piping, sumps and wastewater drains.	Accessibility to visual inspection, cleanliness of area to be inspected, applies to surface defects only, lighting levels, visual acuity of individual performing inspection. Minimum illumination is 15 footcandles for general viewing and 50 footcandles for viewing small anomalies. Individual performing the test should have a visual acuity natural or corrected as measured by reading standard J-2 letters of the Jaeger Chart. Identify cracks, undercut, mechanical defects, gouges, arc strikes, temporary attachment removal area, and incomplete welds.
7.5 Evaluation by Radiography Examination	A non-destructive method for inspection of welds that provides information about the internal condition using radiation. The radiation is directed at the weld and either penetrates, is absorbed, or scatters and is then recorded on film or by a device. There are two recognized methods of conducting radiography: Film/Paper Radiography, and Radioscopy.	Accessible annular plate welds and shell butt welds or at the owner's discretion.	The surface to be examined needs to be accessible from both sides. Discrepancies must be suitably aligned with the radiation beam in order to be reliably detected. Creating the image and the interpretation needs to be accomplished by experienced individuals. Radiation exposure to individuals is a hazard and they must be included in a monitoring program. It is a relatively expensive testing method. Perform prior to erecting shell. SNT-TC-1A Level II NDE personnel are required.

created by the sub-floor structural system irregularities will cause uneven stressing of the floor plates, seam welds, floor to shell weld, and sumps located in the bottom. The stress can lead to early failure of the bottom when the tank is placed back in service and under load from the stored product or the columns and legs of floating pans or roofs.

7.2.1.4 The use of incorrect welding procedures or unqualified welders can result in sub-standard welds that are more likely to fail.

TABLE 1 *Continued*

Procedure	General Description of Procedure	General Application	Thresholds, Results, and Limitations
7.6 Evaluation by Wicking Examination of Corner Weld	Apply highly penetrating oil or dye penetrant to opposite side of first weld pass, and let stand for a period of time. Observe the welded side of the joint.	Shell to bottom plate weld.	Accessibility to viewing, cleanliness of weld area, and visual acuity of individual performing the test. Perform in dry conditions. Test must be performed when ambient temperature is high enough to allow the oil or dye penetrant to flow. Apply dye penetrant or highly penetrating oil to opposite side of first weld pass. Let sit for a minimum of 4 h (12 h is the preferred length of time). Observe the weld side of the joint. Identifies through weld pinholes, porosity, and cracks not visible to the eye. Identifies a leak that passes oil instead of air.
7.7 Evaluation by Bubble Test Examination (Pressure)	Pressure method locates leaks in a pressurized component by the application of a solution or immersion in liquid that will form bubbles as leakage gas passes through it.	Tank floor fillet welded lapped seams, butt welded seams, and shell to bottom weld.	Limited to small tanks or parts of tanks. For visual plus training on the specific procedure used by the manufacturer or fabricator. Training to meet the requirements of SNT-TC-1A.
7.8 Evaluation by Bubble Test Examination (Vacuum)	Apply solution and a vacuum to a localized area.	Tank floor fillet welded lapped seams, butt welded seams, and shell to bottom weld.	Accessibility requires minimum clearance of 15.3 cm (6 in.) between bottom plate and obstruction above test area for placement of device and viewing. Perform test in accordance with a written procedure and ASME BPVC, Section V, Art. 10 App II. Individuals performing the test require visual acuity and training to meet requirements of SNT-TC-1A.
7.9 Evaluation by Liquid Penetrant	Apply penetrant to welds in the tank floor. Discontinuities in the weld such as cracks or voids that are open to the surface will draw in the penetrant. Any discontinuities should show up against the developed background.	This applies to welds in the tank floor including the shell to bottom weld. May be most useful in areas where other physical weld checks cannot be done due to access limitations.	Acceptance Criteria: No recognizable indications that might indicate a through plate defect. Discontinuities must extend to the surface, and be accessible. The weld must be clean and free of dirt, grease, lint, scale, flux, and weld spatter, and so forth. The weld must be uncoated. Individual performing the procedure should have natural or corrected near distance acuity vision to read a Jaeger Type 2 standard chart and have the ability to distinguish color during the observation of the tested weld. Individual should be a Level II or Level III certification in accordance with SNT-TC-1A. Perform test in accordance with a written procedure and ASME BPVC, Section V, Art. 6 or Test Methods E165, E1209, E1219, and E1220.

7.2.1.5 Service conditions that might include the presence of hydrogen sulfide or conditions that may cause weld or plate cracking require the appropriate selection of materials, and quality control for manufacture and fabrication.

7.2.2 *Summary of Test Parameters:*

7.2.2.1 The user will need to ensure good practices, procedures and record keeping, are used throughout the process to avoid or intercept the foregoing conditions or factors that contribute to tank bottom failure. Specification A36/A36M or other steels for use accepted by API 650 provide guidance on oversights by the owner or operator during the manufacturing process that can be used to establish the quality of the steel plate.

7.2.2.2 This control is accomplished on the steel floor plate, floor plate welds, floor plate to shell welds, internal piping supports connected to the floor plates, tank sumps, gaging well

TABLE 1 *Continued*

Procedure	General Description of Procedure	General Application	Thresholds, Results, and Limitations
7.10 Evaluation by Magnetic Particle Examination	The weld area to be inspected is magnetized and ferromagnetic particles placed on the weld. A pattern is formed and is deformed where discontinuities are present. The deformations are more distinguishable for discontinuities near the surface of the weld. A second test is conducted with the magnetic field perpendicular to the original test orientation as a way of picking up undetected discontinuities of the first test. The magnetic particles are color contrasted or made viewable in fluorescent or black light.	Welds in the tank floor and sump including the shell to bottom weld. May be most useful in areas where other physical weld checks cannot be done due to access limitations.	Acceptance Criteria: No recognizable indications that might indicate a through plate defect. Discontinuities below the surface are difficult to detect and not all discontinuities are defects. The weld must be accessible and be clean and free of dirt, grease, lint, scale, flux, and weld spatter, etc. Generally the weld must not be coated. Time consuming. The individual performing the test should have natural or corrected vision distance acuity vision to read a Jaeger Type 2, Standard Chart. They should be Level II or III certified in accordance with SNT-TC-1A. Perform test in accordance with a written standard and ASME BPVC, Section V, Art. 7, or Guide E709.
7.11 Evaluation by Detectable Gas-Beneath Floor Injection	Testing of tank bottoms using detectable gas beneath the tank floor is accomplished by injecting a detectable gas, which is lighter than air, beneath the tank floor in adequate quantity to allow dispersal over the entire underside of the floor. A common gas used for this application is welding grade helium. The floor is then scanned with leak detection equipment.	One hundred percent of all floor plate welds, floor to shell weld, patch plate welds, clip attachment welds, sump welds, weld scars, tear-offs, or other defects away from weld seams should be tested. Special attention should be paid to three plate laps and areas of severe bulges or deformations.	If the subsurface of the floor or interstitial space is below the water table or saturated with water/ product/ liquid, the dispersal of detectable gas along the bottom side of the floor plates may be restricted or impossible. Method of floor construction must be considered. If the floor is anchored to a concrete pad, such as in a cut and cover or bunkered tank, compartmentalization of floor plates or floor sections may exist. In this circumstance, it may be necessary to drill numerous holes in a floor to ensure complete dispersion on the underside. In addition, there is a risk of floor damage and failure of tank floor anchoring system from excessive pressure. This method of testing can detect leak paths smaller than can be detected by vacuum box testing because of its greater sensitivity. Also this method is useful for testing areas of a tank that normally would not be accessible by other methods and the general area of a tank bottom in addition to the welds. As a result of its sensitivity, the procedure should be conducted with individuals possessing a higher level of expertise.
7.12 Evaluation by Detectable Gas Above Floor in Liquid as Inoculate	Testing of tank bottoms using detectable tracer chemical (inoculate) inside is accomplished by injecting a volatile chemical into the receipt line or water draw off line at a concentration of 1 to 10 parts per million (ppm). Inoculate may be injected in gaseous form into an empty tank. Hollow tubes are installed under the tank bottom to extract air samples for analysis. A tank with a secondary containment bottom may have suitable detection tubes.	The entire tank floor is tested so long as detection tubes provide adequate coverage of the tank bottom.	If the subsurface of the floor or interstitial space is below the water table or saturated with water/ product/ liquid, two options are available: (*1*) De-watering or purging prior to sample collection or, (*2*) Extension of waiting time for migration of tracer in the liquid up to 60 days depending upon conditions and tank size.

wear plates, and steel used as wear plates for roof or pan legs, and all exposed plate surfaces.

7.2.3 Evaluating the quality of construction and material is dependent on the schedule, integrity, skill, and experience of

TABLE 1 *Continued*

Procedure	General Description of Procedure	General Application	Thresholds, Results, and Limitations
7.13.2.1 (1) Evaluation by Volumetric Level and Temperature Measurement (A Developing Technology)	Determines leaks in the tank floor by tracking how a level of liquid in a full tank changes over time while accounting for natural variations from product and tank temperature changes, product evaporation, and condensation, and so forth.	Entire tank floor, including plate, sumps and their welds.	This is a developing technology—See Section 7, Evaluation Methods.
7.13.2.1 (2) Evaluation by Mass Measurement (A Developing Technology)	Determines leaks in the tank floor by tracking the amount of pressure exerted by the product in the tank, while accounting for natural variations from tank temperature changes, product evaporation, and condensation, and so forth.	Entire tank floor, including plate, sumps and their welds.	This is a developing technology—See Section 7, Evaluation Methods.
7.14 Evaluation by Acoustic Emission Examination (A developing technology)	The test detects and locates leaks in a tank bottom by measuring the impulsive (intermittent) and repetitive sound of liquid escaping through a small leak path, while the tank is under a hydraulic load. It uses sensors around the shell to detect the sound in conjunction with data collectors/converters to produce an electronic signal, which can be analyzed by algorithms to indicate the location of a possible leak path. The duration of field measurements is normally less than 4 h.	Floor plates (parent material), weld joints between the plates, sump(s), and their weld joints, all of which bear on a sand or similar type foundation.	Type of soil and its porosity effect the frequency of the impulse. The degree of saturation with water or liquid effects the frequency of the signal. Internal and external noise. Tank linings may mask results by obstructing the leak path. This is a developing technology. In general, clusters of dots on a tank map are an indicator of a possible leak, while random dots are allowances needed by the algorithm-sensor testing setup. The procedure should successfully detect 0.5 mm hole during development and field verification.

the manufacturing process, the individuals directing and performing the installation, and the individual inspecting and reviewing records required under this procedure. Tight construction schedules may impact construction quality. The quality of workmanship is a subjective measure and the experience of an inspector determines the ability to detect defects in the materials and workmanship.

7.2.4 *Records:*

7.2.4.1 The tank owner and operator or the owner and operator's representative should request reports, as recommended by Specification A6/A6M, Specification A20/A20M, API 650, and API 653. Rejected conditions require replacement or repair of the affected material until such meet materials and construction requirements.

7.2.5 *Hazards (Cautionary and Generic)*—None.

7.3 *Evaluation of Connected Under-Floor Piping:*

7.3.1 Connected under-floor piping and associated sumps used for water draw or stripping petroleum product from the bottom of the tank can be sources of a leak, and should be tested prior to burying. Such piping that is connected may be: (*1*) Water draw offs, (*2*) Drain dry piping, and (*3*) Sump systems.

7.3.2 *Summary of Test Parameters:*

7.3.2.1 Piping should be manufactured under API accepted standards for construction (refer to Specifications A53/A53M, A106/A106M, and A333/A333M) and monitored for possible leaks during hydrostatic testing. Additional requirements for Electric Resistance Welded (ERW) piping may be necessary.

7.3.2.2 Preparation of the bedding or the foundation that the piping rests on is very important, as piping and sumps that are not adequately supported will be stressed, causing potential for collapse or failure of welds. Refer to Practice D3282 for information on classification of soils and soil aggregate mixtures.

7.3.2.3 The quality of the welds completed on site can be maintained by establishing welding procedures, certifying the capability of the welders who will perform the work, and inspection of the completed work by certified inspectors.

7.3.3 *Application to Portion of the Tank Floor:*

7.3.3.1 This control is performed on the tank piping that is beneath the sub floor and floor plates of a tank bottom, including the sump, bedding material, piping welds and sump welds that are related to the connected piping to the bottom.

7.3.4 *Limitations:*

7.3.4.1 The procedure for evaluating the quality of construction and material is dependent on the schedule, integrity, skill, and experience of the manufacturing process, the individuals directing and performing the installation, and the individual inspecting and reviewing records required under this procedure. The structural integrity and service life are subject to degradation as installation schedules become tighter. The quality of workmanship is a subjective measure under this procedure and the experience of an inspector determines the ability to detect defects in the materials and workmanship.

7.3.5 *Hazards (Cautionary and Generic)*—None.

7.4 *Evaluation by Visual Examination of the Tank Floor:*

FLOW CHART FOR API ESTABLISHED METHODS AND ENHANCING PROCEDURES FOR TANK BOTTOM INTEGRITY

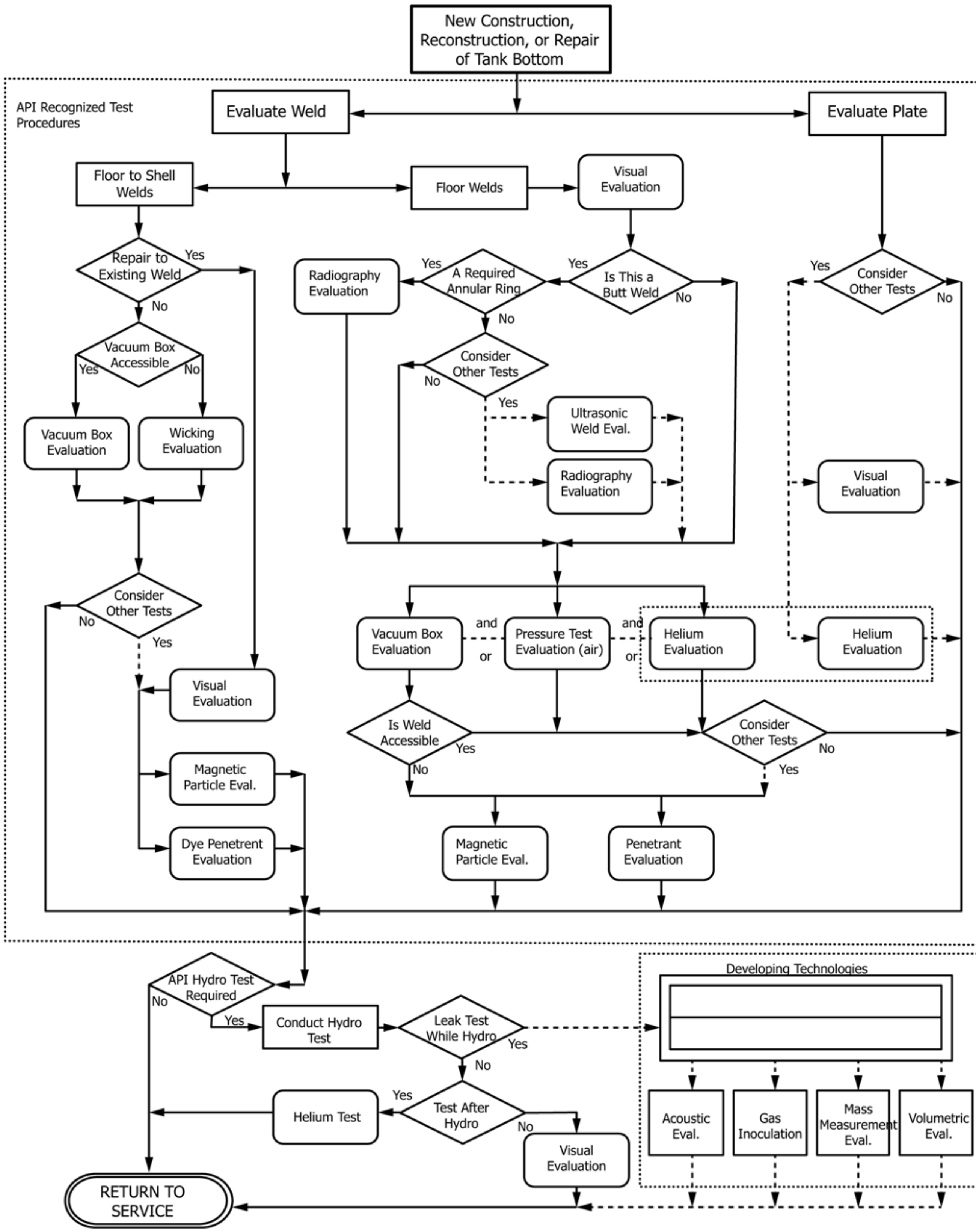

FIG. 2 Flow Chart for API Established Methods and Enhancing Procedures for Tank Bottom Integrity

7.4.1 *Background and History:*

7.4.2 *General Description*—Visual test may be direct type when the tank bottom or steel plate surface is readily accessible to place the eye within 60.9 cm (24 in.) of the surface at an angle of not less than 30°. The minimum illumination is 15 footcandles for general viewing and 50 footcandles for viewing of small anomalies. Visual test may be remote by using mirrors, cameras, or other suitable instruments. The test would detect surface defects such as cracking, weld undercut, corrosion, dents, gouges, weld scars, incomplete welds, and so forth.

7.4.3 *Summary of Test Parameters*—Visual-direct type requires accessibility of the eye to within 60.9 cm (24 in.) of object at an angle of not less than 30° and 15 to 50 footcandles of illumination. Remote type requires instruments.

7.4.4 *Application to Portions of Tank Floor*—All welded floor seams whether lapped or butt type.

7.4.5 *Limitations*—Accessibility to viewing, cleanliness of weld (slag removal, dirt, and so forth). Surface defects only.

7.4.6 *Qualifications of Individuals Performing Test*—Natural or corrected near distance acuity as measured by reading standard J-1 letters of a standard Jaeger chart.

7.4.7 *Reference to Other Test Procedures*—ASME BPVC, Section V, Art. 9.

7.4.8 *Test Reports*—Test reports should be written and traceable and include the following pertinent information: date, name of inspector, type of test, equipment used, defects, and locations.

7.4.9 *Hazards (Cautionary and Generic)*—Confined space requirements apply.

7.5 *Evaluation by Radiography Procedure:*

7.5.1 *General Description:*

7.5.1.1 Radiography is a non-destructive method for inspecting welds that provides information about the internal condition, utilizing radiation. The radiation that is directed at the weld is either absorbed, penetrated, or scattered and then recorded by a device. There are two accepted methods of radiography inspection: Film/Paper Radiography, and Radioscopy. The most traditional manner for recording is on photographic film or paper. The amount of radiation transmitted to the film is a factor of absorption over the length of the weld and is dependent on the mass of various areas and intensity of the beam applied. Interpretation of radiography should be conducted in a room with low levels of light. This permits the observation of the image created in variations of light and dark on the film. The dark areas represent points where greater degrees of penetration and hence an area of lower density. The lighter areas represent impeded or more difficult areas to penetrate and higher density. Absorption rates that differ by more than 1 % are generally detectable when compared to surrounding material areas.

7.5.2 Both making of the exposure and the interpretation of the exposure require the skills of individuals with experience in their respective areas.

7.5.3 *Limitations:*

7.5.3.1 The surface to be examined needs to be accessible (no obstruction to equipment or file placement) from both sides. Discrepancies must be suitably aligned with the radiation beam in order to be reliably detected.

7.5.3.2 It is a relatively expensive testing method.

7.5.4 *Qualifications of Individuals Making and Interpreting Exposure*—Individuals performing this test should be skilled, capable, and familiar with the techniques and procedures recommended by ASM Committee document on Radiographic Inspection and ANSI/AWS B1.10.

7.5.5 *Hazards (Cautionary and Generic):*

7.5.5.1 Radiation exposure to individuals is a hazard and these individuals must be included in a medical monitoring program as established by OSHA.

7.5.5.2 Confined space requirements apply as required by OSHA.

7.6 *Evaluation by Wicking Examination of Corner Weld:*

7.6.1 *Background and History:*

7.6.1.1 This test is a practical test because it provides information regarding the actual hydraulic integrity of the weld with a product less viscous than the product being stored. A leak could be easily located and repaired.

7.6.2 *General Description:*

7.6.2.1 Wicking test of corner weld (shell to bottom weld) is the process of applying a highly penetrating oil or dye penetrant to one side of a weld, then letting it stand for at least four (4) h (12 is preferred) and observing if it penetrates to the other side of the weld.

7.6.3 *Summary of Test Parameters*—Requires proper oil type and minimum visual acuity.

7.6.4 *Application to Portions of Tank Floor*—Corner joint (shell to bottom weld).

7.6.5 *Limitations*—Accessibility to viewing, cleanliness of weld (slag removal, dirt, and so forth). Dry conditions are necessary for reliable test results. Ambient air temperature must be high enough to allow the oil or penetrant to flow freely.

7.6.6 *Qualifications of Individuals Performing Test*—Same as for visual.

7.6.7 *Reference to Other Test Procedures*—API 653 Section 12.1.6.

7.6.8 *Reports*—Test reports should be written and provide the following information: date, name of inspector, type of test, equipment used, defects, and locations.

7.6.9 *Hazards (Cautionary and Generic)*—Confined space requirements apply.

7.7 *Evaluation by Bubble Test Examination-Pressure:*

7.7.1 *Background and History:*

7.7.1.1 This method has its roots in the pressure vessel industry and has been an elemental test for these tanks. The current API Standard 650, Section 7.3.7, includes this type of test for tanks that have been designed to be gas-tight. This method is not applicable to tank roofs that are not gas-tight such as tanks with peripheral circulation vents.

7.7.2 *General Description:*

7.7.2.1 Pressure method locates leaks in a pressurized component by the application of a solution or immersion in liquid that will form bubbles as leakage gas passes through it.

7.7.3 *Summary of Test Parameters*—Requires pressurization and application of exterior solution or immersion in liquid.

7.7.4 *Application to Portions of Tank Floor*—Entire area.

7.7.5 *Limitations*—Small tanks or potions of tanks.

7.7.6 *Qualifications of Individuals Performing Test*—Same as for visual plus training on the specific procedure used by the manufacturer or fabricator. Training to meet the requirements of SNT-TC-1A.

7.7.7 *Reference to Other Test Procedures*—ASME BPVC, Section V, Art. 10, App. I.

7.7.8 *Test Reports*—Written date, name of inspector and certification, test procedure and method, equipment used, test conditions, defects, and locations.

7.7.9 *Hazards (Cautionary and Generic)*—Confined space requirements apply.

7.8 *Evaluation by Bubble Test Examination-Vacuum:*

7.8.1 *Background and History:*

7.8.1.1 This method (vacuum box) has its roots in the pressure vessel industry and has been an elemental test for these tanks. The current API Standard 650 includes this type of test for floor lap joints in Section 7.3.3. The current API Standard 653 includes this type of test for floor lap joints and corner joint in Sections 12.1.6 and 12.1.7 and represents the industry norm.

7.8.2 *General Description:*

7.8.2.1 Vacuum method locates leaks in a pressure boundary that can not be directly pressurized. A solution is applied to a local area and a differential pressure is created which produces bubbles on the surface. This type of test is identified by API 650, Section 7.3.3 as a method for testing bottom plate lap welds and one option for the shell to bottom weld.

7.8.3 *Summary of Test Parameters*—Requires application of vacuum to solution on a local area.

7.8.4 *Application to Portions of Tank Floor*—All fillet welded lapped seams and corner joint (shell to bottom weld).

7.8.5 *Limitations*—Requires minimum vertical clearance of 6 in. between the bottom and any obstruction for placement of device and accessibility to viewing the local area being examined.

7.8.6 *Qualifications of Individuals Performing Test*—Same as for visual plus training on the specific procedure used by the manufacturer or fabricator. Training to meet the requirements of SNT-TC-1A.

7.8.7 *Reference to Other Test Procedures*—ASME BPVC, Section V, Art. 10, App. II.

7.8.8 *Test Reports*—Written, date, name of inspector and certification, test procedure and method, equipment used, test conditions, defects and locations.

7.8.9 *Hazards (Cautionary and Generic)*—Confined space requirements apply.

7.9 *Evaluation by Liquid Penetrant:*

7.9.1 *General Description:*

7.9.1.1 Liquid penetrant inspection is a test method that can be used to locate weld defects such as cracks, seams, laps or porosity that are open to the surface of the weld. Liquid penetrant is applied to the weld where it will enter discontinuities in the surface, primarily by capillary action. The excess penetrant is removed using water or a cleaning agent. The weld is then allowed to dry and a developer is applied. The developer acts as a blotter to draw the penetrant out of the discontinuities back to the surface and as a contrasting background for the penetrant. The dyes are either color contrast (viewable in white light against a contrasting color developer) or fluorescent (visible under ultraviolet or a ⅓ black light). Discontinuities should show clearly as colored marks on a contrast background (visible light type) or a glowing fluorescent mark (ultraviolet light type).

7.9.2 *Summary of Test Parameters*—The test requires liquid penetrant, liquid penetrant developer, an appropriate light source and a qualified inspector.

7.9.3 *Application to Portions of Tank Bottom*—May be used on any weld. The test may be most useful in areas where other physical weld evaluations cannot be done due to access limitations. A special examination of the bottom welds is not required by API 650 or API 653, but is listed as an option for examination of the corner weld.

7.9.4 *Acceptance Criteria:*

7.9.4.1 No recognizable indications that might indicate a through defect.

7.9.5 *Limitations:*

7.9.5.1 Limitations include:

(1) The discontinuities must extend to the surface of the weld,

(2) The weld must be in an accessible location,

(3) The weld must be clean (free of dirt, grease, lint, scale, flux, weld spatter, and so forth),

(4) The weld must not be coated, and

(5) The test checks only the welds.

7.9.6 *Qualifications of Individuals Performing Test:*

7.9.6.1 The test should be performed in accordance with a written procedure and performed by an individual trained in the application of that procedure. The personnel performing the test should be professionally and technically qualified to perform the test. As a minimum, personnel should have:

(1) Sufficient natural or corrected near distance acuity to read a Jaeger Type 2 standard chart and the ability to distinguish between the colors used in the test, and

(2) Level II or Level III certification in accordance with SNT-TC-1A.

7.9.7 *References to Other Test Procedures*—ASME Boiler and Pressure Vessel Code, Section V, Article 6.

7.9.8 *Test Report*—The test report should be written and include the following: Owner's and operator's name, facility name, facility location, tank unique identifier, name of testing organization, test operator name and signature, date of test, equipment used, and defects identified and their locations.

7.9.9 *Hazards (Cautionary and Generic)*—None.

7.10 *Evaluation by Magnetic Particle Examination:*

7.10.1 *General Description:*

7.10.1.1 The weld area to be examined is first magnetized and then ferromagnetic particles are placed on the weld. These will form patterns on the surface of the weld where there are distortions in the magnetic field caused by such weld discontinuities as cracks, seams, laps or porosity. The patterns are most evident for discontinuities located near the surface of the weld and oriented perpendicular to the magnetic field. The test is run a second time with the direction of the new magnetic field set up perpendicular to the old one in order to pick up discontinuities oriented in the other direction. The magnetic particles are either color contrast (viewable in white light) or fluorescent (visible under ultraviolet or a black light) type. The color contrast type is either wet or dry type. Discontinuities should show clearly as colored marks (visible light type) or a glowing fluorescent mark (ultraviolet light type).

7.10.2 *Summary of Test Parameters*—The test requires equipment to magnetize the area, magnetic particles, a light source and a qualified inspector.

7.10.3 *Application to Portions of Tank Bottom*—May be used on any weld. The test may be most useful in areas where other physical weld evaluations cannot be done due to access limitations. It is not required by API 650 and API 653 as a specified examination of the bottom welds, but is listed as an option for examination of the corner weld.

7.10.4 *Acceptance Criteria:*

7.10.4.1 No recognizable indications that would indicate a through thickness defect.

7.10.5 *Limitations:*

7.10.5.1 Limitations include:

(1) The discontinuities below the surface are more difficult to detect than those at the surface,

(2) Not all discontinuities are defects,

(3) The weld must be in an accessible location,

(4) The weld must be clean (free of dirt, grease, lint, scale, flux, weld spatter, etc.),

(5) The weld will generally have to be uncoated, and

(6) The test checks only the welds.

7.10.6 *Qualifications of Individuals Performing Test:*

7.10.6.1 The test should be performed in accordance with a written procedure and performed by an individual trained in the application of that procedure. The personnel performing the test should be professionally and technically qualified to perform the test. As a minimum, personnel should have:

(1) Sufficient natural or corrected near distance acuity to read a Jaeger Type 2 standard chart and the ability to distinguish between the colors used in the test, and

(2) Level II or Level III certification in accordance with SNT-TC-1A.

7.10.7 *References to Other Test Procedures*—ASME Boiler and Pressure Vessel Code, Section V, Article 7.

7.10.8 *Test Report*—The test report should be written and include the following: Owner's and operator's name, facility name, facility location, tank unique identifier, name of testing organization, test operator name and signature, date of test, equipment used, defects identified and their locations.

7.10.9 *Hazards (Cautionary and Generic)*—None.

7.11 *Evaluation by Detectable Gas-Beneath Floor Injection:*

7.11.1 *Background and History:*

7.11.1.1 The technology has been applied to existing, replacement, and new tank floors. The tank must be emptied and cleaned prior to the testing. This test method is best suited for uncoated floors or tank floors prior to coating or lining. This method is also well suited for determining the location of leaks in tank floors having a known or suspected leak.

7.11.2 *General Description:*

7.11.2.1 Testing of tank bottoms using detectable gas beneath the tank floor is accomplished by injecting a detectable gas, which is lighter than air beneath the tank floor in adequate quantity to allow dispersal over the entire underside of the floor. A common gas used for this application is welding grade helium.

7.11.2.2 This method of testing may detect leaks smaller than can be detected by vacuum box testing. The sensitivity of this equipment is dependent on the detectable gas concentrations (background) inside the tank and type of equipment used.

7.11.3 *Summary of Test Parameters:*

7.11.3.1 Detectable gas leak detection equipment used to perform detectable gas leak testing should be in calibration and capable of detecting a minimum gas flow rate of 1×10^{-9} STD CC/sec in accordance with ASME BPV Section V, Art. 10, App IV. The equipment should be calibrated and tested for sensitivity and proper function in accordance with the operating instructions throughout testing.

7.11.3.2 Detectable gas leak testing should be performed in accordance with approved procedures and the detectable gas leak detection equipment operation instructions.

7.11.3.3 Perform detectable gas injection through standpipe or under tank telltale piping system using threaded coupling or other suitable connection. If tank is not equipped with leak detection system or there is no way to inject detectable gas through leak detection system, detectable gas injection may be accomplished by drilling and tapping holes in the tank floor.

7.11.4 *Application to Portions of Tank Floor:*

7.11.4.1 One hundred percent of all floor plate welds, patch plate welds, clip attachment welds, sump welds, weld scars, tear-offs, or other defects away from weld seams should be tested. Special attention should be paid to three plate laps and areas of severe bulges or deformations.

7.11.5 *Limitations:*

7.11.5.1 If the subsurface of the floor or interstitial space is below the water table or saturated with water/product/liquid, the dispersal of detectable gas along the bottom side of the floor plates may be restricted or impossible. Consideration as to the feasibility of the test is required under these circumstances. De-watering or purging may be options.

7.11.5.2 Method of floor construction must be considered. If the floor is anchored to a concrete pad, such as in a cut and cover or bunkered tank, compartmentalization of floor plates or floor sections may exist. In this circumstance, it may be necessary to drill numerous holes in a floor to ensure complete dispersion on the underside. In addition, there is a risk of over pressurization of tank floor and possible damage or failure of the anchoring system. Consideration as to the feasibility of the test is required under these circumstances.

7.11.6 *Qualifications of Individuals Performing Test:*

7.11.6.1 Personnel performing detectable gas leak testing should be professionally and technically qualified to perform the testing. As a minimum, leak-testing personnel should have Level II or Level III certification in detectable gas leak testing in accordance with ASNT SNT-TC-1A.

7.11.7 *Reference to Other Test Procedures:*

7.11.7.1 Floor coverage speeds with the testing equipment to be used should be based on ASME BPV Section V, approved procedures and equipment response rates.

7.11.8 *Test Reports:*

7.11.8.1 Detectable gas leak test reports should include:

(1) Date of test,

(2) Certification level and name of operator,

(3) Test procedure (number) and revision number,

(4) Test method or technique,

(5) Test results,

(6) Component identification,

(7) Test instrument, standard leak, and material identification,

(8) Test conditions, test pressure, and gas concentration,

(9) Gage(s)—manufacturer, model, range, and identification number, and

(10) Temperature measuring device(s) and identification number(s).

7.11.9 *Hazards (Cautionary and Generic):*

7.11.9.1 Confined Space Entry Procedures should be strictly adhered to during detectable gas leak testing procedures. Concentrations of a detectable gas such as helium in a confined space can result in an oxygen deficient condition. Testing personnel should perform additional atmospheric testing of the tank at frequent intervals during leak testing and injection.

7.11.9.2 In addition to confined space entry permits and plaques, signs should be posted on the tank that detectable gas is in use. The signs should be posted at any possible entry point on the tank. In addition, verbal communication of hazards should be made to any individuals performing work at or near the tank and to the owner or supervisor of the facility. Notify any individuals performing work at the facility.

7.11.9.3 Perform detectable gas injection with a flow rate and pressure as indicated in approved procedures. Perform monitoring of the tank floor throughout testing to avoid damage from over pressurization.

7.12 *Evaluation by Detectable Gas Above Floor in Liquid Inoculation:*

7.12.1 *Background and History:*

7.12.1.1 The technology has been applied to existing, replacement, and new tank floors. The tank can be empty or partially full of product or water prior to the testing. This test method may be used on coated floors or tank floors prior to coating or lining. This method is especially useful prior to other inspection services, and is conducted without disruption of operations. It may be useful during acceptance testing of a new tank or bottom by inoculating water just prior to the hydro-test.

7.12.2 *General Description:*

7.12.2.1 Testing of tank bottoms using detectable tracer chemical (inoculate) in the tank is accomplished by injecting a volatile chemical into the receipt line or water draw off line at a concentration on the order of 1 to 10 parts per million (ppm). Hollow tubes are installed under the tank bottom to extract air samples for analysis. A tank with secondary containment bottom may have suitable detection tubes already installed. The chemicals used must be non-ozone-depleting chemicals.

7.12.3 *Summary of Test Parameters:*

7.12.3.1 The leak detection, provided the soil permeability readily allows tracer movement through at greater than 1 Darcy, the analytical equipment used to perform leak testing, should be in calibration and capable of detecting concentrations of inoculate chemical at levels above 0.001 µg/L of air. The equipment should be calibrated and tested for sensitivity and proper function in accordance with the operating instructions throughout testing.

7.12.3.2 Inoculate gas leak testing should be performed in accordance with approved procedures and the analytical equipment operation instructions.

7.12.3.3 Perform inoculate gas collection through under tank tell-tale piping system using threaded coupling or other suitable connection. The under tank gas collection system shall be installed so that the termination point of each pipe covers the entire tank bottom so that no part of the bottom is over 20 ft in lateral direction from each termination point.

7.12.4 *Application to Portions of Tank Floor:*

7.12.4.1 With the inoculate in the in-tank liquid, the entire interior floor is subject to leak detection, providing that location of sampling tubes or tell-tales adequately covers the underside of the tank floor.

7.12.5 *Limitations:*

7.12.5.1 This method may not be effective in areas of frozen ground and where soils are not porous. If the subsurface of the floor or interstitial space is below the water table or saturated with water/product/ liquid, two options are available:

(1) De-watering or purging prior to sample collection or,

(2) Extension of waiting time for migration of inoculate in the liquid up to 60 days depending upon conditions and tank size.

In addition, care must be taken to prevent inoculation vapors from leaving the tank interior through hatches, pipe openings, gauging systems, and so forth, that may lead to false positive readings for the integrity of the floor system.

7.12.6 *Qualifications of Individuals Performing Test:*

7.12.6.1 Personnel performing inoculate leak testing should be professionally and technically qualified to perform the testing. As a minimum, leak-testing personnel should have:

(1) Certification by the technology vendor.

(2) Inspectors should meet the qualifications and certifications of API requirements for testing of tank floors.

7.12.7 *Reference to Other Test Procedures*—Not applicable.

7.12.8 *Test Reports:*

7.12.8.1 Leak test reports should include:

(1) Date of test,

(2) Certification level and name of operator,

(3) Test procedure (number) and revision number,

(4) Test method or technique,

(5) Test results and Tank certification,

(6) Component identification, and

(7) Test instrument, standard leak, and material identification.

7.12.9 *Hazards (Cautionary and Generic)*—None.

7.13 *Evaluation by Leak Detection Systems Using Volumetric/Mass Measurement Technology:*

7.13.1 *Background and History:*

7.13.1.1 Leak detection systems based on volumetric and mass measurement technologies are an outgrowth of the automatic tank gaging industry and are a proven system for leak detection for underground fuel storage tanks (USTs). They have been in general use for USTs for several years and as such are widely accepted. Although they have been used commercially on ASTs with some success, they should be considered a developing technology.

7.13.2 *General Description:*

7.13.2.1 Both volumetric and mass systems operate on the principle of measuring the amount of liquid in a tank over time while eliminating or compensating for those variables in a tank that are unrelated to a leak. Any liquid loss not attributed to those variables may be considered a leak. They have the advantage of directly testing the hydraulic integrity of the tank bottom under near-operational conditions (with liquid in the tank and during the hydrostatic test prior to placing in service). There are several classes of systems, including:

(1) Volumetric Level and Temperature Measurement, and

(2) Mass Measurement.

7.13.3 *Evaluation by Leak Detection by Volumetric Level and Temperature Measurement:*

7.13.3.1 Volumetric level and temperature measurement technologies use sensors to measure the level of a liquid in the tank over time. This level is converted to volume using strapping charts. Additional sensors are used to measure the temperature of the liquid (and tank shell) at various points. After eliminating from consideration the volume changes caused by noise (normally occurring events such as tank and fuel growth or shrinkage due to temperature changes) any remaining product volume drop may be considered a leak. The keys to volumetric level and temperature measurement are *(1)*, the measurement of the liquid level and *(2)*, the ability of the system to compensate for noise.

7.13.3.2 This should be considered a developing technology and as such will not be described in detail here. Prior to using this technology, the owner and operator, or owner's and operator's agent, or both, should thoroughly review API Pub 334.

7.13.4 *Leak Detection by Mass Balancing:*

7.13.4.1 Mass measurement technologies use sensors to measure the pressure of a liquid in the tank over time by use of a differential pressure sensor. Additional sensors are used to measure the temperature of the differential pressure sensor. After eliminating from consideration the volume changes caused by noise (normally occurring events such as tank growth or shrinkage due to temperature changes) any remaining product pressure drop may be considered a leak. The keys to mass measurement are *(1)*, the measurement of the liquid level and *(2)*, the ability of the system to compensate for noise.

7.13.4.2 This should be considered a developing technology and as such will not be described in detail here. Prior to using this technology, the owner and operator, or owner's and operator's agent, or both, should thoroughly review API Pub 334.

7.14 *Evaluation by Acoustic Emission Examination:*

7.14.1 *Background and History:*

7.14.1.1 Acoustic emission testing is a developing technology which is based on the principle that liquid escaping through a fissure in the tank floor or shell produces a sound that is detectable. This technology has the ability to localize a detected leak. The detection method includes the use of sound sensors that can be triangulated to locate a leak point. The technology has been under development since the 1970s.

7.14.2 *General Description and Test Procedure:*

7.14.2.1 Acoustic emission testing is based on the principle that liquid escaping through a fissure in the tank floor or shell produces a sound that is detectable. The demonstration of this principle has shown that two types of sound are produced simultaneously. One type is the continuous hissing sound created by turbulent flow through the opening and may be audible. The second type is an intermittent impulsive sound created by the interaction between liquid flow through a fissure with air bubbles trapped in the backfill material below the floor. This impulsive sound extends beyond the audible frequency range and is the distinguishing characteristic signal upon which passive acoustic emission testing is based. The continuous hissing sound, even though it is generated by flow through a fissure, is considered, along with other detectable sounds, to be noise. For acoustic emission testing, noise is defined as any sound, continuous, or intermittent, or both, which is not a signal.

7.14.3 *Conditions:*

7.14.3.1 Acoustic systems operate on the principle of detection by location. The basis for identifying a leak, a fissure in the tank floor through which a fluid is leaking, is the point of origin of the signal. The frequency of an intermittent impulsive signal greatly depends on the condition of the backfill material. Porous materials, like a well-drained sand, could be expected to generate more impulsive signals per unit of time than cohesive materials, like a well-compacted clay, if all other tank conditions were the same. The degree of saturation of water in the backfill also impacts the frequency of signals. If water, possibly from a hydro-test leak or possibly from natural characteristics of the foundation backfill and its general drainage, significantly displaces air immediately below the floor plate at the location of a fissure, the impulsive signals may be reduced completely. The sources of noise, against which a signal must be discerned, include sounds initiated external to the tank as well as within the tank. The effects of noise initiated external to the tank can often be avoided by testing during quiet periods including low activity of nearby operations. Intermittent sounds initiated within the tank structure may be very similar to impulsive signals and must be accounted for in the reduction and interpretation of the collected data.

NOTE 1—Lining of the tank bottom prior to running this test may increase the chance that a leak path in a bottom plate or weld will be masked.

7.14.4 *Testing Equipment:*

7.14.4.1 The type of sensor used in acoustic emission testing is an accelerometer, which converts sound energy into measurable electrical output. The sensors are clamped around the periphery of the tank shell, usually at evenly spaced intervals and near the bottom. At least one sensor is placed at a higher elevation than the others to differentiate sounds initiated at the liquid surface or by the floating roof from sounds initiated at the bottom. Also, the test operator may choose to cluster some sensors to account for reflected sounds created by echoes from internal piping and structural members.

An echo, if undifferentiated from direct signals, causes errors in locating the origin of the signal.

7.14.5 *Algorithms to Discern Signals and their Point of Origin:*

7.14.5.1 For the acoustic test method to be able to indicate signals apart from noise, data collection algorithms and signal processing algorithms are used. The data recorder receiving all raw output from the sensors feeds these electrical outputs to a data collection algorithm to account for predictable unwanted sounds. The algorithm also is used for discrimination of multiple reflections from direct signals. The use of a high performance algorithm complements the placing of sensors to account for the echo phenomena. The algorithm is configured for known general test conditions of velocity of sound in water, diameter of the tank, height of hydro-test water, and spacing of sensors on the shell.

7.14.6 *Applications to Portions of Tank Floor:*

7.14.6.1 The acoustic emission test method is applicable, theoretically, for concurrently testing the parent metal plates, the floor weld joints, and the sump(s), for example, all areas wetted by and under the head pressure of the tank contents, but excluding under-floor piping.

7.14.7 *Limitations:*

7.14.7.1 *Condition of Backfill/Foundation*—The nature and condition of the backfill must be known, since it is an integral part of the steel bottom and its support "test system."

7.14.7.2 *Type of Tank and External Piping*—The sounds from a floating roof and its sliding seals, though nominally at rest, must be accounted for. Connected piping must be considered, as the noise of normal terminal operations such as pumping, valve actuation, ambient noise, vehicles, trains and airplanes may be transmitted to the tank. The effects of noise initiated external to the tank can often be avoided by testing during quiet periods including low activity of nearby operations. Potential leaks in under-floor piping require special attention in the placement of the sensors.

7.14.7.3 *Pre-Test Waiting Period*—To allow for tank and foundation deformations which occur as a result of the hydro-test loading, a pre-test waiting period is recommended to accommodate and minimize noise from tank deformation.

7.14.7.4 *Weather Conditions*—The effects of weather conditions such as wind and precipitation should be considered to minimize weather related noise. Tests are often put on hold or postponed during periods of adverse weather conditions.

7.14.8 *Qualifications of Individuals Performing Test:*

7.14.8.1 The individuals performing the test must have specific training and experience in acoustic emission testing. Primary areas of expertise are evaluating the specific tank and site conditions for concurring on the applicability of an acoustic emission test, placing the sensors for the test, choosing the appropriate algorithm, and analyzing the test results.

7.14.9 *Reference to Other Test Methods:*

7.14.9.1 The acoustic emission test method is unrelated to the other tank bottom integrity test methods discussed in this document but may be considered a complement to those methods.

7.14.10 *Test Reports:*

7.14.10.1 *Recorded Test Data*—The recorded field data is a map of the tank floor with a plot (dots as a mechanism to display results) of the signals discerned during the test. In general, clusters of dots are an indicator of a possible leak and random dots are allowances needed by the algorithm-sensor testing setup.

7.14.10.2 *Written Report*—The person in charge of the acoustic emission test should issue a written report, which includes an analysis of the recorded field data and an opinion of the tank bottom integrity based on the test and with minimal qualifications of the tank, or foundation conditions, or both.

7.14.11 *Hazards (Cautionary and Generic)*—The normal cautionary awareness of potential energy of hydrostatic head is applicable to this test.

7.14.12 *References:*

7.14.12.1 API Pub. 322.

7.14.12.2 API Pub. 334.

8. Report

8.1 If a report is required it is identified within the individual test procedure.

9. Keywords

9.1 aboveground storage tank; hydraulic integrity; leak; leak prevention repaired tank; newly constructed tank; reconstructed tank; tank bottom; tank release; testing procedures

APPENDIX

(Nonmandatory Information)

X1. RATIONALE

X1.1 Economic and environmental requirements in recent years have placed increasing emphasis on efforts to better manage the repair and operation of aboveground tanks. Releases from petroleum tanks can adversely affect the environment, leading to costly remediation, fines, or an inability to use the tankage until repairs are completed, or combination thereof. Tank owners can reduce their risk by completing recommended inspections and repairs and by use of this guide.

X1.2 This guide is intended to assist owners and operators when they are completing the repair portion on tank bottoms and to help them understand practices that will promote greater reliability of tank bottoms by the elimination of defects that may occur during construction.

X1.3 The guide will give information on accepted practices and emerging technologies that may assist in determining hydraulic integrity of a tank bottom. Use of this guide may reduce the likelihood that a tank bottom will fail during early service.

X1.4 In developing this guide the task group is allowing the tank owner to establish the risks that are acceptable versus the economic requirements of limiting the time a tank is out of service. The guide is to be used on a voluntary basis and in no way is intended to establish a minimum standard of actions. Requiring the use of the guide is not an appropriate action. The guide does, however, show steps that can be taken to reduce the likelihood of tank bottom failures. Information for increasing degrees of confidence is achieved by arranging the procedures and test methods into two main groupings. The groupings are for accepted methods used prior to conducting a hydro-test and methods for use during a hydro-test that include developing technologies.