washington river protection solutions

Double-Shell Tank Construction:

Extent of Condition

T.J. Venetz
Tank and Pipeline Integrity

April 2014

Double-Shell Tanks at Hanford

Double-Shell Tank Construction and Age as of 2014

Tank Farm	Number of Tanks	Construction Period	Construction Project	Initial Operation	Service Life	Current Age
241-AY	2	1968 – 1970	IAP-614	1971	40	43
241-AZ	2	1970 – 1974	HAP-647	1976	20	38
241-SY	3	1974 – 1976	B-101	1977	50	37
241-AW	6	1976 – 1979	B-120	1980	50	34
241-AN	7	1977 – 1980	B-130, B-170	1981	50	33
241-AP	8	1982 – 1986	B-340	1986	50	28
Total	28					

Tank 241-AY-102 Construction Issues

- First-of-a-Kind Construction at Hanford
- Construction Problems
  - Secondary Liner Distortion
  - Insulating Refractory Cracking
  - Primary Tank Bottom Plate Weld Rejection
  - Stress Relief Difficulties
  - Insulating Refractory Damage from Stress Relief and Hydrostatic Testing of Primary Tank leading to Perimeter Replacement

Records Reviewed

- Construction review involved a large quantity of project documentation pulled from records storage.
- Emphasis on Specifications, Letters, Quality Assurance (QA) Inspection Logs, Status Reports, Weld Inspection Records, Non-conformance Reports, Deficiency Reports, and Photographs.
- Represents a targeted review of construction records to identify items of concern.

	Tank Farm	Number of Tanks	Construction Period	Boxes Reviewed
Phase 1	241-AY	2	1968 – 1970	11
	241-AZ	2	1970 – 1974	15
	241-SY	3	1974 – 1976	34
Phase 2	241-AW	6	1976 – 1979	64
	241-AN	7	1977 – 1980	54
	241-AP	8	1982 – 1986	63
	Total	**28**		**241**

- Following completion of Phase 1, the decision was made to proceed to Phase 2.

Extent of Condition Reports

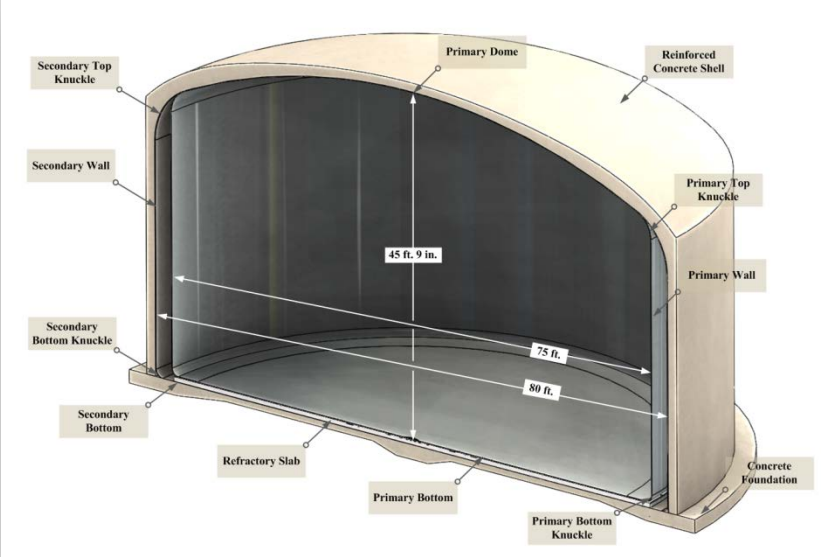
- In total, six (6) Construction Extent of Condition Reviews were developed and approved for public release.
- Tank 241-AY-101 was reviewed independently.
- All other tanks were grouped by tank farm.

Report Number	Report Title
RPP-RPT-54817	*241-AY-101 Tank Construction Extent of Condition Review for Tank Integrity*
RPP-RPT-54818	*241-AZ Tank Farm Construction Extent of Condition Review for Tank Integrity*
RPP-RPT-54819	*241-SY Tank Farm Construction Extent of Condition Review for Tank Integrity*
RPP-RPT-55981	*241-AW Tank Farm Construction Extent of Condition Review for Tank Integrity*
RPP-RPT-55982	*241-AN Tank Farm Construction Extent of Condition Review for Tank Integrity*
RPP-RPT-55983	*241-AP Tank Farm Construction Extent of Condition Review for Tank Integrity*

Tank Construction Contractors

Tank Farm	Primary Contractor	Project #
241-AY	Pittsburgh-Des Moines (PDM) Steel Company	IAP-614
241-AZ	Pittsburgh-Des Moines (PDM) Steel Company	HAP-647
241-SY	Chicago Bridge and Iron (CBI) Company	B-101
241-AW	American Bridge (AB) Company	B-120
241-AN	American Bridge (AB) Company	B-130, B-170
241-AP	American Bridge (AB) Company	B-340

- The primary contractor for each tank farm was chosen with each individual project start.
- Some contractors were chosen for multiple tank farms.
- In general, tank design and construction were similar from farm to farm.
- Any variations will be presented.



General Construction Stages

1. Concrete Foundation

2. Secondary Liner Bottom

3. Castable Refractory

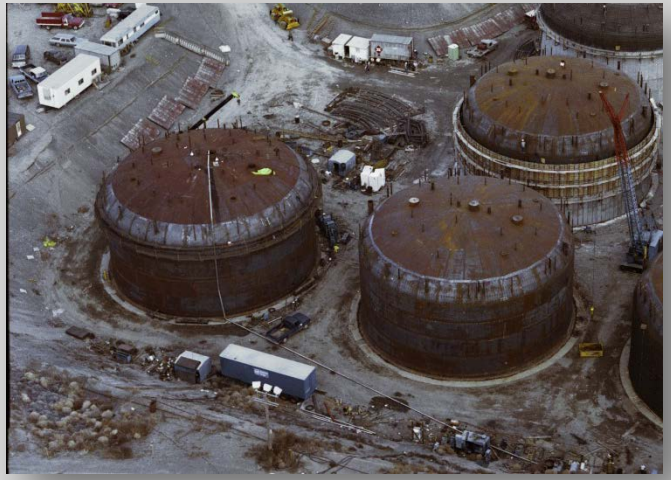
4. Primary Tank Bottom

5. Primary Tank Walls

6. Secondary Liner Walls
7. Primary Tank Dome and Risers

General Construction Stages

8. Primary Tank Stress Relief



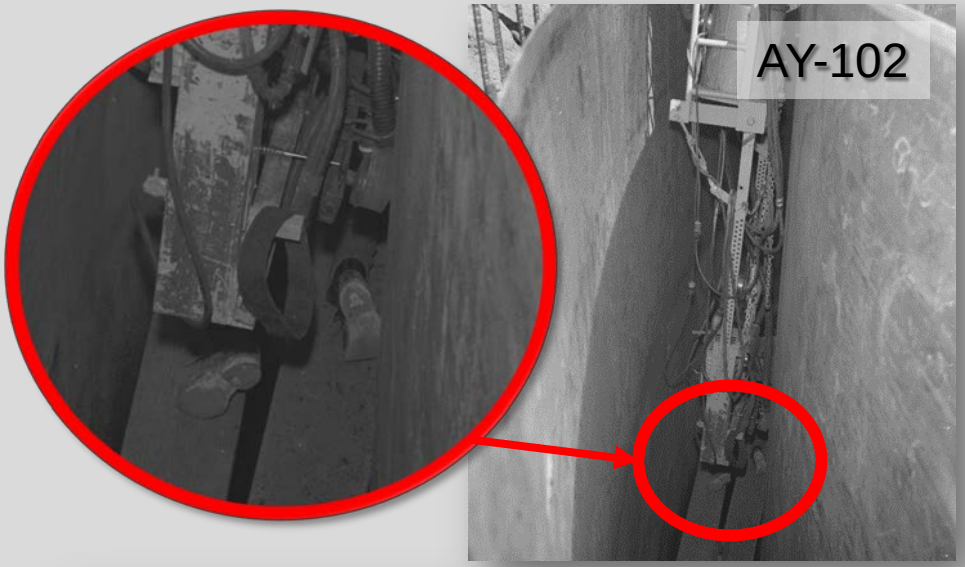
9. Primary Tank Hydrostatic Test

10. Secondary Liner Top Knuckle

11/12. Concrete Shell and Dome

Access Issues During Welding

- Secondary liner completed ahead of primary tank in both 241-AY and AZ Tank Farms.
- Welding primary tank inside completed secondary liner posed unique access challenges.
- Starting with the 241-SY Tank Farm, the primary tank was completed just ahead of the secondary liner.
- Allowed better access to primary tank welds.
- This practice was continued for all other farms.

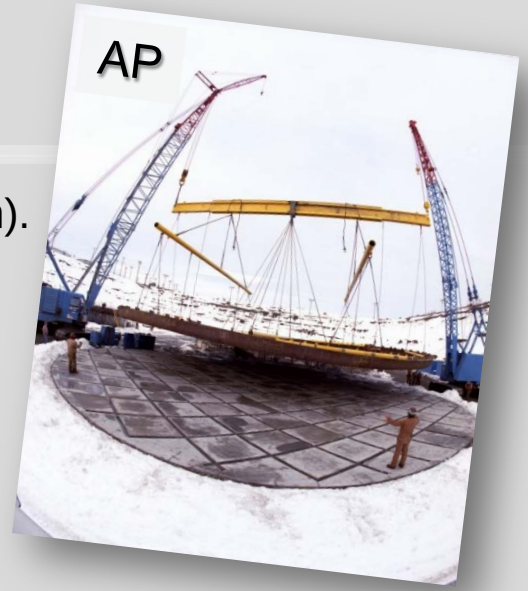


Secondary Liner Bottom Design

- All secondary liners constructed from welded carbon steel.
- Plate thicknesses were increased slightly after construction of the 241-AY Tank Farm.
- A515 carbon steel was a typical material for pressure vessels in the late 1960's (Moderate/High Temp Service).
- A516 carbon steel has smaller grain size and increased resistance to stress corrosion cracking
- A537 carbon steel has smaller grain size, increased notch toughness, and increased resistance to stress corrosion cracking

Tank Farm	Material Type	Plate Thickness (in.)
241-AY	ASTM A515, Gr 60	1/4 (0.25)
241-AZ	ASTM A515, Gr 60	3/8 (0.375)
241-SY	ASTM A516, Gr 65	3/8 (0.375)
241-AW	ASTM A537, Class 1	3/8 (0.375)
241-AN	ASTM A537, Class 1	3/8 (0.375)
241-AP	ASTM A537, Class 1	3/8 (0.375)

Secondary Liner Bottom Issues



- Specification of 3/8” per foot slope for each tank farm (root to crown).
- Tank AY-101: Only slightly less – 6 instances.
- 241-AZ Tank Farm: No NCRs, but inference of minor bulging.
- 241-SY Tank Farm: All tanks had issues.
- 241-AW Tank Farm: Bulges identified in AW-102 and AW-106.
- No identified bulges in 241-AN or 241-AP tank farms.

Tank	Detail
AY-101	Excessive distortion and bulges noted throughout. Maximum slope noted as much as 1 inch per foot. 6 places exceed 2 inch peak-to-valley tolerance.
AY-102	Excessive distortion and bulges noted throughout. Maximum slope noted as much as 1 inch per foot. 22 places exceed 2 inch peak-to-valley tolerance.
AZ-101	Only minor notation, no deficiencies or NCRs found. It was noted that kaolite thickness was increased due to an irregular secondary liner bottom.
AZ-102	Only minor notation, no deficiencies or NCRs found. The log noted that the plate dropped 3/8 inch when kaolite was poured.
SY-101	Out of tolerance in several areas, up to 5/8 inch per foot and an NCR was generated.
SY-102	Out of tolerance in several areas, up to 13/16 inch per foot and an NCR was generated. Flattening attempts were unsuccessful.
SY-103	Weld pattern changed, still out of tolerance, up to 1 inch per foot, NCR generated. Flattening attempts, including a 6000 lb. weight, were unsuccessful.
AW-102	4 bulges identified. All slopes less than 3/4-in./ft. All 241-AW tank farm bulges were accepted based on an engineering evaluation of the 241-SY Bottom Flatness Study authored by Battelle Northwest.
AW-106	19 bulges identified, all bulges less than 3/4 in./ft. and accepted as is. All 241-AW tank farm bulges were accepted based on an engineering evaluation of the 241-SY Bottom Flatness Study authored by Battelle Northwest.

Castable Refractory 241-AY Tank Farm

Castable Refractory Repair with Reinforced Concrete

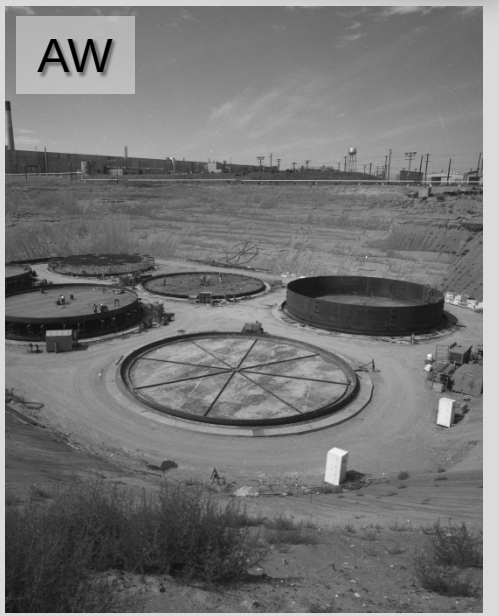
- Extensive cracking and degradation of refractory.
- 21 inch depth removed and replaced with reinforced concrete.
- Done to provide knuckle support.

- Damage attributed to poor weather protection.
- Freezing / water saturation.
- Excessive “steaming” seen during stress relief.

Castable Refractory Degradation

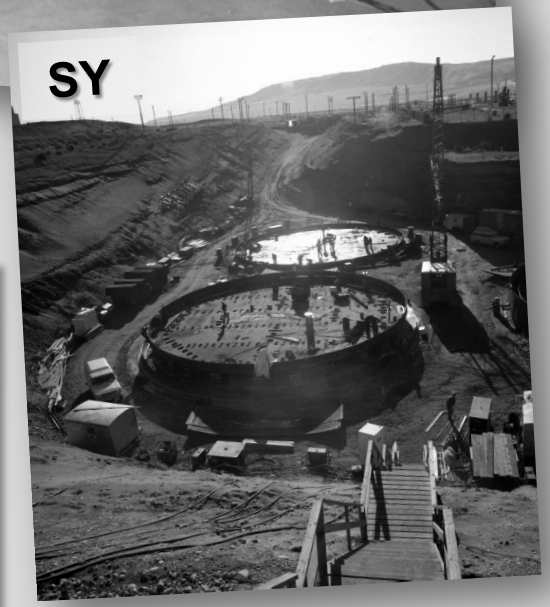
Castable Refractory Issues

- Refractory condition is <u>better</u> in 241-AZ, SY, AW, AN, and AP.
- <u>Tank AY-101</u>: Kaolite 2200LI
  - Similar perimeter condition and repair performed.
- <u>241-AZ Tank Farm</u>: Kaolite 2000
  - Only minor cracking repairs required.
  - Issues with waste compatibility – decomposed in surrogate.
- <u>241-SY Tank Farm</u>: Lite wate 50
  - Some minor cracking repairs required.
  - SY-102: Damage from cribbing – 5ft. x 8 ft. x 2.5 in. area replaced.
- <u>241-AW Tank Farm</u>: Lite Wate 70
  - AW-101: Part of Section D replaced with Enriched Lite Wate 50.
  - AW-102, AW-105, AW-106: Refractory chipped out and replaced.
  - Low compressive strength → Switched to Lite Wate 70.
- <u>241-AN Tank Farm</u>: Lite Wate 70
  - AN-104: 8 ft. x 3/4 in. void between refractory and secondary liner.
  - Drilled hole in the refractory to fill with pourable grout.
- <u>241-AP Tank Farm</u>: Litecrete-60M
  - AP-108: Minor cracking repairs required.



Primary Tank Bottom Design

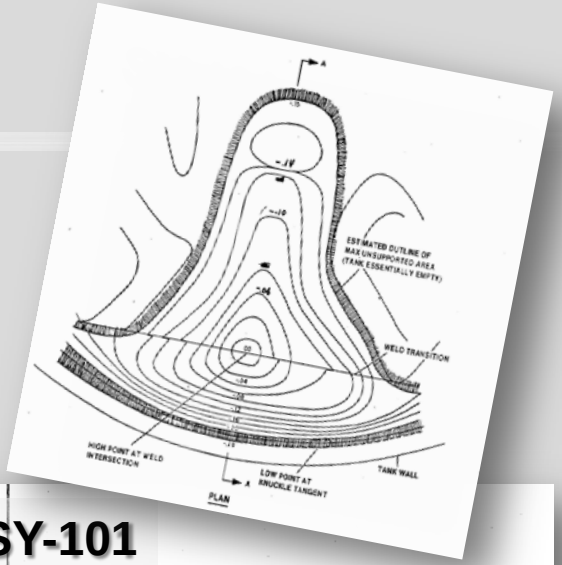
- Same welded carbon steel as secondary liner.
- Rests on the castable refractory pad in all designs.
- 1 in. thick center plate spans center air chamber.

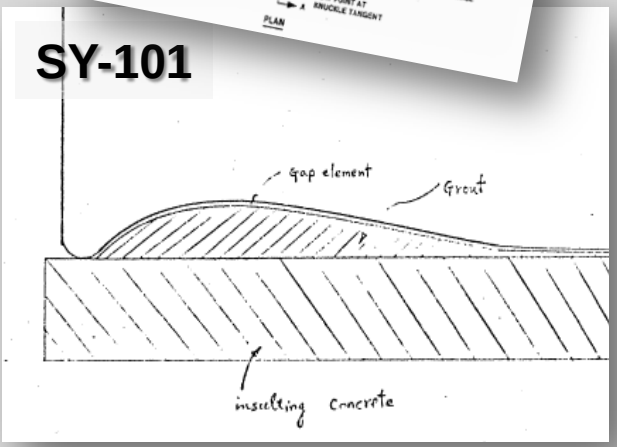


Tank Farm	Material Type	Plate Thickness (in.)
241-AY	ASTM A515-65, Gr 60	3/8 (0.375)
241-AZ	ASTM A515-69, Gr 60	1/2 (0.5)
241-SY	ASTM A516-72, Gr 65	1/2 (0.5)
241-AW	ASTM A537-74a, Class 1	1/2 (0.5)
241-AN	ASTM A537-75, Class 1	1/2 (0.5)
241-AP	ASTM A537-79, Class 1	1/2 (0.5)

Primary Tank Bottom Issues

- Specification of 3/8” per foot slope for each tank farm (root to crown).
- Tank AY-101: Primary bottom flatness described as “generally good.”
- 241-AZ Tank Farm: No indications of bulging.
- 241-SY Tank Farm:
  - SY-101: Several areas out-of-tolerance (Max height = 0.26 ft). Grouted in two locations.
  - SY-102: Initially out-of tolerance. Corrected when lowered.
  - SY-103: Several areas out-of-tolerance. Strain gauge monitoring and acoustic testing during hydrostatic testing used to accept stress levels.
- 241-AW Tank Farm: No indications of bulging.
- 241-AN Tank Farm: AN-102: Initially out-of-tolerance. Corrected when lowered.
- 241-AP Tank Farm: AP-104: Initially out-of-tolerance. Corrected with dead weight.





Tank	Detail
SY-101	Out of tolerance areas noted and plate repairs performed, causing new out of tolerance areas. Maximum bump height of 0.26 feet and bottom grouted in two locations to support primary.
SY-102	Out of tolerance areas noted until primary was lowered and found to be acceptable.
SY-103	Out of tolerance in several areas, up to 13/16 inch per foot. An NCR was generated, which was later accepted based on strain gauge monitoring and acoustic testing during hydrostatic test, showing stresses were acceptable.
AN-102	Initial inspection found the tank bottom to have one out-of-tolerance location. NCR B-130-32 was generated. The NCR was later voided, as a resurvey of the tank bottom found it to be within tolerance.
AP-104	Two out of tolerance areas noted until dead weight was placed on them. Re-survey showed the tank bottom to be within specified tolerances.

Weld Non-Destructive Examination (NDE)

- Construction Specification called for extensive weld NDE on steel liners.

	241-AY	241-AZ	241-SY	241-AW	241-AN	241-AP
100% Visual – Primary and Secondary	✓	✓	✓	✓	✓	✓
100% Radiography – Primary and Secondary	✓	✓	✓	✓	✓	✓
Vacuum Leak Test [1]	✓	✓				
Liquid Penetrant [1]			✓	✓	✓	✓
Magnetic Particle [2]	✓	✓	✓	✓	✓	✓
Hydrostatic Leak Test – Primary [3]	✓	✓	✓	✓	✓	✓

[1] Used on tank bottoms and bottom knuckle, but not on vertical walls
[2] Not used on AZ, SY, and AW secondary liner
[3] Height varied with farm, always above maximum waste level and upper knuckle to dome plate weld

Primary Tank Bottom Weld Rejection

241-AY Tank Farm	
AY-101	10.2%
AY-102	33.8%
241-AZ Tank Farm	
AZ-101	14.5%
AZ-102	6.3%
241-SY Tank Farm	
SY-101	30.1%
SY-102	21.9%
SY-103	25.7%
241-AW Tank Farm	
AW-101	30%
AW-102	31%
AW-103	27%
AW-104	34%
AW-105	31%
AW-106	24%

241-AN Tank Farm	
AN-101	13%
AN-102	13%
AN-103	9%
AN-104	9%
AN-105	15%
AN-106	10%
AN-107	20%
241-AP Tank Farm	
AP-101	6%
AP-102	9%
AP-103	10%
AP-104	9%
AP-105	12%
AP-106	6%
AP-107	7%
AP-108	5%

- Complete primary tank bottom tabulated for each tank.
- Weld seams radiographed in 1 ft. sections.
- Acceptance and rejection counted in these 1 ft. increments.
- All welds were accepted and stress relieved.

$$Weld\ Rejection\ \% = \frac{Rejected\ Weld\ Footage}{Accepted\ Weld\ Footage + Rejected\ Weld\ Footage}\ \text{x}\ 100\%$$

Primary Tank Stress Relief Plan

- Specifications required 1100°F ± 50°F for 1 hour per inch of thickness in all cases.
- ASME code allows for alternate temperatures and hold times.
- This alternate requirement was utilized often.

The time/temperature relationship described is:

F	Hrs./In. Thickness
1050	2
1000	3
950	5
900	10

Primary Tank Stress Relief Issues

- Often couldn't reach 1100°F temp effectively.
  - Difficulties with steaming → Moisture in the refractory ( ).
  - Accurate temperature monitoring → Faulty <u>primary bottom</u> thermocouples ( ).

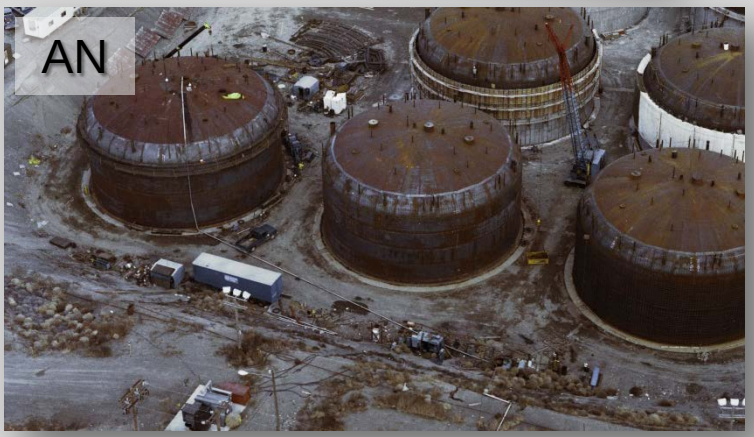
241-AY Tank Farm				
AY-101	1000°F	3 hours		2 days to heat.
AY-102	1000°F	3 hours		5 days to heat.
241-AZ Tank Farm				
AZ-101	1050°F	2 hours		
AZ-102	1000°F	3 hours		
241-SY Tank Farm				
SY-101	1000°F	3 hours		
SY-102	1100°F	1 hour		Steaming
SY-103	1100°F	1 hour		
241-AW Tank Farm				
AW-101	1100°F	1 hour		
AW-102	1000°F	3 hours		
AW-103	1000°F	3 hours		
AW-104	1000°F	3 hours		
AW-105	1000°F	3 hours		Heavy Steaming
AW-106	1000°F	3 hours		Steaming

241-AN Tank Farm				
AN-101	1000°F	3 hours		
AN-102	1000°F	3 hours		
AN-103	1000°F	3 hours		
AN-104	1000°F	3 hours		
AN-105	1000°F	3 hours		Steaming
AN-106	1000°F	3 hours		Steaming
AN-107	1000°F	3 hours		
241-AP Tank Farm				
AP-101	1000°F	3 hours		
AP-102	1000°F	3 hours		
AP-103	1000°F	3 hours		
AP-104	1000°F	3 hours		
AP-105	1000°F	3 hours		
AP-106	1000°F	3 hours		
AP-107	1000°F	3 hours		
AP-108	950°F	5 hours		

Primary Tank Hydrostatic Testing

- Required to hydrostatic leak check the primary tank following stress relief in all cases.
  - Fill to specified height.
  - Hold for 24 hours minimum.
  - Chalk seams to identify leak locations by visual inspection.
- Tanks were all successfully tested.

Tank Farm	Fill Height	Fill Duration
241-AY	39 ft.	24 hours
241-AZ	39 ft.	24 hours
241-SY	39 ft.	24 hours
241-AW	35 ft.	24 hours
241-AN	35 ft.	24 hours
241-AP	40 ft.	24 hours



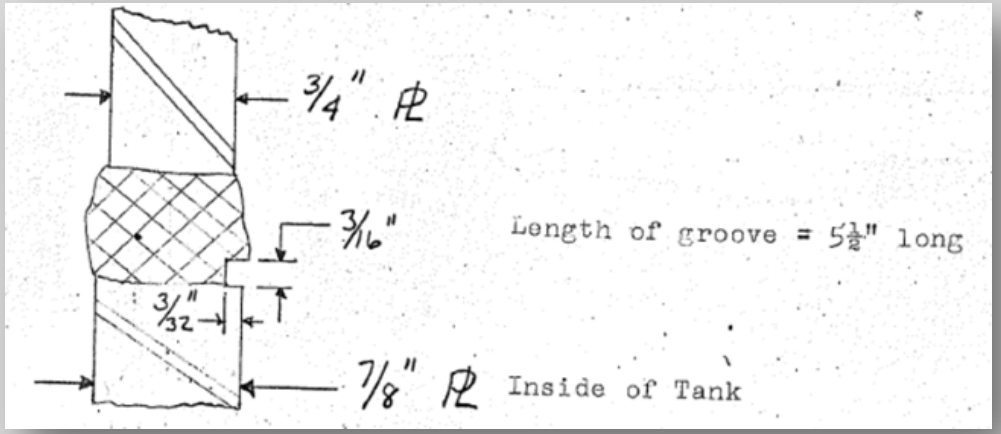
Primary Tank Hydrostatic Testing

- Extensive water storage to provide dome support during concrete dome pouring in AW, AN, and AP.
- 241-AW and 241-AN Tank Farm:
  - Raw water → Leads to minor pitting within the primary tank.
- 241-AP Tank Farm:
  - Corrosion inhibitors and cathodic protection utilized.

Tank	Fill Date	Pump-out Date	Approx. Duration (Months)
AW-101	3/22/1978	12/19/1978	9
AW-102	4/11/1978	12/27/1978	8
AW-103	5/4/1978	12/14/1978	7
AW-104	5/23/1978	1/31/1979	8
AW-105	6/27/1978	12/13/1978	6
AW-106	7/6/1978	2/1/1979	7
AN-101	12/5/1978	8/7/1979	8
AN-102	12/13/1978	7/27/1979	7
AN-103	1/4/1979	7/25/1979	7
AN-104	10/11/1978	8/6/1979	10
AN-105	1/31/1979	8/1/1979	6
AN-106	2/14/1979	7/26/1979	5
AN-107	2/26/1979	7/30/1979	5

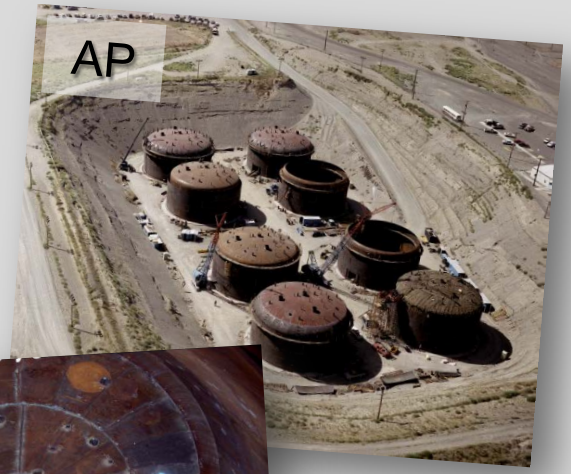
Unique Issues Not Seen in Tank AY-102

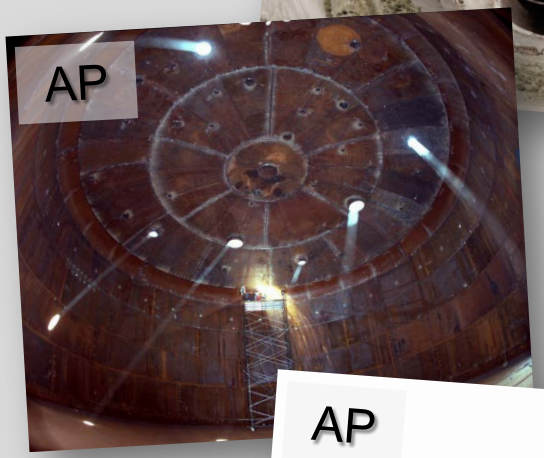
- Plate laminations and surface defects found in 241-AZ, AW, AN, and AP tank farms.
  - Mostly shallow and repaired by surface grinding not to exceed 1/16” depth.
  - Deeper were repaired with weld filler and grinding.
  - Mid-wall laminations found in upper wall of tank AZ-102 – 4 of 6 plates replaced.
- Un-repaired weld grind-out found in tank AZ-101 lower knuckle.

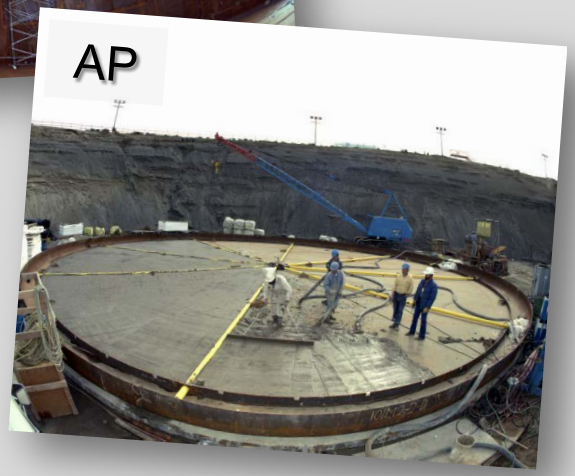


Review Conclusions

- Most problems in AY-102 not repeated in other tank farms.
  - Thicker bottom plates used after 241-AZ tank farm.
  - Better primary tank stress relief operations.
  - No major refractory deficiency.
- More problems seen with new contractors.
  - 241-SY had numerous bottom bulge issues.
  - High weld rework in 241-AW farm, indicative of construction difficulties, not weld quality.

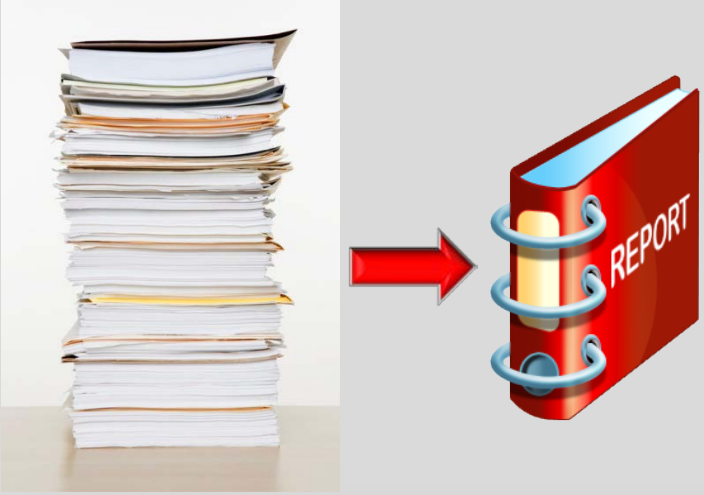






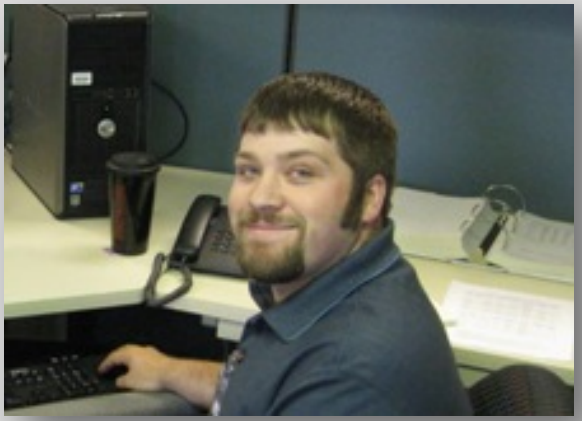
Path Forward

- Summary Document.
  - Review construction variations.
  - Rank tank construction quality.
  - Lessons learned.



- Solicit expert input for potential new construction.
  - Materials of Construction
  - Welding Practices
  - Post-Weld Stress Relief
  - Primary tank support and insulation
  - Weather Protection

Team Acknowledgement



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