

## Hanford Double-Shell Tank Extent-of-Condition Construction Review – 14174

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### ABSTRACT

During routine visual inspections of Hanford double-shell waste tank 241-AY-102 (AY-102), anomalies were identified on the annulus floor which resulted in further evaluations. Following a formal leak assessment in October 2012, Washington River Protection Solutions, LLC (WRPS) determined that the primary tank of AY-102 was leaking. The formal leak assessment, documented in RPP-ASMT-53793, *Tank 241-AY-102 Leak Assessment Report*, identified first-of-a-kind construction difficulties and trial-and-error repairs as major contributing factors to tank failure. To determine if improvements in double-shell tank (DST) construction occurred after construction of tank AY-102, a detailed review and evaluation of historical construction records were performed for the first three DST tank farms constructed, which included tanks 241-AY-101, 241-AZ-101, 241-AZ-102, 241-SY-101, 241-SY-102, and 241-SY-103. The review for these six tanks involved research and review of dozens of boxes of historical project documentation. These reviews form a basis to better understand the current condition of the three oldest Hanford DST farms. They provide a basis for changes to the current tank inspection program and also provide valuable insight into future tank use decisions. If new tanks are constructed in the future, these reviews provide valuable “lessons-learned” information about expected difficulties as well as construction practices and techniques that are likely to be successful.

### INTRODUCTION

This document provides an overview of the construction history of the first three double-shell tank farms constructed at Hanford, noting any difficulties encountered. On November 7, 2012, it was determined that the primary tank of double-shell tank (DST) AY-102 was leaking [1]. It was stated in the leak assessment report for tank AY-102 that bulges in the secondary liner, deterioration of refractory during post-weld stress relieving (post-weld heat treatment), and primary tank floor plate welding rework during construction left residual stresses in the tank that may have accelerated corrosion and contributed to the primary tank failure.

Following identification of the tank AY-102 probable leak cause, an Extent of Condition evaluation was prepared using U.S. Department of Energy’s Energy Facilities Contractors Group (EFCOG) *Guidance for Extent of Conditions Evaluations*. The EFCOG process was used to identify other DSTs with construction, waste storage, or thermal histories similar to that of tank AY-102. The Extent of Condition evaluation identified six tanks with similar construction for additional evaluation, which included tanks 241-AY-101, 241-AZ-101, 241-AZ-102, 241-SY-101, 241-SY-102, and 241-SY-103. One of the evaluations was to identify any similarities in construction that could be precursors for accelerated corrosion and premature failure.

The construction history of the first three double-shell tank farms was reviewed to identify issues similar to those experienced during tank AY-102 construction. Three comprehensive assessments of the construction issues were prepared [2, 3, and 4].

In this paper, the issues impacting integrity are presented based on information found in available construction records, using tank AY-102 as the comparison benchmark.

## **DISCUSSION**

### **Overview of Hanford Double-Shell Tanks**

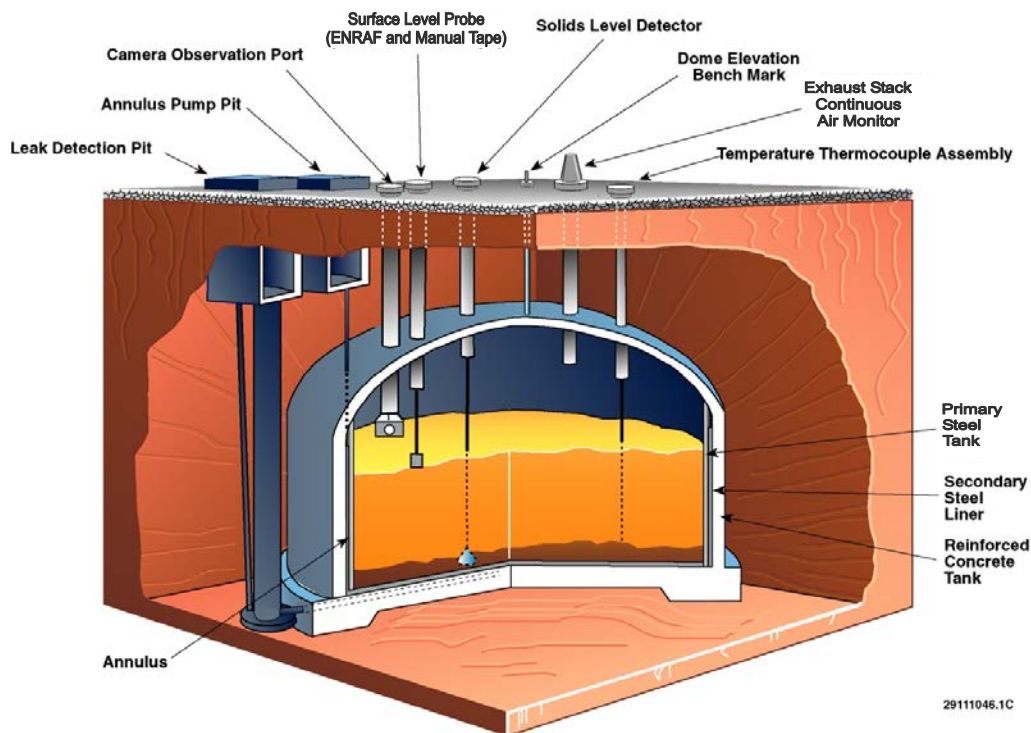
Six double-shell tank (DST) farms were constructed over a period of roughly 18 years (from 1968 to 1986), with a design life of 20 to 50 years. Table I provides the construction dates, the year of initial service, and the expected service life for all of the DSTs.

**TABLE I. Double-shell tank construction and age as of 2013**

<b>Tank Farm</b>	<b>Number of Tanks</b>	<b>Construction Period</b>	<b>Construction Project</b>	<b>Initial Operation</b>	<b>Service Life</b>	<b>Current Age</b>
241-AY	2	1968 – 1970	IAP-614	1971	40	42
241-AZ	2	1970 – 1974	HAP-647	1976	20	37
241-SY	3	1974 – 1976	B-101	1977	50	36
241-AW	6	1976 – 1979	B-120	1980	50	33
241-AN	7	1977 – 1980	B-130, B-170	1981	50	32
241-AP	8	1982 – 1986	B-340	1986	50	27
Total	28					

### **Double-Shell Tank Description**

Each DST consists of a primary carbon steel tank, ~23 meters (75 feet) in diameter, inside of a secondary carbon steel liner, which is surrounded by a reinforced-concrete shell. Both the primary tank and secondary liner are constructed in four courses. The primary steel tank rests atop a 229-mm (8-inch) insulating concrete slab (also called refractory), separating it from the secondary steel liner, and providing for air circulation/leak detection channels under the primary tank bottom plate. An annular space of 0.8 meters (2.5 feet) exists in between the secondary liner and primary tank, allowing for visual examination of the tank wall and secondary liner annular surfaces and ultrasonic volumetric inspections of the primary tank walls and secondary liners, as well as other activities. See Figure 1 for a simplified depiction.



**Fig. 1. Double-shell tank design.**

### **Review Task Description**

The review of the construction records required the retrieval of historical project documents from Federal Records Storage. These records included specifications, letters, Quality Assurance (QA) inspection logs, status reports, weld inspection records, material test reports, photographs, and other project documents. The amount of documentation was large, as seen in Table II. The initial review phase, reported here, focused on the 241-AY, 241-AZ, and 241-SY tanks farms. The effort has continued, with review of the 241-AW, 241-AN, and 241-AP tank farms in process at the time of writing this paper. As the number of tanks increases in later farms, so does the number of records requiring review.

The review focused on those areas of deficiencies and problems identified in the leak assessment of AY-102 [1]. These include a high weld rework rate for the steel liners, bulges in the tank bottoms, refractory damage, and the ineffectiveness of post-weld heat treatment. From the information collected, the resulting quality of construction of the other tanks was assessed and any issues or difficulties similar to those seen in tank AY-102 were noted and discussed. These reviews included a comparative analysis of the tanks within the 241-AY, 241-AZ, and 241-SY tank farms, focusing on the critical difficulties that were identified in the leak assessment for tank AY-102 as well as issues perceived to be unique to each individual tank or tank farm.

**TABLE II. Quantity of project documentation involved in review**

<b>Tank/Tank Farm</b>	<b># of Tanks</b>	<b># of Boxes Reviewed</b>
241-AY	2	8
241-AZ	2	15
241-SY	3	34
241-AW	6	64
241-AN	7	53
241-AP	8	77
Total	28	251

### **General DST Construction Sequence**

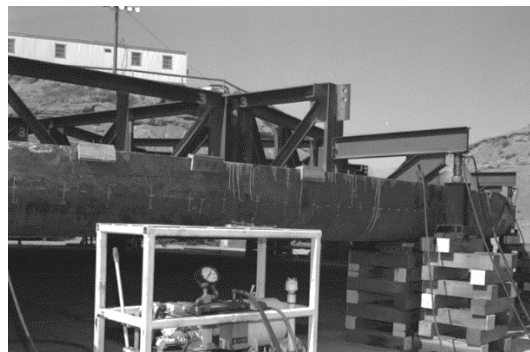
The general sequence of construction for each underground double-shell tank farm was examined. The exact sequence can vary between farms as changes were made to facilitate construction or avoid difficulties encountered. The sequence of construction for the 241-AY and 241-AZ tank farms proceeded as follows:

1. Install the concrete foundation and tertiary leak detection system, which includes a waffle grid in the structural concrete, collection pipes, and the leak detection pit.
2. Fabricate and inspect the secondary liner bottom up to the top of the bottom knuckle plates.
3. Place the secondary liner bottom onto the concrete foundation.
4. Install the air supply piping, thermocouple conduits and insulating retainer ring to be embedded in tank bottom refractory.
5. Install the castable refractory.
6. Fabricate and inspect the secondary liner wall.
7. Fabricate and inspect the primary tank bottom up to the top of the bottom knuckle plates.
8. Place the concrete shell walls and backfill.
9. Place the primary tank bottom onto the refractory.
10. Fabricate and inspect the primary tank walls.
11. Install shoring for tank dome placement and concrete supports.
12. Fabricate the primary tank dome.
13. Perform stress relief of the primary tank.
14. Conduct a hydrostatic test of the primary tank.
15. Complete fabrication of the secondary shell and penetrations.
16. Place concrete over the tank dome.
17. Remove the temporary shoring.
18. Backfill to the top of the dome.
19. Install the waste transfer system of piping, pump pits, and valve pits.
20. Complete backfill.

The general sequence of construction for the 241-AZ tank farm is shown in Figure 2. Changes to this sequence seen in other farms typically involved the sequence of liner fabrication, concrete wall construction, and backfill. As seen in Figure 3, completing the secondary liner first created challenges in welding the more important primary tank liner by restricting primary tank access to the annular space. Subsequent tank farms were built by simultaneously building the primary and secondary liners or completing primary liner fabrication first.



**Concrete Foundations**



**Fabrication of the Secondary Bottom**



**Installation of Refractory**



**Erection of Secondary Liner and Concrete Wall**



**Fabrication of Primary Bottom**



**Erection of Dome Plates**



**Insulation Prior to Heat Treatment**



**Dome Complete and Partial Backfill**

**Fig. 2. 241-AZ tank farm general construction sequence.**



**Fig. 3. Challenges in access when welding 241-AY tank farm primary liners.**

## DISCUSSION OF REVIEW FINDINGS

### Construction Order and Contractor

The order of construction and the principal construction contractor are shown in Table III. During the review, it became evident that following completion of the first DST farm, the 241-AY tank farm, design evaluations and “lessons-learned” meetings occurred to remedy some of the issues encountered during construction and were incorporated into the design and fabrication of the subsequent tank farms. When a new contractor was used in the 241-SYfarm, some construction issues re-emerged, as will be seen later.

**TABLE III. Tank construction order and contractor**

Order	Tank Farm	Contractor
241-AY Tank Farm		
1 <sup>st</sup>	AY-102	Pittsburgh-Des Moines (PDM)Steel Company
2 <sup>nd</sup>	AY-101	
241-AZ Tank Farm		
3 <sup>rd</sup>	AZ-101	Pittsburgh-Des Moines (PDM)Steel Company
4 <sup>th</sup>	AZ-102	
241-SY Tank Farm		
5 <sup>th</sup>	SY-102	Chicago Bridge and Iron (CBI™) <sup>a</sup> Company
6 <sup>th</sup>	SY-101	
7 <sup>th</sup>	SY-103	

<sup>a</sup> CBI is a trademark of Chicago Bridge & Iron Company

### Steel Tank Liner Material and Bottom Plate Thickness

The materials of liner construction and the bottom plate thicknesses are shown in Table IV. After excessive bulging, as seen with the 241-AY bottom fabrication, the plate thickness was increased for both the primary and secondary liner bottoms. The sheet steel used in the 241-AY and 241-AZ tank farms, which were designed to be high temperature aging waste tanks, was American Society for Testing and Materials (ASTM<sup>TM1</sup>) A515, *Carbon Steel, for Intermediate- and Higher-Temperature Service*, Grade 60. In the 241-SY tank farm, the sheet steel was changed to ASTM<sup>TM</sup> A516-72, *Carbon Steel, for Moderate- and Lower-Temperature Service*, Grade 65. The ASTM<sup>TM</sup> A516 is a fine-grain-size metal produced for moderate- and lower-temperature service, while ASTM<sup>TM</sup> A515 is a coarse-grain-size metal produced for moderate- and higher-temperature service. The smaller grain size in ASTM<sup>TM</sup> A516 increases the notch toughness and resistance to stress corrosion cracking over ASTM<sup>TM</sup> A515.

**TABLE IV. Tank liner material and bottom thickness**

<b>Tank Farm</b>	<b>Material Type</b>	<b>Secondary Bottom Plate Thickness</b>	<b>Primary Tank Bottom Plate Thickness</b>
241-AY	ASTM <sup>TM</sup> A515, Gr 60	6 mm (1/4 inch)	10 mm (3/8 inch)
241-AZ	ASTM <sup>TM</sup> A515, Gr 60	10 mm (3/8 inch)	13mm (1/2 inch)
241-SY	ASTM <sup>TM</sup> A516, Gr 65	10 mm (3/8 inch)	13mm (1/2 inch)

### Secondary Liner Bottom Bulges

Extensive problems with bulges in the secondary liner of tank AY-102 were identified in the leak assessment. They contributed to problems with refractory placement and may have led to refractory cracking and damage when the tank was loaded during hydrostatic testing. The secondary liner bulge issue is summarized in Table V. In tank AY-101, only slightly less bulging was noted. In the 241-AZ tank farm, few problems were noted with secondary bulges, although some minor issues were noted during later refractory placement. In the 241-SY tank farm, excessive secondary liner bottom bulging was noted in each tank and efforts to resolve the issue were unsuccessful.

The bulges were ultimately accepted on the basis of liquid penetrant examination and the statement that areas out of tolerance were localized and would not affect the tank function and integrity.

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<sup>1</sup> ASTM is a trademark of American Society for Testing and Materials

**TABLE V. Secondary liner bulges**

<b>Tank</b>	<b>Detail</b>
241-AY-101	Excessive distortion and bulges were noted throughout. Maximum slope of bulges was as being as much as 8 mm per meter (1 inch per foot). The specified maximum slope was 3 mm per meter (3/8 inch per foot). Six places exceeded a 2-inch peak-to-valley tolerance.
241-AY-102	Excessive distortion and bulges were noted throughout. Maximum slope of bulge was noted as being as much as 8 mm per meter (1 inch per foot). Twenty-two places exceed 51 mm (2-inch) peak-to-valley tolerance.
241-AZ-101	Only minor notation, no deficiencies or non-conformance reports (NCRs) found. It was noted that refractory thickness was increased due to an irregular secondary liner bottom.
241-AZ-102	Only minor notation, no deficiencies or NCRs found. The log noted that the plate dropped 10 mm (3/8 inch) when refractory was poured.
241-SY-101	Out of tolerance in several areas, up to 5 mm per meter (5/8 inch per foot) and an NCR was generated.
241-SY-102	Out of tolerance in several areas, up to 6 mm per meter (13/16 inch per foot) and an NCR was generated. Flattening attempts were unsuccessful.
241-SY-103	Weld pattern was changed, liner was still out of tolerance, up to 8 mm per meter (1 inch per foot), NCR generated. Flattening attempts, including using a 26690 Newton (6000 lb.) weight, were unsuccessful.

### Primary Tank Bottom Weld Rework

The weld reject rate for the primary tank bottom in tank AY-102 was noted in the leak assessment as excessive and in excess of 33%. The primary bottom weld reject rate was determined from radiography records and is shown in Table VI. As tank construction progressed, the weld reject rate was lowered considerably throughout construction of the 241-AZ farm. When a new contractor was selected for the 241-SY tank farm, a return to high weld reject rates was seen. It is important to note that eventually all welds were reworked, passed inspection, and were stress relieved. Nonetheless, as the leak in tank AY-102 is in the primary tank bottom, the primary bottom weld reject rate is an important statistic, reflective of overall construction quality.

**TABLE VI. Primary bottom weld reject rate**

<b>Tank</b>	<b>Weld Reject Rate (%)</b>	<b>Detail</b>
241-AY-101	10.2	All welds were accepted and stress relieved.
241-AY-102	33.8	All welds were accepted and stress relieved, although problems achieving soak temperature were encountered.
241-AZ-101	14.5	All welds were accepted and stress relieved.
241-AZ-102	6.3	All welds were accepted and stress relieved.
241-SY-101	30.1	All welds were accepted and stress relieved.
241-SY-102	21.9	All welds were accepted and stress relieved.
241-SY-103	25.7	All welds were accepted and stress relieved.

### Primary Tank Bottom Bulges

Although project documents for the 241-AY farm commonly described primary tank bottom flatness as “generally good,” it was noted that during refractory repairs the primary bottom had pulled up from the refractory in places. These voids were filled with foam during the refractory replacement and repair described later. The bottom plate thickness was increased in the 241-AZ tank farm and bottom flatness was described as “acceptable without flattening.” In the 241-SY



farm, the new contractor used a different plate layout for the bottoms and bulging problems were seen in all of the tanks. In tank SY-101, out-of-tolerance areas were noted and plate repair was attempted, which caused new out-of-tolerance areas to appear. A maximum bump height of 79 mm (3 inches) was measured in the primary tank bottom and the decision was made to support the bottom by filling the bulges with grout. After gaining access through the annulus, two 0.6 meter by 2.4 meter (2 foot by 8 foot) deep sections of the refractory were cut out and refilled with grout. In tank SY-103, out-of-tolerance bulging in several areas was found, up to 6 mm per meter (13/16 inch per foot). Computer modeling of the bulge indicated that excessive stresses might be seen in the lower knuckle. Eventually an empirical solution was used which included strain gage monitoring and acoustic testing during the hydrostatic test. These tests determined that stresses from flattening the bulges were acceptable. A picture of the strain gage monitoring is shown in Figure 4. Additional non-destructive testing was conducted on the primary tank during and after hydrostatic testing such as liquid penetrant examination, magnetic particle testing, and visual examinations.



**Fig. 4. Strain gage monitoring in tank SY-103 to assess impacts from primary bottom bulges.**

### **Stress Relieving Process**

The stress relieving process for tank AY-102 was very difficult, requiring long heat-up times to drive excessive water out of the refractory. There was some uncertainty about whether all portions of the bottoms reached the desired temperature. During attempts to heat up, large amounts of steam were observed leaving the annulus for several hours. Caused by driving off excess moisture in the refractory, this likely contributed to damage of the refractory observed later. By comparison, the heat treatment of all the other tanks went well.

Not all tanks reached the desired 593°C (1100°F) for one hour per 25 mm (1 inch) thickness, but they all met alternate code requirements for stress relieving (typically 538°C (1000°F) for a 3-hour hold). The details are summarized in Table VII.

**TABLE VII. Stress relieving details**

Tank	Detail
241-AY-101	Modifications were made to reduce the thermocouple spread, the 3-hour time requirement was met, total time was just over 2 days, plus overnight hold to dry refractory. Held 3 hours above 538°C (1000°F).
241-AY-102	Required days to remove all the water in the refractory and temperatures were as low as 491°C (915°F) for the 3-hour hold. Required 5 days of heating total.
241-AZ-101	Initial attempt was aborted, modification was made and the second attempt was successful, reached 566°C (1050°F) for 2-hour hold. No refractory steaming noted.
241-AZ-102	Modified procedure used, minimum temperature was 538°C (1000°F) for 3-hour hold.
241-SY-101	Three-hour hold at 538°C (1000°F).
241-SY-102	One-hour hold at 593°C (1100°F). Minor steaming from refractory noted during heat-up.
241-SY-103	One-hour hold at 593°C (1100°F).

### Refractory Material

The refractory material in each tank was varied slightly, but all were high alumina castable refractory concretes. The types of refractory used are shown in Table VIII. The main purpose of the refractory was to protect the tank foundation from the high heat that would be seen during the stress relieving process. It also contains air channels either cast or cut into the top that provides for cooling of the primary tank bottom. Compressive strength requirements were modest, with an initial requirement of 1379 kPa (200 psi) for the 241-AY tank farm being relaxed to 896 kPa (130 psi) in later tank farms. As tank farm construction progressed, changes were also made in the air channel pattern and the refractory pour pattern that simplified installation and assured a more level installation.

**TABLE VIII. Refractory concretes used**

Tank Farm	Refractory Manufacturer	Refractory Material
241-AY	Babcock and Wilcox	Kaolite <sup>TM(b)</sup> 2200-LI
241-AZ	Babcock and Wilcox	Kaolite <sup>TM</sup> 2000
241-SY	Pryor-Giggey	Lite-Wate 50

<sup>b</sup> Kaolite is a trademark of Babcock & Wilcox

Castable refractories are typically poured or “gunned” into place. After air drying or “curing,” the refractory is then “fired” or heated to high temperatures to convert hydrated compounds into a more durable, de-hydrated, ceramic structure. During the initial air-drying and until the firing is completed, protection from freezing and water saturation is important. During construction of the 241-AY tank farm, there were problems with both of these protections. After heat treatment and hydrostatic testing, the refractory material in both tanks was found to be badly cracked and degraded, caused in some part by poor weather protection. Concerns about lack of support in the high-stress knuckle region led to the decision to remove ~533 mm (21 inches) of the refractory and replace it with structural concrete in both tanks. Given the location and access constraints, the effectiveness of this repair and proper concrete placement was identified as a concern during the leak assessment of tank AY-102. As previously mentioned, voids from primary bottom bulging that were beyond the ~533-mm (21-inches) perimeter were filled with foam prior to placement of the structural concrete repair. See Figure 5 for pictures of the refractory repair in progress on tank AY-101.



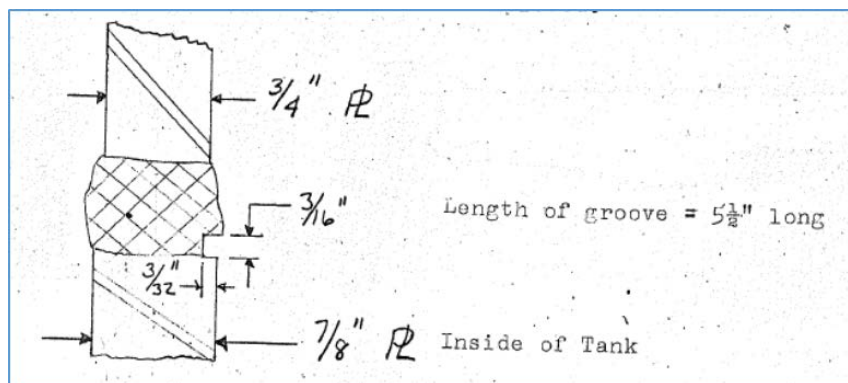
**Figure 5. Refractory repair under bottom knuckle of tank AY-102.**

In comparison, refractory protection and condition in the later tanks were much better. In the 241-AZ tank farm, specific measures were taken to keep the refractory above 10° C (50°F) using heaters and to keep water from rain and snow out by using tarps. There were some failures noted, but protection was generally good. In the 241-SY tank farm, a temporary heating grid and insulating panels were used for tanks SY-101 and SY-102. For tank SY-103, refractory placement was postponed until spring to avoid freezing weather conditions. Inspection of these tanks after hydrostatic testing showed little or no damage to the refractory and no refractory repairs after hydrostatic testing were required in any of the 241-AZ or 241-SY tanks.

#### **Other Unique Issues Not Noted in Tank AY-102**

During the review, other issues were noted that were unique to the tank examined and may have an impact on tank integrity. In the 241-AZ tank farm, laminations in the liner steel plates were found, with provision made to remove surface laminations from the primary tank bottom of tank AZ-101 by surface grinding up to 1.6 mm (1/16 inch) in depth. Several mid-wall laminations were found in the upper shell ring plate of the tank AZ-102 primary tank, which required the replacement of four plates. Ultrasonic thickness inspection was used as the basis for acceptance of two other plates that were within the code allowable.

Both tanks AZ-101 and AZ-102 had leaks found during hydrostatic leak testing in the upper knuckle section above the maximum waste level. As the tank had already been subject to stress relieving, these weld repairs were performed without additional stress relief. An unrepaired weld grind-out was found in the lower knuckle weld seam in tank AZ-101 during final inspection. The groove, sized at approximately 140 mm long by 5 mm wide by 2 mm deep (5-1/2 in. long by 3/16 in. wide by 3/32 in. deep), (see Figure 6) was accepted based on expert opinion. The logs also mentioned that two fires occurred during construction in the annulus of tank AZ-102 and in the bottom of the primary tank in tank AZ-102, but the job logs did not indicate that any significant damage was caused by these two fires. The fire issues are not expected to significantly affect the tank integrity.



**Figure 6. Unrepaired weld grind-out at lower knuckle of tank AZ-101 (construction deficiency report).**

In the 241-SY tank farms, there were relatively minor unique issues identified. For tanks SY-101 and SY-103, the primary bottom had four plates meet at a weld junction when the construction specification called for no more than three. These were accepted based on the ASME Boiler and Pressure Vessel Code (which allowed four) and weld NDE. For tank SY-102, lack of control during lowering of the secondary liner bottom led to temporary distortions of up to 457 mm (18 inches). This was accepted based on actions identified for secondary bulges seen during welding (liquid penetrant examination, and refractory examination and repair, if necessary after partial loading).

## SUMMARY OF FINDINGS

### Tank 241-AY-101

During review of the construction history of the 241-AY tank farm, the most significant deficiency found in the review was the degradation and repair of the refractory in tanks AY-101 and AY-102. Both refractories were exposed to similar conditions of moisture and freezing temperatures during the curing stage, which is believed to have contributed to their friable nature and reduced vertical compressive strength. The refractory repairs required the outer 533 mm (21 inches) of the periphery refractory to be chipped out all the way around the tank and replaced with reinforced structural concrete.

Significant problems arose with welding of the secondary liner and primary tank bottoms of tank AY-102, with a weld rejection rate of 33.8%. Welding improved with fabrication of tank AY-101, with a weld rejection of 10.2%. Regarding tank bottom flatness, tank AY-101 had a total of six instances of secondary liner bottom bulging as compared to tank AY-102 with 22 instances. QA inspections indicated that bulging of the primary tank bottom had not occurred in tank AY-101 and the information discovered substantiates that it met specification. Despite this documentation, photos from refractory repair after stress relief indicate that voids existed between the primary tank and refractory surface. These voids could be attributed to primary tank bottom bulges, which would indicate that unsupported areas of the primary tank exist in tank AY-101. This lack of support was identified as a contributing factor to primary tank failure in tank AY-102.

The post-weld stress relieving of tank AY-101 was more successful when compared to tank AY-102. Tank AY-101 was stress relieved at 538°C (1000°F) for four hours, which did not meet the specification of 593°C (1100°F) for one hour. This reduced-temperature, longer-duration stress relief method was deemed to be an acceptable alternative per provisions of the ASME

Boiler and Pressure Vessel Code, which indicated that it would still produce a suitable stress relief and resistance to stress corrosion cracking.

Although some improvement was seen in the construction of tank AY-101 following tank AY-102, many of the same issues found in tank AY-102 also existed in tank AY-101.

### **241-AZ Tank Farm**

During construction of the 241-AZ tank farm, the second double-shell tank farm built, fewer welding problems of the secondary liner and primary tank bottoms were noted compared to the 241-AY tank farm. The secondary liner bottom thickness in the 241-AZ tank farm was increased to ~10 mm (3/8 inch) from ~6 mm (1/4 inch) in the 241-AY tank farm, and only a minor mention of secondary liner irregularities was noted, requiring the refractory thickness to be increased to ensure a thickness of at least 203 mm (8 inches) in all locations. The thickness of the primary tank bottom was also increased from 10 mm (3/8 inch) in the 241-AY tank farm to 13 mm (1/2 inch) in the 241-AZ tank farm. The overall primary liner weld rejection rates were much lower in the 241-AZ tank farm. Refractory installation and weather protection were improved and, although issues with this protection were noted, no significant refractory repairs were required. The post-weld stress relieving process required modifications, but the changes allowed for more efficient and effective heat treatment in the 241-AZ tank farm compared to the tanks in the 241-AY tank farm.

The most significant deficiency found was the presence of plate laminations. Some surface grinding on the bottom plate of the primary tank AZ-101 occurred. In tank AZ-102, six plates in the upper shell ring were found to have laminations, with four of them severe enough to require replacement prior to heat treatment.

Other minor issues unique to the 241-AZ tank farm were noted. Both primary tanks had leaks found during the hydrostatic test. They were above the normal waste level and repaired without additional stress relieving. A square groove was discovered to have been ground into one weld in the lower knuckle in the tank AZ-101 primary side wall after heat treatment, but this condition was evaluated and accepted as-is. Fires occurred during construction in the annulus of tank AZ-102 and in the bottom of the primary tank in tank AZ-102 but the job logs did not indicate that any significant damage was caused by these two fires. These issues are not expected to significantly affect the tank integrity.

Following completion of the 241-AY tank farm, design evaluations and “lessons-learned” meetings occurred to remedy issues encountered during construction and resulting changes were incorporated into the 241-AZ tank farm. Although there were improvements in the construction of the 241-AZ tank farm, issues were still noted, some unique to tanks AZ-101 and AZ-102.

### **241-SY Tank Farm**

During construction of the 241-SY tank farm, the third double-shell tank farm built, a new contractor was used. Weld rejection rates for all the 241-SY tank farm tanks were similar to the weld rejection rate in tank AY-102. The secondary liner bottom thickness was increased to 10 mm (3/8 inch) from 6 mm (1/4 inch) and the primary tank bottom was increased from 10 mm (3/8 inch) to 13 mm (1/2 inch). The plate material was also changed from ASTM™ A515-65 carbon steel in the 241-AY tank farm to ASTM™ A516-72 carbon steel in the 241-SY tank farm.

Minor issues were noted for refractory installation and weather protection, but no significant refractory repairs were required. The post-weld stress relieving process was more disciplined and effective in the 241-SY tank farm. All tanks were successfully post-weld stress relieved with no deficiencies noted.

The most significant deficiency found in the 241-SY tank farm was the presence of bulging in the primary and secondary bottoms. The maximum root-to-crown slope was found in the tank SY-103 secondary tank bottom and had a slope of 8 mm per meter (1 inch per foot) or almost three times the allowable specification. Structural analysis and strain gage testing of the bulge was conducted and results indicated the stresses in the tank to be less than the yield strength of the material. Bulging in tank SY-101 was similar in size, shape, and location to the bulge in tank SY-103. However, it was decided to grout the area underneath two bulges to support the primary tank in those locations.

Various other issues related to difficulties in liner fabrication were noted. All of these issues were evaluated and accepted “as-is” with no stated impact on structural tank integrity.

The 241-SY tank farm had improved construction practices in some areas as compared to tank AY-102, yet many of the construction issues experienced by tank AY-102 re-emerged. Overall, the conditions of the tank liners in the 241-SY tank farm are considered to be similar to tank AY-102. Factors thought to have caused unsupported areas in the primary tank bottom and the potential for areas of high residual stress in tank AY-102 are also present in all of the 241-SY tank farm tanks.

## **CONCLUSIONS**

In the 241-AY tank farm, some construction improvements were already evident in tank AY-101, the second DST constructed, even as tank AY-102 was being completed. Some issues were improved (lower primary liner weld rework rate, fewer secondary liner bulges, and an improved post-weld stress relieving process). The insulating refractory degradation was still severe and required major repairs. Fewer instances of an unsupported primary bottom are expected in this tank.

In the 241-AZ tank farm, the second DST farm constructed, the same construction contractor was used and continued improvement and far fewer issues were noted. The primary liner weld rework rate was low and the effectiveness of the post-weld stress relieving process was judged to be greater. The thickness of the primary liner bottom plate was increased to 13 mm (1/2 inch). The thickness of the secondary liner was increased and fewer issues were noted with liner bulging. Refractory weather protection was more evident and no major refractory repairs were required.

In the 241-SY tank farm, the third DST farm constructed, a new contractor was selected. The refractory construction, weather protection, and the post-weld stress relieving process continued to improve. Unfortunately, other serious issues re-emerged, including pervasive problems with maintaining tank bottom liner flatness in both the secondary liner and primary tank, and the primary weld rework rate was nearly as high as that in tank AY-102. Various efforts were attempted to improve bottom flatness issues or mitigate the bulge impact. Ultimately, it can be concluded that those factors that caused unsupported areas and the potential for areas of high residual stress in tank AY-102 are present in all of the 241-SY tank farm tanks.

WRPS is expanding the EOC construction history reviews to include the remaining DST tank

farms (the 241-AW, 241-AN, and 241-AP tank farms) that were completed after the 241-SY tank farm. The conditions of these next three tank farms will be assessed by means of a similar construction records review to gain further insight into the future outlook of current DST storage on the Hanford site.

These reviews will aid the DST Integrity Project by better understanding the current condition of the Hanford DST farms. The results provide a basis for changes to the current tank inspection program and also provide valuable insight into future tank use decisions. If new tanks are constructed in the future, these reviews provide valuable “lessons-learned” information about expected difficulties, as well as construction practices and techniques that are likely to be successful.

## **REFERENCES**

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