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Standard Guide for Three Methods of Assessing Buried Steel Tanks[1]

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INTRODUCTION

The purpose of this guide is to provide three methods of inspecting and assessing buried steel tank(s) for corrosion damage and determining the suitability of these tanks prior to application of cathodic protection.

1. Scope

1.1 This guide covers procedures to be implemented prior to the application of cathodic protection for evaluating the suitability of a tank for upgrading by cathodic protection alone.

1.2 Three procedures are described and identified as Methods A, B, and C.

1.2.1 *Method A*—Noninvasive with primary emphasis on statistical and electrochemical analysis of external site environment corrosion data.

1.2.2 *Method B*—Invasive ultrasonic thickness testing with external corrosion evaluation.

1.2.3 *Method C*—Invasive permanently recorded visual inspection and evaluation including external corrosion assessment.

1.3 This guide presents the methodology and the procedures utilizing site and tank specific data for determining a tank's condition and the suitability for such tanks to be upgraded with cathodic protection.

1.4 The tank's condition shall be assessed using Method A, B, or C. Prior to assessing the tank, a preliminary site survey shall be performed pursuant to Section 8 and the tank shall be tightness tested pursuant to 5.2 to establish that the tank is not leaking.

1.5 While this guide provides minimum procedures for assessing a tank's condition, this guide does not provide minimum installation procedures or requirements for upgrades of the tank by cathodic protection.

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

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

2. Referenced Documents

2.1 The most recent version of the following documents should be consulted as references by those using this guide:

2.2 *ASTM Standards:* [2]

D 2216 Test Methods for a Laboratory Determination of Water (Moisture) Content of Soil and Rock

E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method

E 797 Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method

E 1323 Guide for Evaluating Laboratory Measurement Practices and the Statistical Analysis of the Resulting Data

E 1526 Practice for Evaluating the Performance of Release Detection Systems for Underground Storage Tank Systems[3]

G 51 Test Method for pH of Soil for Use in Corrosion Testing

G 57 Test Methods for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method

2.3 *American Society for Nondestructive Testing Standard:*[4]

ASNT SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

[1] This guide is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.10 on Corrosion in Soils.

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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] Withdrawn.

[4] Available from The American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518.

2.4 *NACE International Standards:*[5]

RP-0169 Standard Recommended Practice-Control on External Corrosion on Underground or Submerged Metallic Piping Systems

RP-0187 Standard Recommended Practice-Design Considerations for Corrosion Control of Reinforcing Steel in Concrete

RP-0285 Standard Recommended Practice-Corrosion Control of Underground Storage Tank Systems by Cathodic Protection

2.5 *Environmental Protection Agency Methods:*[6]

EPA SW 846 Test Methods for Evaluating Solid Waste

EPA 371.1 Measurement of Sulfate Reducing Bacteria

2.6 *National Fire Protection Association (NFPA)*[7]

NFPA 329 Recommended Practice for Handling Underground Releases of Flammable and Combustible Liquids

2.7 *Underwriters Laboratories Inc.*[8]

UL 58 Steel Underground Tanks for Flammable and Combustible Liquids

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *buried*—to be placed in the ground and covered with earth.

3.1.2 *cathodic protection*—an applied technique to prevent further corrosion of a metal surface by making that surface the cathode of an electrochemical cell. For example, a tank system can be cathodically protected through the application of either galvanic anodes or impressed current.

3.1.3 *corrosion specialist/cathodic protection specialist*—a competent person who by reason of knowledge of the physical sciences and the principles of engineering and mathematics, acquired by education and related practical experience, is qualified to engage in the practice of corrosion control on buried or submerged metallic piping systems and metallic tanks. Such persons shall be registered professional engineers or persons recognized as corrosion specialists or cathodic protection specialists by NACE, if their professional activities include suitable experiences in external corrosion control on buried or submerged metallic piping and tanks.

3.1.4 *corrosion technician*—a person possessing basic knowledge of corrosion and corrosion control, who is capable of performing routine, well defined work under the supervision of the corrosion specialist/cathodic protection specialist.

3.1.5 *invasive procedure*—a method of determining the corrosion status of a tank by assessing the tank from the inside as part of the upgrade procedure. Further, for the purposes of this guide, it does not require manned entry into the tank. (See *non-invasive*.)

3.1.6 *noninvasive procedure*—a method of determining the corrosion status of a tank from the characteristics of its surroundings with minimal entry into the tank. Further, for the purposes of this guide, it does not require manned entry into the tank. (See *invasive*.)

3.1.7 *pH*—the numerical value of the negative logarithm of the hydrogen ion concentration in moles per litre in an electrolyte.

3.1.8 *tank tightness test*—a method capable of detecting a 0.1 gal/h leak rate, while accounting for any applicable effects of thermal expansion or contraction of the product, of vapor pockets, of tank deformation, of evaporation or condensation, and of the location of the water table. The method must be capable of detecting a 0.1 gal/h leak rate with a probability of detection of at least 0.95 and a probability of false alarm of at most 0.05 or in accordance with NFPA 329.

3.1.9 *underground storage tank (UST)*—any one or combination of tanks (including connected underground piping), the volume of which is 10 % or more beneath the surface of the ground.

3.1.10 *upgrade*—the addition to or retrofit of UST systems using approaches including, but not limited to, cathodic protection to improve the ability of a UST system to prevent a release.

3.1.11 *unconditional probability of corrosion failure*—the probability of corrosion failure which includes a determination of whether localized, pitting, or general corrosion is occurring.

3.1.12 *UST*—see underground storage tank (see 3.1.9).

3.1.13 *redox potential*—potential of platinized platinum electrode in a redox environment (reversible system). The value of redox potential depends on whether the system is in the oxidized, partially oxidized, partially reduced, or reduced state.

3.2 *limitations*—The user of this guide is encouraged to review any available third party verification information provided as part of the vendor selection process.

3.3 *vendor provided information*—The user is referred to Annex A1 for a specific form and format of information which must be provided by a vendor. This information consists of historic performance data on a method and is mandated as part of the guide.

4. Significance and Use

4.1 This guide provides three methods for determining the suitability of a buried steel tank to be upgraded with cathodic protection.

4.2 This guide may be used to assess any UST, including non-regulated USTs.

4.3 This guide provides three alternative methods but does not recommend any specific method or application. The responsibility for selection of a method rests with the user.

4.4 This guide has specific requirements for vendor provided information which should be requested and reviewed by the user.

5. Permits, Plans and Tank Leak Testing

5.1 Prior to engaging in any activities relating to the alteration, repair, or upgrade of any UST system, consult all necessary authorities to obtain any required permits.

5.2 *Tank Leak Testing*:

[5] Available from National Association of Corrosion Engineers (NACE), 1440 South Creek Dr., Houston, TX 77084-4906.

[6] Available from Underwriters Laboratories (UL), Corporate Progress, 333 Pfingsten Rd., Northbrook, IL 60062.

[7] Available from US Environmental Protection Agency, Office of Underground Storage Tanks, 401 "M" St. SW, Washington, DC 20460.

[8] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.

5.2.1 To establish that tanks are not leaking prior to assessment, they shall be assessed by a leak detection system. This leak detection assessment alone is not sufficient to determine that a tank is suitable for upgrading with cathodic protection under this guide.

5.2.2 A tightness test or another release detection system in accordance with NFPA 329 shall be used. Any release detection must be capable of detecting a leak from any portion of the tank that routinely contains product, and be independently evaluated and certified in accordance with Practice E 1526 or the equivalent. Leak detection results shall be provided to the corrosion specialist/cathodic protection specialist.

5.2.3 This testing shall be accomplished within six months prior to performing any of the assessment procedures.

6. Required Approvals and Certifications

6.1 The corrosion assessment work carried out under this guide shall be performed under the responsible direction of a corrosion specialist/cathodic protection specialist as defined in 3.1.3.

6.2 The corrosion specialist/cathodic protection specialist shall certify to the tank owner or operator that the personnel performing the assessment work on the tank are knowledgeable of all the applicable procedures in this guide.

6.3 The corrosion specialist/cathodic protection specialist shall certify to the tank owner or operator that all work was performed in strict accordance with this guide.

7. General Safety Requirements

7.1 All personnel shall comply with applicable federal, state, and local health and safety codes and regulations.

8. Preliminary Site Survey

8.1 A corrosion technician, under the responsible direction of the corrosion specialist/cathodic protection specialist, shall obtain tank site specific information as appropriate to the method of assessment to be used.

8.1.1 *Facility Information*:

8.1.1.1 Address or location, and

8.1.1.2 Name and telephone number of owner and operator contact personnel.

8.1.2 *Tank and Piping Details*:

8.1.2.1 Number and capacity,

8.1.2.2 Location and dimensions,

8.1.2.3 Age,

8.1.2.4 Material of construction,

8.1.2.5 Electrical isolation,

8.1.2.6 Type of product stored,

8.1.2.7 Names of site contact personnel,

8.1.2.8 Backfill material,

8.1.2.9 Coatings and linings,

8.1.2.10 Leak history,

8.1.2.11 Repair history,

8.1.2.12 Site plans,

8.1.2.13 Installation specifications,

8.1.2.14 Tank excavation liners, and

8.1.2.15 As-built drawings.

8.1.3 *Information Not in the Immediate Vicinity of the Tanks*—The presence of the following items, that are external to the tank area, shall be investigated and included as appropriate to the method of assessment of the suitability of tanks for upgrading with cathodic protection:

8.1.3.1 Stray dc current sources,

8.1.3.2 Existing cathodic protection systems,

8.1.3.3 Steel product and vent piping and fittings, and

8.1.3.4 Adjacent subsurface metallic/steel-reinforced concrete structures.

8.2 *Preliminary Evaluation*—Prior to assessing the tank, a preliminary site survey must be performed pursuant to Section 8 and a tightness test must be performed pursuant to 5.2 to establish that the tank is not leaking.

9. Method A—Noninvasive with Primary Emphasis on Statistical and Electrochemical Analysis of External Site Environment Corrosion Data (1,2)

9.1 *Field and Laboratory Testing—Noninvasive with Primary Emphasis on Statistical and Electrochemical Analysis of External Site Environment Corrosion Data.*

9.1.1 Tests shall be conducted by, or as directed by a corrosion specialist/cathodic protection specialist.

9.1.2 *Field Testing Procedures*—Tests to be performed shall include, but are not limited to, the following:

9.1.2.1 *Stray Currents*—Perform tests to detect the presence of stray currents at each tank site. This test shall consist of measuring structure-to-soil potentials at right angles at a minimum of two locations within the tank facilities and observing the measurements for not less than 2 h at a time when such influences are most likely to occur. The monitor shall consist of a field data acquisition unit, with a minimum of 10-MΩ input impedance, used in conjunction with a stable reference cell(s) placed in contact with the soil in the vicinity of the tank. The instrument shall measure and store structure-to-electrolyte potential (voltage) data at least every 5 s throughout the entire duration of field investigation at the site or for 2 h, whichever is greater. If variations of ±50 mV or greater are measured during the test period, make 24-h recording measurements to confirm stray current effects.

9.1.2.2 *Tank Information*:

(a) Locate all tanks and confirm materials of construction, age, capacity, and dimensions. Produce detailed site sketches describing the layout of the UST system and above grade pertinent details for each site.

(b) Determine the presence and extent of internal corrosion immediately below the fill riser. If the depth of corrosion penetration in the tank shell exceeds 50 % of the tank wall thickness, the UST shall be declared to have failed the test and the procedure.

(c) Determine if the tanks and piping are electrically continuous.

9.1.2.3 *Bore Hole Tests*:

(*a*) Determine locations for soil borings in the field. Make two test holes for each tank excavation zone with four or fewer tanks. For tank excavation zones with more than four tanks, make one additional bore hole for each two additional tanks, or part thereof. Make the tank bore holes at opposite diagonal ends of the tank excavation zone. The tank excavation zone

shall be considered to extend no farther than 4 ft from the nearest tank. Complete the holes to the bottom of the deepest tank.

(*b*) In each tank bore hole, record measurements as the boring progresses. At 2-ft (0.6-m) intervals, make the following tests:

(*1*) Measure the soil resistivity using the Wenner four pin method in accordance with Test Methods G 57.

(*2*) Make structure-to-soil potential measurements in each bore hole using a minimum 10-MΩ input impedance digital voltmeter and a calibrated copper-copper sulfate reference electrode sensing tip in direct contact with the soil in the bore hole.

(*c*) Measure the depth of observed, perched, or static water table in each bore hole, if encountered.

(*d*) In accordance with industry practices, gather one soil sample each at the top, mid depth, and bottom of each hole using either a split spoon or core sampling tube and place, seal, and preserve the soil samples in containers for laboratory analysis.

(*e*) Backfill each hole and seal with a concrete or asphalt plug.

9.1.2.4 *Other Field Considerations*—The corrosion specialist/cathodic protection specialist may also consider, but not be limited to, performing and evaluating the following tests:

(a) Current requirement,

(b) Coating resistance, and

(c) Coating efficiency.

9.1.3 *Laboratory Testing Procedures*—Send soil samples collected at each site to a qualified soil laboratory where they shall be tested in accordance with EPA SW 846, Guide E 1323, or other recognized industry test methods. The report shall include the results of all test methods used in the evaluation. At a minimum, obtain the following data:

9.1.3.1 Soil resistivity/conductivity,

9.1.3.2 Moisture content,

9.1.3.3 Soil pH,

9.1.3.4 Soluble chloride ion concentration, and

9.1.3.5 Sulfide ion concentration.

9.1.4 The corrosion specialist/cathodic protection specialist shall also consider, but not be limited to, performing and evaluating the following tests. The report shall include all test methods used in the evaluation:

9.1.4.1 Redox potential, and

9.1.4.2 Sulfate ion concentration.

9.1.4.3 Any other tests required by the external corrosion rate analysis model.

9.1.5 *Quality Control*—One soil sample of every ten samples analyzed shall be subjected to an independent quality control analysis of all data gathered in 9.1.3. If the results of the quality control analysis fail to agree with the original analysis (within limits of experimental accuracy), reanalyze all samples collected since the last successful quality control analysis.

9.2 *Analysis and Determination of Suitability of a Tank for Upgrading with Cathodic Protection-Noninvasive with Primary Emphasis on Statistical Analysis of External Site Environment Corrosion Data*.

9.2.1 *Basis for Analysis*—By examining the environment in the specific vicinity of the tank, a relationship between the aggressiveness of the environment and the rate of corrosion can be statistically established. Base the statistical analysis model used on a sufficient size data base with various factors that are accounted for statistically to reach a confidence level of 0.99. This will achieve consistency and reliability of the results. One general form of the multivariate, non-linear regression analysis, which contains the minimum essential variables, is as follows:

$$E\ (\text{Age}) = f(R, M, Cl, \text{pH}, S, SC, TS, P) \quad (1)$$

where:

E (Age)	=	unconditional predicted age to corrosion failure,
R	=	resistivity,
M	=	moisture content,
Cl	=	chloride ion concentration,
pH	=	soil pH,
S	=	sulfide ion concentration,
SC	=	stray current magnitude,
TS	=	tank size, and
P	=	tank structure to soil potential.

9.2.2 *Criteria of Acceptance for Upgrading With Cathodic Protection* (using RP 0169, RP 0187, and RP 0285)—To be acceptable as a means of determining the condition of tanks and their suitability for upgrading with cathodic protection, the procedure used shall, at a minimum, meet the following criteria:

9.2.2.1 The procedure shall be based on an evaluation of all data gathered *in situ* in each bore hole together with all soil sample data and the stray dc earth current monitor measurements taken at each site.

9.2.2.2 The mathematical formulation of the procedure shall conform to accepted physical and electrochemical characteristics of the tank corrosion process. Independent professional validation of these processes shall be done by an individual or individuals with experience in the relevant scientific or engineering disciplines.

9.2.2.3 Parameter estimates shall be based on data derived from at least 100 sites where a minimum of 200 tanks were excavated, fully exposed, and evaluated by a qualified corrosion specialist/cathodic protection specialist. Maximum likelihood estimation or another procedure that meets the standards of statistical or electrochemical admissibility shall be required. Data used in estimation shall contain representative samples of leaking and non-leaking tanks.

9.2.2.4 Models proposed shall be specific as to soil type and incorporate depth of ground water and rainfall experienced in the immediate geographical area where testing takes place.

9.2.2.5 The standard deviation of the predicted time to corrosion failure shall not exceed 1.5 years. The model shall generate an unconditional probability of corrosion failure based upon a comparison of actual tank age to its expected leak-free life.

9.2.3 *Report Including Results, Analysis, and Recommendations*—The corrosion specialist/cathodic protection specialist shall prepare a report including results, analysis, and recommendations as follows:

9.2.3.1 Base the report conclusions on the expected leak-free life of a tank at a specific site as determined by the analysis of the data necessary to determine which tanks are suitable for upgrading with cathodic protection.

9.2.3.2 The report shall provide the expected leak-free life and present and future probabilities of corrosion failure for all tanks investigated.

9.2.3.3 The report shall include a listing of tanks whose age is less than the expected leak-free life and for those tanks where the probability of corrosion perforation is less than 0.05.

9.3 Cathodic protection can be applied to those tanks that have been tested in accordance with Sections 8 and 9 and meet the following criteria:

9.3.1 The tank is confirmed to be leak free in accordance with 5.2.

9.3.2 The tank age is less than the expected leak-free life.

9.3.3 The probability of corrosion perforation of the tank is less than 0.05.

9.3.4 Either a tank tightness test is conducted between three and six months after the tank is cathodically protected, or monthly monitoring with another leak detection system is implemented within one month after the addition of cathodic protection. Any leak detection system must meet 5.2.2.

9.4 A form is included in Annex A1 which must be utilized to report the results of the authenticated vendor provided information. A research report containing examples of actual authenticated vendor provided information is filed and available from ASTM.[4]

10. Method B—Invasive Ultrasonic Thickness Testing with External Corrosion Evaluation

10.1 *Field and Laboratory Testing—Invasive Ultrasonic Thickness Testing with External Corrosion Evaluation*:

10.1.1 Conduct the following procedures when assessing the suitability of a steel tank for upgrading with cathodic protection using an invasive method.

10.1.2 Conduct tests by, or as directed by, the corrosion specialist/cathodic protection specialist.

10.1.3 Before a tank is suitable for upgrading with cathodic protection using an invasive approach, the following site-specific tests shall be conducted for each tank excavation zone in accordance with industry recognized standard practices:

10.1.3.1 Perform the tests described in 9.1.2.1.

10.1.3.2 Soil resistivity in accordance with Test Methods G 57. These values shall be measured in the immediate vicinity of the tank excavation zone and shall, as a minimum, be measured at depths of 5, 7½ , 10, 12½ , and 15 ft (1.5, 2.3, 3.5, and 5 m).

10.1.3.3 Structure to soil potential in accordance with NACE RP-0285 with at least five such measurements spaced uniformly about each tank excavation zone.

10.1.3.4 Soil pH in accordance with Test Methods G 51, soil chlorides and sulfides in accordance with EPA SW 846 uniformly gathered from three locations about each tank excavation zone.

10.1.3.5 Electrical continuity/isolation in accordance with NACE RP-0285 of each UST being evaluated.

10.1.4 The corrosion specialist/cathodic protection specialist should also consider, but not be limited to, performing and evaluating the following tests:

10.1.4.1 Redox potential,

10.1.4.2 Current requirement,

10.1.4.3 Coating resistance,

10.1.4.4 Coating efficiency,

10.1.4.5 Wall thickness.

10.1.4.6 Soluble chloride ion concentration,

10.1.4.7 Sulfide ion concentration,

10.1.4.8 Sulfate ion concentration, and

10.1.4.9 Any other tests deemed necessary.

10.2 *Invasive Ultrasonic Thickness Testing with External Corrosion Evaluation*:

10.2.1 This subsection provides the general procedure for assessing tanks prior to upgrading with cathodic protection through the use of invasive ultrasonic thickness testing in combination with the leak detection testing in accordance with 5.2 and external corrosion evaluation procedures contained in 10.1. This procedure may be conducted using either manually manipulated or computer controlled remote controlled (robotic) ultrasonic sensor placement, control and measurement devices which do not require manned entry into the UST.

10.2.2 *Certification*—Corrosion technicians performing invasive ultrasonic thickness testing shall also be certified in accordance with ASNT recommended practice SNT-TC-1A and qualified under similar written practice with the equipment and procedures to be employed.

10.2.3 *Surface Preparation*—In accordance with Practice E 114, the interior surface of the tank to be examined shall be uniform and free of loose scale, loose paint, dirt, or other deposits that affect examination. If any such loose scale, loose paint, dirt, or other deposits exist which would prevent accurate ultrasonic thickness measurement of the remaining steel wall, they shall be removed prior to performing these measurements. Tightly adhering paint, scale, or bonded coatings do not need to be removed if they present uniform attenuation characteristics.

10.2.4 *Calibration*—Calibrate the thickness measurement sensor in accordance with Practice E 797.

10.2.5 *Couplant*—Any couplant used shall be the stored product or a material compatible with the stored product and shall be appropriate for the surface finish of the material to be examined. The surface finish and couplant of the reference standards shall be acoustically similar to those of the tank and the couplant therein.

10.2.6 *Ultrasonic Gaging*:

10.2.6.1 The invasive ultrasonic inspection shall make located wall thickness measurements of at least 15 % of the entire tank interior surface area excluding man way entries. The thickness measurements shall be uniformly distributed over the surface of the tank. The invasive ultrasonic inspection equipment shall be capable of accessing at least 95 % of the tank interior surface area excluding man way entries and other tank penetration fittings. In areas where corrosion damage is more severe, as determined by the corrosion technician, additional measurements shall be made as directed by the

corrosion specialist/cathodic protection specialist so as to provide a sufficient amount of inspection data to accurately define the extent of corrosion and to ensure an accurate leak-free life prediction.

10.2.6.2 Depending on surface conditions, the minimum ultrasonic thickness measurement capability may vary from 0.050 to 0.125 in. (1.2 to 3.2 mm). The instrumentation should be able to measure remaining wall thickness of the tank to an accuracy of ±0.010 in. (0.25 mm) and to detect a flat bottom pit of 0.125-in. (3.2-mm) diameter.

10.2.6.3 The maximum allowable position error in each wall thickness measurement position location coordinate is 5 % of the maximum tank dimension.

10.2.7 *Ultrasonic Test Reports*—Record the following data as a minimum for future reference at the time of each investigation:

10.2.7.1 Operator's name and certification level,

10.2.7.2 Instrument description including make, model, and serial number and setup couplant,

10.2.7.3 Instrument calibration certification including date performed,

10.2.7.4 Cable type and length,

10.2.7.5 Mode of scanning (manual or automatic),

10.2.7.6 Search unit description, such as, type, size, frequency, special shoes,

10.2.7.7 Reference standards (and calibration data required to duplicate the examination), and

10.2.7.8 Location data (coordinates) for thickness measurement data points.

10.2.8 Invasive ultrasonic wall thickness measurement may pose certain safety hazards. It is the responsibility of the user of this guide to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

10.3 *Data Analysis and Determination of Suitability of a Tank for Upgrading With Cathodic Protection (RP 0169 and RP 0187) Using Invasive Ultrasonic Thickness Testing and Evaluation Including External Site Environment Corrosion Assessment*:

10.3.1 This alternative method includes a mathematical corrosion prediction model and an analytical report. The analytical report contains the tank, soil chemistry (using Guide E 1323), and inspection data. The model is then used to estimate the leak-free life of the tank using the tank information, ultrasonic thickness measurement test data, and soil chemistry data.

10.3.2 *Prediction Model*:

10.3.2.1 Use a prediction model to determine the probability of an individual tank leak as a result of corrosion. It shall yield the years of leak-free life remaining and the probability of a potential leak of the tank in a specific soil condition. The model shall be based on tank inspection data collected and shall include all of the site specific parameters listed in 10.1.3.1-10.1.3.5 and any test(s) performed in 10.1.4. The mathematical formulation used in the prediction model shall be based on accepted physical and electrochemical characteristics of the tank corrosion process.

10.3.2.2 Consider the tank suitable for upgrading with cathodic protection if there is:

(a) No measured pitting which perforates the tank wall,

(b) Ninety-eight percent of all ultrasonic thickness measurements made on the tank shall be greater than or equal to 50 % of the minimum recommended wall thickness as provided in Underwriters Laboratories Standard UL 58 or the documented original tank wall thickness,

(c) The average metal wall thickness of each 1 m_2 is greater than 85 % of the original wall thickness, and

(d) The results of the prediction model (for example CERL N 91/18), as determined by the corrosion specialist/cathodic protection specialist, support that cathodic protection is both reasonable and viable.

10.3.3 *Inspection Report*—This report shall summarize all tank data collected from the inspection and provide results from the prediction model for each tank including recommendations with respect to each tank's suitability for upgrading using cathodic protection. The corrosion specialist/cathodic protection specialist shall be responsible for all data analysis and recommendations.

10.4 Cathodic protection can be applied to those tanks which have been evaluated using one of the procedures provided for in Sections 8 and 10 and meet the following criteria

10.4.1 Passes all requirements defined in 10.3.2.2.

10.4.2 Either a tank tightness test is conducted between three and six months after the tank is cathodically protected, or monthly monitoring with another leak detection system is implemented within one month after the addition of cathodic protection. Any leak detection system must meet 5.2.2.

10.5 A form is included in the Annex A1 which must be utilized to report the results of the authenticated vendor provided information. A research report containing examples of actual authenticated vendor provided information is filed and available from ASTM.[4]

11. Method C—Invasive Permanently Recorded Visual Inspection and Evaluation Including External Corrosion Assessment

11.1 *External Corrosion Assessment Data Gathering*:

11.1.1 Conduct the following procedures when assessing the suitability of a steel tank for upgrading with cathodic protection using an invasive method.

11.1.2 Conduct tests by, or as directed by a corrosion specialist/cathodic protection specialist.

11.1.3 Before a tank is suitable for upgrading with cathodic protection using an invasive approach, the following site-specific tests shall be conducted for each tank excavation zone in accordance with industry recognized standard practices:

11.1.3.1 Perform tests as described in 9.1.2.1.

11.1.3.2 Soil resistivity in accordance with Test Methods G 57. These values shall be measured in the immediate vicinity of the tank excavation zone and shall, as a minimum, be measured at depths of 5, 7½ , 11, 12½ , and 15 ft (1.5, 2.3, 3.5, and 5 m).

11.1.3.3 Structure to soil potential in accordance with NACE RP-0285 with at least five such measurements spaced uniformly about each tank excavation zone.

11.1.3.4 Soil pH in accordance with Test Method G 51, soil chlorides and sulfides in accordance with EPA SW 846 and Guide E 1323 uniformly gathered from three locations about each tank excavation zone.

11.1.3.5 Electrical continuity/isolation in accordance with NACE RP-0285 of each UST being evaluated.

11.1.4 The corrosion specialist/cathodic protection specialist should also consider, as a minimum but not be limited to, performing and evaluating the following tests:

11.1.4.1 Redox potential,

11.1.4.2 Current requirement,

11.1.4.3 Coating resistance,

11.1.4.4 Coating efficiency,

11.1.4.5 Wall thickness,

11.1.4.6 Soluble chloride ion concentration,

11.1.4.7 Sulfide ion concentration,

11.1.4.8 Sulfate ion concentration, and

11.1.4.9 Any other tests deemed necessary.

11.2 *Field Testing Using Invasive Permanently Recorded Visual inspection*:

11.2.1 This subsection provides the general procedure for internally visually inspecting, recording and archieving the results of the visual inspection of USTs without manned physical entry into the tanks. This information is used in combination with the data obtained from the external testing procedures defined in 11.1.3 to assess the tank's suitability for upgrading with cathodic protection.

11.2.2 The visual inspection is part of a total assessment procedure that includes leak detection testing in accordance with 5.2 and external corrosion evaluation as delineated in 11.1. The recorded documentation (for example, photographic film, digital or analog tape) is archived and is a permanent record of the visual inspection.

11.2.3 *Technical Certification*—The person performing this inspection shall be a corrosion technician. The corrosion specialist/cathodic protection specialist shall conduct an analysis of any suspect corrosion activity that may fail a tank.

11.2.4 *UST Qualification*—The field and laboratory testing (in accordance with 11.1) is completed either prior to or in conjunction with performing the internal visual tank inspection. In the event these tests reveal any indication of structural or electrochemical characteristics that are incompatible with the effective use of cathodic protection, the tank shall be considered to have failed the test and the internal visual inspection shall be aborted.

11.2.5 *UST Preparation*—Prior to conducting the internal visual inspection, the tank must be emptied, cleaned, if necessary, and purged.

11.2.6 *Emptying Tanks*—Tanks to be inspected must be taken out of operation and all liquid product removed that would otherwise preclude accurate visual inspection of the tank. Employ applicable safety precautions and procedures.

11.2.7 *Purging Tanks*—Prior to placing any visual inspection, recording or lighting apparatus within the fill pipe or tank, the atmosphere within the tank must be purged to avoid any combustible hydrocarbon/air vapor mixture. Purging may be accomplished by pressure feeding a blanket of carbon dioxide or another inert gas into the tank until sufficient air is displaced to render the interior tank atmosphere safe. As an alternative to purging by an inert gas, the tank may be freed of flammable vapor mixtures by air purging.

11.2.7.1 All instruments used within the tank, including those used for characterization of the atmosphere, must be certified as intrinsically safe for the appropriate class(es), division(s), and group(s) by a competent authority.

11.2.8 *Cleaning Tanks*—Determined by the corrosion specialist/cathodic protection specialist upon reviewing the visual record, the tank shall be sufficiently free (clean) of sludge, thick oxides, or other dense residual materials as to allow the internal surface of the tank to be evaluated. At least 98 % of the interior surface area of the tank must be visible for inspection.

11.2.8.1 If the corrosion specialist/cathodic protection specialist determines the interior surfaces were not adequately clean, the corrosion specialist/cathodic protection specialist shall reject the tank for upgrade with cathodic protection until such time the condition has been corrected and the tank re-evaluated.

11.2.9 *Lighting Equipment*—The *in-tank* visual recording system shall be equipped with lighting capable of adequately illuminating the interior steel surfaces so that the defect sizes defined in 11.2.10.1 can be visually observed and permanently recorded.

11.2.10 *Visual inspection Resolution*:

11.2.10.1 The visual inspection method must identify and permanently record the presence of all detectable pits or corrosion by-products tubercles while observing and permanently recording the condition of at least 98 % of the tanks' interior surfaces.

11.2.11 *Visual Recording*—The minimum resolution of the visual recording system shall be capable of identifying the location and degree of corrosion activity as listed in 11.2.10.1. The system shall also permanently embed the time, structure site, UST location, and date of the visual examination in the visual record. It shall also provide for permanently recording the observation comments of the visual inspector.

11.2.12 *Inspection and Recording*—After the tank has been tested and found to be safe in accordance with 11.2.7, and the permanent recording apparatus is in place, the inspection shall be made by a qualified technician working under the supervision of the responsible corrosion specialist/cathodic protection specialist in accordance with the following minimum requirements:

11.2.12.1 Scan all interior tank surfaces to assess the general inspection conditions and to ensure the tank is sufficiently clean to permit effective visual inspection.

11.2.12.2 At the start of the recording process, record the date, time, and all necessary tank identification data including company name and address, project identification number, tank size, age and identification number, and corrosion technician's name.

11.2.12.3 Systematically perform and record the visual corrosion condition on at least 98 % of the internal tank surfaces.

11.2.12.4 Permanently record in the visual record all pertinent or unique observations, corrosion activity or damage, and location relative to the internal tank surface observed by the corrosion technician.

11.2.12.5 Permanently record a summation commentary of the corrosion technician.

11.2.13 *Corrosion Activity*—The corrosion technician shall identify any evidence of corrosion including:

11.2.13.1 *Perforations*—Water intrusion or other visual evidence.

11.2.13.2 *Rust Tuberculation*—Active dark red/maroon crust.

11.2.13.3 *Streaks*—Elongated in shape, dark red/black in color at apex.

11.2.13.4 *Discoloration*—Patches showing dark reddish/black center, becoming lighter toward the edges, usually irregularly spaced, 3 to 9 in. (7.5 to 23 cm) in diameter.

11.2.13.5 *Pitting*—Black in center-bottom of crater, light red or bright metal near perimeter.

11.2.13.6 *Scaling or Delaminations*—Typical exfoliation, no discoloration, layered flakes in small 2 to 4-in. (5 to 11-cm) diameter irregular patches.

11.2.13.7 *Weld Deterioration*—Little discoloration, except possible black/maroon deposit beneath interface; deterioration of metal within the weld sometimes with cracks and undercuts.

11.2.13.8 *Cracks*—Usually no discoloration, typically near welds, openings, fittings, connections, and other stress concentration sites.

11.2.14 *Passive Corrosion Films*:

11.2.14.1 *General Overall Rust Film*—Light red, pink, or pink/beige; smooth to slightly pockmarked. This is not active corrosion, but an *alpha oxide* film that is protective or passivating.

11.3 *Data Analysis and Report on Determination of Suitability of a Tank for Upgrading with Cathodic Protection Using Invasive Visual Inspection with External Corrosion Evaluation*:

11.3.1 The examining corrosion technician may record comments to aid the corrosion specialist/cathodic protection specialist in evaluation of the tank's internal surfaces. If no corrosion or deterioration is evident, the report shall so indicate.

11.3.2 The corrosion specialist/cathodic protection specialist shall be responsible to view the visual permanent record and make a final determination on the suitability of each tank tested for upgrading.

11.3.3 After review of the visual permanent record including all notations and comments, a report shall be prepared and submitted to the UST owner/operator by the corrosion specialist/cathodic protection specialist including the upgrading suitability determination made for each tank. This visual record and report shall be kept on file by the UST owner/operator as part of the required documentation.

11.3.4 Any evidence of a perforation or significant corrosion, as defined in accordance with 11.2.13, is confirmed by the corrosion specialist/cathodic protection specialist, or if the corrosion specialist/cathodic protection specialist's analysis of the site corrosion data as defined in 11.1 and as evaluated in 11.3.5 indicates the tank is not a candidate for upgrading by cathodic protection alone. Significant evidence of corrosion exists when the corrosion has advanced enough to compromise the integrity and useful life of the tank.

11.3.5 *Corrosion Data Evaluation Alternatives for Invasive Visual Inspection Procedure*:

11.3.5.1 *Prediction Model*—Use a prediction model to determine the probability of an individual tank leak as a result of corrosion. It shall yield the years of leak-free life remaining and the probability of a potential leak of the tank in a specific soil condition. The model shall be based on tank inspection data collected and shall include all of the site specific parameters listed in 11.1.3-11.1.3.5 and any test(s) performed in 11.1.4. The mathematical formulation used in the prediction model shall be based on accepted physical and electrochemical characteristics of the tank corrosion process. Consider the tank suitable for upgrading with cathodic protection if the results of the prediction model (for example CERL N 91/18) **(3)**, as determined by the corrosion specialist/cathodic protection specialist, support that cathodic protection is both reasonable and viable or as detailed in 11.3.5.2.

11.3.5.2 *Site Specific Value Criteria*—Corrosion data for which tanks shall not be considered suitable for upgrade when a statistical prediction model as defined in 11.3.5.1 is not used:

(a) Soil resistivity at the average tank depth less than 700 Ω-cm,

(b) Soil pH less than 4.0,

(c) Soluble chloride ion concentration greater than 500 ppm,

(d) A positive sulfide test indicating the presence of sulfate-reducing bacteria in accordance with EPA SW 846.

(e) Average tank-to-soil potential on the UST are more positive than –300 mV with respect to a saturated copper-copper sulfate electrode.

11.4 Requirements for applying cathodic protection to tanks which have been tested in accordance with Sections 8 and 11 and meet the following criteria:

11.4.1 Those tanks that have been tested, found to be leak free, and found acceptable for upgrading in accordance with Sections 8 and 11 and meet the criteria defined in 11.3.4 together with either 11.3.5.1 or 11.3.5.2, and

11.4.2 Either a tank tightness test is conducted between three and six months after the tank is cathodically protected, or monthly monitoring with another leak detection system is implemented within one month after the addition of cathodic protection. Any leak detection system must meet 5.2.2.

11.5 A form is included in Annex A1 which must be utilized to report the results of the authenticated vendor provided information. A research report containing examples of actual authenticated vendor provided information is filed and available from ASTM.[9]

12. Keywords

12.1 assessment; cathodic protection; corrosion; criteria; EPA; evaluation; inspection; model; prediction; regulation;

[9] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: G01–1019..

rust; statistical; steel; suitability; tank; ultrasonic; underground storage tank; upgrade; UST; video; visual

ANNEX

(Mandatory Information)

A1. THIRD PARTY VERIFICATION

A1.1 See Fig. A1.1.

[Company Name] has been in business for [ ] years performing underground storage tank (UST) evaluations and believe the following information to be accurate and representative of our company's activities.

1. Total number of tanks assessed : _____
2. Total number of tanks that failed our assessment : _____
3. Total number of tanks that passed our assessment : _____
4. Total number of tanks with another assessed result : _____
5. Total number of those that passed, were upgraded with CP and that later failed : _____

This data has been verified to the best of our abilities by [ ] per Standard sect. 3.1.1.

_____ _____

(Notarized by a notary public in the State where the company performed the verification)

FIG. A1.1 Third Party Verification Form

REFERENCES

(**1**) Bushman, J., B. and Mehalick, T., E. "Statistical Analysis of Soil Characteristics to Predict Mean Time to Corrosion Failure of Underground Metallic Structures," ASTM STP 1013, ASTM, 1989.

(**2**) Rogers, W., F. "Statistical Prediction of Corrosion Failures," NACE International, CORROSION 89, Paper No. 596.

(**3**) Piskin et al, "Leakage Potential of Underground Storage Tanks," USACERL Technical Report N-91/18, US Army Construction Engineering Laboratories, Champaign, IL 61826-9005, June 1991.