Storage Tank Inspection, Maintenance, and Failure

Fluid Fertilizer Foundation
December 10, 2013
Tank Failure History

Storage Tank Failure is as old as storage tank usage...

- On January 15, 1919 a molasses tank ruptured.
- The cast iron tank was filled to the top
- 2.5 million gallons of molasses flowed from the tank in seconds, producing a 40 ft wave traveling at 35 mph
- 150 people were injured with a final death toll of 21.

http://en.wikipedia.org/wiki/Boston_Molasses_Disaster
A Massachusetts court determined that insufficient inspections contributed to the accident.

The company was found liable, concluding shoddy construction and overfilling the tank was to blame along with a sudden expansion of the molasses (the temperature was 2°F the previous day)

The company paid $1 Million in fines
Tank Failure History

• 87 South Dakota: a school is evacuated after a nearby AST begins leaking. SD legislature begins process to control use of ASTs
• 3/97 Washington: a 500k gallon storage tank of Potassium Thiosulfate has a weld rupture resulting in a loss of 100k gallons of material
• 3/97 Iowa: a 1M gallon tank amm phosphate tank ruptures. 2 additional tanks are damaged
• 7/99 Michigan: a 1M gallon APP ruptures and damages 3 adjacent tanks
• 1/00 Ohio: a 1M gallon fertilizer tank ruptures and damages 4 adjacent tanks and 5 tractor-trailer rigs. More than 800k gallons spill into the Ohio River
• 3/00 Ohio: a 1.5M gallon amm phosphate tank ruptures and damages 2 adjacent tanks. Some released liquid flows into nearby creeks
• 10/00 Montana: a 2M gallon nitrogen fertilizer intermediate tank has a massive roof failure; no loss of product but tank is significantly damaged
• 2008 Virginia: catastrophic failure of a 2M gallon UAN tank. TFI guidelines and Virginal law were updated as a result.
Tank Failure History

http://www.csb.gov/allied-terminals-investigative-photos/

http://www.csb.gov/assets/1/19/Allied_Terminals_Report_Final_7_13_09.pdf
Tank Failure History

Figure 1. Collapsed storage tank.
Take UAN Corrosion Seriously

Summary: When there is a lack of attention and little effort on maintenance, corrosion caused by fertilizers (including UAN) can result in financial losses, environmental damage, and even loss of life. However, these potential risks can be greatly reduced with only a small amount of effort and minimal expense on the part of the dealer or grower.
Why do tanks fail?

- Corrosion
- Improper Construction
- Specific Gravity of fluid incompatible with tank wall
- Internal/External forces or events (fire, flood, wind, impact, etc.)
- Seismic zone design not compatible with area
Seismic Zones

United States Seismic Zones Map

Seismic Zones (Ground Acceleration)

- Zone 0 = 0.0g
- Zone 1 = 0.075g
- Zone 2A = 0.15g
- Zone 2B = 0.20g
- Zone 3 = 0.30g
- Zone 4 = 0.40g

Source: 1997 Edition UBC.
Seismic Zones

How do tanks fail?

Catastrophically: Failure can be quick and can cause damage or loss of adjacent equipment. Dangerous to personnel

- Wall blowout
- Explosion
- Total Roof Collapse

Non-Catastrophically: Slow, general corrosion type failures. These can often be repaired

- Pinhole leaks
- General Corrosion
Where can tanks fail?

- Roof
- Weld
- Wall Plate
- Internal Floor
- External Floor
Tank Failure - Roofs

- Internal Beam Failure
- Corrosion due to build-up of moisture, acids, salts, etc.
- Weight due to condensing material (sulfur)
Tank Failure - Roofs

- Salt (sulfur) build-up.
- Salts are acidic in nature
Tank Failure - Roofs

This is actually the result of poor surface preparation prior to coating.
Tank Failure – Plugged Vent

Plugged vents lead to either vacuum or over-pressure catastrophic failures!
Tank Failure – Plugged Vent
Preventing Roof Failure

• External Rafters/Self Supporting Roofs
• Nitrogen Blanketing
• Coatings (reduce corrosion likelihood but note previous slide)
  • PVRV (pressure vacuum relief valves) or Conservation Vents
  • Goose necks with screens (to prevent bird nesting)
  • Purge vent and PVRV/Inspection/Cleaning
Tank Failure - Wall and Weld

- Poor welding procedures are the main culprit of weld failure
- Specific gravity too heavy for tank wall thickness
- Corrosion – Pitting, cracking, and general thinning can cause loss of containment

- This tank has a bladder
- Corrosion occurred on the south side only
Preventing Weld and Wall Failure

• Coatings – Epoxy Phenolic, Fiberglass, rubberized asphalts
• Bladders – Rubber
• Material of Construction – Stainless, Fiberglass, Poly/HDPE
• Certified welders based on recommended construction and repair procedures (API 650 and API 653)
• Regular inspections (external and internal)
• Wall thickness rated for liquid specific gravity
Tank Failure – Internal Floor

Built up solids can create stagnant voids where accelerated corrosion can take place. Pitting ensues.
Tank Failure – External (Underside) Floor

Non-uniform tank base can allow moisture to collect underneath tank

Remove excess gravel and dirt from bottom seam of tank

Additionally, if there’s been previous spills or leaks the underside may be exposed to a chemical or bacterial corrosive environment
Tank Failure – External (Underside) Floor

• Sulfur Reducing Bacteria (SRB): Occurs with tank floors sitting on soil or sand. Moisture, nutrients, and proper temperature (40°F – 120°F) are required for growth to occur.

• Chloride cracking – stainless steels are susceptible to chloride attacks. Insulation can often be the source of chlorides. If insulation gets wet and with a little heat, cracking can occur.
Preventing Floor Failure

- Concrete Foundations – Best Practice for new tanks
- Internal Coatings
- Full draining of liquids/thorough circulation of liquids
- Routine Solids removal
- Cathodic Protection
- Moisture Barriers at floor/foundation joint
- Liquid/Vapor Corrosion Inhibitor program (new)
Tank Failure Prevention Summary

- Inspection Program
- Code/Procedure Based Construction
- Proper Metallurgy (Best Practice)
- External roof supports/self supporting roofs
- Concrete Foundations (Best Practice)
- Linings/Coatings/Bladders (If needed beyond metallurgy – ensure surface preparation and coating are done to code/standard)
- Tank meets physical requirements (wall thickness rated for SG)
- Solids removal/minimization (with a means to do so – Best Practice)
- Vapor barriers
- Cathodic Protection
- Liquid/Vapor Corrosion Inhibitor program (new)
- Product Corrosion Inhibitors
- Proper maximum liquid inventory (taking into account liquid expansion)
Inspection/Testing Methods

- X-Ray
- Hydrostatic (leak test) – holes
- Ultrasonic Thickness (UT) – pitting
- Vacuum – floors/floor joints
- Dye Penetrant – cracks
- Magnetic Particle – cracks
- Magnetic Flux Leakage – pits on tank floor
- Eddy Current – flaws in structure
- Visual

- A handheld UT gauge is roughly $2,000
To quote Ben Franklin, “An ounce of prevention is worth a pound of cure.”

A pyramid is usually used to show “risk and corrective action.”

~ 74% of tank problems are noticed as a small leak.
~15% are medium leaks
~10% are large leaks
~0.2% are ruptures

Fix the small problems to avoid the larger ones

http://www.ogp.org.uk/pubs/434-03.pdf
EPA Recommended Inspection Program

Recommended Elements for a Hybrid Inspection Program
Here is a partial list of items to consider regarding the elements of a hybrid inspection program.

For shop-built tanks:
- Visually inspect exterior of tank;
- Evaluate external pitting;
- Evaluate “hoop stress and longitudinal stress risks” where corrosion of the shell is present;
- Evaluate condition and operation of appurtenances;
- Evaluate welds;
- Establish corrosion rates and determine the inspection interval and suitability for continued service;
- Evaluate tank bottom where it is in contact with ground and no cathodic protection is provided;
- Evaluate the structural integrity of the foundation;
- Evaluate anchor bolts in areas where required; and
- Evaluate the tank to determine it is hydraulically sound and not leaking.

For field-erected tanks:
- Evaluate foundation;
- Evaluate settlement;
- Determine safe product fill height;
- Determine shell corrosion rate and remaining life;
- Determine bottom corrosion rate and remaining life;
- Determine the inspection interval and suitability for continued service;
- Evaluate welds;
- Evaluate coatings and linings;
- Evaluate repairs for risk of brittle fracture; and
- Evaluate the tank to determine it is hydraulically sound and not leaking.
Tank Guidelines

• API STD 650 - Welded Steel Tanks for Oil Storage
• API RP 651 – Cathodic Protection of Aboveground Petroleum Storage Tanks
• API RP 652 – Lining of Aboveground Petroleum Storage Tank Bottoms
• API STD 653 - Tank Inspection, Repair, Alteration, and Reconstruction

American Petroleum Institute
1220 L St. NW
Washington DC 20005
http://www.api.org
(202) 682-8000
Tank Guidelines

The Fertilizer Institute (TFI) Publication

Aboveground Storage Tanks Containing Liquid Fertilizer Recommended Mechanical Integrity Practices

The Fertilizer Institute
820 First St., NE
Washington, DC 20002
http://www.tfi.org
(202) 962-0490
Tank Guidelines

The Canadian Fertilizer Institute Publication

Canadian Fertilizer Industry Storage and Handling Guidelines 2001

Canadian Fertilizer Institute
350 Sparks Street, Suite 802
Ottawa, ON K1R 7S8

(613) 230-2600

http://www.cfi.ca
### Table Key:
- **A**: Acceptable if compatible with container or appurtenances
- **N**: Not acceptable because of chemical compatibility
- **1**: Acceptable if product is treated with corrosion inhibitor
- **2**: Acceptable if warranted by equipment manufacturer for the intended use
- **3**: Acceptable if cleaned after seasonal use and is used to store materials less than three months (cumulative) annually

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<th>Product</th>
<th>Urea Ammonia Nitrate</th>
<th>Ammonium Thiosulfate</th>
<th>Ammonium Polyphosphate</th>
<th>Potassium Phosphate</th>
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Source: Wisconsin Department of Agriculture, Trade and Consumer Protection