Improve storage tank inspections

Applying new guidelines, operators can detect structural problems early and prevent catastrophic releases


Using industry-developed standards such as API 653, operators and owners can prevent catastrophic tank failures from aboveground, atmospheric-storage tanks. Improved tank-inspection programs confirm that 1. A tank isn’t leaking, and 2. It will not leak before the next inspection. API 653 addresses suitability-for-service and repair and alteration requirements for large, atmospheric aboveground-storage tanks. Because of the potential release volume from these larger tanks, maintenance engineers need updated preventative maintenance and inspection techniques that consider future tank failures due to brittle fracture or other causes. These guidelines use stress thickness-measurements to evaluate corroded and pitted areas. Core inspection areas are: tank roof, shell, bottom and foundation.

Because of confusion over how and why to use API 653, many operators have delayed including these engineering-based directives into their inspection programs. Operators blame as reasons for not using the guidelines: finding noncompliance tanks, high repair costs, perceived liability, etc. However, the cost of litigation and fines from accidental releases can justify repairs and definitely warrant setting up this level of inspection. Also, many states are adopting API 653 requirements as part of their state-environment regulations.

A better understanding of API 653 and its uses can cancel some user fears and improve plant inspection and maintenance programs.

ELEMENTS OF AN API 653 TANK INSPECTION

API 653 addresses aboveground, atmospheric pressure, steel storage tanks. Two things should be remembered about API 653: 1. Its purpose is to prevent catastrophic-tank failure due to brittle fracture, and 2. It is an engineering-driven document. In this latter respect, it departs from previous inspection specifications, since it requires an engineering analysis of the inspection data. Thickness measurements must be evaluated to ensure that the tank is structurally sound and within allowable stresses for the required design conditions, and will not leak before the next inspection. Confirming that a tank will not leak goes beyond merely ensuring that it will not fail catastrophically, since even a small leak is considered unacceptable. Section 2 of API 653 addresses tank suitability-for-service and specifies tank inspection requirements. API 653 also defines requirements for repairs and alterations, and dismantling and reconstruction.

An inspection program should address the four main storage-tank components: the roof, shell, bottom and foundation (Fig. 1). There are several subcategories within these main components, including the tank bottom-to-shell connection, shell penetrations and roof connections. Appendix C of API 653 contains checklists to perform in-service and out-of-service visual inspections. Some checklist items relate to tank-operational factors, such as whether the level control is operational, while other items relate to structural integrity issues. One way to use these checklists is extract those items that influence structural integrity and over-filling protection measures for a third-
Tank construction has a long history. Their use grew rapidly with the oil discoveries of the late 1800s. In 1928, API published the first edition of riveted-tank specifications. API 12C, Welded Storage Tank Specification, the predecessor to the present API 650, was published in 1936. Based on a 1989 API survey, there are approximately 700,000 aboveground-atmospheric storage tanks in the U.S. Only 5% of these tanks provide 67% of the available storage capacity. Unfortunately, these large tanks have received the most attention from industry and regulatory agencies.

In 1988, another API survey documented tank release incidences. Tank rupture accounted for only 5.4% of the 132 releases that occurred worldwide between 1970 and 1988. However, tank rupture accounted for almost 19% of the released material. The cost of cleanup damage to the environment and adverse publicity associated with these releases spawned present tank regulations and the development of API 653.

API 653—The beginning. In 1988, one catastrophic brittle failure of a tank spilled 750,000 gallons of diesel fuel into adjacent storm sewers that emptied into a nearby river. The owner spent several million dollars in cleanup costs and fines. This failure, along with two other spills that occurred at about the same time, galvanized Congress into action. Congress urged API to address requirements for existing aboveground-storage tanks. API working groups, representing tank owners, fabricators, trade groups and other interested parties, drafted different sections of the proposed standard. The draft standard generated about 100 pages of comments, which were all resolved. The final API 653 standard was published in January 1991.

Aboveground-storage tanks have a history of problems, and API 653 was not generated in a vacuum. API 653 and API 650, represent over 65 years of background and experience with aboveground-storage tanks, party tank inspection, and leave operational-related items for the owner to assess.

The roof. API 653 requires an evaluation of the roof thickness, its support system and any change in service conditions. Roof plates that are below 0.09 in. thick in an area of 100 in.² must be repaired or replaced to prevent personnel from falling through the roof.

Shell. A thorough inspection of the tank shell is more critical, because the shell sees the highest pressure stresses and is where most spectacular failures occur. Wall-thickness measurement is required, as well as visual examination for obvious flaws and deterioration. API 653 provides equations to calculate the minimum required shell-course thicknesses and methods to evaluate corroded and pitted areas (Fig. 2).

API 653 recognizes that fabrication and inspection records for existing, old storage tanks may be incomplete and the original degree of inspection and the construction material may be unknown. However, it still allows a safe, structural integrity evaluation of such tanks by using conservative assumptions. In these cases, shell-thickness calculations must use a low weld joint efficiency of 0.7. Also, it must be assumed that a relatively low-strength material was used. These evaluation requirements can place an artificial limitation on the maximum acceptable liquid-fill height where the original weld-joint efficiency or material strength was higher than what API 653 would allow. This stresses the importance of maintaining proper tank-design, fabrication and inspection records.

API 653 does not explicitly state how many thickness-measurement points must be used in each shell course or plate. Thus, the owner must decide the quantity of measurements to identify severely corroded areas in each shell course. If the tank is out-of-service and the interior is accessible for visual examination, a minimum number of measurements should establish nominal thicknesses, when combined with additional inspection of localized corroded areas. The required future-corrosion allowance is estimated to ensure that the shell will not thin below the minimum acceptable level before the next inspection.

One area not addressed by API 653 is how to handle existing shell details that are not permitted for a current repair or alteration. A common occurrence with tank inspections is finding lap-patch repairs. Shell-lap patches are not permitted by API 653. However, it does not address how to handle existing lap patches on tank shells. One way to proceed is to decide whether the lap patch is on a plate that is over or under 0.5 in. thick. This thickness has been established as a threshold for susceptibility to brittle fracture. If the lap patch is on a plate greater than 0.5 in. thick, it would be prudent to inspect the condition of the attachment welds and schedule replacement with an insert plate. The attachment welds for remaining lap patches should be inspected for cracks, and the patch-plate thickness and attachment-weld size should be confirmed as adequate for the imposed hydrostatic head. The liquid-fill height may be reduced if the lap patch is proven inadequate and should be replaced with an insert patch.

Bottom. Another area where API 653 inspection requirements depart from historical practices is the tank bottom. API requires that both the topside and underside of the tank bottom be considered when evaluating remaining thickness. General corrosion and pitting rates are also considered. The primary concern here is for leaks through the bottom into the environment. However, larger minimum thickness requirements are specified for the bottom annular ring, since the annular ring also performs a load-bearing function. Again, API 653 does not mandate specific bottom-plate inspection procedures or the extent of inspection.

Few alternatives are available to inspect the tank bottom for underside corrosion. Commercially available inspection techniques include those based on magnetic-flux exclusion (MFE) and automated ultrasonics. Both inspection techniques require that the floor is free of dirt, sediment and corrosion products, and that it is dry. A recommended minimum inspection would be an MFE inspection of all floor plates with ultrasonic follow-up of suspect areas, vacuum-box testing of floor-plate welds and dry magnetic particle or liquid penetrant inspection of the shell-to-bottom weld. Again, future general corrosion and pitting rates, both topside and underside, are estimated to evaluate the acceptability of the current bottom thickness.

Foundation. The tank-foundation inspection is one of the more controversial sections of API 653. The controversy is based on the acceptance criteria for differential settlement analysis is to prevent overstressing the tank.
shell, bottom or shell-to-bottom weld or causing failure or sinking of a floating roof due to excessive shell ovalization. A complete settlement analysis requires entering the tank and taking bottom-settlement measurements.

**Engineering solutions to tank inspection findings.** A potential consequence of doing an API 653-tank inspection is dealing with a tank that doesn't comply with its requirements. Some owners may be reluctant to incorporate API 653 into their tank inspection program. Reluctance occurs due to the cost of potential repairs to bring a tank into compliance or perceived liability of having an inspection report that includes a noncompliance statement. Unfortunately, this approach is like sticking one's head in the sand. It is always better to be aware of a potential problem and the options for rectifying it, than to risk a failure. In addition, several states are referencing API 653 in their tank regulatory requirements. Therefore, it cannot be ignored in those locations. In addition, since API 653 is an industry-developed document, ignoring its provisions would place an owner in a less defensible position should a leak or more extensive failure occur.

A lesser known aspect of API 653 is that it permits flexibility in addressing out-of-compliance inspection results. API 653 states that certain conditions are unacceptable unless a more extensive analysis is done. Common deficiencies associated with tank inspections are:

- Product-height limitations based on 0.7 weld joint-efficiency factor or lower strength material in the shell-thickness calculations or that resulting from thin shell measurements.
- Localized corroded areas in the shell that can't be repaired without taking the tank out of service.
- Excessive differential shell or bottom settlement.

Depending on the extent of the particular problem, all of the mentioned situations can be addressed, and perhaps forgiven, by a more detailed-engineering analysis, coupled with additional inspection. Often, this additional evaluation will cost less than the repair option or fill-height limitation. The most common engineering-analysis tools to address tank-shell deficiencies include:

- Distinguish locations of thinned areas based on their proximity to vertical and horizontal shell welds. In this way, the weld-joint efficiency applies to areas near the welds. In addition, a distinction can be made between vertical welds, which govern the wall thickness when joint efficiency is considered and horizontal welds.
- Do thickness "averaging." With this approach, credit is taken for reinforcement provided by thicker regions that are next to corroded regions of a tank shell.
- Perform thickness calculations based on specific elevations of corroded regions. This accounts for actual hydrostatic head imposed at the corroded region, rather than making its minimum required thickness equal to that required at the bottom of the particular shell course.
- Do thickness calculations using the API 650 variable design-point method. This iterative design approach uses a more accurate approximation of actual shell stress and typically results in a smaller required shell thickness than the basic approach.
- Perform a "design by analysis" as detailed in the
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