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FOCUS

NDT of Welded Steel Tanks

by Ronald T. Nisbet* and Michael D. Pesce†

This article is intended as a brief introduction to the NDT methods used for the examination of welded steel tanks. It will address the NDT methods specified by the relevant standards; where, how and when they should be applied; and the basic technology involved. Tanks may be inspected during construction to gather baseline data or after a period of operation. The examination of tanks includes roofs, shells or walls and bottoms (Fig. 1).

Relevant Standards

The Steel Tank Institute/Steel Plate Fabricators Association (STI/SPFA) and the American Petroleum Institute (API) publish the following standards:

- STI SP001, *Standard for the Inspection of Aboveground Storage Tanks* [for inspection of tanks with diameters of 9 m (30 ft) or less].
- ANSI/API 510, *Pressure Vessel Inspection Code: Maintenance Inspection, Rating, Repair and Alteration.*
- API 570, *Piping Inspection Code: In-Service Inspection, Rating, Repair and Alteration of Piping Systems.*
- API Standard 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks.*
- API Standard 650, *Welded Steel Tanks for Oil Storage.*
- API Standard 653, *Tank Inspection, Repair, Alteration and Reconstruction.*

API conducts examinations and issues certifications to qualifying inspectors in accordance with API Standard 653. These certified inspectors are qualified to perform inspection of aboveground steel storage tanks in accordance with the requirements of API Standard 650 and API Standard 653. These inspections include nondestructive testing.

Inspection Requirements

API Standard 653 defines the inspection requirements for external only in-service inspections and internal/external out-of-service

Figure 1. Aboveground storage tanks.

* International Energy Services Company, 3445 Kashiwa St., Torrance, CA 90505; (310) 257-8222, fax (310) 257-8220; e-mail <rtnisbet@earthlink.net>.
† HMT Inspection, 777 E. Market St., Warren, OH 44481; (330) 393-6705; e-mail <mpesce@hmttank.com>.

inspections and provides criteria for inspection intervals. The API Standard 653 certified inspector will use the specified criteria and apply the required inspection methods to provide comprehensive evaluation of the tank and determine the interval until the next required inspection.

Engineering evaluations per API 510, API 570 and API Standard 653 are based on data gathered from field inspection and evaluated using information recommended by codes or standards including:

- settlement evaluations,
- corrosion rate calculations,
- safe fill height calculations,
- seismic evaluation,
- brittle fracture evaluation,
- maximum working pressure and
- other referenced evaluations.

Other engineering services include fitness-for-service evaluation, inspections intended to verify compliance with environmental regulations and specialized assessments such as out-of-roundness surveys and verticality evaluations. Useful information for a tank maintenance program is provided by field drawings converted to computer-assisted layouts for the final report of the tank roof, shell and bottom, as applicable, with color photos of the tank and its appurtenances.

Nondestructive Testing Methods

For the following methods, technicians should be certified by their employer in accordance with the employer's written practice.

Visual Testing. Visual testing (VT) is a preliminary inspection method performed on all tanks and will always complement other NDT methods.

An experienced inspector will notice problem areas where paint is discolored by leakage or where corrosion has marred the surface. More systematic visual testing can be required by standards and written practices. Photography can document the visual tests and may be required by the employer's procedures.

Direct and remote visual testing are the two techniques for determining the condition of a part or material, alignment of mating surfaces or components and evidence of leaking welds. Direct testing involves viewing the surface at a distance of not more than 0.6 m (24 in.) and at an angle of not less than 30°. Mirrors and magnifiers may be used to assist in this direct technique. Adequate lighting should always be provided for visual testing.

Remote visual testing may use aids such as borescopes, fiber optics, binoculars, video cameras and other equipment. Class I, Division I, explosion-proof cameras can be effective in finding problem areas, as well as providing a cost savings to the owner, allowing for inspection while the tank remains in service.

Magnetic Flux Leakage. In the magnetic flux leakage (MFL) technique, a section of the tank bottom is magnetized to, or near to, saturation of flux between the poles of the bridge. Any significant thinning of the bottom plate will result in some of the magnetic flux being forced into, or leaking into, the air around the area of reduction (Fig. 2a). Sensors to detect these flux leakages are placed between the poles of the bridge. MFL is a qualitative test method, so indications located by this technology require follow-up testing. Ultrasonic testing (UT) checks for soil side indications, and pit gaging checks for product side indications.

Small scanners, both manual and motorized, provide additional coverage for inspection adjacent to the internal shell-to-bottom weld and beneath steam coils, under internal piping, and near other areas of obstruction that might limit use of a full-size scanner (Fig. 2b).

MFL is recognized as a separate test method independent from other techniques of the electromagnetic test method by *Recommended Practice No. SNT-TC-1A (2006)*.

Saturated Low Frequency Eddy Current. The saturated low frequency eddy current (SLOFEC) scanner is designed to inspect tank bottoms with reinforced coatings up to 8 mm (0.30 in.) thick. The scanner uses eddy current and other electromagnetic technologies to inspect through thick coatings. SLOFEC can detect metal loss as well as locate the area of metal loss (soil side or product side) on the plates. This method of testing does not disturb the coating.

Ultrasonic Thickness Testing. Ultrasonic thickness testing is used to measure MFL indications for soil side metal loss. Follow-up quantification is commonly referred to as "prove up."

The principles of ultrasonic thickness testing are thoroughly covered in training literature. Adjustment should be made for coated surfaces, and suitable transducers should be used for pitted surfaces and for faster surface coverage. Crawler systems can access the exterior tank shell/wall. Surface preparation and proper technique are both essential for a quality inspection.

Magnetic Particle Testing. Magnetic particle testing (MT) is used for the detection of surface or near-surface discontinuities in ferromagnetic materials. In carbon steel tanks, MT is most often performed on, but is not limited to, the internal shell-to-bottom weld, sump welds, shell penetration welds, vertical welds, junction welds (shell horizontal-to-vertical welds), bottom and shell weld overlays (puddle welds), patch/base/bearing plate welds and butt welded inserts. Surface preparation and proper technique are both essential for a quality inspection.

Liquid Penetrant Testing. Liquid penetrant testing (PT) is used for the detection of discontinuities open to the surface of nonporous metals and other materials. In aboveground tanks, PT is most often performed on, but is not limited to, the internal shell-to-bottom weld, sump welds and shell penetration welds. Surface preparation and proper technique are both essential for a quality inspection.

Vacuum Box Bubble Testing. A technique of leak testing, vacuum box bubble testing (VBBT) is the leak test most often used in aboveground tanks. VBBT is used for detecting small leaks or pinholes in welds. There are several acceptable bubble test solutions available. Care should be taken to not use common liquid detergents because too many bubbles can affect test interpretation. VBBT is most often performed on, but is not limited to, bottom plate-to-plate lap welds, the internal shell-to-bottom weld, bottom weld overlays (puddle welds) and patch–to–base plate welds. Surface preparation and proper technique are both essential for a quality inspection.

Mass Spectrometer Leak Testing. Also a technique under the leak testing method, mass spectrometer leak testing (MSLT) has proven to be very effective in the detection of leaks in many components including tank bottoms, sumps, roof pontoons, roof drain systems and heat exchangers.

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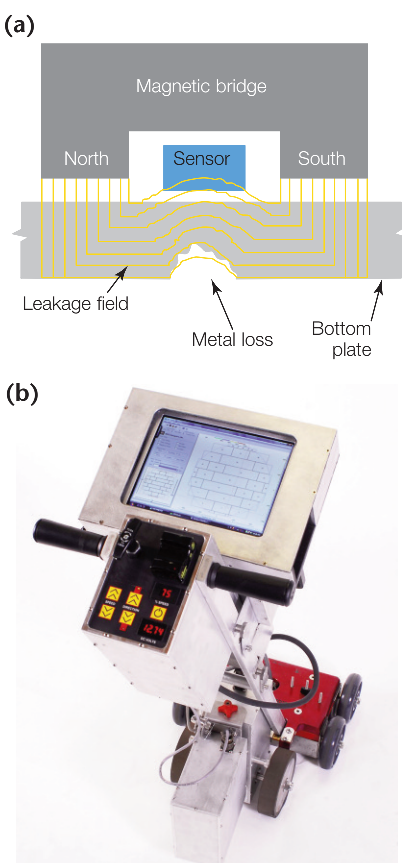

Figure 2. Magnetic flux leakage method: (a) schematic of bridge; (b) tank bottom scanner incorporating magnetic flux leakage test bridge.

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The most common tracer gas is helium, a nontoxic, inert (nonexplosive) gas. One of the smallest elements on the periodic table, helium can pass through apertures that liquid cannot. Thus, it is a very effective medium for detecting leaks. Surface preparation and proper technique are both essential for MSLT.

Alternating Current Field Measurement. Alternating current field measurement (ACFM) is another noncontact technique to detect and size surface breaking cracks through coatings up to 5 mm (0.20 in.) thick. An ET technique, ACFM is commonly used to detect surface discontinuities in tank shell-to-bottom welds, bottom lap welds, sump welds and shell penetration welds and to detect stress corrosion cracking in ethanol tanks. Surface preparation requirements are less than for other NDT methods, although proper technique is essential for quality inspection.

Radiography. Radiographic testing (RT) is performed on tank welds for the detection of discontinuities. Radiographic testing is generally performed on a specified number of new construction welds and when a major repair or alteration has been performed.

Gamma radiographic testing uses isotopes, radioactive elements. Preplanning and proper execution are critical for safety when performing this technique.

Ultrasonic Testing in Lieu of Radiographic Testing.

API Standard 650, Appendix U, details the rules for using the ultrasonic method to test tank construction welds in lieu of radiography. This requires that the ultrasonic test method shall be performed using automated, computer-based acquisition. A manual scan of adjacent base metal for laminar flaws is permitted.

Examination must be conducted using a preapproved strategy or scan plan, and the procedure must be qualified using a calibration block with known discontinuities such as might be encountered during the examination.

The flaw acceptance criteria are given in Appendix U, Paragraph U.6.6 and Table U-1.

Experience with ultrasonic testing in lieu of radiographic testing has shown excellent detection of planar flaws. In addition, the amount of down time normally alloted to radiography exclusion periods is reduced, providing significant cost savings.