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Tank Talk

# *Coating Inspection and Structural Deficiencies*

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*Chief Engineer*

In August of 2010, the roof of a large municipal water storage tank in suburban Chicago collapsed. The tank had performed without incident for more than 35 years. There were no early indications or warnings of roof problems prior to the roof failure. The tank coating had been inspected a number of times after the tank was initially constructed. This article discusses what happened, how the roof failure could have been prevented and lessons learned from this incident.

## *Roof Description*

The roof of the 128 ft diameter tank consisted of 3/16" lap-welded steel plate supported atop 50 radial rafters spanning from the cylindrical shell to a compression ring girder at the center of the roof. The roof was designed to be self-supporting without vertical support columns. The rafters were rolled in a vertical plane to a large circular radius so that the roof formed a dome or umbrella shape when fully erected. The design of the roof relied on a single row of angle-section purlins between adjacent rafters to provide lateral stability to the roof framing system. The roof rafters were not welded to the roof plate with the exception that small non-structural tack welds were used during the original roof erection process to hold the roof plates in place until they could be fully lap-welded together. The original design called for two bolts at each end of each purlin to attach the purlin to a bracket plate that was welded to the rafter.

Collapsed Roof Structure on Tank Interior

## *What Happened?*

The first sign of a potential problem with the tank was unusual loud noises coming from the tank. External inspection revealed that the umbrella roof had inverted and there was evidence of torn rafter clip attachment welds around the top of the shell. No tank leaks were found. Following the collapse of the roof, an internal inspection revealed that the roof framing had collapsed or "spiraled down". Closer inspection revealed that only one bolt was in place at the end attachment to the rafter for the majority of the purlins. (See Photo No. 2) At the time of the inspection, there was no evidence that the second bolt at these connections had ever been in place. Several of the purlin ends where the second bolt was missing had deteriorated to the point that they were no longer capable of transferring load or performing their intended function to provide lateral stability to the roof structure. Without this lateral stability, the main rafters were vulnerable to "roll-over" or spiraling down under the self-weight of the roof and any external loads, such as wind. The collapse most likely resulted from progressive failure of the purlins as the load had to be carried by fewer and fewer of them. A contributing factor to the collapse was the accelerated corrosion in the empty bolt holes at the end of the purlins due to the coating failure within and on the edges of these holes.

## *How Could the Failure Have Been Prevented?*

The primary focus for many municipal water tank inspection companies is on the protective coating issues for the tank. Most inspection companies do not have professional tank engineers on staff. As a result, structural deficiencies, especially those that have existed for a long time, may receive insufficient attention during the inspection and evaluation of the tank. In the case of the subject tank, the structural implications of the several missing purlin bolts may not have been fully understood by the previous inspector(s).

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## *Inside This Issue*

# Underwater Tank Inspections

*OMG!! There's something swimming in my water tank!*

*By: Jim Peyer, Field Services Manager*
*Certified Commercial Diver*

A growing number of Tank Owners elect to have the interiors of their tanks evaluated with water still in the tank. Their reasons vary, but some of the more common scenarios include:

- The tank can't take the tank out of service long enough to accommodate a dry inspection.
- The tank maybe fairly new and a dry inspection may not be necessary.
- It may be a warranty or annual inspection.
- It may be an inspection to locate or examine specific failures such as a floor leak, weld crack, or piping problems.
- Water conservation.
- Maybe you just don't want to empty the tank!

There are currently two popular methods of underwater tank inspection: dive evaluations, and evaluations using remotely operated equipment (ROVs). Each has its use, and they can sometimes be used interchangeably, depending on the Tank Owner's needs.

## *Dive Evaluations*

**Safety first!** Diving inside of a water tank isn't quite like pleasure diving off the coral reefs in the Caribbean or swimming in your backyard pool. A tank is a confined space, not designed for occupancy. The divers accessing your tank must not only be skilled divers, they must also be familiar with tank configurations and the piping and appurtenances that may be inside the tank. The diver must consider many things when planning the dive:

- Will the dive be using scuba or surface supplied air. Are you using mixed gases?
- Do you have the correct suit for warmth in colder water or are you in south Texas in the summer and heat exhaustion could come into play.
- What kind of access do you have to the tank's manholes and is the manhole big enough to accommodate a diver in full gear. (That would also include the backup diver.) Do you have to don your gear in the water?
- What kind of emergency services are nearby and how do you get a hold of them?
- Have any rescue services been notified (fire station) that you will be diving and rescue may be needed?
- Are the teams' rescue, first aid, oxygen certifications up to date and the rescue items such as backboard, oxygen, and first aid kits readily available?
- Weather. Hot. Cold. Rain. Snow. Ice on or in the tank? Lightning? High winds?
- Can you pull up equipment safely? Can you secure the equipment on the tank?
- Not enough can be said about secure knots and knot tying capabilities.
- How do you get to the water if there is no interior ladder?
- Is the dive team well rested and physically able to carry out the dive?
- What is the dive plan and its contingencies?
- Lighting? Is it day or night? Are manholes open? Is the interior coated white or is it coal tar?
- Are there drawings for the tank showing the piping, basins, columns, baffle walls, added chambers, etc.?
- Did you look around the exterior to see where components might be such as shell manholes, piping, and overflows? Is there evidence of overfilling which may have caused rafter damage and container distortions? On concrete tanks, have you checked the roof condition?
- Did you make sure your equipment has been checked and fully functional?
- Is the communication/tether line in good condition and working?
- Did you check the atmospheric readings above the high water line, in case a quick assent had to be made, or if a team member is rafting in conjunction with the dive?
- Will there be constant communication between diver, tender, and team mates?

**Sanitary Issues in Potable Water**: Divers accessing potable water must use suits and dive equipment dedicated for use in potable water. Disinfection of the diver and all equipment must be according to the most current ANSI/AWWA C652 standard.

**The Inspection**: Once inside the tank, the diver, back-up diver, and ground person work as a team to collect all required data. The dive team member looking from the manhole, interior ladder, or from a raft without diving can obtain a good deal of information. This is valuable as the diver may not be close enough to access things such as rafter measurements, coating thicknesses, and adhesions. The diver must be careful to stir up any sediment in the tank as little as possible. When practical, we recommend that the water department take the tank offline as far ahead of time as possible, to give the water a chance to settle out for the best visibility. This will also improve the quality of the photographs or video taken of conditions inside the tank.

## *ROV Evaluations*

A more recent development in tank inspections is the ROV. These remotely operated camera devices are propelled through the water, controlled by an operator on the tank exterior. Many feature live-feed video and other "bells and whistles." And while they are very useful in many situations – particularly when there are safety concerns about putting a diver into the tank – all they do is take pictures that must be interpreted by someone else. Many of the tests performed during a dry or dive evaluation are impractical with an ROV.

*Underwater Evaluations continued from page 2*

### *Pros and Cons*

Underwater interior evaluations do have several benefits.

- The tank does not need to be removed from service and emptied. However, as a safety precaution, tanks should be taken offline while the diver is in the tank. The tank does not have to be removed from service for an ROV evaluation, although taking the tank offline and allow the sediment in the water to settle does result in better visibility.
- If the roof support structure is suspect, a dive or ROV evaluation is easy to combine with a rafting evaluation to get up close to the roof members for evaluation.
- The general condition of the interior coatings can be assess underwater.

However, a drained evaluation is still the most thorough evaluation and is recommended prior to preparing specifications for rehabilitation. Once the tank is drained and cleaned out, the exposed surfaces on the interior, including the floor of the tank where corrosion is often found, can be thoroughly evaluated. This allows specifications to be prepared and bids received that encompass the complete scope of work.

### *A word to the wise…*

Whatever type of tank evaluation you select — drained, dive, or ROV — have the evaluation performed by an experienced, properly tank professional backed by registered professional engineers experienced in the design, specification, and maintenance. The method is not nearly as important as the information you derive from the evaluation. The engineering report should include the information required to allow you to make informed decisions about tank maintenance and how to meet the short-term and long-term water system needs.

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# Update on Steel Tank-Related AWWA Standards

*By: Stephen W. Meier, P.E., S.E.*
*Managing Principal*
*Chair, AWWA Steel Tank Committee*

The latest AWWA Standards for steel tanks will include:

**D100-11**(effective July 1, 2011) – Welded Carbon Steel Tanks for Water Storage
**D102-11**– Coating Steel Water-Storage Tanks
**D103-09** – Factory-Coated Bolted Steel Tanks for Water Storage
**D104-11** – Automatically Controlled Impressed-Current Cathodic Protection
**D106-10** – Sacrificial-Anode Cathodic Protection
**D107-10 –** Composite Elevated Tanks for Water Storage
**D108-10** – Aluminum Dome Roof

In order to comply with the ANSI recommended five-year revision cycle, the Standards Committees and Revision Task Forces are continually working to update the standards. As soon as a revision is released, work begins immediately on the next revision. The following is a summary of the recent changes:

**D100-11:** Minor revisions were included in the latest D100

Section 3:

- Modified to match wind exposures of ASCE 7-05.
- Requirement to use AWWA D108 for aluminum dome roofs was added.
- ASME Sec VIII, Div 2 allowed for anchor bolt chair detailed analysis.

Section 10: Included an erection tolerance multiplier for ground storage tanks with small compressive stresses.

Section 11: Leak testing of shell-to-bottom joint was made mandatory.

Section 13:

- Site-specific analysis for short-period tank on soils susceptible to liquefaction not required.
- Site-specific procedure of FEMA 450 deleted and procedure per ASCE 7-05 referenced.

Section 14: Clarification of Design Metal Temperature (DMT)-thickness requirements for Category 1 and 2 with impact testing.

**D102-11**: The 2011 revision of D102 included updates to the coating systems.

- OCS (Outside Coating System)-3: Changed to 3-coat system of zinc-rich primer with intermediate and finish coats of single-component, water-based acrylic or acrylic emulsion.
- New OCS-7 added: 3-coat system consisting of first and intermediate of 2- component water-based epoxy and finish coat of 2-component, water-based aliphatic polyurethane.

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*Standards Update continued from page 3*

- ICS (Inside Coating System)-3: Changed 1 or 2 coat optional epoxy or inorganic/organic zinc-rich primer and 2-component epoxy finish coat with 96% minimum solids.

Other changes in D102-11 included:

- Narrative on shop and pre-construction priming added.
- Commentary on spot repair versus full removal added.
- Commentary on abrasive blast cleaning versus water-jetting added.
- Clarification on stripe coating added.
- Commentary on tank lettering, logos, signage added. Default checklist of optional requirements added (Appendix C).

**D103-09**: Major revisions were included in the 2009 revision of D103.

- All contractual language was removed.
- Environmental loads in accordance with ASCE 7 were added.
- Numerous detail changes in materials, welding, accessories and inspection requirements were included.

**D104-11**: Included editorial clarifications and update of references.

**D107-10**: After 17 years and over 1,200 tanks later, we finally have a standard for the construction of composite elevated tanks!

**D108-10**: The aluminum dome standard is a new standard, extracted from D100 and D103 as a stand-alone standard and includes updated information concerning the erection and use of aluminum domes on water storage tanks.

## *What's next?*

Currently under development is a re-organization of standards to help eliminate some of the redundancy between the standards, thereby making future revisions more timely and up-to-date. The re-organization will include a **General Tank Standard** that includes the commonalities between the standards such as welding, construction tolerances, seismic and wind load requirements. Several **Product Standards** will include product-specific technical requirements, and **Component Standards** will be issued for things like coatings, cathodic protection, and roof construction.

**Stephen W. Meier, P.E., S.E.** chairs the American Water Works Association Steel Tank Committee. In this capacity he oversees the development and revision of all standards related to steel tanks. Steve is Technical Editor of the recently published *Steel Water Storage Tank Handbook.*

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The failure of the tank roof could have been prevented by recognizing that the missing purlin bolts were a non-compliance with the tank construction drawings on record and represented a significant risk to the stability of the roof structure. A professional tank engineer, had one been involved in previous inspections, would almost certainly have recognized this non-compliance and failure risk before allowing the tank to be returned to service.

Only one attachment bolt in place.

## *Lessons Learned*

A critical step in the inspection of a tank, whether for municipal water or any material, is the review and evaluation of the inspection data by a qualified tank engineer. A professional tank engineer is trained and qualified to understand the engineering design and performance requirements for the tank and will recognize structural deficiencies that may be overlooked by the coating inspector.

The tank owner should specify the following wording in tank inspection contracts and requests for quotations: "The inspection company shall identify and report any observed deterioration, structural deficiencies or damage that may have occurred since the tank was constructed. Any deviations of the existing tank condition from how the tank was originally designed and constructed shall be considered structural deficiencies or modifications and shall be analyzed by a professional tank engineer for their effects on the structural integrity of the tank."

**John M. Lieb, P.E.** is a nationally recognized expert in the design of plate structures including specialty plate structures for petroleum, chemical, granular, and water industries throughout the world. Mr. Lieb has over 35 years experience as an Engineer, including 24 with a major tank constructor.

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