Maintaining Aged Steel Water Tanks: What To Look For and Why

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Steel water tanks have served this country well. For instance, one of the oldest steel water tanks still in service in the U.S. is a 277,000-gallon (1.02-million-liter) riveted standpipe constructed in 1886 and put in service the next year by Baraboo City Water Works in Baraboo, WI.

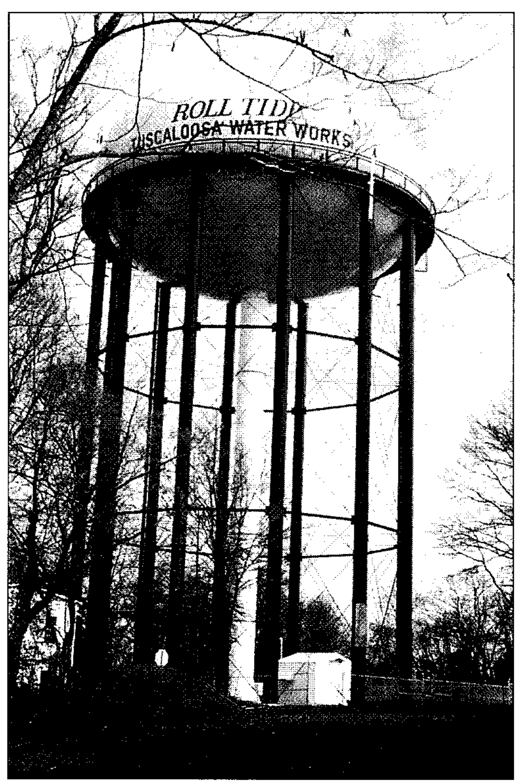
Because many steel tanks have been in service for so long, their successful repainting can depend on an understanding of their history. The present article identifies problems that may be encountered when repainting aged steel water tanks, describes the practices that may have caused the problems, and gives guidance on what to look for when undertaking maintenance of aged steel tanks.

Early Repair Practices that Required More Repairs

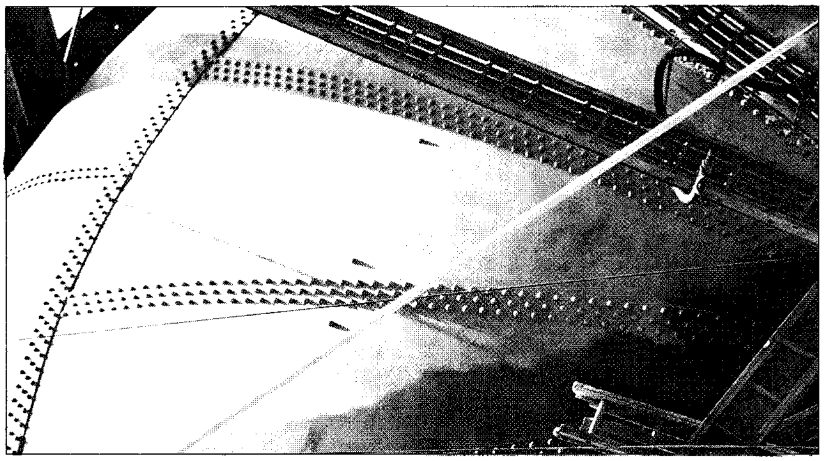
Despite the apparent lack of technical sophistication in some of the early practices, surface preparation and coating specifications were not the worst problems with tank maintenance. The biggest headaches were caused by repair scams. By submitting a "loss-leader" price to paint the tank, an itinerant maintenance contractor would convince the town to empty the tank and take it out of service. After a cursory inspection, the contractor would notify the municipal officials that major repairs were needed. Once the repairs were made and the tank was refilled, it would likely leak and require more repairs. To understand what caused these leaks, let's look at how the tanks were constructed.

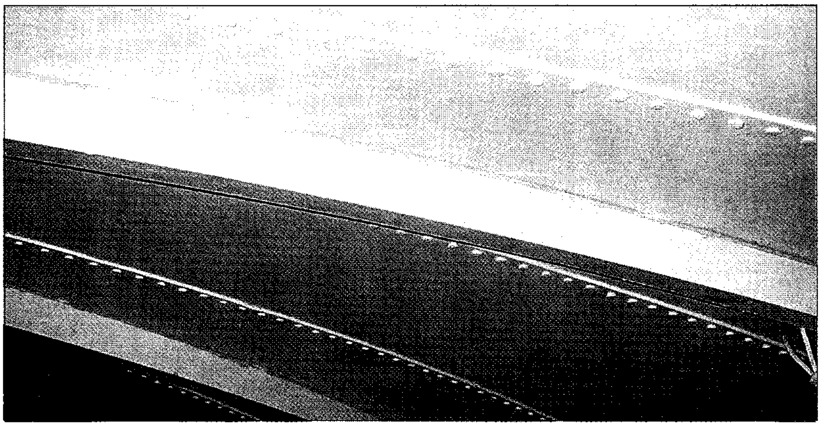
Riveted Construction

The first steel tanks were constructed from steel or wrought iron plates fastened together with rivets. The plates were overlapped about 2 in. (5 cm). Holes in overlap areas were punched or drilled and reamed so that rivets could be placed through them. The rivets were heated to red-hot, thrown to the riveter, and placed into the hole. The straight shank extending through the 2 plates was literally



■ *Courtesy of Tank Industry Consultants and Tuscaloosa Water Works*





■ (top) Blast cleaning the outside of the bottom of a riveted elevated tank

Courtesy of Tank Industry Consultants

■ (bottom) Newly recoated interior of roof of elevated tank. Note seam sealer on the roof stiffening angle.

Courtesy of Tank Industry Consultants

forged into a head approximating the size of the original head, but on the other end of the rivet. The shank was pounded with a cup-shaped hammer, usually powered by air. On the original rivet head side of the plate was a worker with a bucking anvil. His job was to resist the pounding from the other side of the plate so that the rivet shank would expand to fill the holes in the plate and form a second head on the hammer side. A seal was thus formed between the two heads on the liquid (tank interior) side of the plates in such a way that the distressed edge would form a seal with the adjoining plate. This peening operation was called caulking, and the rounded chisel-like tool used, a caulking hammer.

Introduction of Welding in Construction and Repair

During the 1930s, electric-arc welding of steel plates in the field became a reality. The transition from riveted construction to welded construction continued to the mid-fifties. Prior to field welding, leaks in riveted seams were sealed by re-caulking the seams. When that didn't work, litharge mixed with linseed oil or litharge and red-lead paint were applied to the seams and rivet heads.

World War II accelerated the progress of electric arc welding and the number of available welding operators. It didn't take long for the tank maintenance industry to learn that repairs could be made to riveted tanks by welding seams, rivets, or pits that had corroded into the steel plates. Maintenance contractors also learned that few owners went inside their tanks (especially elevated ones) to check on the work being done by the repair crew.

The welding of riveted tanks put into motion an unending cycle of welding, leaks, more welding, and still more leaks. When welding was performed on or near a riveted seam, the heat expanded the steel, disturbing the seal at the caulked seams and the rivet heads. Consequently, when the tank was filled after the steel cooled, the heat-distorted seams would leak. Even welding pits near the seams caused distortions in the seams and created leaks. This meant that the contractor could sell the tank owner even more welding repairs, many times leading to the welding of all seams and rivets in the submerged area of the tank. A lack of understanding of the principle of riveted steel plate design led to many unnecessary repairs.

As welded tanks began to appear, the cyclic effect of tank welding repairs due to the riveted seams wasn't understood by purveyors of tank maintenance, and welding of pits and rewelding of seams continued. It wasn't until the 1980s that most tank owners became aware that all pits did not have to be repaired. There is still much confusion today about when to weld and when to not weld pits.[1]

To Weld or Not To Weld

Unless severely deteriorated, rivets and seams usually will not require welding. If a tank is leaking at the seams or rivets, solventless epoxy seam sealers complying with ANSI/NSF Standard 61 and compatible with the adjacent or underlying coatings can be applied. This seam sealer will not, however, add to the structural capability of the tank.

When it is necessary to weld seams or rivets on a tank, one need not weld the entire tank container as had been the past practice. Once the structurally deteriorated areas are welded, the adjacent areas can be sealed with epoxy seam sealer for a distance to assure that the areas where the original seal was disturbed by the heat of the welding process will be leak-free.

Some riveted tanks built in the 1800s and early 1900s were constructed of wrought iron plates. Unless very special welding procedures are utilized, these wrought iron plates will crack when heat is applied. Some welded tanks built around 1960, prior to the introduction of alternative (high strength) material design methods into the American Water Works Association (AWWA) standards, were constructed of high strength but very brittle plate. Again, very special welding and repair procedures must be used to prevent a structural failure. These structural deficiencies caused by welding may not manifest themselves until well after the tank is placed in service, is filled (or subject to stress), and is exposed to low temperatures. Many tanks constructed before 1970 contain ASTM A-7 steel. This structural grade of steel used since the days of riveted construction was produced to physical strength criteria, with little control over other metallurgical characteristics that could affect weldability or performance at low temperatures. Welding repairs to tanks using A-7 steel should be made with caution.

Coating Problems with Mill Scale

Early Practice

While mill scale is now recognized as a problem for coating adhesion, before the 1950s mill scale was not seen as a problem. Some people in the industry actually thought that removing mill scale would remove the first line of defense against corrosion. In fact, in the early 1900s, many steel water tanks were painted with a graphite-based coating that was applied directly over mill scale. Red lead-pigmented primers applied over mill scale were the standard before the 1930s.

Early Methods of Removing Mill Scale

In the 1950s, the tank industry began recognizing the anode-cathode relationship between the mill scale (cathodic) and the bare steel (anodic). Cracks in the mill scale exposed the bare steel to the mill scale and resulted in corrosion. Also in the 1950s, industry consensus was that the removal of the mill scale was important for corrosion protection of the steel and good coating adhesion. In 1962, the AWWA released the D102, "Tentative AWWA Standard for Painting and Repainting Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks for Water Storage."[2] One option listed in D102, though not the system of choice, was to remove loose mill scale and rust and apply a prime coat of linseed oil-based red lead paint. (D102 was adopted in 1964.)

Once it became apparent that removing mill scale from the steel surfaces was advantageous, one of the accepted methods of removing mill scale was by flame descaling. Another fairly common method was pickling. During the pickling process, the steel was usually subjected to an acid bath followed by several rinses, and, in some cases, a final rinse in a corrosion inhibitor. Fabricators who did not have pickling equipment cleaned the steel by abrasive blasting prior to priming.[3] For faster handling of shop-primed steel and more efficient application of ensuing field coats, faster drying Type II or Type IV (Federal Specification TT-P-86) red lead was frequently used instead of the slower drying rust penetrating Type I red lead primer. Although pickling proved to be a successful method of removing mill scale in fabrication facilities, pickling in the field was not feasible. Automated shop cleaning machines also came into use.

Even though fabricators began using these updated methods of surface preparation in their shops in the 1960s, field blasting of the weld seams and abraded areas was not always performed. Hand or power wire brushing these areas was permitted prior to field spot priming. There was little concern for establishing a profile on the steel, and descaling and pickling did not impart sufficient profile on the steel.

Effect of Pickling Residues

Some pickling processes utilized caustic (alkaline) materials to neutralize the action of the pickling acid. Although these alkaline materials were to be rinsed from the steel, residues frequently remained on the steel. This alkaline residue combined with the oils in the primers and saponified. The saponified coating materials became brittle, and the soap forming beneath the coatings caused a premature release of the coating from the steel. Failures of this nature appeared to be worse when the coatings contained heavy pigment loads of alkaline particles and oil-type vehicles.

What to Look for Today

It is very important to determine if mill scale is present on an existing structure. The adhesion of the existing coatings and any new coatings added to them is limited by the adhesion of the primer to the steel. If the mill scale is tightly adherent, it will prevent adhesion of a coating. Thus, it may be necessary to remove the mill scale and create a profile by blast cleaning.

It is important to know the degree of original surface preparation of areas where no mill scale is present. Wire brushing usually did not remove all rust and contaminants, and areas such as field welded seams will usually be subject to early coating failure.

Existing Coatings—What To Expect

Before the 1900s, water tanks were usually black. After black, most tanks were aluminum colored, thanks to a coating system that consisted of a lead-based primer with a finish coat of aluminum flakes in a varnish-type vehicle. These aluminum-pigmented coatings were the standard of the industry until about 1960. Colored alkyd and long-oil enamels started being used on new construction. On repaint projects, the white or colored enamels were usually applied over the existing aluminum coatings when a change in color was desired.

The 1960s also saw the advent of the use of vinyl coatings for the exterior and interior of water tanks. Bituminous and asphaltic coatings continued to be used. Phenolic vehicles with zinc or aluminum pigments were used on the potable water contact surfaces, although many primers continued to be pigmented with lead. Epoxy ester coatings were also being marketed.

By 1970, two-component epoxy materials were the mainstay of the new tank industry for the interior of potable water tanks and were being used in tank maintenance practices. A product commonly referred to as "wax-grease" was included in the 1964 edition of D102. Wax-grease was used primarily as an interior maintenance coating on tanks and had been on the market for almost 70 years. Although the AWWA standard called for the surfaces to be blast cleaned to an SSPC-SP 10, Near-White, prior to the application of the wax-grease coating, it was more commonly applied directly over the existing coating, rust, and mill scale. When applied this way, wax-grease was usually ineffective as a corrosion deterrent.

Of the coating options available for the exteriors of the tanks, red lead primed alkyd systems continued to predominate, although vinyls were used on tanks in severe environments or in locations where a dry-fall coating was beneficial to minimize damage to adjacent property. Most of these vinyls had red-lead-pigmented primers. Other proprietary dry-fall coating systems of modified acrylic or modified alkyds were also available. The seventies also brought the use of two-component polyurethane materials for the exterior surfaces. Both alkyd and epoxy underlying coats were used for the polyurethane finish coats. Although used for several years prior to the 1978 revision to the D102 AWWA "Standard for Painting Steel Water-Storage Tanks,"[4] polyurethane systems were not included in the systems recommended in this revision of the standard. (To this date, there has been no revision to the 1978 AWWA D102 standard, and its ANSI accreditation has been withdrawn.)

Impact of Product and Color Changes

Color Changes

As the aluminum finish coatings on the tank exteriors aged, they eroded slightly. The addition of another coat of aluminum flakes blended in varnish or an alkyd vehicle seemed to reinforce the underlying coatings. Attempts to change the color of a tank by topcoating the aluminum coating with a colored or white enamel would usually lead to premature coating failure at the aluminum-to-enamel interface.

Formulation Changes

Some coating manufacturers have kept the same coating material designation numbers (product number) while changing formulations. This occurred in the early to mid-seventies when material shortages were prevalent and substitutions were necessary in order to meet the demand for products. Published product data sheets did not always reflect the changes in formulation. Additionally, the replacement of lead, chromates, and other regulated pigments with more environmentally friendly and less toxic materials has been done, but, in the case of a few manufacturers, the product numbers have remained the same as before the pigments were replaced. This second type of change in product content should be reflected on the manufacturer's published product data sheets in effect at the time of the product sale, so don't assume that the product data sheet in your file truly indicated the composition of the coating under investigation.

In addition, in the past, alkyd coatings were the "workhorse" coatings used on the exterior of water tanks. Life before topcoating cycles sometimes reached over 20 years. It is believed that their amazingly good record of success was dependent on the presence of the relatively insoluble lead pigments used as a corrosion inhibitor in the primer. The exterior of many tanks are subject to nearly constant condensation. This is usually due to the fact that the well water in the tank is colder than the dew point temperature of the air surrounding the tank. The water usually becomes stratified (by temperature) in the tank. This can manifest a "sweat line." It is for this reason that large plate riser pipes and elevated tank bottoms and reservoir or standpipe lower shell levels are showing premature coating failures, not previously indicated when lead-based primers were used. The corrosion inhibitors used in today's alkyd primers appear to be readily soluble in water and therefore are not serving as a good subbase for the ensuing alkyd enamel intermediate and finish coats. The present-day alkyd coatings appear to soften and easily become permeated, causing intermediate coat adhesion failure.

Solvent Changes

Some of the fast-dry materials resulted in brittle films. Their "hot solvents" permeated the underlying old coatings, and their escape by evaporation was deterred due to the quick drying of the surface of the new topcoats. This combination of brittle coatings and disturbed adhesion of the underlying coatings can precipitate premature failures of future recoating projects. In addition, coating over aged coatings, even if theoretically compatible materials are used, can cause premature failures due to the lack of cohesive forces within the deteriorated underlying coating materials.

Identifying Changes

For all these reasons, you need to check the paint for its content and especially for lead or other hazardous constituents.

Do not rely on the specifications for the past work—there is usually little correlation between the specifications and what was applied to the tank. Even contractors' submittals should not be relied upon because changes were often made later that were not documented. Add in the number of unrecorded repaintings that may have taken place, and you have another exercise in detective work.

Conclusion

Corrosion failures on aged steel water tanks are often associated with mill scale, improper welding, and coating incompatibility, all of which may have resulted from earlier maintenance practices once thought to be reliable. It has been said that if we do not remember our history, we are doomed to repeat it. Certainly knowing the maintenance history of a tank can help the specifiers and tank owners determine the causes of coating failure, avoid the same failures, and identify appropriate avenues of remediation.

References

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3. *Systems and Specifications, Steel Structures Painting Manual, Volume 2,* Steel Structures Painting Council, Fifth Edition, 1989, pp. 25, 51-52.
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