Incident Report #II-935221-2019 (#15840) (FINAL)

SUPPORTING INFORMATION	Incident Date			November 3, 2019
	Location			Port Alberni, BC
	Regulated industry sector			Boilers, Pressure Vessels & Refrigeration - Refrigeration system
	Impact	Injury	Qty injuries	0
			Injury description	None
			Injury rating	None
		Damage	Damage description	Cracking in the shell of a direct expansion chiller vessel resulted in an uncontrolled ammonia leak.
			Damage rating	Moderate
	Incident rating			Moderate
	Incident overview			A new direct expansion chiller was installed at an ice arena to replace an existing chiller. After almost 20 weeks of service, an ammonia leak was detected, which released ammonia into the machinery room. The low level (25 ppm) ammonia alarm sounded and the ventilation system was activated to continuously evacuate vapours to the outdoors while the location and nature of the leak were investigated. The plant remained operating for approximately two days in this leaking condition before the source of the leak was found. The source was found to be a crack in the chiller shell. The plant was shut down by the City on order from Technical Safety BC due to the uncontrolled nature of the leak and due to uncertainty around the condition of the chiller vessel.
INVESTIGATION CONCLUSIONS	Site, system and components			The refrigeration system contains ammonia and provides a chilling effect to the brine by evaporation in a chiller (Figures 1 & 2). The cooled brine is circulated under the ice surface to maintain its frozen condition. The failure occurred in a relatively new chiller that had been in use for approximately 20 weeks in the refrigeration plant of a skating rink complex. The chiller involved in the incident is known as a direct expansion chiller. This chiller design is unique in that it requires a relatively low charge of ammonia compared to traditional flooded chillers. However, the ammonia charge in the new chiller was still sufficient to cause serious harm if an uncontrolled release occurs. This is the first chiller of this design commissioned in British Columbia. The basic design of the chiller includes a cylindrical shell sealed at each end by hemispherical caps (“heads”). These heads are bolted to the shell. To facilitate fastening of the heads, flanges are welded to both ends of the shell to accept the heads. The ammonia leak occurred in the flange-to-shell weld on the north end of the chiller vessel.

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Failure scenario(s)	At 6 am on November 3, 2019 an ammonia leak reached 25 ppm which activated an alarm in the ammonia detection system. The source of the ammonia leak was found on November 5, 2019 to be coming from a weld crack[1] in the chiller vessel (Figure 3). The weld crack that allowed ammonia to leak was one of multiple internal cracks found in the chiller. One of these cracks grew while the chiller was in service due to stresses from normal operation until the crack penetrated the vessel shell, releasing ammonia into the room. Cracks can form inside welds during manufacturing if certain precautions are not taken. Precautions that can reduce the risk of cracks forming after the weld was completed include welding procedures that avoid formation of internal defects and high residual stresses. Quality control test procedures such as ultrasonic testing are available to detect internal weld deficiencies. These procedures were not included in the manufacturer's quality control and quality assurance plans. Stress corrosion cracking is also a possible cause of failures at this weld location. This can be avoided with manufacturing procedures that include post weld heat treating and operating practices that include adding water to anhydrous ammonia.
Facts and evidence	EQUIPMENT This facility originally had a conventional flooded chiller installed. It was replaced with the new direct expansion chiller in June 2019. The volume of liquid ammonia in this direct expansion chiller was limited to a charge of 45 pounds of ammonia which is an amount significantly reduced from the conventional flooded chiller. However, a sudden and uncontrolled release of ammonia can still be hazardous to life and health. The new chiller was commissioned on June 18, 2019. Manufacturer's documentation provided the following information. Chiller manufacturing details: - Constructed in 2018 in the United States to ASME Section VIII, Division 1 and registered with National Board of Boiler and Pressure Vessel Inspectors. - The vessel was designed to sustain a maximum pressure of 250 psi (pounds per square inch) on the shell side (ammonia side) at temperatures between -29° and +93° Celsius (-20° F to 200° F). - The nominal thickness of the shell is 0.375 inches and the tubesheet is 1.5 inches. Both are fabricated from normalized carbon steel, ASTM SA-516 Grade 70N. This is a widely accepted material for construction of pressure vessels. - The welded joint between the head flange and shell was a full penetration groove weld with a 0.375 inch fillet weld (Figure 5). The weld is deposited using a manual gas metal arc (GMAW) welding process with a short circuiting mode of transfer for the root pass and spray transfer mode for the fill and cap passes. The welder holding the welding gun applies the weld when the weld joint is in a flat position while the vessel is rotated. The welding procedure is qualified to ASME Section IX with a minimum pre-heat and maximum inter-pass temperatures of 16° Celsius and 204 °Celsius respectively.

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Technical Safety BC's investigation found that post-weld heat treatment (PWHT) was not performed on this chiller as it was not a requirement of the ASME manufacturing code used. The advantage of post-weld heat treatment is that it relieves stresses which can prevent the weld from becoming brittle and can help resist cracking.

During welding, a tack weld is used to position the flange at a specified distance from the shell. The ASME code requires that these tack welds be removed or the edges grinded before the welder applies a welding bead.

The International Institute of Ammonia Refrigeration (IIAR-2) provides recommendations to PWHT chillers to remove residual stresses normally created during a welding process. Although these stresses should typically not pose a problem, it is left to the discretion of the manufacturer (designer) to determine if PWHT is needed for their specific vessel and refrigeration process.

IIAR-2 is not an adopted code in BC. The adopted code, CSA B51, exempts refrigeration type anhydrous ammonia pressure vessels from PWHT. However, the application of PWHT remains at the discretion of the manufacturer.

Weld quality assurance techniques such as ultrasonic testing were not performed and were not specified by the code of construction. Ultrasonic testing is used to reveal cracks internal to welds that would not be detected by the dye penetrant testing used by the manufacturer.

The manufacturer opted for a pneumatic test with nitrogen rather than a standard hydrodynamic test using water. The nitrogen was applied at 275 psi for 30 minutes upon completion of construction; the vessel passed this test. Nitrogen is an inert gas that can fully displace oxygen from the vessel using a gas that prevents corrosion. To satisfy the ASME code requirements for this alternative test using gas (i.e., nitrogen) all shell joints including the two shell-to-head flange welds were tested with liquid penetrant with acceptable results.

The installation of the chiller in the refrigeration plant of the ice skating facility was carried out by a licensed contractor under an installation permit.

Chiller installation details:

- Upon installation the chiller was pneumatically pressure tested at 275 psi for two hours and 34 minutes, then held overnight at 200 psi and then for 10 days at 100 psi, with successful results. Compressed air was used up to 110 psi followed by nitrogen up to the test pressure of 275 psi.
- Upon completion of the pressure test, the system was evacuated and placed under a vacuum for approximately 14 days. The purpose of this procedure is to remove any gas or liquid contaminants. This procedure also provides an indication that the system is airtight. No indication of leaks was noted during the test.
- Following the vacuum procedure, a charge of new anhydrous ammonia vapour was added and the chiller system was started on June 28, 2019.

Plant operational details:

- The chiller maintains brine temperature levels in the range of -6° to -15° C.
- The chiller is subjected to relatively low in-service stresses due to an operating pressure below 50 psi. The chiller is protected from overpressure by a pressure relief valve set at 250 psi.

- When the low level ammonia alarm is activated at 25 ppm, the owner contacts a refrigeration contractor to investigate the leak. The owner's emergency procedure does not require evacuation of the building unless the ammonia levels are above 200 ppm.

FAILURE EVENT

On Sunday November 3, 2019 at 6 a.m. an ammonia leak reached 25 ppm which activated an alarm in the ammonia detection system. The ice facility operator responded immediately by activating the high speed fan to safely evacuate the vapours from the machinery room to the outdoors. At 11:45 a.m. the ammonia levels were noted at 80 ppm. The refrigeration technician arrived on-site at 1 p.m. and investigated the leak under self-contained breathing apparatus at 1:10 p.m. The refrigeration technician located the source of the leak at 1 p.m. on November 5, 2019. The leak was identified to be originating from the shell-to-inlet head flange circumferential weld on the direct expansion chiller.

The chiller continued to operate with ammonia leaking while the refrigeration contractor was looking for the source of the leak. Two days later. on November 5, 2019, the incident was reported to Technical Safety BC by an arena patron and the plant was shut down due to the nature of the uncontrolled leak.

Weld failure assessment:

A company was retained by the refrigeration contractor to conduct non-destructive testing to locate the source of the ammonia leak. Visible liquid penetrant inspection (LPI) conducted on the shell-to-inlet flange circumferential weld identified a 0.250-inch-long crack originating from the weld and extending into the base metal of the chiller shell (Figure 3). The crack was located at the 9 o'clock position (viewed from south end of vessel) and was perpendicular to the weld, as shown in Figure 3.

The full size of the crack through the weld and shell was determined by sequential grinding and LPI at 1/16-inch-deep to 1/8-inch-deep intervals. This revealed the crack to be subsurface to the weld extending from the flange into the shell of the chiller as shown in Figure 4. The final crack length was measured to be ¾-inch long and extended fully through the wall of the shell. It was evident from these inspection results that the crack started inside the weld and propagated to the surface over time. This raised suspicions that other internal cracks could be present. Ultrasonic testing is commonly used to detect the presence of internal cracks in these cases. The refrigeration contractor hired a welding contractor to repair the weld crack but did not conduct ultrasonic testing to determine if any more cracks were present.

The contractor hired a non-destructive testing (NDT) firm to inspect the repaired weld. Magnetic particle inspection (MPI) was conducted on the root pass and liquid penetrant inspection (LPI) on the final completed weld. No indications of surface cracking were found in the weld repair.

A pneumatic pressure test was carried out at 275 psi and no leaks were found on the repaired weld. However the test identified another crack indication approximately 3 inches away from the first crack on the same weld bead. This second crack was also repaired. This second weld crack increased concerns over the weld manufacturing quality of this new chiller vessel. Weld cracks in a chiller shell should not be expected in relatively new chillers and longitudinal cracks of this nature are highly unusual. Therefore, before placing the chiller back into service and risking another ammonia leak, Technical Safety BC determined that a more detailed examination of the weld quality was warranted.

A professional engineering and testing firm was engaged to conduct detailed ultrasonic inspection of all the welds in the chiller to determine if there was any further cracking or if there were other weld discontinuities.

CAUSAL INVESTIGATION

A professional engineering and testing firm conducted an analysis to determine the cause of weld cracks and provided an assessment of all the welds to verify the integrity of the vessel. The initial NDT weld inspection involved testing for surface cracks only. However, the first two cracks were found to have extended all the way through the internal welds. To determine if there was any internal cracking, shear wave ultrasonic testing (SWUT) was used and LPI was completed on all shell circumferential and longitudinal weld joints to check for surface cracking. The SWUT revealed an additional nine subsurface crack indications on the lower half of the same circumferential weld containing the first two cracks.

A total of 11 weld cracks were found in the same weld (Figures 5 & 9). No deficiencies were noted during examination of the other welds in the vessel. Progressive grinding of the weld in the ten new locations found large internal cracks of a similar nature to the original weld failures, being longitudinal into the chiller shell (Figures 6 & 7).

Repairs were carried out in a similar fashion at all crack locations until all 11 cracks were repaired. The steel was pre-heated prior to each weld pass to reduce residual stress and promote good weld quality. Gas tungsten arc weld (GTAW) and shielded metal arc welding (SMAW) processes were used as preferred techniques for good weld quality. The chiller vessel was successfully pneumatically tested at 275 psi to confirm that the welds were sufficiently repaired. All of the welds in the chiller therefore passed inspection and the chiller was structurally sound.

FAILURE ANALYSIS

The chiller manufacturer's analysis of the failure determined that the cause of the weld cracks was stress corrosion cracking (SCC). This conclusion was based on the following:

(1) Anhydrous (water-free) ammonia was used, whereas the ammonia should contain at least 0.2% water to inhibit SCC;
(2) Oxygen may have contaminated the ammonia, as oxygen is known to promote SCC in ammonia chillers. The ammonia was not tested to verify the presence of oxygen.

An independent failure analysis was conducted by professional engineers and metallurgists to determine the cause of the weld failures. All of the possible causes of weld cracking in this vessel were considered. This analysis process identified and evaluated two potential causes of weld cracking:

1. Environmental cracking (SCC); and
2. Manufacturing procedures and omissions.

The independent professional engineers' report concluded and presented evidence that the chiller weld failures were due to a combination of factory weld cracking followed by low cycle fatigue cracking. Given the uniform spacing of the cracks, it is possible that some of the cracks may correspond with tack welds in the assembly of the flange to the shell. The root cause and contributing factors were identified and detailed in a failure analysis report (see Appendix B).

The factors that did not support SCC as a possible cause in the engineers analysis include the following:

a. Ammoniacal SCC follows sustained static stress in mild steel, such as stress present in the heat-affected zone of welds with high residual stresses. Such cracks due to SCC are often oriented parallel to the weld bead. The weld cracks found in the chiller shell were oriented perpendicular to the heat-affected zone and propagated in a straight line with no visible branching (Figure 4).
b. Ammoniacal SCC has a distinctive branched pattern. The weld cracks found in the chiller followed a straight pattern with no branching. The presence of fine cracking associated with SCC was not confirmed given that testing at this microscopic level would require destructive examination of the chiller.
c. Ammoniacal SCC requires oxygen to be present in the ammonia. The chiller commissioning process followed by the installation contractor was designed to remove any oxygen or moisture from the ammonia. Further, fresh anhydrous ammonia was installed when the chiller was first started. The refrigeration plant is designed to prevent oxygen from entering the system during operation.
d. SCC would typically affect all of the welds in the vessel. The cracks found in this chiller were all located at one end, in the same weld.

The manufacturer provided further information in support of SCC. All of the weld cracks were found on the lower 180° of the circumferential weld. SCC is known to occur in the lower quadrant of flooded chillers where the weld is in constant contact with liquid ammonia, but the direct expansion chiller used in this case is not flooded with ammonia but rather uses a smaller amount of ammonia that is sprayed onto the brine tubes and exhausted from the top of the chiller. Although in a direct expansion chiller, it is not flooded with ammonia there may still be a film of liquid ammonia on the bottom half of the vessel. Therefore, it may still be possible for SCC to occur preferentially on the bottom half of the vessel.

Although the liquid film may be present on the bottom half of this chiller, the cracking was found at one end only. The manufacturer stated this may be due to the temperature difference within the chiller that can cause (a) increased wetting of ammonia at one end of the chiller, and/or (b) the chiller being 2° C warmer at one end which can increase the rate of corrosion reactions.

<u>Weld and crack characteristics</u>:

Weld cracks can be small and impossible to detect with the naked eye, which is why LPI is typically used to reveal surface cracks using a coloured dye. This testing was completed during the weld repair to confirm there were no cracks on the multiple weld passes. The chiller manufacturer reported that no testing was conducted on the internal weld passes when the vessel was constructed. Therefore, it may not have been possible for the manufacturer to detect internal cracks before they were covered by overlaying weld passes. However, overlaying weld passes may also re-melt and rejoin surface cracks in the underlying weld pass.

Cracks in the internal weld passes can occur due to inadequate control of the welding process resulting in high residual stresses remaining in the weld after manufacturing is complete. The exact cause of the cracks is not known but weld process control would be suspect. Welding process control problems can include a number of factors due to machine settings or malfunction (e.g. inadequate pre-heat inter-pass temperatures) and human error while manually applying the root pass and all of the overlaying weld passes.

The manufacturer reported that the shell-to-flange weld was performed in a rotating device where the welds are performed in a flat position. This is the preferred weld position for a uniformly placed weld. Residual stresses tend to be magnified toward the end of each circumferential weld pass which could result in a point of high residual stress where each weld pass overlaps itself. Partial stress relief would be provided by multiple weld passes.

The manufacturer used a gas metal arc weld (GMAW) method for the root pass (first weld) in this welded joint. A warning published by the National Board of Boiler and Pressure Vessel Inspectors states this process has a tendency to create “cold lap” defects if not applied by a skilled welder using the correct technique. The GMAW process is also known for its propensity to produce lack-of-fusion defects and is normally not recommended for pressure vessels unless the joint is back welded (back welding was not specified for the incident chiller). If not properly performed, GMAW can cause residual stress.

The high residual stresses can cause cracks to form or cause existing cracks to grow and propagate to the surface during operation. Operational stresses from thermal expansion and contraction as well as internal pressure were introduced during the four months of operation. This can cause the internal cracks to grow and propagate, known as fatigue crack growth. It is also possible that SCC can cause cracks to grow. In the absence of SCC or fatigue, it is possible that small internal weld cracks may never grow to the extent that they cause leaks. In the case of this chiller, one of the cracks did propagate to the surface causing the initial uncontrolled release of ammonia. Similarly, the second crack also propagated in service and ultimately broke through the surface when the pneumatic test was applied for the initial repair.

All 11 of the cracks present in the chiller originated as subsurface cracks in the weld (see Appendix B). The cracks were found to be longer at the root weld than at the external surface of the shell, indicating they initiated as internal cracks in the weld located at the inner surface of the shell. These could go undetected during pressure tests in the manufacturing plant and during initial start-up. However, these internal cracks can grow due to the small, added stresses experienced while the chiller is in operation. These stresses can be caused by cyclical fatigue or could contribute to SCC. The cracks may grow individually or join to form larger subsurface cracks that reach the surface as one large crack and could cause a larger release of ammonia..

The manufacturer referred to industry articles warning of SCC in anhydrous ammonia storage vessels. Control measures to prevent SCC include preventing air contamination, addition of at least 0.2% water, PWHT for stress relief and periodic inspection. Given the literature supplied by the manufacturer, chiller manufacturers may consider conducting PWHT and providing chiller operating instructions that require the addition of water to anhydrous ammonia, removal of oxygen and periodic ultrasonic inspection (less than five month intervals). Further, the manufacture stated

	that the use of lower strength steel to construct the chiller would also reduce the tendency for SCC. The ammonia was not tested to verify the presence of oxygen or water so the possible contribution to SCC could not be confirmed or eliminated. It is known that PWHT was not conducted on this chiller, the lack of which can allow SCC in some cases. High residual stresses caused by weld metal shrinkage can provide conditions for SCC. However, these residual stresses should be present on other welds in this vessel. All of the welds were ultrasonically tested and cracking was only found in one circumferential weld. Given the findings of this incident. the following measures may be considered to prevent cracking in anhydrous ammonia chillers: 1. Construct chillers using lower strength steel as it is less susceptible to SCC than high strength steel. 2. Add at least 0.2% water to anhydrous ammonia. 3. Conduct PWHT. 4. Conduct ultrasonic testing of completed welds.
Causes and contributing factors	The sudden and uncontrolled release of ammonia from a new direct expansion chiller was due to a weld failure. A total of 11 cracks were found in a circumferential weld at one end of the chiller. One of these cracks extended entirely through the shell causing the ammonia leak. Based on the available evidence, the cracks were likely due to welding deficiencies followed by low cycle fatigue cracking while in service. A possible, but less likely, alternative cause or contributing factor is SCC. Probable contributing factors include lack of PWHT to relieve residual stresses inside the weld.

Appendix A: Photographs and Diagrams
Appendix B: Chiller Failure – Root Cause Analysis

Appendix A: Photographs and Diagrams

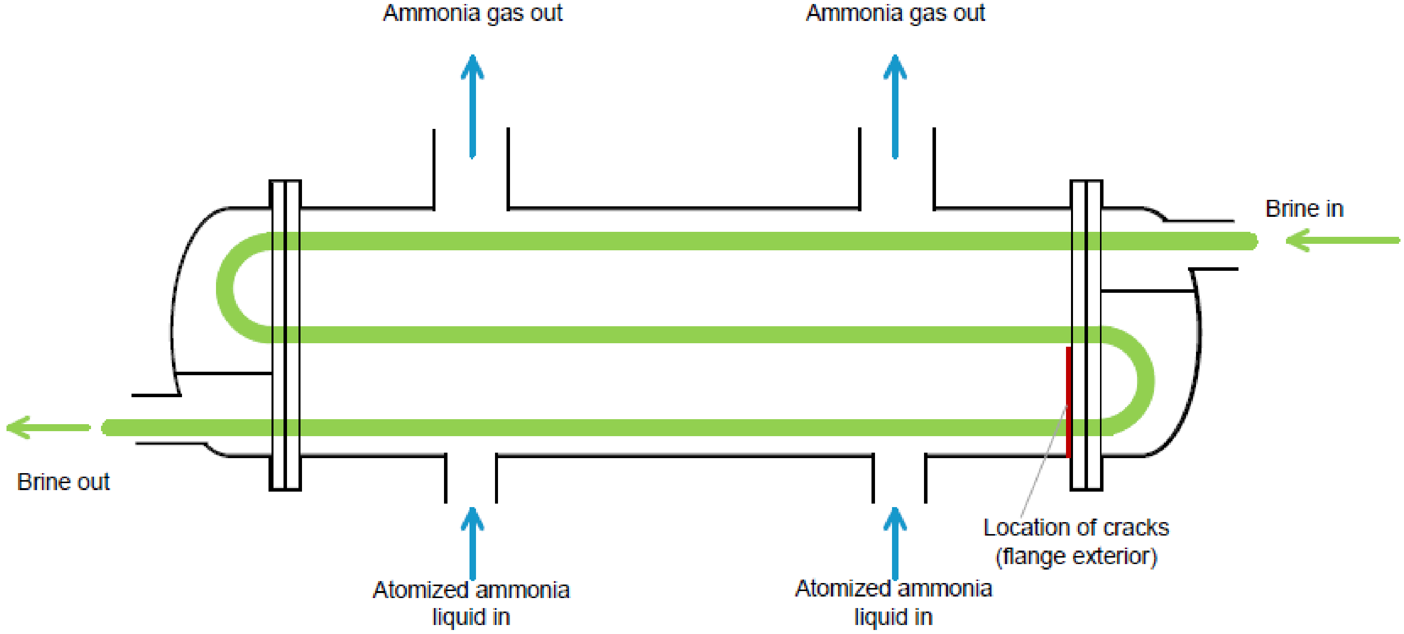

Figure 1: Schematic diagram of incident chiller showing the general flow direction of brine and ammonia.

Figure 2: Location of weld failures along 180° of the circumferential shell to head flange weld.

Figure 3: First crack found in the weld, revealed using liquid dye penetrant inspection. The crack was 0.250-inches-long and extended from the weld into the parent material.

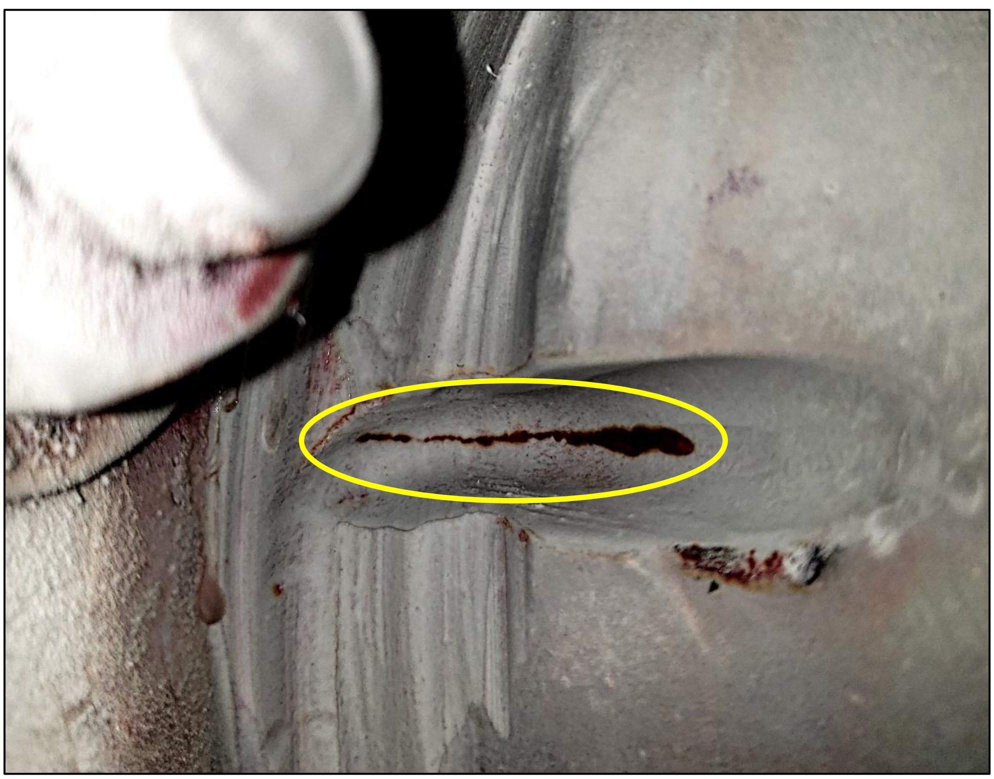
Figure 4: Larger internal crack (from Figure 3) visible after surface grinding. The crack was approximately 0.750-inches-long and extended up to the flange.

Figure 5: Location of 10 weld cracks found by ultrasonic testing. (Source: Acuren report)

Figure 6: Large internal cracks found when welds ground to reveal inner shell surface. (Source: Acuren report)

Figure 7: Close up view of typical weld crack size at the inner shell surface. (Source: Acuren report).

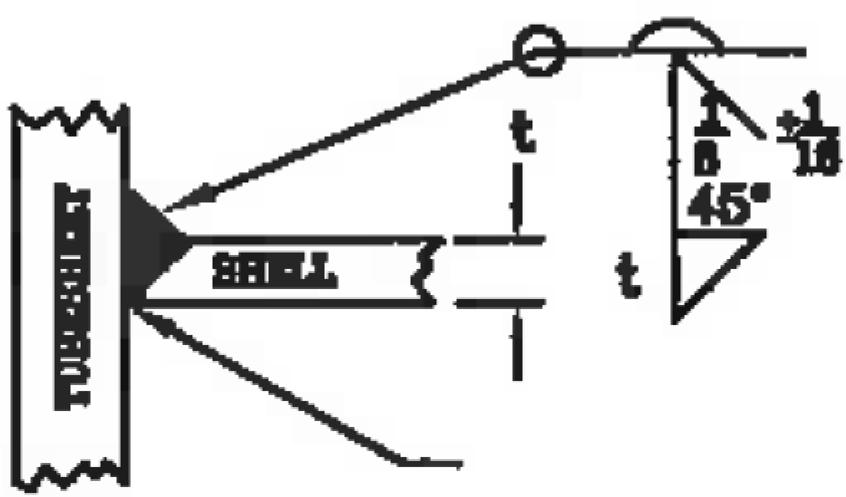

Figure 8: Weld joint detail between the shell and tubesheet [head flange]. Source: manufacturer's assembly drawing.

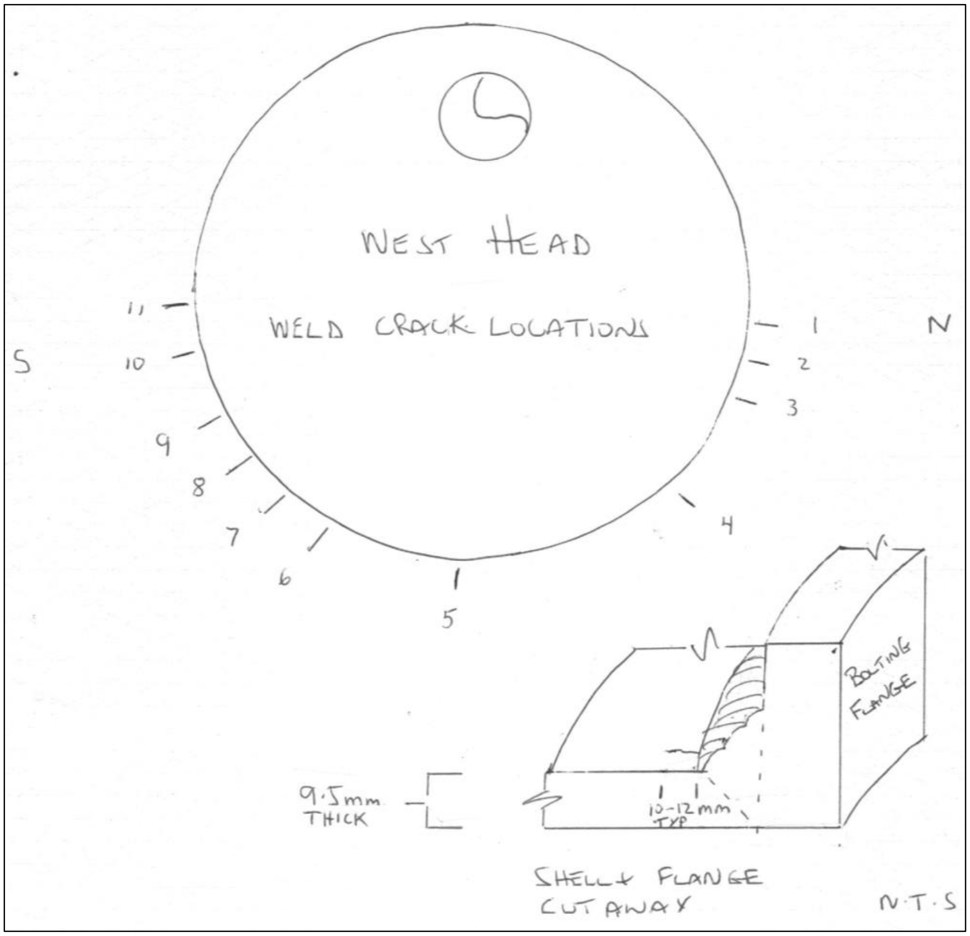

Figure 9: Location of 11 weld cracks found and weld joint detail between the shell and flange. (Source: Acuren report)

Appendix B: Chiller Failure – Root Cause Analysis

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ACUREN

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PORT ALBERNI SPORTSPLEX CHILLER FAILURE – ROOT CAUSE ANALYSIS

Prepared for:

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Attention: Eric Lalli

File Number: 60515372
Date: November 29, 2019

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1.0 INTRODUCTION

A chiller unit on the refrigeration system at the Port Alberni Sports Complex suffered an ammonia leak in service. The leak was isolated and found to be on the East end of the unit (nearest to the outside wall) at the flange to shell weld. The leaking defect was examined by NDT (Kodiak Inspection) and repaired by Geo-Tech Industries. During pneumatic testing of the vessel (275 psi), a second pin-hole leak was found at a different location around the flange to shell joint.

Subsequent to the discovery of the second leaking defect, Acuren was asked to examine the chiller with detailed NDT and determine the extent of the cracking. This work was completed by [redacted]) on 8 November, 2019. A total of 10 cracks were discovered during this inspection. The cracks (11 in total) were repaired by Geo-Tech Industries and successfully pressure tested at 275 psi (pneumatic) on 11 November, 2019.

Acuren was asked to provide a root cause analysis for the cracking observed on the chiller shell to flange welded joint.

2.0 INVESTIGATION

2.1 Site visit

[redacted] P.Eng. travelled to the Port Alberni site on 9 November 2019. The chiller had been stripped of its insulation and checked for defects at 100% of the weld locations. Both MT and UT were used for the inspection. An overall view of the stripped chiller is shown in Figures 1 and 2. A total of 10 new cracks were found on the lower half of the chiller end (see NDT reports; Appendix B). All of these cracks were similar in shape and were transverse to the flange weld. Grinding revealed a short axial crack extension into the parent shell material in every case (Figure 3).

The cracks were removed to their full depth and length and checked for complete removal with MT. The cracks were longer along the interior of the shell than on the exterior surface. This indicates that the cracks originated on the interior surface of the shell.

The gap opening between the two sides of the cracks ranged between 1 and 2 mm (Figures 4 and 5). Residual compressor oil was visible draining from the cracks around the bottom of the vessel. The bulk of this oil was removed, but the interior surface was coated with a thin film of oil and presented a source of hydrogen for welding.

2.2 Repair Welding

The ammonia vessel is constructed from material meeting the specification requirements of SA516 grade 70. The tank wall thickness is 3/8". The U1 Manufacturers data report is shown in Appendix C.

Repair welding was performed using Geo – Tech welding procedures GTI-CS7 and GTI-CS9 (Appendix D). The root and hot passes were performed using the GTAW process and ER70 S3 filler metal (Figure 6). The fill and capping passes were performed using the SMAW process and E7018 welding rods.

Removal of the oil film was essential to get a good root pass. Oil removal was achieved by baking with a propane torch until evidence of the film was gone. The crack at the bottom of the shell continued to bleed some oil due to additional accumulation of oil at the bottom of the vessel. Attempts to place the root pass on the bottom crack initially resulted in hydrogen cracking. A brake cleaning fluid was applied to accelerate removal of any traces of oil. Once all evidence of oil was removed, the root pass was placed without cracking. All of the root passes were checked with MT before proceeding to the hot pass.

The preheat on the vessel was re-applied prior to placing the hot pass. The hot passes on all 10 cracks were applied successfully with no evidence of cracking (MT applied after each pass).

Preheat was re-applied prior to start of fill and capping passes. MT was performed after the final capping pass on each longitudinal weld. The longitudinal shell repair welds were ground prior to placing of the final flange fillet welds. The final flange to vessel fillet welds were checked with MT as shown in Appendix B.

Final MT and pneumatic pressure testing (275 psi) were performed after a minimum waiting period of 24 hours. This allowed time for any possible hydrogen cracking to occur in the weld metal or Heat Affected Zone of the weld. No cracking was found with any of the repair welds. A bubble test performed at a reduced pressure of 250 psi did not reveal any leaks.

2.3 Hardness Testing

Hardness testing was performed on the weld metal and heat affected zone of typical repair welds. The hardness test report is shown in Appendix E. The original weld metal and the repair weld metal is slightly harder than the parent SA516 grade 70 material (HB 195). No excessive hardness was detected in the HAZ or weld metal of the repair welds.

3.0 DISCUSSION

The original leaking defect was repaired before Acuren was asked to attend the site. Grinding of new cracks found was also done before arrival at site. No samples could therefore be obtained from the area of the cracks. In any case, crack samples would have been impossible to retrieve without damaging the clad tubesheet and/or some of the adjacent titanium tubes.

The cause of the observed cracking can be deduced from our knowledge of the manufacturing method, the materials of construction, and the appearance of the cracks as found with the vessel.

The material of construction is SA516 grade 70, which has a maximum tensile strength of 90,000 psi. The chemistry of this steel is restricted to a maximum carbon content of 0.27 % and a maximum manganese content of 1.30%. The maximum carbon equivalent would be close to 0.50.

It is understood that the shell to flange welds are performed in a rotating device where the welds are performed in the flat position. Although this ensures a uniformly placed weld, the residual stresses associated with the weld would be magnified toward the end of a full circumferential pass. Multiple passes would allow the root passes and hot passes to become partially stress relieved. The U1 form indicates that no NDT was performed on the completed shell to flange welds.

UT evaluation of the shell seam and the shell to flange welds detected cracks at the locations shown in Appendix B. All of the cracks are on the bottom 180 ° of the shell and relatively uniformly spaced around the shell circumference. No cracks were found at any other location.

Cracking of the type observed would not be expected with welded pressure vessels of this type. If cracking does develop, it is likely caused by one of two things:

1. Environmental cracking (Stress Corrosion Cracking),

2. Manufacturing issues resulting in weld cracks

Ammoniacal stress corrosion cracking requires oxygen to be present in the ammonia. This type of cracking is branched and follows the heat affected zone of any welds in the area where residual stresses are high. In this case, the cracks into the parent shell material were straight and did not contain any visible branches. The cracks appeared to propagate just beyond the edge of the fillet weld heat affected zone then arrested. Cracks were only found in one location on the vessel. For these reasons, it is unlikely that SCC was the cause of the cracking.

The uniform distribution of the cracks may indicate that tack welds were present at the crack locations. Improperly fused tack welds may have caused cracking to the edge of the HAZ which remained stable until the unit was put into service. This type of cracking would happen immediately before the hot pass was installed. The sharp crack tip could have grown by cyclic stresses (low cycle fatigue) placed on the unit while in operation. It is understood that the vessel was cycled between 30 psi and 50 psi many times per day in normal service. Even though the nominal stresses in the unit are low, the cyclic stresses are magnified at the crack tip and may be sufficient to propagate fatigue cracks.

4.0 CONCLUSIONS

The circumstantial evidence indicates that the chiller shell to flange weld on the East end of the unit failed due to a combination of factory weld cracking followed by low cycle fatigue cracking. No evidence of stress corrosion cracking was found. The uniform spacing of the cracks may correspond with tack welds used in the assembly of the flange to the shell.

[redacted] P.Eng.

Note: Unless otherwise instructed, we shall dispose of all parts and test samples sixty days from the date of this report.

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APPENDIX A

FIGURES A-1 - A-6

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Figure A-1 Overall view of stripped chiller. Heads are titanium alloy.

Figure A-2 Opposite side of chiller flange showing location of cracks labelled 1, 2, 3, and 4.

Figure A-3 Short axial crack entering the shell of the vessel.

Figure A-4 Ground out crack showing opening of 1 -2 mm and depth of 3/8".

Figure A-5 Second ground out crack showing opening of 1 -2 mm and depth of 3/8"

Figure A-6 Typical crack after hot pass is placed.

APPENDIX B

NDT REPORTS

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VANCOUVER, BC
V5M 4T5

APPENDIX: A

DATE: November 7 & 8, 2019
ACUREN JOB #: 60515372
REPORT #: 1
CONTRACT/PO: Pending
WORK LOCATION: Port Alberni

ATTENTION: **ERIC LALLI**
PROJECT: Alberni Valley Multiplex
ITEM(S) EXAMINED: Brine Chiller

PART #: s/n 18173X   MATERIAL: Carbon steel   THICKNESS: .375

SCOPE: Carry out an ultrasonic weld examination of the 32" diameter vessel bolting flange groove welds. In addition scan the vessel long seam weld to determine if any similar transverse indications are present.

TYPE OF INSPECTION: Ultrasonic

TEST DETAILS:

ACCEPTANCE STANDARD: Crack Detection   REVISION: N/A
PROCEDURE/TECHNIQUE: CAN-UT-14P002   REVISION: 07

TYPE: Flaw Detection   METHOD: Contact

INSTRUMENT: Olympus   MODEL: Epoch 600   S/N: 100048111   CAL DUE: June 1, 2020

CAL. BLOCK: IIW   S/N: 1026   CABLE-TYPE: Coaxial   LENGTH: 5'

CAL. BLOCK: N/A   S/N: N/A   COUPLANT: N/A

Probe & Technique Details:

	Test Angle (°)	Probe Type	Crystal Size	Freq. (MHz)	Serial Number	Damp ng Ω	Test From	Reference Reflector	Transfer Value	Reference		Scan dB	Range
										dB	% FSH		
1	0	Single	12.7mm	5	14A010LZ	50	One side	BWE	N/A	45	80	+6	50mm
2	70	Single	12.7mm	2.25	G0034R1	50	One side	SDH	N/A	52	70	+12	125mm

TEST SURFACE CONDITION: Clean Bare Metal   TEST SURFACE TEMPERATURE: 10°C to 12°C

RESULTS:

The east head and vessel long seam weld did not reveal any transverse indications at the time of the inspection similar to the west head.

The west head revealed 9 additional subsurface transverse crack indications running perpendicular to the circumferential groove weld.

Number 11 was the initial weld repair made by Geo Tech, the number 10 location was discovered by Geo Tech during their pressure test after the initial weld repair.

All crack locations were identified on the vessel shell. All cracks ran into the shell plate out below the toe of the fillet weld for a distance of 8mm -12mm.

CLIENT:

CLIENT SIGNATURE
ACCEPTED & ACKNOWLEDGED BY

ACUREN TECHNICIAN:

1st Technician   2nd Technician

REV EWER:

TOTAL HOURS   S.T.   O.T.   SHIFT
1ST TECHNICIAN: Day ☐
2ND TECHNICIAN: PM ☐
KILOMETRES: OTHER CHARGES: YES ☐ NO ☐
(IF YES, SEE DAILY OR PROJECT TIME REPORT)

FIGURE B-1: ALBERNI VALLEY MULTIPLEX CHILLER

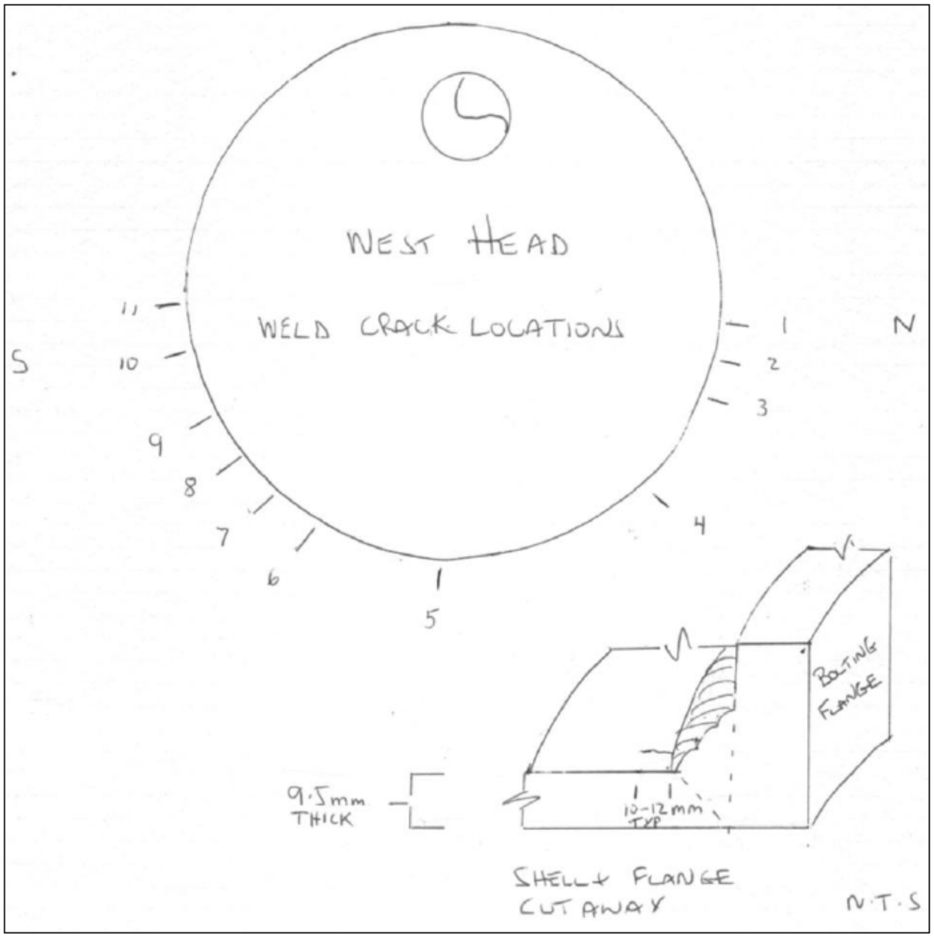


Photo 1:

Vessel overview.

Acuren Group Inc.
12271 Horseshoe Way
Richmond, BC, Canada V7A 4V4
www.acuren.com

Phone: 604.275.3800
Fax: 604.274.7235

A Higher Level of Reliability

NONDESTRUCTIVE EXAMINATION

CLIENT: TECHNICAL SAFETY B.C.
600 - 2889 EAST 12TH AVENUE
VANCOUVER, BC
V5M 4T5

APPENDIX: B

DATE: November 10 & 11, 2019
ACUREN JOB #: 60515372
REPORT #: 2
CONTRACT/PO: Pending
WORK LOCATION: Port Alberni

ATTENTION: **ERIC LALLI**
PROJECT: Alberni Valley Multiplex
ITEM(S) EXAMINED: Brine Chiller Crack Repairs

PART #: N/A MATERIAL: Carbon steel THICKNESS: .375"

SCOPE: Carry out PT inspections of all crack excavation sites on the west head to ensure crack removal prior to rewelding. Carry out MT inspections of all 10 completed crack site TIG weld root passes and subsequent stick weld fill and cover passes. Also carry out a final inspection of the completed fillet weld to the bolting flange.

TYPES OF INSPECTION: Liquid Penetrant; Magnetic Particle

RESULTS:

With the exception of location #10 which required additional grinding to remove the original indication all other cracks had been removed on the first attempt with LPI.

All TIG root passes have been inspected and found acceptable with MPI.

All stick filler passes and the final fillet weld have been inspected with MPI and found acceptable.

A post 24-hour inspection of all repair welds was also carried out with acceptable results.

In addition the writer witnessed all pressure tests post 24-hr weld repair. All results were found acceptable and were recorded on the Geo Tech traveller.

CLIENT: ______ ______
CLIENT SIGNATURE
ACCEPTED & ACKNOWLEDGED BY

ACUREN TECHNICIAN: [redacted]
1st Technician   2nd Technician

[redacted]

REVIEWER: [redacted]

TOTAL HOURS S.T. O.T. SHIFT
1ST TECHNICIAN: Day ☐
2ND TECHNICIAN: PM ☐
KILOMETRES: OTHER CHARGES: YES ☐ NO ☐
(IF YES, SEE DAILY OR PROJECT TIME REPORT)

(Generated Using: CAN-QUA-02F007)

Photo B-1:

Brine Chiller overview.

Photo B-2:

Location #5 excavation site.

Photo B-3:

Locations 6-10 excavation sites.

Photo B-4:

Locations 1-4 excavation inspection prior to rewelding.

Photo B-5:

Close-up of typical excavation site with fillet removed.

Photo B-6:

Location #5 final root pass inspection.

Photo B-7:

Location 1-4 root pass.

Photo B-8:

Locations 6-10 root pass.

Photo B-9:

Final fillet weld inspection.

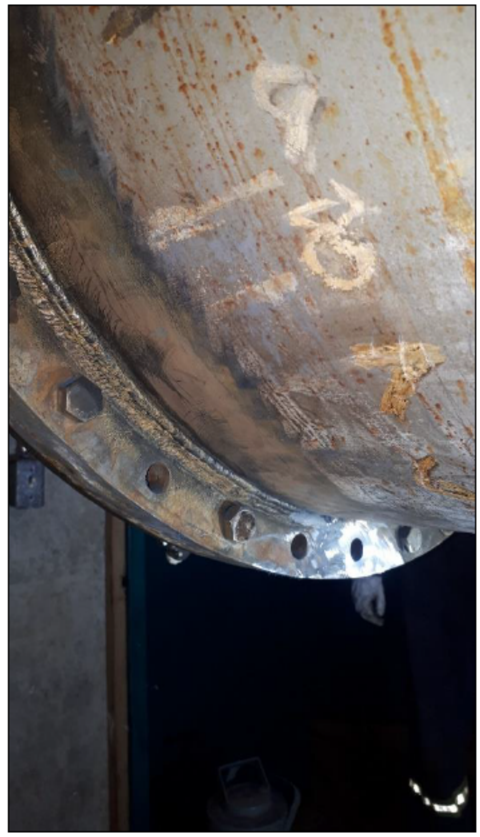


Photo B-10:

Final fillet weld inspection.

Photo B-11:

Final fillet weld inspection.

TEST DETAILS: LIQUID PENETRANT

ACCEPTANCE STANDARD: ASME VIII, Div. 1, Appx 8			REVISION: 2017
PROCEDURE/TECHNIQUE: CAN-PT-14P001			REVISION: 13
TYPE: Vis ble		METHOD: Water Washable	
FAM LY BRAND: Chemetall Oakite		LIGHTING EQUIPMENT: Flashlight	
PENETRANT: 906	DWELL T ME: 20 Min.	BLACKLIGHT MAKE: N/A	S/N: N/A
PENETRANT REMOVER: Water	DRY TIME: 5 Min.	LIGHT METER S/N: 11010146	CAL DUE: Nov 24, 2019
DEVELOPER: 9D1B	DWELL T ME: 15 Min.	LIGHT INTENSITY: > 100 fc (1076 lx)	
DEVELOPER TYPE: Non Aqueous			
BATCH NOS. (WHEN REQUIRED): PENETRANT: 65121713		REMOVER: N/A	DEVELOPER: 65100115
TEST SURFACE CONDITION: Clean Bare Metal		TEST SURFACE TEMPERATURE: 12°C to 14°C	

TEST DETAILS: MAGNETIC PARTICLE

ACCEPTANCE STANDARD: ASME VIII, Div. 1, Appx 6			REVISION: 2017
PROCEDURE/TECHNIQUE: CAN-MT-14P001			REVISION: 15
TYPE: Dry Visible		METHOD: Yoke	
PARTICLE BRAND: Magnaflux	PRODUCT NO.: 8A	CURRENT: AC	MT INSTRUMENT: Parker B-300
PARTICLE COLOUR: Blue		MT INSTRUMENT S/N: 15850	CAL DUE: Jan 15, 2020
SUSPENSION: N/A		LIFT CHECK BEFORE USE: Yes	L FT WEIGHT S/N: 16050
CONTRAST PA NT: N/A	PRODUCT NO.: N/A	LIGHT NG EQUIPMENT: Flashlight	
MAG TIME (SECONDS): 5	DEMAG REQUIRED?: No	BLACKLIGHT MAKE: N/A	S/N: N/A
TECHNIQUE DEMONSTRATED OVER A PA NTED SURFACE?: N/A		LIGHT METER S/N: 11010146	CAL DUE: Nov 24, 2019
		LIGHT INTENSITY: > 100 fc (1076 lx)	
TEST SURFACE CONDITION: As Welded		TEST SURFACE TEMPERATURE: 12°C to 14°C	

APPENDIX C

U1 FORM

ISOTHERM, INC.
7401 Commercial Blvd. E * PO Box 172370 * Arlington, Texas 76003 * Ph (817) 472-9922 * Fax (817) 472-5878

10

U-1 for Heat Exchanger.

Manufacturer of Heat Transfer & Refrigeration Equipment
e-mail. info@iso-therm.com, www.iso-therm.com

FORM U-1 MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS

As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1

1. Manufactured and certified by **Isotherm, Inc., 7401 Commercial Blvd. East, Arlington, Texas, 76001**
(Name and address of Manufacturer)

2. Manufactured for **ACCENT REFRIGERATION SYSTEMS, 1097 Langford Pkwy #206, Victoria, British Columbia, V9B 0A5, CANADA**
(Name and address of Purchaser)

3. Location of installation **Not Known**
(Name and address)

4. Type **Horizontal** (Horizontal, vertical, or sphere) — **SHELL & TUBE SX CHILLER** (Tank, separator, jkt. vessel, heat exch., etc.) — **18173X** (Manufacturer's serial number)

L1680.1 (CRN) — **18097A, Rev. 01** (Drawing number) — **3073** (National Board number) — **2018** (Year built)

5. ASME Code, Section VIII, Div. 1 — **2017/ N/A** [Edition and Addenda, if applicable (date)] — **N/A** (Code Case Number) — **N/A** [Special Service per UG-120(d)]

Items 6-11 incl. to be completed for single wall vessels, jackets of jacketed vessels, shell of heat exchangers, or chamber of multichamber vessels.

6. Shell: (a) Number of course(s) **2** (b) Overall length **11' 8.75"**

Course(s)			Material	Thickness		Long. Joint (Cat. A)			Circum. Joint (Cat. A, B, & C)			Heat Treatment	
No.	Diameter	Length	Spec./Grade or Type	Nom.	Corr.	Type	Full, Spot, None	Eff.	Type	Full, Spot, None	Eff.	Temp.	Time
1	32" OD	10'	SA516-70	3/8"	0"	1	None	0.70	1	None	0.70	N/A	N/A
1	32" OD	1' 8.625"	SA516-70	3/8"	0"	1	None	0.70	1	None	0.70	N/A	N/A

Body Flanges on Shells

No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting: Num & Size	Bolting: Bolting Material	Bolting: Washer (OD, ID, thk)	Bolting: Washer Material
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

7. Heads: (a) **N/A** (Material spec. number, grade or type) (H.T. - time and temp.) (b) **N/A** (Material spec. number, grade or type) (H.T. - time and temp.)

	Location (Top, Bottom, Ends)	Thickness: Min.	Thickness: Corr.	Radius: Crown	Radius: Knuckle	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure: Convex	Side to Pressure: Concave	Category A: Type	Category A: Full, Spot, None	Category A: Eff.
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Body Flanges on Heads

	Location	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Bolting: Num & Size	Bolting: Bolting Material	Bolting: Washer (OD, ID, thk)	Bolting: Washer Material
(a)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A	N/A	N/A

8. Type of jacket **N/A** Jacket closure **N/A** (Describe as ogee & weld, bar, etc.)

If bar, give dimensions; if bolted, describe or sketch **N/A**

9. MAWP **250 psi** (Internal) **N/A** (External) at max. temp. **200 °F** (Internal) **N/A** (External) Min. design metal temp. **-20 °F** at **250 psi**

10. Impact test **No** [Indicate yes or no and the component(s) impact tested] at test temperature of **N/A**

11. Hydro., pneu., or comb. test pressure **Pneu. at 275 psi** Proof test **N/A**

Items 12 and 13 to be completed for tube sections.

12. Tubesheet **SB265-1/SA516-70** [Stationary (material spec. no.)] — **36"** [Diameter (subject to press.)] — **1 1/2"** (Nominal thickness) — **0"** (Corr. allow.) — **Welded** Attachment (welded or bolted)

N/A [Floating (material spec. no.)] — **N/A** (Diameter) — **N/A** (Nominal thickness) — **N/A** (Corr. allow.) — **N/A** (Attachment)

13. Tubes **SB338-2** (Material spec. no., grade or type) — **3/4"** (O. D.) — **B.W.G. 20** (Nominal thickness) — **826** (Number) — **Straight** [Type (Straight or U)]

FORM U1

Manufactured by **Isotherm, Inc., 7401 Commercial Blvd. East, Arlington, Texas, 76001**

Manufacturer's Serial No. **18173X** CRN **L1680.1** National Board No. **3073**

Items 14-18 incl. to be completed for inner chambers of jacketed vessels or channels of heat exchangers.

14. Shell: (a) No. of course(s) **N/A** (b) Overall length **N/A**

Course(s)			Material	Thickness		Long. Joint (Cat. A)			Circum. Joint (Cat. A, B, & C)			Heat Treatment	
No.	Diameter	Length	Spec./Grade or Type	Nom.	Corr.	Type	Full, Spot, None	Eff.	Type	Full, Spot, None	Eff.	Temp.	Time
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Body Flanges on Shells

No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting: Num & Size	Bolting: Bolting Material	Bolting: Washer (OD, ID, thk)	Bolting: Washer Material
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

15. Heads: (a) **N/A** (Material spec. number, grade or type) (H.T. - time and temp.) (b) **N/A** (Material spec. number, grade or type) (H.T. - time and temp.)

	Location (Top, Bottom, Ends)	Thickness		Radius		Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure		Category A		
		Min.	Corr.	Crown	Knuckle					Convex	Concave	Type	Full, Spot, None	Eff.
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Body Flanges on Heads

	Location	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Bolting: Num & Size	Bolting: Bolting Material	Bolting: Washer (OD, ID, thk)	Bolting: Washer Material
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

16. MAWP **N/A** (Internal) **N/A** (External) at max. temp. **N/A** (Internal) **N/A** (External) Min. design metal temp. **N/A** at **N/A**.

17. Impact test **N/A** [Indicate yes or no and the component(s) impact tested] at test temperature of **N/A**.

18. Hydro., pneu., or comb. test pressure **N/A** Proof test **N/A**

19. Nozzles, inspection, and safety valve openings:

Purpose (Inlet, Outlet, Drain, etc.)	No.	Diameter or Size	Type	Material: Nozzle	Material: Flange	Nozzle Thickness: Nom.	Nozzle Thickness: Corr.	Reinforcement Material	Attachment Details: Nozzle	Attachment Details: Flange	Location (Insp. Open.)
SS INLET	2	1 1/2"	W.E.	SA106B		0.200"	0"	Inherent	Fig. UW-16.1(c) w/o backing		
SS OUTLET	2	8"	W.E.	SA106B		0.322"	0"	Inherent	Fig. UW-16.1(c) w/o backing		
SS RELIEF	1	3/4"	NPTF F Cplng	SA105		3000#	0"	Inherent	Fig. UW-16.1(c) w/o backing		
SS OIL DRAIN	2	1"	NPTF F Cplng	SA105		3000#	0"	Inherent	Fig. UW-16.1(c) w/o backing		

20. Supports: Skirt **No** (Yes or no) Lugs **N/A** (Number) Legs **N/A** (Number) Others **2 Cradle Assemblies** (Describe) Attached **Item 6, Welded** (Where and how)

21. Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors have been furnished for the following items of the report (list the name of part, item number, Manufacturer's name, and identifying number):

N/A

22. Remarks

Length of tubes: 12'

Model:SX-3212D. Non lethal, non corrosive service. Pressure relief devices by others. Impact test exempt as per UCS-66(a). Tube side code exempt. Tube side test pressure 25 PSIG.

ACUREN

FORM U1 Page 3 of 3

Manufactured by **Isotherm, Inc., 7401 Commercial Blvd. East, Arlington, Texas, 76001**

Manufacturer's Serial No. **18173X** CRN **L1680.1** National Board No. **3073**

CERTIFICATE OF SHOP COMPLIANCE

We certify that the statements in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. U Certificate of Authorization Number **31095** Expires **June 17, 2020**

Date 12/21/2018 Name Isotherm, Inc. (Manufacturer) Signed [redacted] (Representative)

CERTIFICATE OF SHOP INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by

OneCIS Insurance Company, of Lynn, MA

have inspected the pressure vessel described in this Manufacturer's Data Report on **January 9, 2019**, and state that,

to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. By signing this certificate neither the Inspector nor his/her employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his/her employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 01/09/2019 Signed [redacted] (Authorized Inspector) Commissions: [redacted] (National Board Authorized Inspector Commission number)

CERTIFICATE OF FIELD ASSEMBLY COMPLIANCE

We certify that the statements made in this report are correct and that the field assembly construction of all parts of this vessel conforms with the requirements of ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. U Certificate of Authorization Number ________ Expires ________

Date ________ Name ________ (Assembler) Signed ________ (Representative)

CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by The National Board of Boiler and Pressure Vessel Inspectors and employed by

________,

have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data items ________, not included in the certificate of shop inspection, have been inspected by me and to the best of my knowledge and belief, the Manufacturer has constructed and assembled this pressure vessel in accordance with the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. The described vessel was inspected and subjected to a pressure test of ________. By signing this certificate neither the Inspector nor his/her employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his/her employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date ________ Signed ________ (Authorized Inspector) Commission ________ (National Board Authorized Inspector Commission number)

3245139 exe: v6.3.62 U1-16

ACUREN

APPENDIX D

GEO-TECH WELDING PROCEDURES

QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATION (WPS)

(See QW-200.1, Section IX, ASME Boiler and Pressure Vessel Code)

npany Name Geo-Tech Industries Inc. By:

Welding Procedure Specification No. GTI-CS 7 Date August 23, 1993 Supporting PQR No.(s) GTI-CS 7

Revision No. 0 Date August 23, 1993

Welding Process (es) GTAW Type(s) MANUAL

(Automatic, Manual, Machine or Semi-Auto.)

JOINTS (QW-402)

Joint Design ALL ASME GROOVE & FILLET TYPES

Backing (Yes) (No) X

Backing Material (Type) NONE

(Refer to both backing and retainers.)

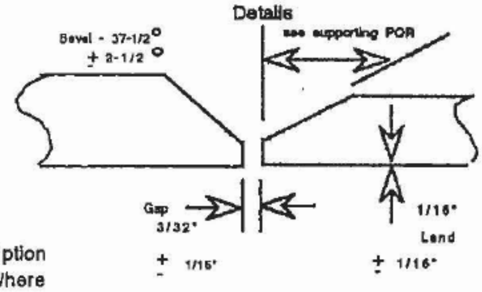
☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

Sketches, Production Drawings, Weld Symbols or Written Description should show the general arrangement of the parts to be welded. Where applicable, the root spacing and the details of weld groove may be specified.

(At the option of the Mfgr., sketches may be attached to illustrate joint design, weld layers and bead sequence, e.g. for notch toughness procedures, for multiple process procedures, etc.)

Details



*BASE METALS (QW-403)

P-No. 1 Group No. 1 & 2 to P-No. 1 Group No. 1 & 2

OR

Specification type and grade

to Specification type and grade

OR

Chem. Analysis and Mech. Prop.

to Chem. Analysis and Mech. Prop.

Thickness Range:

Base Metal: Groove 3/16" thru 1" Fillet ALL SIZES, THICKNESSES & DIAMETERS

Pipe Dia. Range: Groove ALL Fillet ALL SIZES, THICKNESSES & DIAMETERS

Other NO PASS GREATER THAN 1/2" T.

*FILLER METALS (QW-404)	GTAW	
Spec. No. (SFA)	5.18	
AWS No. (Class)	ERXXSX	
F-No.	6	
A-No.	1	
Size of Filler Metals	3/32" & 1/8"	
Deposited Weld Metal	1/2"	
Thickness Range:	3/16" MIN.	
Groove	1" MAX	
Fillet	ALL	
Electrode-Flux (Class)	NONE	
Flux Trade Name	NONE	
Consumable Insert	NONE	
Other	NONE	REGISTERED 92.9.16

*Each base metal-filler metal combination should be recorded individually.

BC BOILERS & PRESSURE VESSELS BRANCH

QW-482 (Back) WPS No. GTI-CS7 Rev. 0

POSITIONS (QW-405)
Position(s) of Groove ALL
Welding Progression: Up X Down X
Position(s) of Fillet ALL

POSTWELD HEAT TREATMENT (QW-407)
Temperature Range NONE
Time Range NONE

PREHEAT (QW-406)
Preheat Temp. Min. 60 F
Interpass Temp. Max. 400 F
Preheat Maintenance NONE
(Continuous or special heating where applicable should be recorded)

GAS (QW-408)

	Gases	Percent Composition (Mixture)	Flow Rate
Shielding	ARGON	100%	20-45 CFH
Trailing	NONE	NONE	NONE
Backing	NONE	NONE	NONE

ELECTRICAL CHARACTERISTICS (QW-409)
Current AC or DC DC Polarity STRAIGHT
Amps (Range) 60 - 130 Volts (Range) 18 - 28
(Amps and volts range should be recorded for each electrode size, position, and thickness, etc. This information may be listed in a tabular form similar to that shown below.)

Tungsten Electrode Size and Type 3/32" - 1/8" 2% THORIATED
(Pure Tungsten, 2% Thoriated, etc.)
Mode of Metal Transfer for GMAW NONE
(Spray arc, short circuiting arc, etc.)
Electrode Wire feed speed range 5" - 7" IPM

TECHNIQUE (QW-410)
String or Weave Bead STRING & WEAVE
Orifice or Gas Cup Size 3/8" THRU 3/4"
Initial and Interpass Cleaning (Brushing, Grinding, etc.) WIRE BRUSH OR GRINDING
Method of Back Gouging GRIND AND/OR ARC AIR IF REQ'D.
Oscillation MAX 3 TIMES ROD DIAMETER
Contact Tube to Work Distance NONE
Multiple or Single Pass (per side) MULTIPLE
Multiple or Single Electrodes SINGLE
Travel Speed (Range) 2" to 6" IPM
Peening NONE
Other NONE

Weld Layer(s)	Process	Filler Metal Class	Filler Metal Dia.	Current Type Polar.	Current Amp. Range	Volt Range	Travel Speed Range	Other (eg., Remarks, Comments, Hot Wire Addition, Technique, Torch Angle, Etc.)
ALL	GTAW	ERXXSX	3/32	DCEN	90-170	16-23	2 - 6 IPM	NONE
AND/OR								
ALL	GTAW	ERXXSX	1/8	DCEN	90-170	16-23	2 - 6 IPM	NONE

BC BOILERS & PRESSURE VESSELS BRANCH

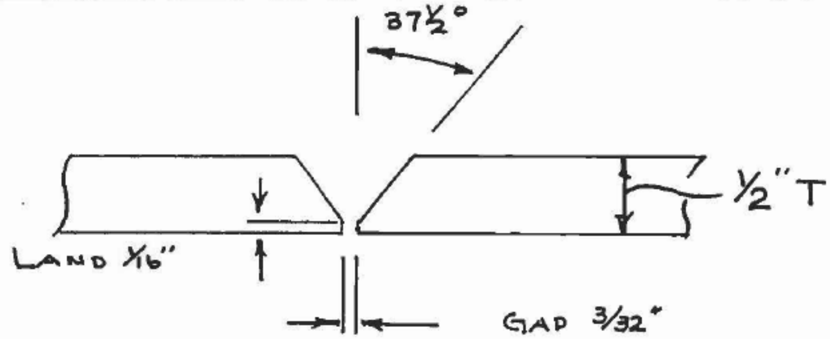
ACUREN

QW-483 PROCEDURE QUALIFICATION RECORD (PQR)

(See QW-200.2, Section IX, ASME Boiler & Pressure Vessel Code)
Record actual Conditions Used to Weld Test Coupon

Company Name: Geo-Tech Industries INC. 8338 Crofton Road Crofton, B.C.
Procedure Qualification Record No.: GTI - CS 7 Date: August 23, 1993
W.P.S.: GTI - CS 7
Welding Process(es): GTAW
Types (manual, Automatic, Semi-auto): MANUAL

Joints (QW 402)



Groove Design of Test Coupon
(For combination qualification, the deposited weld metal thickness shall be recorded for each filler metal or process used)

BASE METALS (QW 403)
Material Specs.: SA516
Type or Grade: 70
P-No.: 1 to P-No.: 1
Thickness of Test Coupon: .500"
Diameter of Test Coupon: PLATE
Other: NONE

POSTWELD HEAT TREATMENT (QW407)
Temperature: NONE
Time: NONE
Other: NONE

GAS (QW-408)

	Gases	Percent Composition (Mixture)	Flow rate
Shielding	ARGON	100 %	22 CFH
Trailing	NONE	NONE	NONE
Backing	NONE	NONE	NONE

FILLER METALS (QW404)
SFA Specification: 5.18
AWS Classification: ER70 - S
Filler metal F-No.: F6
Weld Metal Analysis A-No.: A-1
Size of Filler Metal: 3/32" & 1/8"
Other: NONE

Weld Metal Thickness: .500"

ELECTRICAL CHARACTERISTICS (QW 409)
Current: DC
Polarity: DCEN STRAIGHT
Amps: 129 Volts: 19
Tungsten Electrode size: 3/32
Other: 2% THORIATED

POSITION (QW 405)
Position of Groove: 3 G
Weld Progression (Uphill, Downhill): UPHILL
Other: NONE

TECHNIQUE (QW 410)
Travel Speed: 2" IPM
String or Weave bead: STRING & WEAVE
Oscillation: 3 x ROD DIAMETER
Multipass or Single pass (per side): MULTIPASS
Single or multiple Electrodes: SINGLE
Other: NONE

PREHEAT (QW-406)
Preheat Temp.: 50 F
Interpass Temp.: 400 F
Other: NONE

BC BOILERS & PRESSURE VESSELS BRANCH

ACUREN

QW-483 (Back)

PQR No. GTI - CS7

Tensile Test (QW-150)

Specimen No.	Width	Thickness	Area	Ultimate Total Load lb.	Ultimate Unit Stress psi	Type of Failure & Location
1	0.758	0.488	0.370	29,800	80,500	WELD
2	0.755	0.484	0.365	29,200	80,000	WELD

Guided-Bend Tests (QW-160)

Type and Figure No.	Result
SIDE BEND 1	ACCEPTABLE
SIDE BEND 2	ACCEPTABLE
SIDE BEND 3	ACCEPTABLE
SIDE BEND 4	ACCEPTABLE

Toughness Tests (QW-170)

Specimen No.	Notch Location	Notch Type	Test Temp.	Impact Values	Lateral Exp.		Drop Weight	
					% Shear	Mils	Break	No Break
			NONE					

Fillet-Weld Tests (QW-170)

Result --Satisfactory: Yes NONE No Penetration into Parent Metal: Yes NONE No

Macro --Results NONE

B.C. BOILERS & PRESSURE VESSELS BRANCH

Other Tests

Type of Test VISUAL EXAMINATION - ACCEPTABLE PER QW 190

Deposit Analysis NONE TAKEN

Other NONE

Welder's Name GREG GICAS Clock No. 6 M Stamp No.

Tests conducted by: COAST TESTING Laboratory Test No. 3807 T/A 21

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Manufacturer GEO - TECH IND.

Date AUGUST 23, 1993 By

(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code.)

ACUREN

COAST TESTING

TENSILE AND GUIDED BEND TEST REPORT

AUG 23 1993

CUSTOMER: Geo-Tech Industries Inc.

ADDRESS: P.O. Box 310, Crofton, B.C. V0R 1K0

ATTENTION: [redacted]

PURCHASE ORDER NO: 1163

DATE TESTED: August 13, 1993

COAST JOB NO: 3807

MATERIAL DESCRIPTION: Butt Welded Plate, ½" thick, SA516 Grade 70, Welded per GTI-CS7

SPECIMEN TYPE: Tension: QW-462.1 (a)
Side Bend: QW-462.2

GOVERNING SPECIFICATION: ASME IX

TECHNICIAN: [redacted]

	SPECIMEN IDENTIFICATION			
	1	2	3	4
Dimensions				
Width (in.)	0.758	0.755		
Thickness (in.)	0.488	0.484		
Area (in.^{2})	0.370	0.365		
Yield Load (lb.)				
Yield Strength (psi)				
Specified (min. psi)				
Ultimate Load (lb.)	29,800	29,200		
Ultimate Strength (psi)	**80,500**	**80,000**		
Specified (min. psi)	70,000	70,000		
Elongation in 2 in. G.L. (%)				
Specified (min. %)				
Reduction in Area (%)				
Location of Fracture	Weld	Weld		
Hardness				
Guided Root Bend Test				
Guided Face Bend Test				
Guided Side Bend Test	Pass	Pass	Pass	Pass

REMARKS:

B.C. BOILERS & PRESSURE VESSELS BRANCH

(q:bend1.frm)

Rev. 92/01

ACUREN

QW-484 SUGGESTED FORMAT FOR MANUFACTURER'S RECORD OF WELDER OR WELDING OPERATOR QUALIFICATION TESTS (WPQ)
(See QW-301, Section IX, ASME Boiler and Pressure Vessel Code)

Welder's name [redacted] Clock number 6 M Stamp number [redacted]
Welding process(es) used GTAW Type MANUAL
Identification of WPS followed by welder during welding of test coupon GTI - CS 7
Base material(s) welded CARBON STEEL PLATE Thickness .500"

Manual or Semi-Automatic Variables for Each Process (QW-350)	Actual Values	Range Qualified
Backing (metal, weld metal, welded from both sides, flux, etc.)(QW-402)	NONE	NONE
ASME P-No. 1 to ASME P-No. (QW-403)	P1 to P1	P1 to P1
(X) Plate or ( ) Pipe (enter pipe diameter, if pipe)	PLATE	PLATE & PIPE/24"ø
Filler metal specification (SFA-No.) 5.18 Classification (QW-404)	ER70S 6	ERXXSX
Filler metal F-No.	F6	F6
Consumable Insert for GTAW or PAW	ARGON	ARGON
Weld deposit thickness for each welding process	.500"	1"
Welding position (1G,5G, etc.) (QW-405)	3G	1G - 3G
Welding progession (uphill/downhill)	UPHILL	UPHILL
Backing gas for GTAW, PAW or GMAW; fuel gas for OFW (QW-408)	ARGON	ARGON
GMAW transfer mode (QW-409)	NONE	NONE
GTAW welding current type/polarity	DC-STRAIGHT	DC-STRAIGHT

Machine Welding Variables for the Process used (QW-360)	Actual Values	Range Qualified
Direct/remote visual control	NONE	NONE
Automatic voltage control (GTAW)	NONE	NONE
Automatic joint tracking	NONE	NONE
Welding position (1G, 5G, etc.)	NONE	NONE
Consumable Insert	NONE	NONE
Backing (metal, weld metal, welded from both sides, flux, etc.)	NONE	NONE

Guided Bend Test Results

B.C. BOILERS & PRESSURE VESSELS BRANCH

Guided Bend Tests Type	QW-462.2 (Side) Results	QW-462.3(a) (Trans. R&F) Type	QW-462.3(b)(Long. R&F) Results
SIDE BENDS 1	ACCEPTABLE	NONE	NONE
SIDE BENDS 2	ACCEPTABLE	NONE	NONE
SIDE BENDS 3	ACCEPTABLE	NONE	NONE
SIDE BENDS 4	ACCEPTABLE	NONE	NONE

Visual examination results (QW 302.4) ACCEPTABLE PER QW-190
Radiographic test results (QW-304 and QW -305) NONE
(For alternative qualification of groove welds by radiography)
Fillet weld -fracture test NONE Length and % of defects in.
Macro test fusion NONE Fillet leg size in. X in. Concavity/convexity in.
Welding test conducted by [redacted] - GEO-TECH IND.
Mechanical tests conducted by COAST TESTING Laboratory test no. 3807 T/A 21
We certify that the statements in this record are correct and that the test coupons were prepared, welded and tested in accordance with the requirements of Section IX of ASME Code.

Organization GEO-TECH INDUSTRIES INC.

Date AUGUST 23, 1993. By [redacted]

ACUREN

QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATION (WPS)

(See Qw-200.1, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name: Geo-Tech Industries Inc. By

Welding Procedure Specification No. GTI-CS-9 Date Sept. 9, 2003 Supporting PQR No.(s) GTI-CS-9

Revision No 0 Date By:

Welding Process (es) Shielded metal arc welding Type(s) Manual (Automatic, Manual, Machine or Semi-Auto)

JOINTS (QW-402)

Joint Design: Groove and/or fillet

Backing (Yes) Optional (No) None required

Backing Material (Type) None required, retainers not used (Refer to both backing and retainers.)

[X] Metal [ ] Non-fusing Metal

[ ] Nonmetallic [ ] Other

Sketches, production drawings, weld symbols or written description should show the general arrangement of the parts to be welded. Where applicable, the root spacing and the details of weld grove may be specified.

(At the option of the Mfgr., sketches may be attached to illustrate joint design, weld layers and bead sequence, e.g. for notch toughness procedures, for multiple process procedures, etc.)

DETAILS

"See fabrication drawing"

Welding Procedure Specifications ACCEPTED
Reg. No. W.P. GTI-CS-9
Weld Process SMAW
P No. 1 to P No. 1
F No. 3 & 4 A No. 1
Th. Cust. Min. 0.187" Max. 1.062"
yr 2003 mo 09 day 10 Signed McBirley
Province of British Columbia
Ministry of Municipal Affairs
Boiler & Pressure Vessel Safety Program

*BASE METALS (QW-403)

P-No. 1 Group No. 1 or 2 To P-No. 1 Group No. 1 or 2

Or

Specification type and grade

To specification type and grade

Or

Chemical Analysis and mechanical properties

To Chemical Analysis and mechanical properties

Thickness Range:

Base Metal: Groove .187" to 1.062" Fillet All

Pipe Dia. Range: Groove All Fillet All

Other No single pass to exceed ½" in thickness

*FILLER METALS (QW-404)

Spec. No. (SFA)	5.1	5.5	
AWS No. (Class)	E6010	E7018-XX	
F-No.	3	4	
A-No.	1	1	
Size of Filler Metals	.09-.156"	.09"-.187"	
Deposited Weld Metal			
Thickness Range:			
Groove:	.187" to .250"	.187" to .800"	
Fillet:	All	All	
Electrode-Flux (Class)	Cellulose	Basic	
Flux Trade Name	None	None	
Consumable Insert	Not used	Not used	
Other	Root/hot pass	Fill/cap	

*Each base metal-filler metal combination should be recorded individually.

QW-482 (Back) WPS No. GTI-CS-9 Rev. 0

POSITION (QW-405)

Position(s) of Groove: All
Welding Progression: Yes Down Yes
Position(s) of Fillet: All

POSTWELD HEAT TREATMENT (QW-407)

Temperature Range: None
Time Range: Not applicable

PREHEAT (QW-406)

Preheat Temperature Min.: 32 deg. F.
Inter-pass Temperature Max: 400 deg. F.
Preheat Maintenance: 32 deg. F.
(Continuous or special heating where applicable should be recorded)

GAS (QW-408)

	Gases	(Mixture)	Flow Rate
Shielding	None	------------	------------
Trailing	None	------------	------------
Backing	None	------------	------------

ELECTRICAL CHARACTERISTICS (QW-409)

Current AC or DC: Direct current Polarity: Electrode positive
Amps (Range): 70-300 Volts (Range): 28-42

(Amps and volts range should be recorded for each electrode size, position and thickness, etc. This information may be listed in a tabular form similar to that shown below.)

Tungsten Electrode Size and Type: Not used
Mode of Metal Transfer for GMAW: Not applicable
Electrode Wire feed speed range: Not applicable

TECHNIQUE (QW-410)

String or Weave Bead: Either
Orifice or Gas cup Size: Not applicable
Initial and Inter-pass Cleaning (Brushing, Grinding, etc.): Chip off slag between passes and wire brush

Method of Back Gouging: Air arc or grinding
Oscillation: Not used
Contact Tube to Work Distance: Not applicable
Multiple or Single Pass (per side): Either
Multiple or Single Electrodes: Single
Travel Speed (Range): 5-15 Inches per minute
Peening: Not allowed
Other:

Weld Layer(s)	Process	Filler Metal		Current		Volt Range	Travel Speed Range	Other (eg., Remarks, comments, Hot wire Addition, Technique, Torch Angle, etc.)
		Class	Dia	Type Polar	Amp. Range			
Root	SMAW	E6010	.125”	DCEP	80-140	28-32		
Hot pass	SMAW	E6010	.125”	DCEP	80-140	30-34		
Fill	SMAW	E7018-H4	.092”	DCEP	70-100	28-32		
Cap	SMAW	E7018-H4	.125”	DCEP	90-160	32-36		
Fill/cap	SMAW	E7018-H4	.156	DCEP	130-220	34-40		
Fill/cap	SMAW	E7018-H4	.187”	DCEP	200-300	36-42		

ACUREN

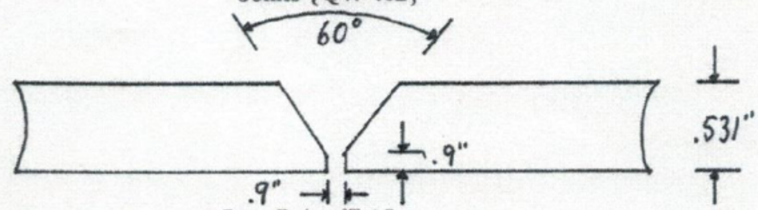
QW-483 PROCEDURE QUALIFICATION RECORD {PQR}

{See QW-200.2, Section IX, ASME Boiler & Pressure Vessel Code}

Record actual conditions used to weld test coupons

Company Name	Geo-Tech Industries Inc.
Procedure Qualification Record No.	GTI-CS-9
Date	September 9, 2002
W.P.S.	GTI-CS-9
Welding Process(es)	Shielded metal arc welding
Types {manual, automatic, semi-automatic}	Manual

Joints {QW 402}



Groove Design of Test Coupon

(For combination qualification, the deposited weld metal thickness shall be recorded for each filler metal or process used)

BASE METAL {QW 403}

Material Specs.	SA106
Type or Grade	B
P-No.	1
Thickness of Test Coupon	.531" nom.
Diameter of Test Coupon	4.5" nom.
Other	None

FILLER METALS {QW 404}

SFA Specification	5.1/5.5
AWS Classification	E6010/E7018-H4
Filler Metal F-No.	3/4
Weld Metal Analysis A-No.	1
Size of Filler Metal	.125"/ .094" and .125"
Other	Root and hot pass E6010/Fill and cap E7018
Weld Metal Thickness	.531"

POSITION {QW 405}

Position of Groove	6G
Weld Progress (Uphill, Downhill)	Uphill
Other	None

PREHEAT {QW 406}

Preheat Temp.	65 deg. F
Inter-pass Temp.	400 deg. F.
Other	None

POSTWELD HEAT TREATMENT {QW 407}

Temperature	None
Time	Not applicable
Other	None

GAS {QW 408}

	Gases	Percent Composition (Mixture)	Flow rate
Shielding	None	------------	------------
Trailing	None	------------	------------
Backing	None	------------	------------

ELECTRICAL CHARACTERISTICS {QW 409}

Current	Direct current
Polarity	Electrode positive
Amps	70/90
Volts	30/32
Tungsten Electrode Size	None
Other	None

TECHNIQUE {QW 410}

Travel Speed	8-10 ipm
String or Weave Bead	String
Oscillation	None
Multi-pass or Single pass {per side}	Multi-pass
Single or Multiple Electrodes	Single
Other	None

QW-483 PQR No. GTI-CS-9

Tensile test (QW-150)

Specimen No.	Width Inches	Thickness Inches	Area Square Inches	Ultimate Total Load lb.	Ultimate Unit Stress psi.	Type of failure, and location
T-1	.718	.523	.376	28062	746000	Ductile, base metal
T-2	.720	.549	.395	29440	74500	Ductile, base metal

Guided-Bend tests (QW-160)

Type and Figure No.	Result
Side bend 1 as per QW 463.1(e)	Acceptable
Side bend 2 as per QW 463.1(e)	Acceptable
Side bend 3 as per QW 463.1(e)	Acceptable
Side bend 4 as per QW 463.1(e)	Acceptable

Toughness Test (QW-170)

Specimen No.	Notch Location	Notch Type	Test Temp.	Impact Values	Lateral Exp.		Drop Weight	
					% Shear	Mils	Break	No Break

Fillet-Weld Tests (QW-170)

Result-Satisfactory: Yes _____ No _____ Penetration into Parent Metal: Yes _____ No. _____

Macro-Results _____

Other Tests

Type of Test: None taken

Deposit Analysis: None taken

Other: None

Welder's Name [redacted] Clock No. _____ Stamp No. [redacted]

Test Conducted by: Bacon Donaldson Laboratory Test No. TA-15 P.O. #1003-5080

We certify that the statements in this record are correct and that the test welds were prepared welded and tested in accordance with the requirements of Section IX of the ASME Code.

Date September 9, 2003 Manufacturer Geo-Tech Industries Inc.

By [redacted]

(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by code.)

[redacted]

ACUREN

Bacon Donaldson

Bacon Donaldson
12271 Horseshoe Way
Richmond, BC, Canada V7A 4V4

Phone: (604) 277-2322
Fax: (604) 274-7235

Consulting Engineers
A Rockwood Company

ISO 9002

WELD PROCEDURE QUALIFICATION TEST

GEO-TECH INDUSTRIES INC.
8338 Crofton Road
Crofton BC
V0R 1R0

Date: September 8, 2003
File No: A0360400362
P.O. No: 1003-5080
Report No: 1

Attention: [redacted]

Sample Description: Groove Weld Steel Pipe Test Coupon

PQR No: GTI-CS-9
Welding Process: SMAW, Manual
Position: 6G
Base Material: SA106 Grade B
Filler Material: E6010/E7018-X
Test Sample Size: 4" Sch 160 Pipe
Welder ID: [redacted]
Test Specification: ASME Section IX : 2001

TENSILE TEST

Specimen Identification	Width (in)	Thickness (in)	Area (in^2)	Ultimate Load (lbf)	Tensile Strength (ksi)	Character and Location of Failure
T-1	0.718	0.523	0.376	28,062	74.6	Ductile, Base Metal
T-2	0.720	0.549	0.395	29,440	74.5	Ductile, Base Metal

BEND TEST

Specimen Identification	Type of Bend	Results	Specimen Identification	Type of Bend	Results
S-1	Side	Acceptable	S-3	Side	Acceptable
S-2	Side	Acceptable	S-4	Side	Acceptable

- Province of British Columbia authorized testing agency for boiler, pressure vessel and pressure piping: No. TA-15.
- Test machine calibrated to ASTM E4 and CSA A23.2-9C specifications.
- Specimens will be disposed of after 30 days unless alternate provisions are made.

Reported by: [redacted]

Reviewed by: [redacted]

A03604-00362_01-01R0 G01100 WPQ R1

ACUREN

QW-484 SUGGESTED FORMAT FOR MANUFACTURER'S RECORD OF WELDER OR WELDING OPERATOR QUALIFICATION TESTS (WPQ)
(See QW-301, Section IX, ASME Boiler and Pressure Vessel Code)

Welder's Name [redacted] Clock Number ______ Stamp Number [redacted]
Welding Process(es) used Shielded metal arc welding Type Manual
Identification of WPS followed by welder during welding of test coupon GTI-CS-9
Base material(s) welded SA106 B Thickness .593" nom.

Manual or Semi-Automatic Variables for Each Process	(QW-350)	Actual Values	Range Qualified
Backing (metal, weld metal, welded from both sides flux, etc.)	(QW-402)	None	With/without
ASME P-No. 1 To ASME P-No.	(QW-403)	1 to 1	1 to 1
( ) Plate or (X) Pipe (enter pipe diameter, if pipe)		10.75" O.D.	2 7/8" O.D. up
Filler metal specification (SFA-No.) 5.1 Classification	(QW-404)	E6010/E7018	E60XX/E7018-X
Filler metal F-No.		F3/F4	F3/F4
Consumable insert for GTAW or PAW		Not used	Not used
Weld deposit thickness for each welding process		.593"	3/16"-8"
Welding position (1G, 5G, etc.)	(QW-405)	6G	All
Welding progression (uphill/downhill)		Uphill	Uphill
Backing gas for GTAW, PAW or GMAW: fuel gas for OFW	(QW-408)	Not applicable	Not applicable
GMAW transfer mode (QW-409)		Not applicable	Not applicable
GTAW/SMAW welding current type/polarity		DCEP	DCEP

Machine Welding Variables for the Process used	(QW-360)	Actual Values	Range Qualified
Direct/remote visual control		Not applicable	Not applicable
Automatic voltage control (GTAW)		Not applicable	Not applicable
Automatic joint tracking		Not applicable	Not applicable
Welding position (1G, 5G, etc.)		Not applicable	Not applicable
Consumable insert		Not applicable	Not applicable
Backing (metal, weld metal, welded from both sides, flux, etc.)		Not applicable	Not applicable

Guided Bend Test Results

Guided Bend Tests Type	QW-462.2 (Side) Results	QW-462.3 (a)(Trans. R&F) Type	QW-462.3(b)(Long, R&F) Results
QW by RT			

Visual examination results (QW302.4) Acceptable
Radiographic test results (QW-304 and QW-305) Acceptable
(For alternative qualification of groove welds by radiography) Not applicable
Fillet weld-fracture test None Length and % of defects Not applicable In.
Macro test fusion None Fillet leg size N/A In. X N/A In. Concavity/convexity N/A In.
Welding test conducted by Geo-Tech Industries Inc.
Mechanical tests conducted by Acuren (Radiography) Laboratory test no. Job #6376

We certify that the statements in this record are correct and that the test coupons were prepared welded and tested in accordance with the requirements of Section IX of ASME Code.

Organization Geo-Tech Industries Inc.
Date November 17, 2005 [redacted] By [redacted]

ACUREN

APPENDIX E

HARDNESS TEST REPORT

Acuren Group Inc.
12271 Horseshoe Way
Richmond, BC, Canada V7A 4V4
www.acuren.com
Phone: 604.275.3800
Fax: 604.274.7235

A Higher Level of Reliability

FIELD HARDNESS TESTING

CLIENT: TECHNICAL SAFETY B.C.
600 - 2889 EAST 12TH AVENUE
VANCOUVER, BC
V5M 4T5

APPENDIX: E

DATE: November 25, 2019
ACUREN JOB #: 60515372
REPORT #: 3
CONTRACT/PO: Pending
WO: N/A
WORK LOCATION: On site

ATTENTION: **ERIC LALLI**
PROJECT: Alberni Valley Multiplex
ITEM(S) EXAMINED: Brine Chiller

PART #: s/n 18173X
MATERIAL: Carbon Steel
SCOPE: Hardness testing of shell HAZ, fillet weld and flange HAZ

TEST DETAILS:

ACCEPTANCE STANDARD: Client's Information
ACCEPTANCE RANGE: --
REV. DATE: N/A
PROCEDURE/TECHNIQUE: CAN-HT-15P002
REV. #: 05
INSTRUMENT MAKE: GE
MODEL: Mic 10
S/N: 34101-5356
PROBE S/N: 33766-3134
CAL DUE DATE: May 9, 2020
TYPE: ☐ HV(UCI) 10 ☐ HV(UCI) 5 ☐ HLD ☒ HBW ☐ HRA ☐ HRBW ☐ HRC
ACUREN MARKING: ☐ Low Stress Stamp ☐ Ink ☐ None

CHECK STANDARDS:

SERIAL #	CERT FIED VALUE(S)	STANDARD MATERIAL	MEASURED VALUE(S)					Accept Yes (✓) No (×)
0805125	225 HBW10/3000	STEEL	224	223	225	223	223	✓

RESULTS:

*'Accept' means the instrument indicated material matches the specified material within the limits of the instrument. Use N/A when not applicable.

DESCRIPTION	LOCATION						Accept Yes (✓) No (×)
	1	2	3	4	5	Average	
Shell HAZ 1	194	192	209	205	202	200	
Shell HAZ 2	192	209	207	206	198	202	
Shell HAZ 3	196	201	193	201	192	197	
Shell HAZ 4	192	209	205	200	194	200	
Shell HAZ 5	219	211	202	199	196	205	
Shell HAZ 6	224	224	209	209	201	213	
Shell HAZ 7	213	199	206	196	207	204	
Shell HAZ 8	207	207	210	195	214	207	
Shell HAZ 9	213	223	226	218	217	219	
Shell HAZ 10 (Original Weld)	206	213	214	197	200	206	
Weld 1	242	245	229	221	238	235	
Weld 2	220	207	209	213	213	212	
Weld 3	234	219	227	219	227	225	
Flange HAZ 1	204	204	210	202	216	207	
Flange HAZ 2	189	188	177	185	175	183	

COMMENTS:

Shell HAZ readings taken along entire repair weld length, readings in between bolts. Approximately one reading every other bolt or about 3 inches.

CLIENT REPRESENTATIVE: ____________ (PRINT) [redacted]
DTR No.: N/A
1ST TECHNICIAN: [redacted] AScT (PRINT) (SIGNAT [redacted]
REVIEWER: [redacted] P.Eng.

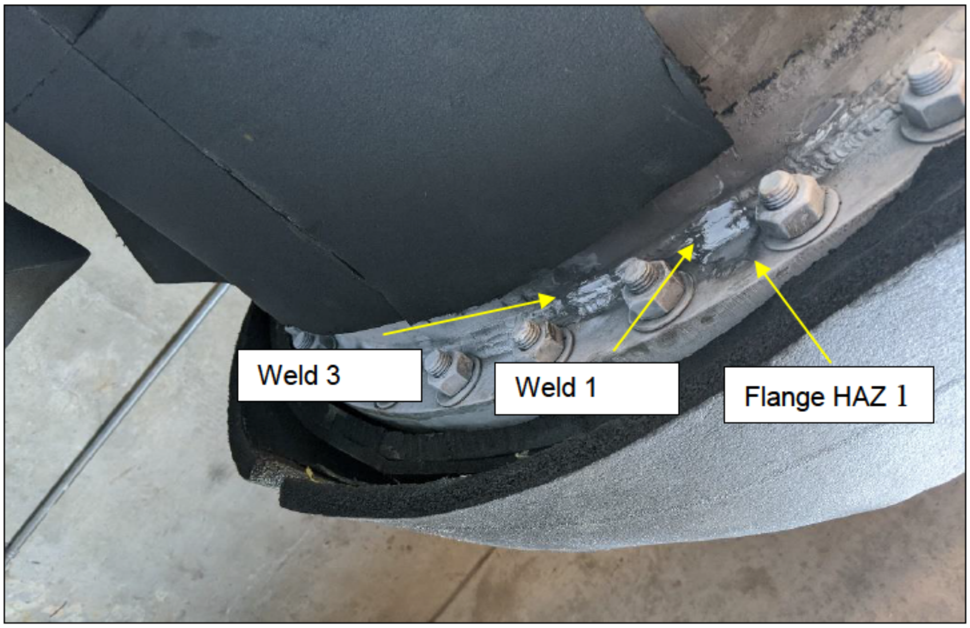


Figure 2 Repair Weld Hardness Locations

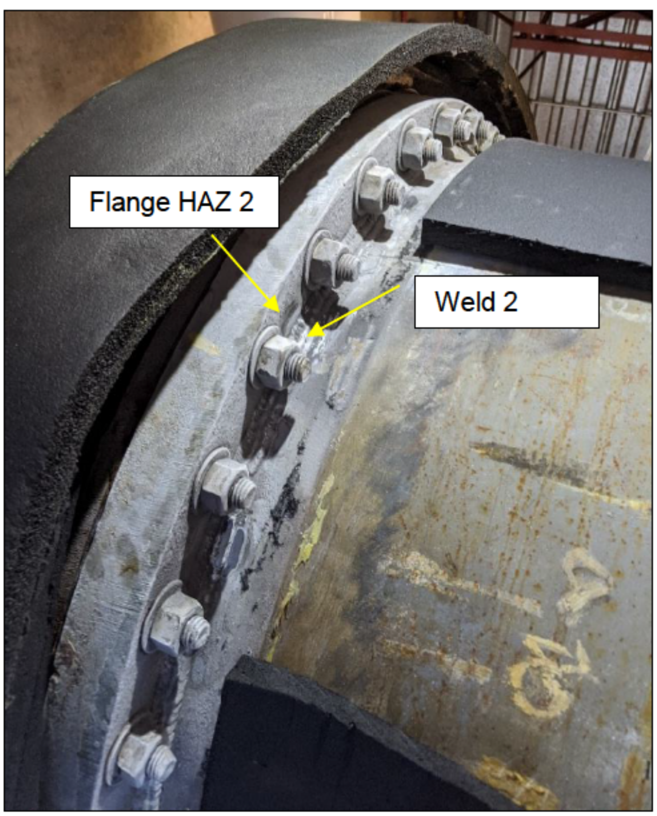


Figure 3 Repair Weld Hardness Locations