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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]

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

E114 Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method

E797 Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method

E1323 Guide for Evaluating Laboratory Measurement Practices and the Statistical Analysis of the Resulting Data [3]

E1526 Practice for Evaluating the Performance of Release Detection Systems for Underground Storage Tank Systems[4]

G51 Test Method for Measuring pH of Soil for Use in Corrosion Testing

G57 Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method

2.3 *American Society for Nondestructive Testing Standard:*[5]

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

2.4 *NACE International Standards:*[6]

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] Withdrawn.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

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

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

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:*[7]
EPA SW 846 Test Methods for Evaluating Solid Waste
EPA 371.1 Measurement of Sulfate Reducing Bacteria

2.6 *National Fire Protection Association (NFPA)*[8]
NFPA 329 Recommended Practice for Handling Underground Releases of Flammable and Combustible Liquids

2.7 *Underwriters Laboratories Inc.*[9]
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*:

5.2.1 To establish that tanks are not leaking prior to assessment, they shall be assessed by a leak detection system. This

[7] Available from Underwriters Laboratories (UL), Corporate Progress, 333 Pfingsten Rd., Northbrook, IL 60062.
[8] Available from US Environmental Protection Agency, Office of Underground Storage Tanks, 401 "M" St. SW, Washington, DC 20460.
[9] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.

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 E1526 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 G57.

(*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 E1323, 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:

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

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: