API 653 TANK INSPECTION,
TANK MAINTENANCE,
AND
CAUSES OF TANK FAILURE

HEARTLAND
TANK SERVICES, INC.


32-0-0

API 653 Tank Inspections

Why Inspect Your Tanks?

- Prevent leaks into your secondary containment or to groundwater (if you do not have a secondary containment system)
- Establish a baseline of tank condition and corrosion rates
- Identify problems to perform repairs before you have a significant leak or release - **Maintain your capital asset**
- Minimize chance of catastrophic tank failure

PROPER INSPECTION PROTOCOL

INSPECTOR CREDENTIALS

- Certified API 653 Inspector
  - Four years minimum experience with storage tanks
  - Must pass test conducted by American Petroleum Institute (API)
    - Inspectors receive an individual inspector number
    - Inspector testing required every three years

PROPER INSPECTION PROTOCOL

- Visual inspection of welds, plates, and appurtenances
- UT (Ultra-sonic Thickness) testing of shell courses, floor, and roof
- Vacuum testing of all floor weld seams – unless epoxy coated
- Identify bottom side corrosion on floors
- Settlement Survey
    - Checking for planar tilt
    - Check for floor bulges or depressions
- Provide calculations for safe or maximum fill height

Weld deterioration

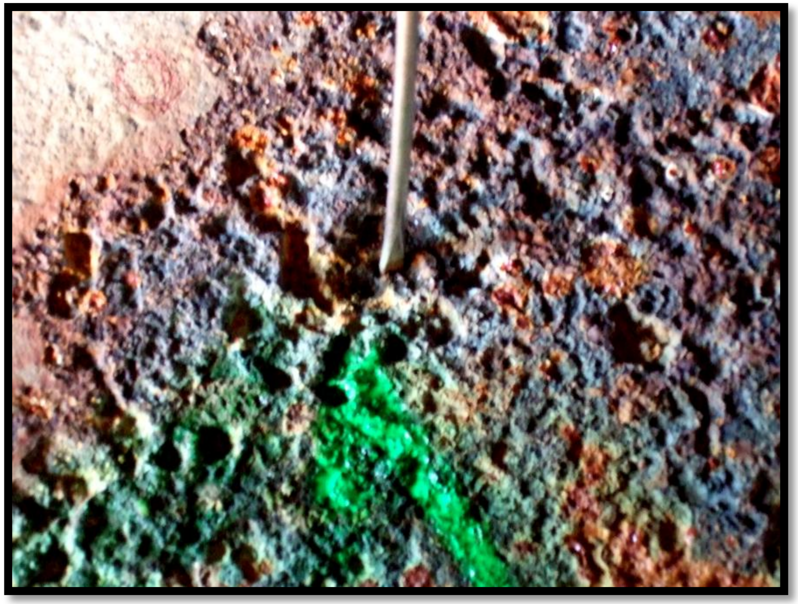


Plate corrosion

Interior piping corrosion

Shell corrosion

Weld deterioration and four-way junction – NON API

Four-corner insert with reinforcing backup – NON API

Evidence of interior shell corrosion

Foundation evaluation

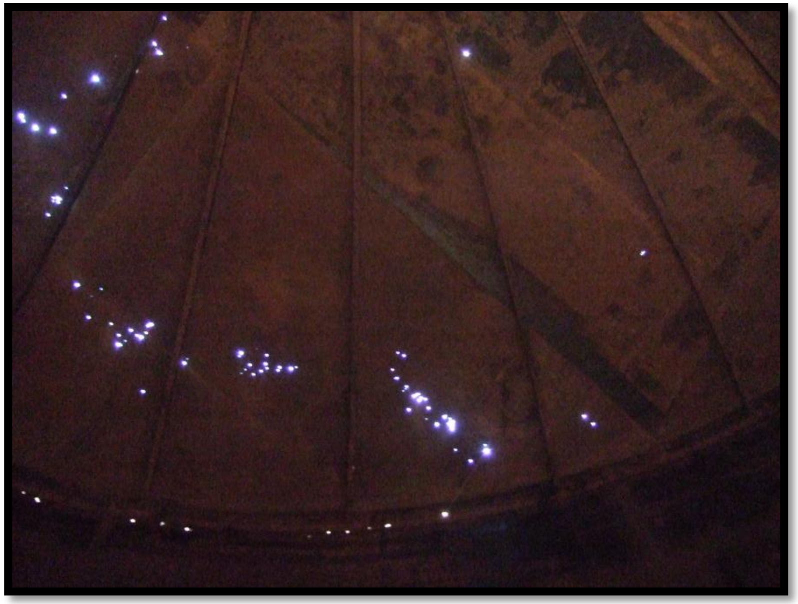
Floor plate corrosion

Lap-welded seam leak

Floor coupon with bottom side corrosion

Floor top side corrosion

Severe roof corrosion



Star light . . . Star bright!

1.0 Executive Summary

On August 5, 2010, an API Standard 653 Out-of-Service inspection was completed on the primary tank of a double-wall above ground storage tank used for storing 28% Nitrogen Solution at the Martin, Ohio facility owned by Helena Chemical Company, Inc. This inspection was conducted to collect data in order to evaluate the tank's mechanical integrity and fitness for continued service. The inspection was conducted in accordance with client criterion for Non Destructive Examination (NDE) which included visual, vacuum and Ultrasonic Thickness (UT) Examinations.

Tank #1 was built in 2000 by Ebert Enterprises using A-36 materials to API 650 specifications for storing 28% Nitrogen Solution. The primary tank measures 73' diameter x 32' high. External welds on the shell, roof and floor of the primary tank were visually examined. The joints on the shell plates were butt-welded vertically and horizontally. Joints on roof and floor plates were lap-welded. External shell was visually examined and there is no external coating of primary tank #1.Neither radiograph nor soil reports were available at the time of the inspection.

Ultrasonic Thickness (UT) measurements were performed on the tank's shell plates in six (6) locations according to a consistent test pattern. On the lower courses, every sheet was numbered and tested. On the upper courses, four (4) sheets on each course were numbered and tested. On the roof plates, a single measurement was taken in the center of each plate. The sheet numbers and locations are depicted in Appendix C

Summary Conclusions:

- The thicknesses of all shell courses and roof plates are above API minimum thickness requirements.
- MAXIMUM FILL HEIGHT IS 31.2' WITH 28% NITROGEN SOLUTION.
- All floor plates are above API minimum thickness requirements.
- Internal vertical & horizontal shell welds are in good condition.
- External shell and welds are in good condition.

Summary of Recommendations:

- Coat the internal shell and floor with proper epoxy coating to prevent corrosion.
- Keep product below the internal roof structure.

Based in The Fertilizer Institute recommendations and the state of Ohio permit requirements, this tank's next inspection intervals are.

- UT Thickness: 08/05/15
- Internal: 08/05/15
- External: 08/05/15

2.0 Tank Data

Tank #:	#2	***Diameter:***	53’
Client:		***Height/Length:***	32’
Location:	, Nebraska	***Corr. Allowance***	0.000
Inspection Date:	August 17, 2010	***Joint Eff:***	1.00
Type Inspection:	API 653 Out-of-Service	***Specific Gravity***	1.35
Test Methods:	Visual & UT	***Plate Spec:***	A 36M
Manufacturer:	HMT, Inc.	***Course 1 t:***	0.312
Year Built:	1998	***Course 2 t:***	0.250
Const. Code:	API 650	***Course 3 t:***	0.250
Capacity:	528,073 gallons	***Course 4 t:***	0.250
Shell Const:	Butt-Welded	***Course 5 t:***	
Roof Type:	Fixed / Cone	***Course 6 t:***	
Foundation:	Earthen	***Course 7 t:***	
Fill Height without Liner:	32’	***Course 8 t:***	
Fill Height with Liner:	30’ 2”	***Roof / Head 1 t:***	0.187
Product:	10-34-0 Nitrogen Solution	***Bttm / Head 2 t:***	

3.0 Inspection Results

3.1 Foundation:

3.1.1 The PRIMARY TANK was constructed inside a larger secondary containment tank and seal welded to secondary tank floor. Welds were visually examined and found to be in good condition.

3.1.2 A settlement survey of the primary tank was completed from the inside of the tank. Beginning at the shell man-way moving clockwise around the tank, eight (8) equally-spaced measurements were performed around the outer circumference of the tank at the chime. Results reveal the primary tank was found to be within the parameters allowed by API Specifications and the tank is fit for continued service.

3.2 Shell:

3.2.1 UT measurements were performed on all shell courses on the primary tank. A weld joint efficiency of 0.90 and a specific gravity of 1.33 were used in the minimum thickness calculations. Results reveal all shell courses to be above the API minimum thickness requirements. All shell courses are fit for continued service.

3.2.2 Calculation results from this inspection reveal the maximum fill height of the primary tank is 32.0' according to API Specifications. However, fill height should remain below the roof rafter system.

3.2.3 During the external visual examination of the primary tank's shell plates, an overall smooth surface texture was observed.

3.2.4 Welds in the external vertical and horizontal shell weld joints were visually examined and found to be in good condition.

3.2.5 Welds on the internal side of the shell were visually examined and generalized corrosion was observed.

3.3 Appurtenances:

3.3.1 The primary tank is equipped with:

- two (2) 6" nozzles located in the lower first shell course on the south side of tank.
- two (2) leak monitors attached to secondary tank.

3.3.2 Welds on all nozzles and re-pads were visually examined and found to be in good condition and fit for continued service. Welds on valve couplings were visually examined and found to be in good condition.

3.4 Roof:

3.4.1 UT measurements were performed in the center of each roof plate on the primary tank. Results reveal all roof plates to be above API minimum thickness requirements and are fit for continued service.

3.4.2 Welds in roof plate joints were visually examined and found to be in good condition with no corrosion present.

3.4.3 The primary tank is equipped with one (1) 10" roof vent and one (1) 12" roof vent. Welds on roof vents were visually examined and found to be in good condition. The roof vents are equipped with proper screens and were found to be in good condition.

3.4.4 Roof of the primary tank is equipped with one (1) 24" roof man-way. Welds on man-way and attachments were visually examined and found to be in good condition and fit for continued service.

3.4.5 Roof of the primary tank is equipped with one (1) 6" gauge hatch, three (3) 1 ¼ " gauge pipes, and one (1) 38" x 38" access hatch on the east side of the roof between the primary and secondary tanks. Welds on all roof attachments were visually examined and found to be in good condition.

Tank Shell Minimum Thickness and Remaining Life Calculations				Date	8/17/2010
File No	Report No	Client	Inspector	Tank No	Temp. (°F)
41	HTS-10- 118		Richard Buntt	#2	

SHELL MINIMUM THICKNESS CALCULATIONS

$$t_{min} = \frac{2.6D(H-1)G}{SE}$$

Where:

H = The height above the bottom of the course of study to the maximum liquid level height of the product, in feet (meters). For corroded or pitted areas, H = the height from the bottom of the corroded or pitted area to the maximum liquid level height of the product, in feet (meters).

tmin = The calculated minimum acceptable shell thickness, in inches (must be greater than 0.1 inch (2.5 mm) for any course). The minimum acceptable shell thickness allowed by API-653 for tank size, in inches (mm) or an alternate tmin based on low pressure calulations (int and/or ext pressures) or nominal thickness minus design corrosion allowance.

D = Nominal diameter of tank, in feet (meters).

G = Highest specific gravity of the contents (including test water if tank will, or may, be tested in the future).

S = Maximum allowable stress, in psi. For welded tanks; use the smaller of 0.80Y of 0.429T for bottom and second course or the smaller of 0.88Y or 0.472T for all other courses. For riveted tanks; S = 21,000 psi. (145 MPa)

Y = Specified minimum yield strength of the plate, in psi; use 30,000 psi (200 MPa) if not known (N/A for riveted tanks).

T = The smaller of the specified minimum tensile strength of the plate or 80k psi (550 MPa); use 55,000 psi (380 MPa) if not known (N/A for riveted tanks).

E = Original joint efficiency for the tank. For welded tanks; use API-653, Table 4-2 ; use E = 1.0 when evaluating the retirement thickness in a corroded plate, when away from welds or joints by at least the greater of one inch (250 mm) or twice the plate thickness. For riveted tanks; use E = 1.0 for shell plates greater than 6 inches (150 mm) away from rivets; use the value of E from API-653 Table 2-1 when within 6 inches (150 mm) of rivets.

D (ft)	G	E	Fill Height (ft)
53	1.35	1.00	32.0

	Material	Crs H (ft)	H (ft)	S (psi)	tmin (in)
Course 1	A 36M	8.00	32.00	24900	0.232
Course 2	A 36M	8.00	24.00	24900	0.172
Course 3	A 36M	8.00	16.00	27400	0.102
Course 4	A 36M	8.00	8.00	27400	0.100

Tank Shell Minimum Thickness and Remaining Life Calculations				Date	8/17/2010
File No	Report No	Client	Inspector	Tank No	Temp. (°F)
41	HTS-10- 118		Richard Buntt	#2	

SHELL REMAINING LIFE CALCULATIONS

Ca = tact-tmin = Remaining Corrosion Allowance (inches (mm))
Cr = tprev-tact / Y = Corrosion Rate (inches (mm) per year)
RL = Ca / Cr = Remaining Life (years)
Y = 12 = Tank age (years)

Where:

Ca = Remaining corrosion allowance of the shell course under consideration, in inches (mm).

Cr = Corrosion rate of the shell course under consideration, in inches (mm) per year.

FHc = Calculated Fill Height = SEtact/2.6DG+1 (SEtact/4.6DG+.3)

tact = Minimum thickness measurement of the shell course under consideration, as recorded at the time of inspection, in inches (mm).

tmin = minimum required thickness of shell course, at the maximum allowable fill height, in inches (mm)

tprev = previous thickness measurement of shell course under consideration, as recorded at last inspection or nominal thickness if no previous thickness measurements, in inches (mm).

RL = Estimated remaining life of the shell course under consideration, in years.

Y = Time span between thickness readings or age of the tank if nominal thickness is used for tprev, in years.

Course	tprev	tact	tmin	Ca	Cr	RL	FHc
Course 1	0.312	0.301	0.232	0.069	0.0009	75.7	41.29
Course 2	0.250	0.240	0.172	0.068	0.0008	81.8	41.12
Course 3	0.250	0.241	0.102	0.139	0.0008	185.5	52.50
Course 4	0.250	0.234	0.100	0.134	0.0013	100.5	59.47

SHELL SETTLEMENT SURVEY
API-653 APPENDIX B SETTLEMENT EVALUATION

Date: 6/9/2010

File No	Report No	Client	Inspector	Tank No	1st Crs Plt Spec
7	HTS-10-221		Doug Perry	#1	Unknown

S <= 11L^2Y/2EH

U = Measured out-of-plane settlement in relation to a cosine curve, in feet
S = Deflection, in feet, (out-of-plane distortion)
L = Arc length between measurement points, in feet
Y = Yield strength, in pounds per square inch (psi)
E - Young's modulus, in pounds per square inch (psi)
H = Tank height, in feet

D	L	Y	E	H	S - Max Permissible
52	20.42	30000	29000000	31.5	0.075

	Feet	Inches	Feet	U	S	Results
Point 1	3	9.000	3.75	0.000	0.002	SAT
Point 2	3	9.200	3.77	0.007	0.000	SAT
Point 3	3	9.400	3.78	0.014	-0.001	SAT
Point 4	3	9.600	3.80	0.022	0.016	SAT
Point 5	3	9.400	3.78	-0.002	-0.009	SAT
Point 6	3	9.400	3.78	-0.008	0.008	SAT
Point 7	3	9.200	3.77	-0.030	-0.010	SAT
Point 8	3	9.200	3.77	-0.032	0.008	SAT
Point 9	3	9.000	3.75	-0.050	-0.010	SAT
Point 10	3	9.000	3.75	-0.049	-0.024	SAT
Point 11	3	9.000	3.75	-0.046	-0.009	SAT
Point 12	3	9.200	3.77	-0.025	0.008	SAT
Point 13	3	9.200	3.77	-0.019	-0.010	SAT
Point 14	3	9.400	3.78	0.006	0.017	SAT
Point 15	3	9.200	3.77	-0.002	0.000	SAT
Point 16	3	9.000	3.75	-0.010	-0.009	SAT

High Point: 3.75 Ft

Low Point: 3.80 Ft

Planar Tilt: 0.05 Ft; 0.60 In.

Cosine Curve R^2: 0.24

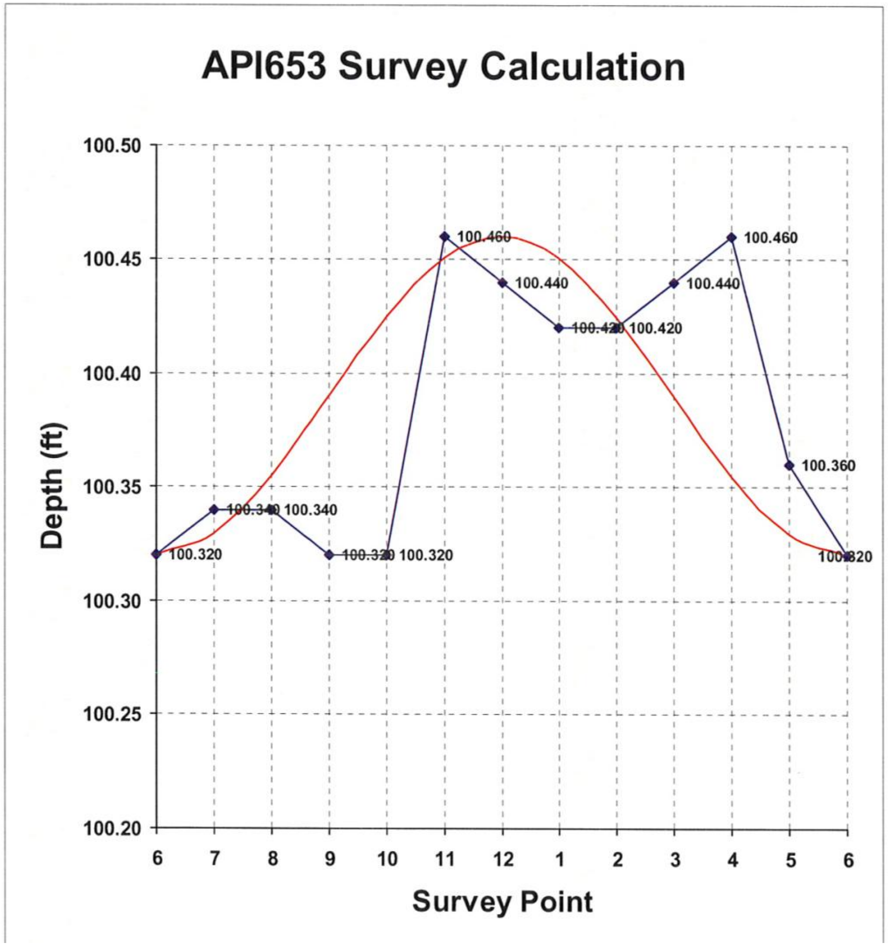
Notes:

Sixteen equally spaced settlement measurements were performed around the outside circumference of the tank at the floor plate that sticks out beyond the shell.

SHELL SETTLEMENT SURVEY
API-653 APPENDIX B SETTLEMENT EVALUATION

Date 8/7/2010

Report No	Client	Inspector	Tank No	1st Crs Plt Spec
HTS-10-155		Richard Buntt	#17	A 36M



API-653 ATMOSPHERIC STORAGE TANK FIXED ROOF EVALUATION
MINIMUM THICKNESS, REMAINING LIFE, PRESSURE CALCULATIONS

Date: 10/12/2010

File No	Report No	Client	Inspector	Tank No	Temp. °F	Ca
60	HTS-10-271		Doug Perry	#1		0.000

Where;
Ca = remaining corrosion allowance of the tank component under consideration, in inches (t act - t min).
Cr = corrosion rate of the tank component under consideration, in inches per year (t prev - t act / Y).
oz = unit of measurement, (weight, in ounces, per square inch), (16 oz per pound)
psi = unit of measurement, (weight, in pounds, per square inch)
RL = estimated remaining life of the tank component under consideration, in years (Ca / Cr).
t act = actual thickness measurement of the tank component under consideration, as recorded at the time of inspection, in inches.
t min = minimum required thickness of tank component, at the design MAWP at the design temperature (200°F for atm AST's), in inches (greater of psi/wt or 0.090").
t nom = design nominal thickness of tank component under consideration, in inches.
t prev = previous thickness measurement of the tank component under consideration, as recorded at last inspection or nominal thickness if no previous thickness measurements, in inches.
t yn = thickness of the tank component under consideration at the next inspection at twice the calculated corrosion rate, in inches (t act - (2*Cr*Yn).
wt = weight of plate per cubic inch.
wc = unit of measurement, (height, in inches, of water column bearing on 1 square inch area), (27.7 wc per pound)
Y = time span between thickness readings or age of the tank component if tnom is used for tprev, in years.
Yn = estimated time span to next inspection of the tank component under consideration, in years

ROOF PLATES - REMAINING LIFE

Y	t prev	t act	t min	Cr	Ca	RL
15	0.187	0.176	0.090	0.00073	0.086	117

ROOF MAXIMUM ALLOWABLE INTERNAL PRESSURE

Material Catagory	wt	Yn	t yn	psi	oz.	wc
CS/Crom. Stl	0.2833	5	0.169	0.048	0.765	1.32

RELIEF VALVE SETTING EVALUATION

Setting	Unit	=	(psi)	Max Allowed	
				0.765	oz

Relief setting is satisfactory

Ultrasonic Thickness Measurements were performed in the center of each roof plate at the time of the examination.

STORAGE TANK FLOOR EVALUATION
MINIMUM REMAINING THICKNESS (MRT) CALCULATIONS

Date: 10/12/2010

File No	Report No	Client	Initials	Tank No	Temp. °F
60	HTS-10-271		Doug Perry	#1	

Liner	CP Protec.	50mil Liner	Leak Det.	Ca	Shell tmin	Shell tnom	D	H	S
No	No	No	No						

Where;
Ca = corrosion allowance, in inches.
MRT = minimum remaining thickness at the end of interval Or. This value must meet the requirements of Table 4-1 and sections 2.4.7.4 and 2.4.8.
Or = In-service interval of operation (years to next internal inspection) not to exceed that allowed by 4.4.2.
RTbc = minimum remaining thickness from bottom side corrosion after repairs.
RTip = minimum remaining thickness from internal corrosion after repairs.
StPr = maximum rate of corrosion not repaired on the top side. StPr = 0 for coated areas of the bottom. The expected life of the floor must equal or exceed Or to use StPr = 0.
tmin = minimum allowable thickness in accordance with requirements of Table 4-1 and sections 2.4.7.4 and 2.4.8
to = original (nominal) thickness of floor plate under consideration, in inches.
UPr = maximum rate of corrosion on the bottom side. To calculate the corrosion rate, use the minimum remaining thickness after repairs. Assume a linear rate based on the age of the tanks. UPr = 0 for areas that have effective cathodic protection.
D = nominal diameter of tank, in ft.,
H =Height, in feet, from the bottom of the 1st shell course to the maximum allowable fill height
S = Stresses are calculated from [2.34 D (H-1)]/t

GENERAL PLATES - AFTER INSPECTION / REPAIRS

Age	to	RTbc	RTip	UPr	StPr	Or	MRT	tmin	Results
15	0.250	0.237	0.237	0.00087	0.00087	5	0.228	0.100	ACCEPTABLE

PLATES IN CRITICAL ZONE (3") - AFTER INSPECTION / REPAIRS

Age	to	RTbc	RTip	UPr	StPr	Or	MRT	tmin	Results
15	0.250	0.237	0.237	0.00087	0.00087	5	0.228	0.100	ACCEPTABLE

ANNULAR PLATES - AFTER INSPECTION / REPAIRS

Age	to	RTbc	RTip	UPr	StPr	Or	MRT	tmin	Results

Ultrasonic Thickness Measurements were performed in five designated locations on each floor plate.

API-653 STORAGE TANK EVALUATION

AST Component Inspection Data

Report No	Client	Inspector	Vessel	Date
HTS-10			#2	

Component Thickness Measurements (in inches)

CML	Component	Location	tml-1	tml-2	tml-3	tml-4	tml-5	tml-6	Minimum
001	Shell Crs 1	Plt1	0.342	0.345	0.334	0.336	0.345	0.335	0.334
002	Shell Crs 1	Plt2	0.340	0.328	0.350	0.357	0.333	0.371	0.328
003	Shell Crs 1	Plt3	0.323	0.337	0.325	0.316	0.323	0.332	0.316
004	Shell Crs 1	Plt4	0.327	0.364	0.355	0.361	0.325	0.366	0.325
005	Shell Crs 1	Plt5	0.334	0.348	0.344	0.363	0.340	0.373	0.334
006	Shell Crs 1	Plt6	0.352	0.355	0.358	0.359	0.350	0.347	0.347
007	Shell Crs 2	Plt1	0.221	0.282	0.247	0.218	0.226	0.243	0.218
008	Shell Crs 2	Plt2	0.224	0.231	0.226	0.229	0.222	0.256	0.222
009	Shell Crs 2	Plt3	0.219	0.224	0.229	0.220	0.218	0.270	0.218
010	Shell Crs 2	Plt4	0.213	0.233	0.209	0.252	0.207	0.252	0.207
011	Shell Crs 2	Plt5	0.214	0.266	0.248	0.226	0.227	0.250	0.214
012	Shell Crs 2	Plt6	0.251	0.233	0.223	0.253	0.223	0.273	0.223
013	Shell Crs 3	Plt1 N.	0.212	0.204	0.195				0.195
014	Shell Crs 3	Plt2 S.	0.210	0.205	0.204				0.204
015	Shell Crs 3	Plt3 E.	0.189	0.185	0.183				0.183
016	Shell Crs 3	Plt4 W.	0.211	0.204	0.207				0.204
017	Shell Crs 4	Plt1 N.	0.196	0.217	0.194				0.194
018	Shell Crs 3	Plt2 S.	0.203	0.200	0.212				0.200
019	Shell Crs 4	Plt3 E.	0.189	0.190	0.195				0.189
020	Shell Crs 4	Plt4 W.	0.189	0.183	0.187				0.183
021	Roof	Plt1	0.213						0.213
022	Roof	Plt2	0.185						0.185
023	Roof	Plt3	0.186						0.186

Shell CML Locations

Primrose, NE
Tank #1
15' diameter x 55' high
October 13, 2010

Course 3, 4, 5 & 6

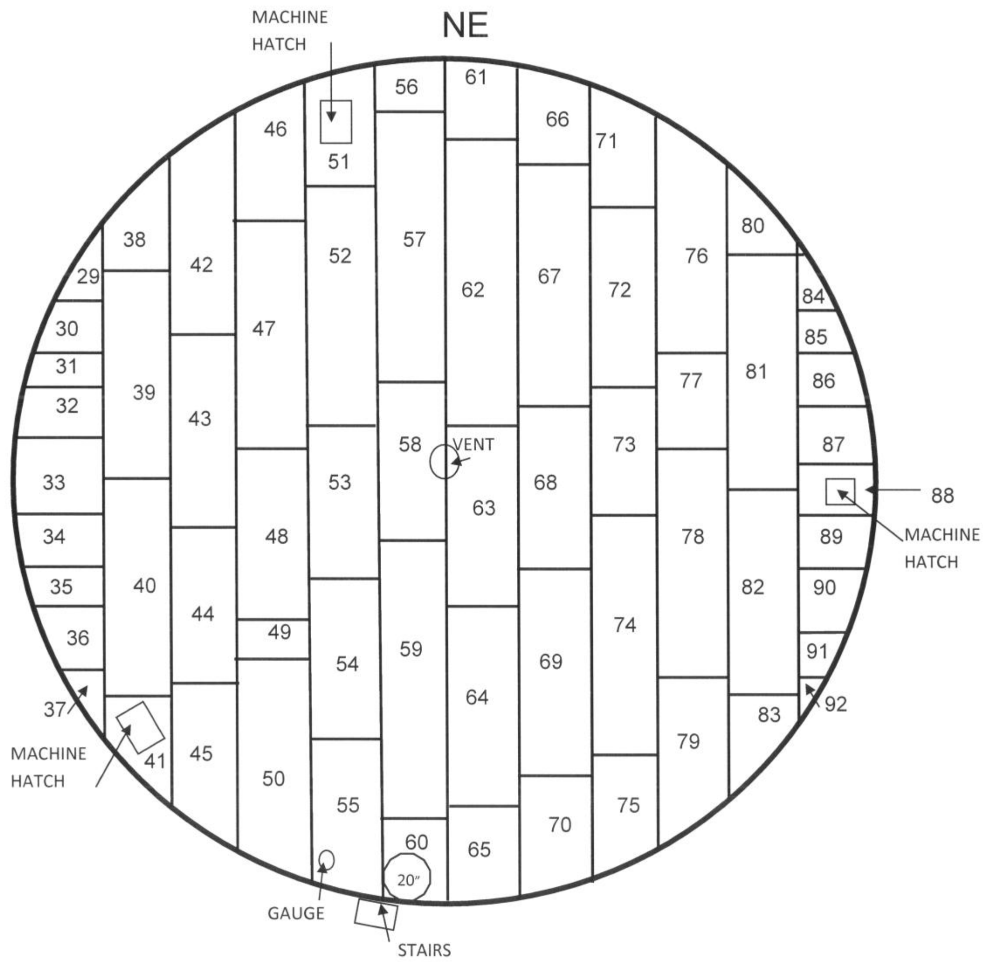
NORTH	SOUTH	EAST	WEST
21	22	23	24
17	18	19	20
13	14	15	16
9	10	11	12

Courses 1 & 2

5	6	7	8
1	2	3	4

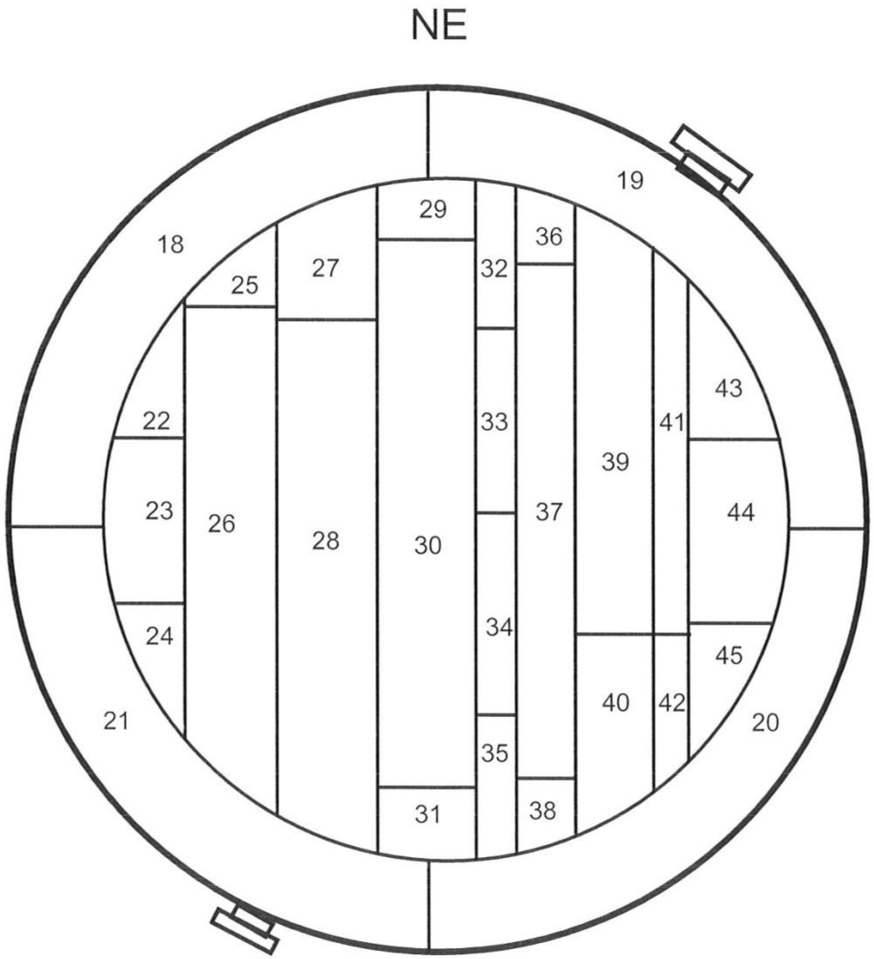
Roof CML Locations

Garden City, KS
Tank #8
104' diameter x 32' high
August 5, 2010



Floor CML Locations

Crop Production Services, Inc.
Alpaugh, CA
Tank #150
33.2' diameter x 32' high
June 7, 2010




08/18/2010


08/11/2010

TANK INSPECTIONS ARE NOT ALWAYS A BAD THING

THIS IS A HAPPY TANK

TANK MAINTENANCE – COMMON SENSE APPROACH

- Conduct monthly/weekly walk-around of your tank(s)
  - Look for stains on steel where leak may be occurring
  - Check valve function and nozzle welds
  - Check associated piping
  - Check foundation for wash-out/deterioration
- Keep good records of product in and out

TANK MAINTENANCE – COMMON SENSE APPROACH

- Open up your tank a minimum of every two years and conduct your own visual inspection inside
  - Check for weld deterioration and corrosion
  - If tank is coated, visually check coating for blisters or cracks
- Keep a record of inspections and results
- If tank has an internal containment liner, check leak monitor weekly
- Conduct an API-653 inspection of your tank every five years as recommended by **TFI (The Fertilizer Institute)**

WHAT IS THE API 650 SPECIFICATION

API - AMERICAN PETROLEUM INSTITUTE

Worldwide Standard for Above Ground Storage Tank Design and Construction

- Provides requirements for calculations of shell plate thickness, man-way and nozzle design
- Provides procedures for shell, roof and floor construction
- Specifies material requirements and minimum thickness requirements
- Specifies weld construction requirements, weld spacing, and x-ray requirements

CAUSES OF CATASTROPHIC TANK FAILURE

TANK FAILURES – COMMON CAUSES

- Tank shell plates not thick enough for specific gravity of product stored
- Over-filling of tank – over pressure
- Cut-down and re-erected tanks using improper cutting and re-welding procedures
- Improper weld procedures
  - Lack of full weld penetrations (lack of weld fusion)
  - Improper weld seam spacing
  - Lack of radiograph (x-ray) of newly constructed tanks or on repaired tanks

TANK FAILURES – COMMON CAUSES

- Lack of weld fusion - #1 common cause
  - Welders not certified and tested to weld procedure
- Weld deterioration/corrosion – especially in lower horizontal and vertical weld seams
- Brittle fracture of steel
- Lack of proper certified inspections
- Tank erectors who know little about API Specifications and procedures – these companies attract customers with a “cheap” price. Make certain your contractor can verify that your tank meets API Specifications. **DO YOUR OWN HOMEWORK**

Cut-down and re-welded tank

Improper weld spacing

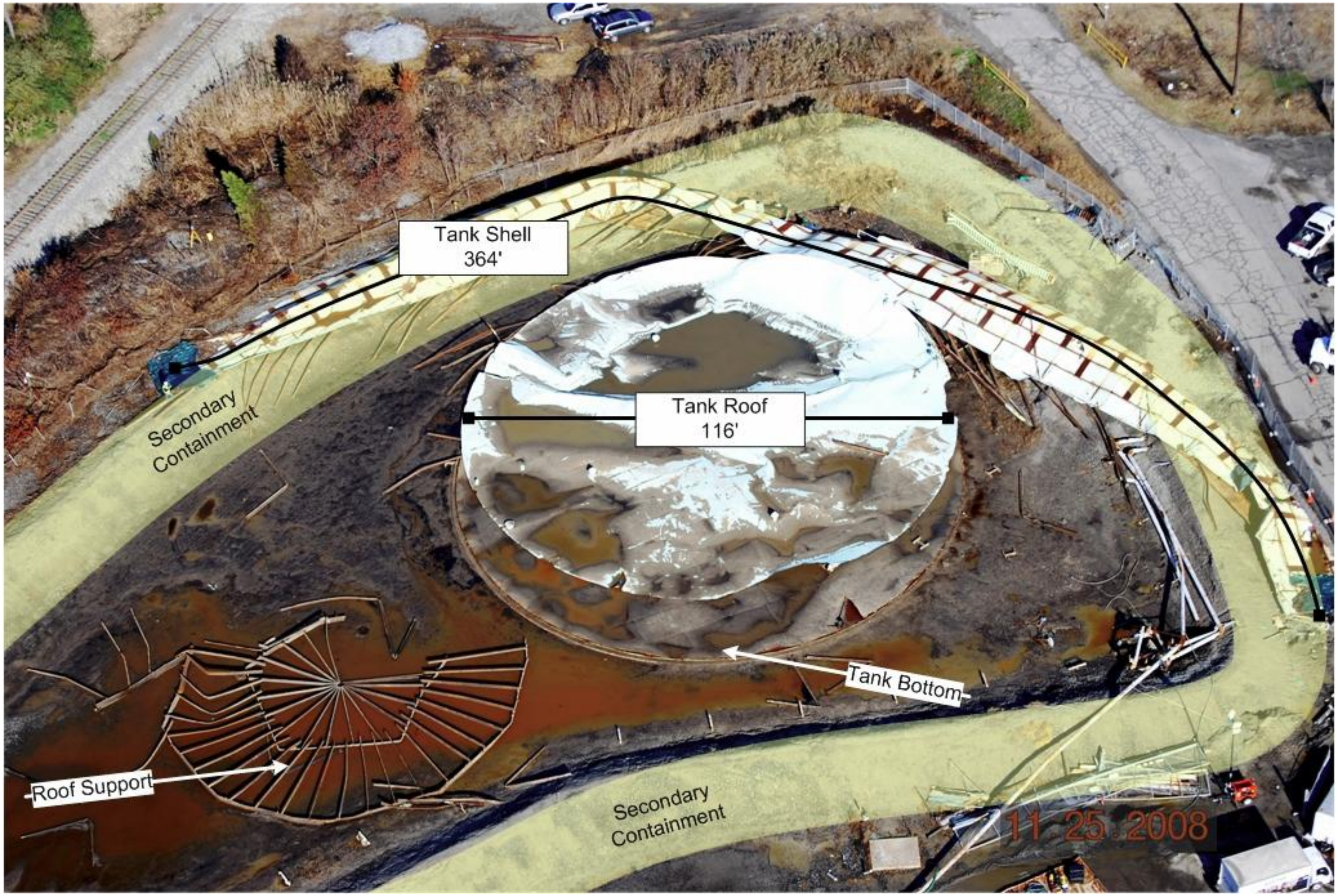
Double wall 500,000 gallon tank, Illinois 2008

Cause – overfilling and lack of fusion on weld seams

Yards of destruction

Original tank foundation

Weld seam rupture. Force of rupture "pushes back". Rupture on side of camera location.


Tank Shell
364'
Tank Roof
116'
Secondary
Containment
Tank Bottom
Roof Support
Secondary
Containment
11 25 2008

earthquake video