Storage Tank Inspection, Maintenance, and Failure

Fluid Fertilizer Foundation
December 10, 2013

Tank Failure History

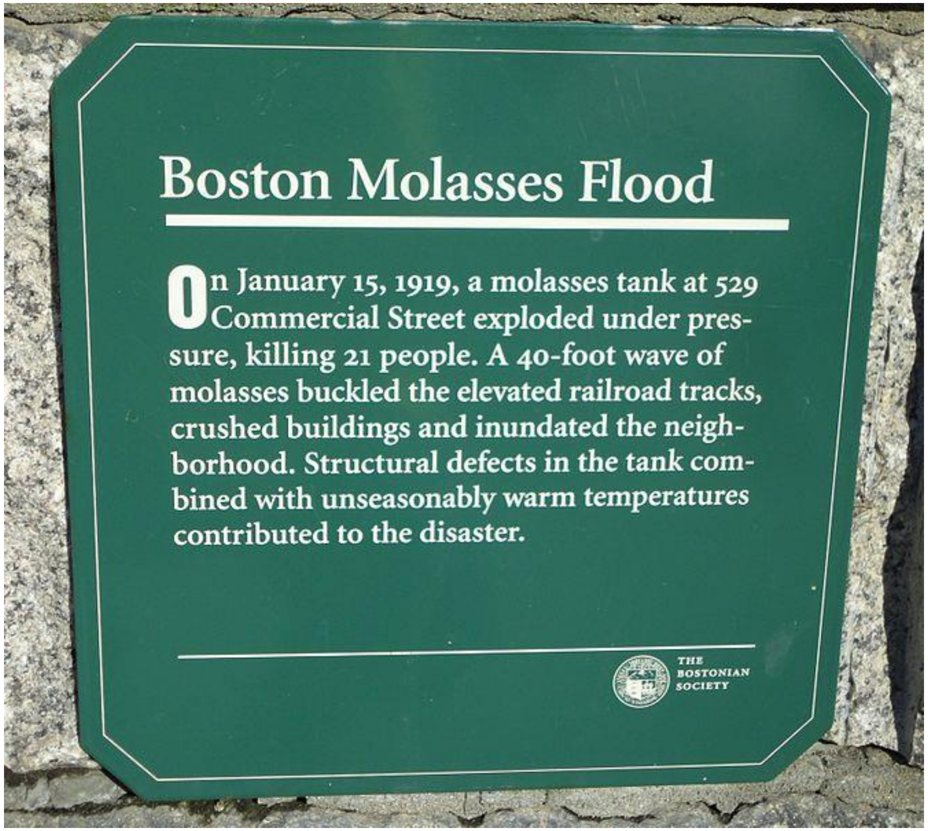
Storage Tank Failure is as old as storage tank usage…

http://en.wikipedia.org/wiki/Boston_Molasses_Disaster

- 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.

Tank Failure History

- 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.

Fluid JOURNAL
Official Journal of the Fluid Fertilizer Foundation
Winter 2009
Vol. 17 No. 1, Issue #63

Phil Bureman and Dr. Craig Myers

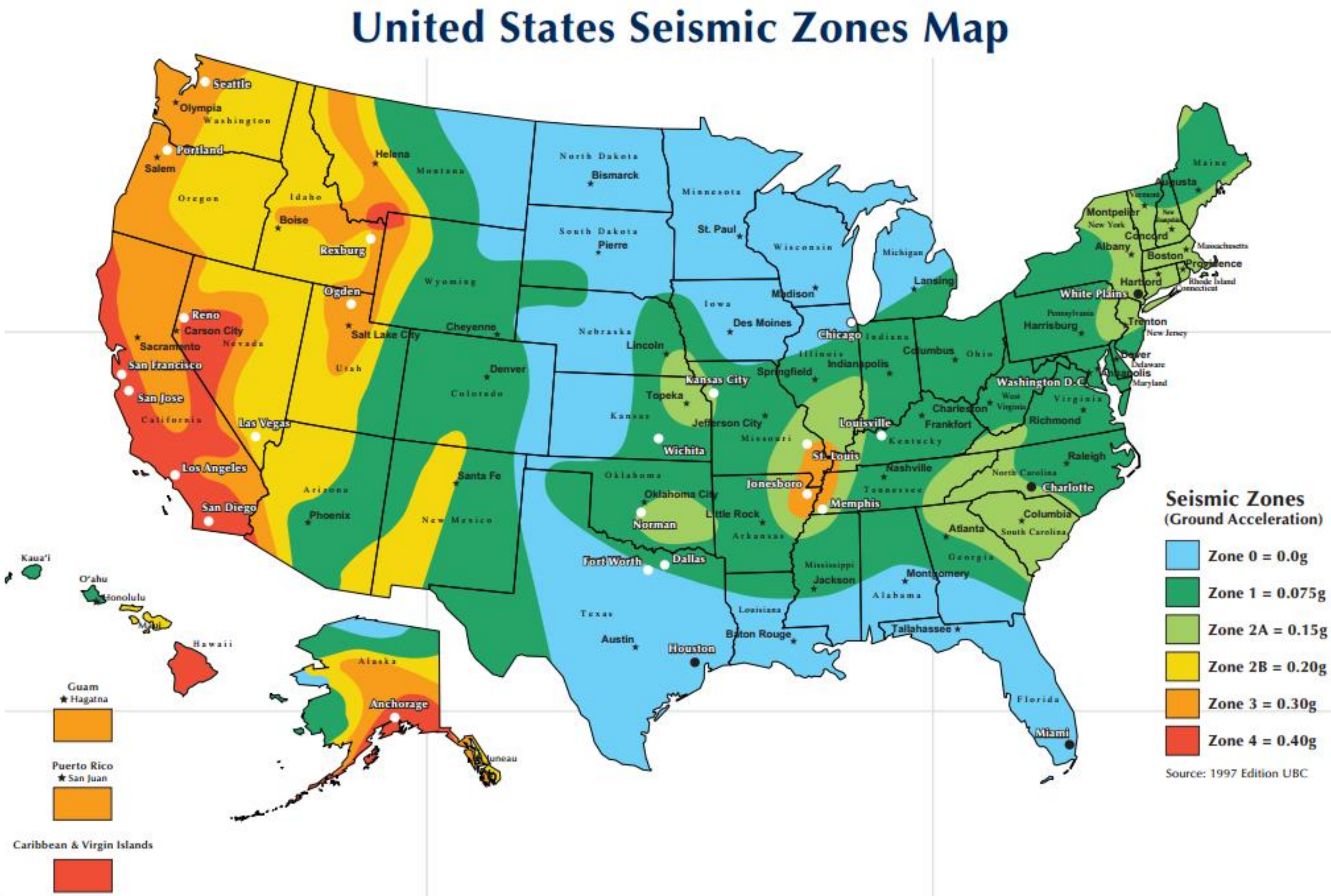
Take UAN Corrosion Seriously

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.*

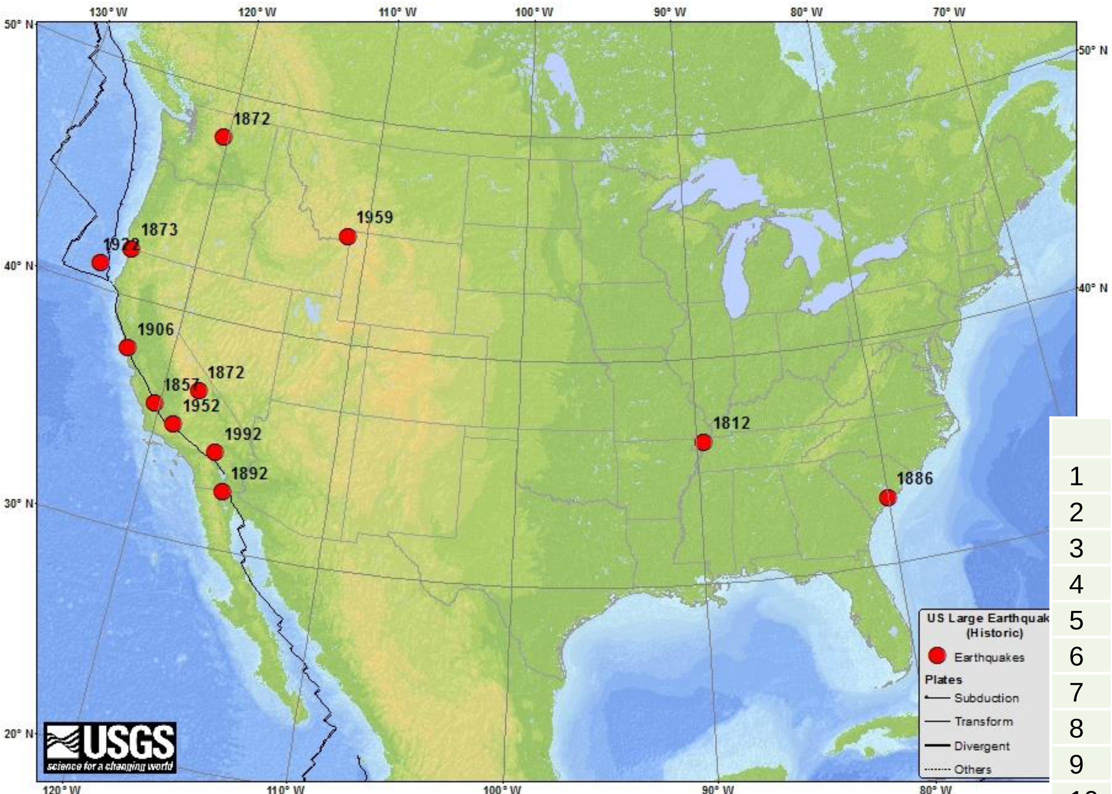
Why do tanks fail?

- 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



Seismic Zones



http://earthquake.usgs.gov/earthquakes/states/10_largest_us.php

	Location	Date Time UTC	Magnitude
1	Cascadia subduction zone	1700 01 26 UTC	˜9
2	Fort Tejon, California	1857 01 09 16:24 UTC	7.9
3	San Francisco, California	1906 04 18 13:12 UTC	7.8
4	Imperial Valley, California	1892 02 24 07:20 UTC	7.8
5	New Madrid, Missouri	1811 12 16 08:15 UTC	7.7
6	New Madrid, Missouri	1812 02 07 09:45 UTC	7.7
7	New Madrid, Missouri	1812 01 23 15:00 UTC	7.5
8	Owens Valley, California	1872 03 26 10:30 UTC	7.4
9	Landers, California	1992 06 28 11:57 UTC	7.3
10	Hebgen Lake, Montana	1959 08 18 06:37 UTC	7.3
11	Kern County, California	1952 07 21 11:52 UTC	7.3
12	West of Eureka, California	1922 01 31 13:17 UTC	7.3
13	Charleston, South Carolina	1886 09 01 02:51 UTC	7.3
14	California - Oregon Coast	1873 11 23 05:00 UTC	7.3
15	N Cascades, Washington	1872 12 15 05:40 UTC	7.3

How do tanks fail?

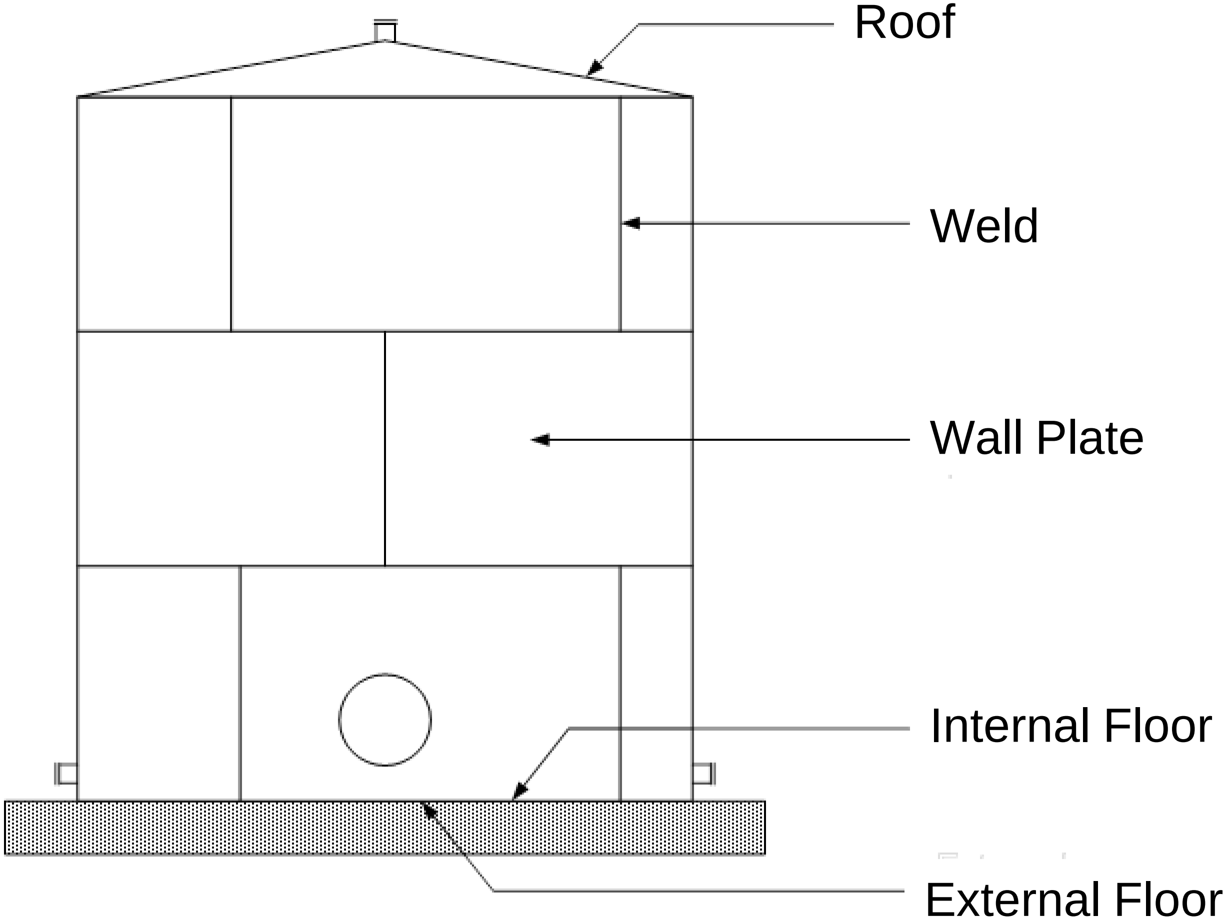
Catastrophically: Failure can be quick and can cause damage or loss of adjacent equipment. Dangerous to personnel

- 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?



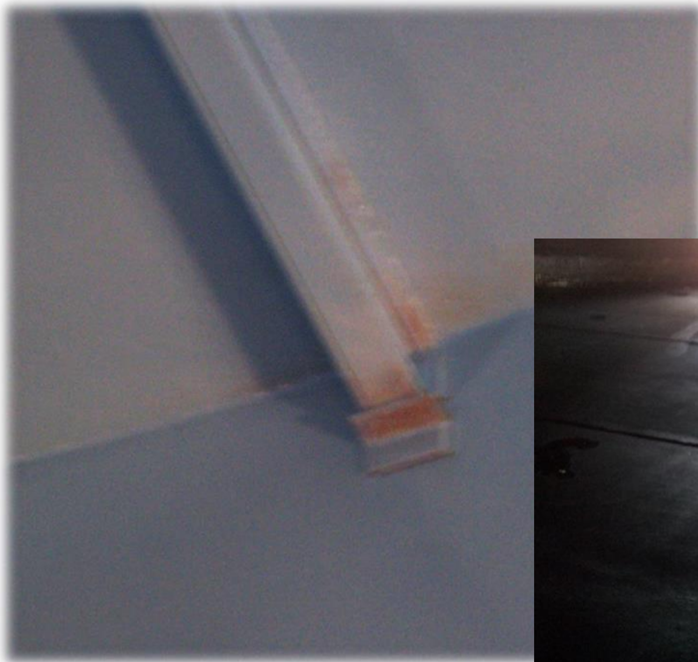
Tank Failure - Roofs

- 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

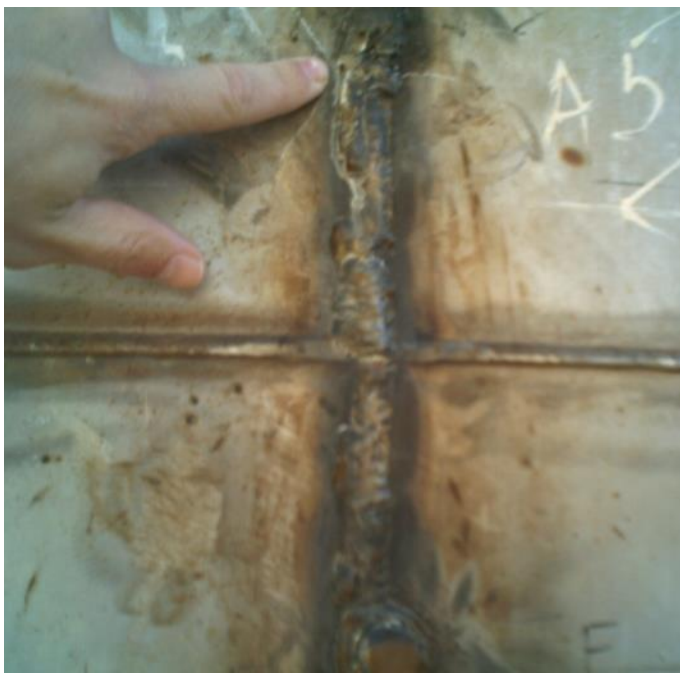
Preventing Roof Failure

- 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



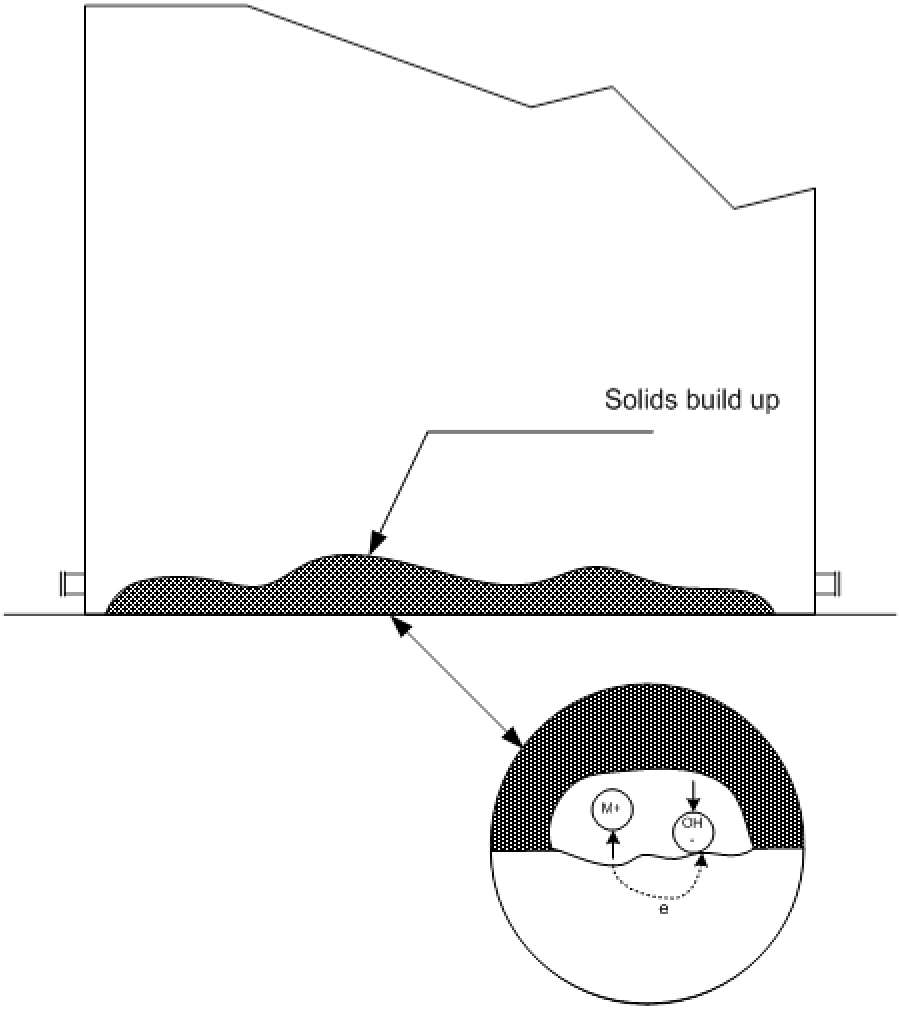
- This tank has a bladder
- Corrosion occurred on the south side only

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

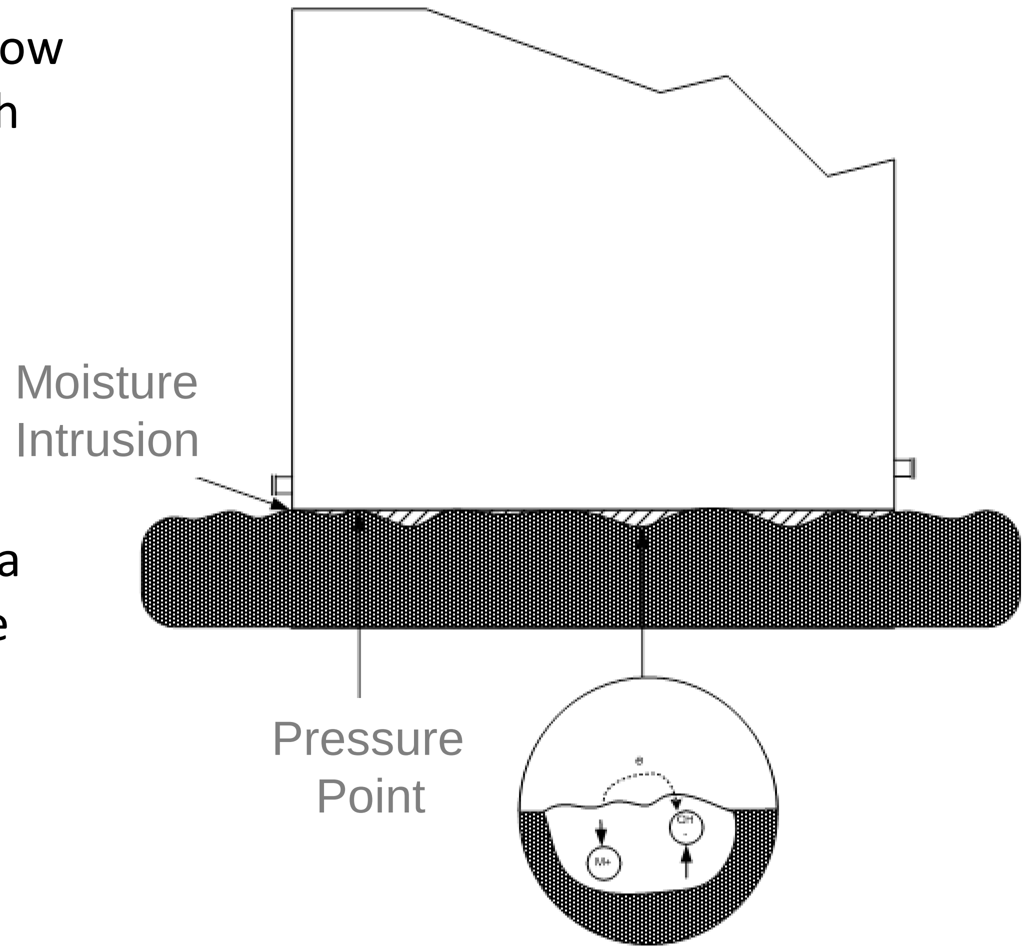


Tank Failure – External (Underside) Floor

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



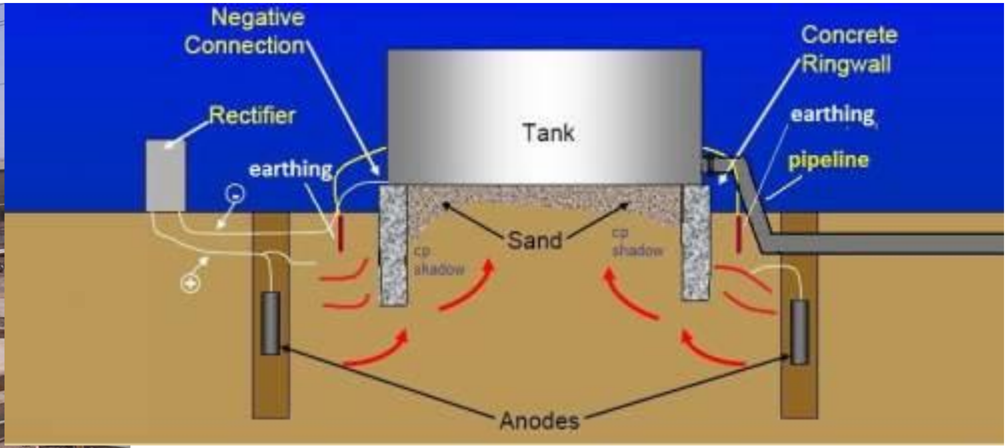
Tank Failure – External (Underside) Floor

- 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)

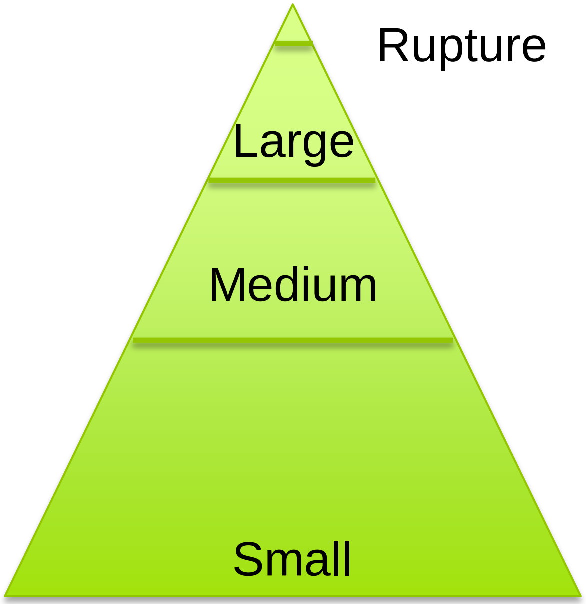
Inspection/Testing Methods

- 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

Inspection – It starts here

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

CHEMICAL COMPATIBILITY FOR LIQUIDS FERTILIZERS

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

Product	Urea Ammonia Nitrate	Ammonium Thiosulfate	Ammonium Poly-phosphate	Potassium Phosphate	Potassium Hydroxide	Potash Solutions	Mixed Fertilizers, Starters
Container Material							
Stainless Steel	A	A	A	A	A	A	A
Mild Steel	1	1	A	N	N	3	3
Mild Steel with Liner	2	2	A	2	2	2	2
Aluminum	A	A	N	N	N	N	N
Fiberglass	A	A	A	A	2	A	A
Poly or Plastic	A	A	A	A	2	A	A
Brass or Copper Alloys	N	N	N	N	N	N	N
Plugs, Valves, Tank Inserts							
Stainless Steel	A	A	A	A	A	A	A
Nickel Stainless Insert	A	A	A	A	2	A	A
Fully Lined Metal Stainless Insert	A	A	A	A	N	A	A
Nylon Ball Valve	A	A	A	A	A	A	A
Forged Steel	A	A	A	2	N	A	A
Cast Iron/Mild Steel	N	N	A	N	N	N	N
Poly or Plastic	A	A	A	A	2	A	A
Brass or Copper Alloys	N	N	N	N	N	N	N
Plumbing							
Stainless Steel	A	A	A	A	A	A	A
Forged Steel	A	A	A	2	N	A	A
Cast Iron/Mild Steel	1	1	A	N	N	3	3
Galvanized	N	N	A	N	N	N	3
PVC/Other Synthetics	2	2	2	A	2	2	2

Source: Wisconsin Department of Agriculture, Trade and Consumer Protection