# Investigator-In-Charge
# FACTUAL REPORT

## August 27, 2016, Rupture of a DOT-105 Rail Tank Car and Subsequent Chlorine Release

## New Martinsville, West Virginia

**DCA16SH002**

**Report Date: June 30, 2017**

**Contents**

## A. Accident Identification

Facility: Axiall Corporation
Tank Car No.: AXLX1702
Location: New Martinsville, West Virginia
Date/Time: August 27, 2016, 8:26 a.m. EDT
NTSB No.: DCA16SH002

## B. Parties to the Investigation

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## C. Accident Summary

Axiall Corporation (Axiall) produces chlorine, hydrochloric acid, calcium hypochlorite (Cal-Hypo), sodium hydroxide pellets, and caustic soda at a 500-acre chemical manufacturing facility, known as the "Natrium plant," in New Martinsville, West Virginia. Primary products produced at the Natrium Plant are chlorine, sodium hydroxide, muriatic acid, and calcium hypochlorite. Axiall ships chlorine to industrial facilities for the manufacture of plastics, synthetics, pharmaceuticals, textiles, petroleum refining, metal cleaning, and a host of other uses.

Axiall acquired the Natrium plant from PPG Industries in 2013 and has a work force of about 500 persons. The facility is located on the Ohio River at the southern end of Marshall County, about five miles north of the town of New Martinsville, West Virginia (Figure 1). The facility is bounded by a Covestro, LLC industrial manufacturing facility to the south, the Ohio River to the west, a Blue Racer Midstream facility to the north, and West Virginia Route 2 and undeveloped steeply sloped terrain to the east.


*Figure 1: Incident location, New Martinsville, West Virginia.*

Natrium plant chlorine products are shipped by water and rail transportation. The rail tank car chlorine loading rack consists of three tracks within an enclosure that is generally situated in the center of the manufacturing facility on the western side of the property near the river.

On August 27, 2016, about 8:26 a.m., Eastern Daylight Time, a specification DOT 105J500W tank car, AXLX1702, experienced a sudden crack in the tank shell shortly after being filled with liquefied compressed chlorine at the rail car loading rack. The incident occurred on plant property on Track 10 about three to four car-lengths north of the tank car loading shed (Figure 2). The tank car had not been offered into transportation at the time of the occurrence. Over the following 2 ½ hour period, the entire 178,400-pound load of chlorine was released and formed a large vapor cloud that migrated south along the Ohio River valley.

*Figure 2: Fresh track ballast added to incident location on Axiall Corporation Track 10.*

Chlorine is a gas at normal temperatures and pressures and presents a toxic inhalation hazard that may be fatal if inhaled or absorbed through the skin. After the release, 5 Axiall and 3 contractor employees were treated for exposure injuries and released, including 2 persons transported offsite to the hospital. Significant vegetation damage occurred downwind (south) from the release. No water contamination was reported. The accident occurred with weather conditions of lifting fog after sunrise, a temperature of 72° F, and light wind from the north at 1 mph. As of April 22, 2017, Axiall Corporation reported that it did not have sufficient information to determine or estimate total monetary damages related to the chlorine release.

On August 31, 2016, NTSB investigators traveled to New Martinsville, West Virginia to inspect the tank car and collect physical and documentary evidence. Investigators found the accident tank car had been moved to a remote work area where an Axiall contractor removed the parts of the jacket and insulation around the tank bottom to expose the shell crack.

Investigators examined the damaged tank car and found the release occurred through an approximately 42-inch long crack in the 4$^{th}$ ring of the tank near the inboard end of the A end stub sill cradle pad. The NTSB retained custody of relevant tank car parts for further metallurgical examination at NTSB headquarters in Washington, D.C.

## D. Hazardous Materials Information

### *Health and Safety Guidance*

Chlorine is a gas at atmospheric conditions, with toxic and corrosive properties. Chlorine is used to manufacture a wide variety of chemicals, including industrial bleaching agents, household products, and biocide in water and waste water treatment. Chlorine is shipped as a liquefied compressed gas when transported in rail tank cars. Chlorine is classified for transportation as a Class 2.3 poison gas and poisonous by inhalation (PIH) in Hazard Zone B.[1] In addition to being classified a Class 2.3 poison gas, chlorine exhibits subsidiary hazard classes 5.1 (oxidizer) and 8 (corrosive).

Chlorine gas appears green-yellow, is highly reactive, and has a pungent and suffocating odor. It rapidly combines with both inorganic and organic substances. Reaction with moist surfaces produces hydrochloric and hypochlorous acids.[2] When released, liquid chlorine evaporates quickly and forms a vapor cloud that is heavier than air. One volume of liquid forms about 460 volumes of gas.

Chlorine gas is highly irritating and reacts directly with tissues of the respiratory tract and eyes. The National Advisory Committee for the Development of Acute Exposure Guideline Levels for Hazardous Substances has developed exposure guidelines for high-priority acutely toxic chemical such as chlorine. These guidelines presented in Table 1 are known as AEGL-1, AEGL-2, and AEGL-3, and are distinguished by the severity of toxic effects.[3]

TABLE 1. Summary of AEGLs Values for Chlorine (ppm [mg/m$^3$])[4]

| Exposure time | 10 min | 30 min | 1 h | 4 h | 8 h |
|---|---|---|---|---|---|
| AEGL-1 (Non-disabling) | 0.5 (1.5) | 0.5 (1.5) | 0.5 (1.5) | 0.5 (1.5) | 0.5 (1.5) |
| AEGL-2 (Disabling) | 2.8 (8.1) | 2.8 (8.1) | 2.0 (5.8) | 1.0 (2.9) | 0.7 (2.0) |
| AEGL-3 (Lethal) | 50 (145) | 28 (81) | 20 (58) | 10 (29) | 7.1 (21) |

[1] See 49 CFR 173.115(c). Hazard zone means one of four levels of hazard (Hazard Zones A through D) assigned to gases and liquids that are poisonous by inhalation. Hazard zones are based on the acute inhalation toxicity of gases and vapors, with Hazard Zone B having a $LC_{50}$ of greater than 200 ppm and less than or equal to 1,000 ppm.

[2] *Acute Exposure Guideline Levels for Selected Airborne Chemicals, Volume 4*. National Academy of Sciences (Washington, D.C. 2004).

[3] Acute exposure guideline levels (AEGLs) are used in emergency planning, response, and prevention in the community, workplace, transportation, the military, and remediation of Superfund sites.

[4] National Academy of Sciences (2004)

The AEGL-1 is the airborne concentration above which persons could experience non-disabling reversible effects, but notable discomfort or irritation.

The AEGL-2 is the airborne concentration above which persons could experience irreversible or serious long-lasting health effects, or an impaired ability to escape.

The AEGL-3 is the airborne concentration above which it is predicted that the general population could experience life-threatening health effects or death.

For occupational exposures, the OSHA ceiling exposure limit for chlorine is 1 part-per-million.[5] The OSHA-established immediately dangerous to life and health (IDLH) value for chlorine is 10 parts-per-million.[6] The National Institute for Occupational Safety and Health (NIOSH) recommends that first responders use self-contained breathing apparatus with a Level A chemical protective suit when entering an area where the concentration exceeds the IDLH.

The Emergency Response Guidebook (ERG) recommends that in the event of a release from a rail car, the initial isolation distance should be 3,000 feet in all directions.[7] Isolation and protection guidance provided by the ERG further recommends that in low wind of less than 6 mph during daylight hours, persons downwind should be protected for a distance of 6.2 miles.

### *Chlorine Effects on Mechanical Integrity*

Moisture reacts with chlorine to form hydrochloric and hypochlorous acids, which can cause corrosion to tank car equipment and to piping and handling systems.[8] At temperatures below 250°F, equipment fabricated from carbon steel is not aggressively attacked in dry chlorine service.[9] However, dry chlorine has an extremely high affinity for moisture and very small amounts of moisture entering chlorine handling systems can create an environment conducive to rapid corrosion in carbon steel tank cars.

Chlorine tank cars are often unloaded by a process known as pressure padding with dry air or dry nitrogen to increase the pressure in the vapor space above the liquid to a level sufficient to force liquid chlorine from the tank car. To avoid introducing corrosion-causing moisture into the tank car, the Chlorine Institute recommends that air used for padding be

[5] The OSHA ceiling or short-term exposure limit (STEL) is a 15-minute period of maximum exposure that should not be exceeded during a single work shift.

[6] OSHA defines immediately dangerous to life and health as an atmosphere that poses an immediate threat to life, would cause irreversible adverse health effects, or would impair an individual's ability to escape.

[7] PHMSA, Transport Canada, and the Secretaria De Commicaciones Y Transportes publish the ERG as a guide to aid first responders in quickly identifying hazards of materials involved in incidents, and to protect themselves and the general public during the initial phase of an emergency response.

[8] *Recommended Practices for Handling Chlorine Tank Cars*, Pamphlet 66 (Arlington, VA: The Chlorine Institute, 5th ed. 2015).

[9] The Chlorine Institute defines dry chlorine as chlorine with its water content dissolved in solution. If a condition is reached anywhere in the system that will allow the water to exceed its solubility and form a second liquid phase, the chlorine is defined as wet.

dried to a dew point of -40°F or below, measured at operating pressure and that moisture concentrations be continuously monitored and controlled.

## E. Tank Car Design and Modifications

The specifications for class DOT-105 pressure tank cars are contained in Title 49 CFR Part 179, Subpart C. Current special commodity requirements for tank cars in chlorine service include fabrication from normalized carbon steel with ASTM Specification A 516, Grade 70, or AAR Specification TC-128, Grade A or B.

***Tank car AXLX1702 Equipment Features***

Tank car AXLX1702 was a DOT Specification 105J500W that was built in June 1979 by ACF Industries, Incorporated – AMCAR Division, Milton, Pennsylvania (Figure 3). The tank car was part of a 53-tank car order that were built under Certificate of Construction A791013. Because tank car AXLX1702 was built after July 1, 1974, it had been qualified for a 50-year service life limit.[10]

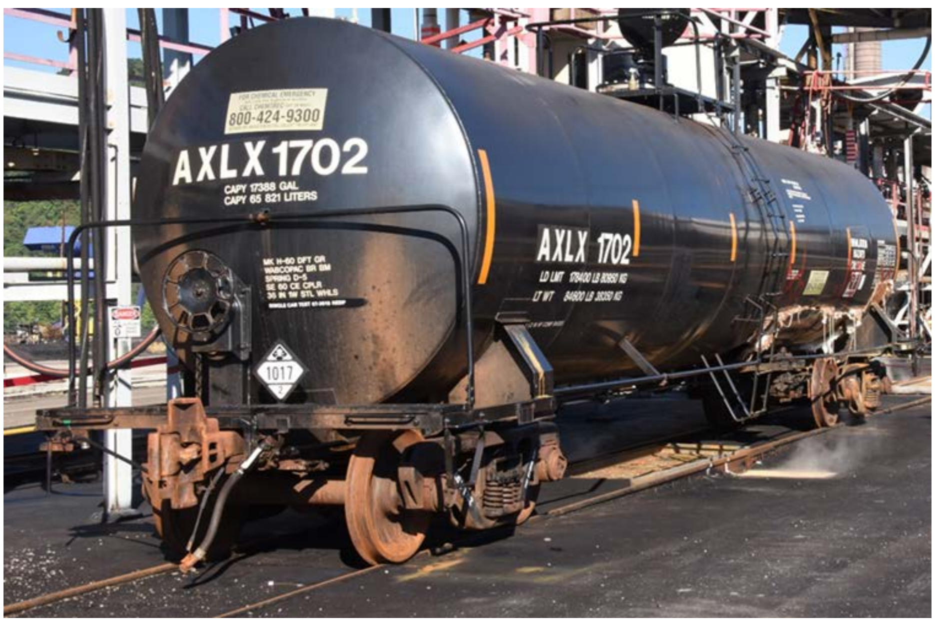


*Figure 3: Tank Car AXLX1702, August 27, 2016.*[11]

[10] AAR MSRP M-1002, paragraph 1.3.10 states there is no life limit on a tank car tank if the tank conforms to both the federal regulations and AAR requirements. Underframes built prior to July 1, 1974 had an AAR life limit of 40 years unless rebuilt or granted extended service status.

[11] Courtesy Axiall Corporation.

AXLX1702 has been used for chlorine transportation its entire service life.[12] The tank car was originally owned by PPG Industries at which time the car was stenciled PPGX1702. The tank car has been a part of the Axiall Corporation fleet since 2013.

AXLX1702 had a full water capacity of 17,388 gallons (144,812 pounds), a stenciled load limit of 178,400 pounds, and a maximum gross rail load of 263,000 pounds. The interior diameter was 100.4498 inches, and the length was 43 feet 8 3/4 inches between tank heads.

The material of construction was AAR TC-128 grade B non-normalized carbon steel. The tank was constructed with two elliptically shaped heads and five barrel sections, or rings, all joined by submerged arc welding. The elliptical tank heads had an original thickness of 13/16-inch (0.8125-inch). The original tank shell thickness was 0.7751-inch for each of the five barrel sections. The minimum allowable shell service life thickness was 0.7438-inch.[13] Federal regulations specify a minimum plate thickness for Specification 105A500W of 11/16-inch (0.6875-inch), and less than that calculated by a formula provided in 49 CFR 179.100-6.[14] See Section G of this report for shell thickness measurement data.

The tank car was equipped with an Emerson Crosby-style Type H-50155-JQ-375-RD safety relief valve with a specified set pressure of 360 psig, rated at 4,935 s.c.f.m. air at 375 psig. The valve was built in October 2003 and Midland Manufacturing Corporation repaired the valve in May 2016. See Section L of this report for the safety valve inspection and function testing.

The tank was originally built with an 11-gauge (0.1196-inch) jacket and 4 inches of urethane foam insulation. Texana Tank Car Mfg. performed a conversion in July 2010 that replaced the urethane foam with a combination of 2 inches of ceramic wool and 2 inches of fiberglass insulation over the ceramic wool.

***ACF-200 Stub Sill Underframe***

Tank car AXLX1702 was equipped with a type ACF-200 stub sill underframe. About 2,186 specification DOT-105 pressure tank cars are equipped with this underframe design.[15] The design uses cradle pads welded to the tank to transfer running loads from the stub sills through the tank. The cradle pads extend from the respective tank heads across most of the adjacent two rings of the tank. The tank crack occurred at the toe of the inboard end of the A6 welds (red lines in Figure 4).[16]

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[12] While Axiall records reflect that the tank car was built in June 1979, the build date stencil incorrectly indicated the car was built in December 1981.

[13] Minimum allowable service life thicknesses for tank shells are specified in Company Specific Requirements, AllTranstek, LLC (August 8, 2014).

[14] The thickness shall not be less than 5/8-inch when steel of 65,000 to 80,000 p.s.i. minimum tensile strength is used, and 9/16-inch when steel of 81,000 p.s.i. minimum tensile strength is used.

[15] Source: Umler®

[16] The designation A6 comes from an industry convention for identification of longitudinal cradle pad fillet welds.

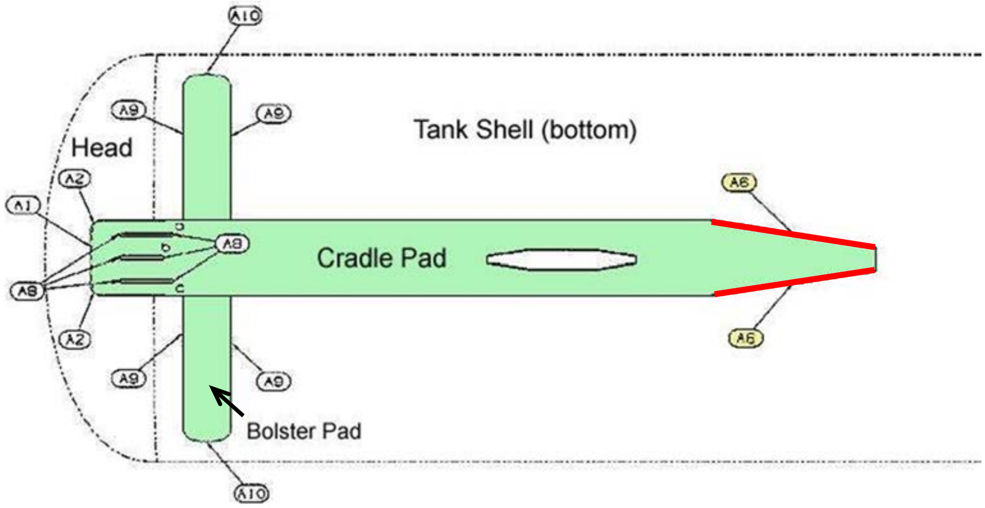


*Figure 4: ACF-200 underframe general layout and weld identification numbers from AAR Data Collection Template. The red highlighted A6 welds are referenced in later sections of this report.*

On May 5, 2006, the Federal Railroad Administration (FRA) published Safety Advisory 2006-04 noting a series of defects in some tank cars equipped with ACF-200 stub sills. The notice discussed defects, including tank head cracks, pad-to-tank cracks, sill web cracks, and tank shell buckling that in some instances has led to hazardous materials incidents.[17]

On October 5, 2006, the FRA published Safety Advisory 2006-04, Notice No. 2 to announce the availability of revised ACF Industries Incorporated Maintenance Bulletin TC-200 (Revision A) to address fatigue-related safety concerns for unmodified general service tank cars with the ACF-200 stub sill design.[18] The advisory includes the option of installing a support between the tank head and stub sill, known as the P-470 angle brace.[19] The application of the P470 brace transforms the underframe into the ACF 270 stub sill design. The bulletin states that American Railcar Leasing should be consulted prior to retrofitting multi-compartment cars, electric heater cars, pressure tank cars, or underframes previously modified from original construction. The incident tank car AXLX1702 was not equipped with the P470 or other such head brace.

The FRA safety advisory recommended that ACF-200 tank car owners obtain a copy of the revised maintenance bulletin and enter into discussions with the car builder and decide the best course of action regarding inspection of and modifications to the ACF 270 design. The FRA further recommended that tank car owners should modify the ACF-200 tank cars to the ACF 270 design at the earliest of any of the following events:

- A tank car due for requalification under 49 CFR 180.509;

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[17] Federal Railroad Administration Safety Advisory 2006-04: Federal Register 71, no. 87 (May 5, 2006): 26604.

[18] Federal Railroad Administration Safety Advisory 2006-04 (Notice No. 2): Federal Register 71, no. 193 (October 5, 2006): 58907.

[19] *ACF-200 Stub Sill Underframe Inspection, Repair, and Enhancement*, ACF Maintenance Bulletin TC-200, Revision A, (American Railcar Leasing, 2006).

- A tank car recalled under an AAR maintenance advisory requiring modification in the draft sill area;
- A tank car that has been in service for 150,000 miles; or
- A tank car requires general repairs and the repairs consume, or are expected to consume least 36 hours of shop time.

The FRA safety advisory further recommended that first priority in modifying unretrofitted ACF-200 tank cars to the ACF 270 design should go to general service tank cars, and then to the pressure tank car fleet. However, ACF Maintenance Bulletin TC-200 states that the ACF 270 enhancement was established only for general service tank cars built with an ACF-200 underframe between 1969 and 1996. The maintenance bulletin states: "This procedure may be used only on ACF built tank cars with stub sill style 200 underframes and solely at the discretion of the car owner." The maintenance bulletin also states that the retrofit is not intended for pressure tank cars, such as specification DOT-105. As of April 2017, the UMLER database identifies 1,759 general service tank cars with ACF 270 stub sill enhancements, none of which are in the Axiall fleet.[20] UMLER does not list any pressure tank cars that are equipped with the P-470 stub sill enhancement.

For general service tank cars ACF Maintenance Bulletin TC-200 further recommends inspecting the inboard cradle pad termination and repair any tank shell and weld cracks found. If a crack exists in Area 1 (Figure 4), then the crack should be removed by gouging and/or grinding the existing weld to the 45º line and no weld repair is required. The bulletin states that if a crack extends into Area 2 on the illustration, then the weld should be repaired in accordance with Appendix R and W of the *AAR Standards and Specifications for Tank Cars, M-1002*. The repair weld should not extend beyond the 45º lines shown in Figure 5.

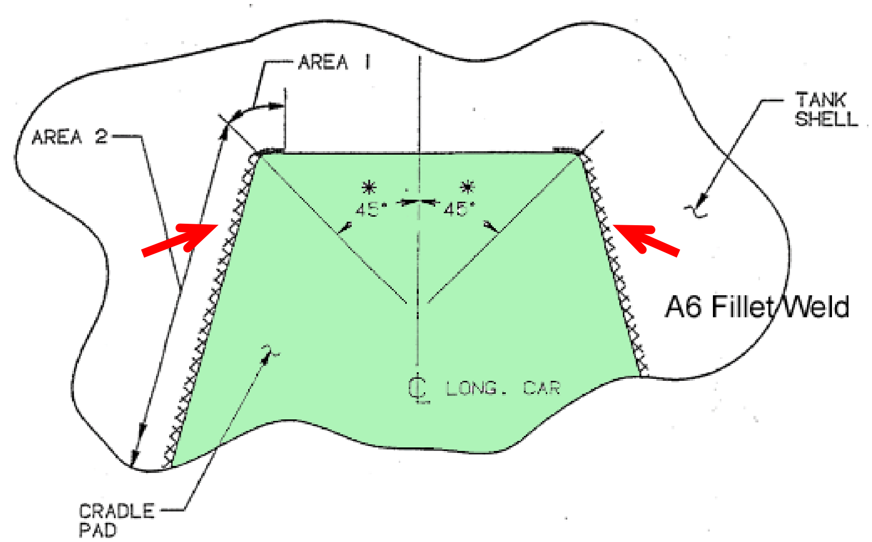
The *Axiall Corporation Rail Fleet Maintenance Manual* (V. 7.0, August 2015), *Specific Requirements for all Axiall Railcars Shopped for Scheduled and Non-scheduled Maintenance and Repair*, and AllTranstek maintenance procedures contain instructions applicable to tank cars equipped with ACF-200 underframes. The instructions do not distinguish between pressure and non-pressure tank cars and contain ACF-200 underframe inspection requirements that state such tank cars shall have a SS-3 stub sill inspection every 5 years until modified.[21]

Rescar told NTSB investigators that the provisions of Axiall Corporation's qualification and maintenance manual governs stub sill inspections and repair welding on pressure tank cars, not ACF Maintenance Bulletin TC-200 (Revision A).

[20] UMLER® is an acronym for the Railinc Corp. Universal Machine Language Equipment Register, an equipment management and information system and the industry's central repository for registered rail and intermodal equipment in North America.

[21] *Requirements for SS-3 Inspections of Tank Car Stub Sills*, Casualty Prevention Circular CPC-1114, Association of American Railroads (Washington, D.C. 2001). The AAR stub sill inspection program became effective April 15, 1999 and the results of inspections are reported to AAR on Form SS-3. The AAR Tank Car Inspection Database (TCID) is now available for car owners to report alterations, modifications, conversions, and tank car damage formerly reported on Forms R-1, R-2, and SS-3. The SS-3 inspection is limited to the structural integrity of underframe components outboard from the body bolster web. See also footnote 38 for Axiall's position regarding the applicability of these instructions to tank cars in chlorine service.

Axiall's maintenance administration contractor, AllTranstek, LLC told NTSB investigators that even though the requirement to perform an SS-3 inspection every 5 years on ACF-200 stub sill cars was set forth in the Axiall fleet maintenance manual, in practice Axiall only applied this to cars that had not yet been modified as required for the TC-200 bulletin or Texana Tank Car Company drawing TNC T-215-1.




* 45° MEASURED BETWEEN LONGITUDINAL CENTER-LINE AND CENTER OF RADIUSED PORTION OF CRADLE PAD.

IF A CRACK EXISTS IN:

AREA 1
A. GRIND OR ARC-GOUGE AND GRIND TO REMOVE BOTH CRACKED AND SOUND SOUND WELD METAL TO THE 45° LINE AS SHOWN.
B. GRIND CRADLE PAD AND TANK SHELL SMOOTH, AND GRIND A SMOOTH TERMINATION ON THE WELD.
C. DYE CHECK TANK SHELL AND 1" OF THE REMAINING WELD.
D. REMOVE AN EQUAL AMOUNT OF WELD FROM ADJACENT CRADLE PAD CORNER AND DYE CHECK AREA.

AREA 2 REPAIR IN ACCORDANCE WITH M-1002, APPENDIX R&W.

*Figure 5. Diagram of Cradle Pad and Weld Repair Instructions from ACF Maintenance Bulletin TC-200. Red arrows added to denote the A6 fillet welds.*

## F. Tank Car Qualification and Maintenance

***Regulatory Background***

In 1995, RSPA published final rule HM-201 to establish Subpart F of 49 CFR Part 180 for qualification and maintenance of tank cars.[22] The 2012 PHMSA final rule HM-216B subjected 2016 repairs to the tank car to additional federal qualification and maintenance regulations that were not applicable to the 2010 repairs (see Section G of this report).[23]

The Subpart F qualification regulations require the inspection and testing of tank car tanks, service equipment and safety systems, and the use of nondestructive testing (NDT) techniques at an interval of no greater than ten years. The qualification inspection and testing must be performed by an AAR certified facility.

The Subpart F regulations further establish the minimum acceptable framework for a tank car owner's qualification program in which written procedures must be developed for use by tank car facility employees. The written procedures must identify where to inspect, how to inspect, and the acceptance criteria. Alternative inspection and test procedures or intervals based on a damage-tolerance analysis or service reliability assessment must be approved by the FRA Associate Administrator for Railroad Safety. For establishing alternative inspection and test procedures or intervals, a damage-tolerance analysis must include a determination of the probable locations and modes of damage due to fatigue, corrosion, and accidental damage. If the procedures are based on a service reliability assessment, it must be supported by analysis of systematically collected data.[24] The inspection procedures and intervals identified in the owner's qualification program are intended to prevent failure between inspections and minimize the risk of shipping hazardous materials.

Tank car facilities must incorporate the owner's qualification program into their quality assurance program.[25] The quality assurance program must be approved by the AAR and is intended to ensure that repaired tank cars conform to specification requirements.[26] Among the required elements of the program are procedures for evaluating the sensitivity and reliability of the inspection and testing techniques, identification of the minimum detectable crack length, and acceptance criteria.

Tank car owners are required to have a tank car facility perform structural inspections and tests at the specified interval or whenever a tank car shows evidence of abrasion, corrosion, cracks, dents, distortions, defects in welds, or any other condition that may make the tank

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[22] *Crashworthiness Protection Requirements for Tank Cars; Detection and Repair of Cracks, Pits, Corrosion, Lining Flaws, Thermal Protection Flaws, and Other Defects of Tank Car Tanks*, Final Rule, Research and Special Programs Administration, 60 FR 49048 (September 21, 1995)

[23] *Hazardous Materials: Incorporating Rail Special Permits into the Hazardous Materials Regulations*, Final Rule, Pipeline and Hazardous Materials Safety Administration, 77 FR 37962 (June 25, 2012)

[24] See 49 CFR 180.509(l)

[25] See 49 CFR 180.501(b)

[26] *Specification for Quality Assurance*, Specification M-1003, Association of American Railroads (August 2014).

car unsafe for transportation.[27] Inspections are also required following any accident or fire damage that compromises safe operation. At a minimum, every 10 years the owner must ensure the tank car receives an internal and external visual inspection for the above-mentioned defects, structural integrity inspection and tests, and material thickness tests.[28]

The structural integrity inspection and tests must include transverse fillet welds and the termination of longitudinal fillet welds greater than 0.25 inch within 4 feet of the bottom longitudinal centerline. This would include the shell location where the crack occurred in AXLX1702. The tank car facility must inspect and test by one or more of the following methods as directed by the car owner's written instructions and applicable AllTranstek fleet maintenance procedures:

- Dye penetrant testing (PT)
- Radiographic examination (RT)
- Magnetic particle testing (MT)
- Ultrasonic testing (UT)
- Direct, remote, or enhanced visual inspection (VT)

Repairs done to address any defects identified from inspections and testing must be done in compliance with the applicable requirements of 49 CFR Part 180, the *AAR Standards and Specifications for Tank Cars, M-1002*, and the owner's requirements.

### *Association of American Railroads Standards, Specifications, and Recommended Practices*

Federal regulations state that qualification, as relevant to a tank car, means that its components conform not only to the DOT specification to which it was designed and the owner's acceptance criteria, but also to the applicable AAR Specifications for Tank Cars.[29] The AAR *Manual of Standards and Recommended Practices (MSRP) M-1002* Appendix B describes the process and procedures that tank car facilities must follow to obtain and maintain certification to perform activities such as repair, alteration, and qualification. Certified facilities must comply with the AAR specifications, federal regulations, and AAR interchange rules. M-1002 Appendices R, T, and W contain specifications relating to crack and corrosion repair procedures, nondestructive testing, and welding. As of 2016, there were about 392 approved tank car facilities in North America.[30]

At the time work was performed on AXLX1702, the Rescar Companies facility in DuBois, Pennsylvania was M-1002 certified through June 21, 2018 and M-1003 certified through

[27] See 49 CFR 180.509

[28] Thickness testing may be required more frequently if the tank car is used to transport a material that is corrosive or reactive to the tank, or if the shell thickness has been reduced from as-built but still exceeds the minimum allowable thickness.

[29] See 49 CFR 180.503

[30] *AAR Approved M-1002 Tank Car Facilities*, Casualty Prevention Circular CPC-1322, Association of American Railroads (Washington, D.C. 2016).

November 22, 2016.[31] The Rescar DuBois facility was qualified as a Repair Level 2 facility, meaning that the company had demonstrated proficiency in performing welding to tank car tank material, nondestructive testing, and post-weld heat treatment. Rescar's certification authorized the company to perform tank car repairs, alterations, conversions, and qualifications. Rescar was also authorized to recondition, repair, remove and replace, and qualify tank car service equipment. Further, Rescar was authorized to inspect, remove, install, repair, and qualify interior linings and coatings for tank cars that transport materials that are corrosive to the tank.

The Axiall Corporation Natrium facility in New Martinsville, West Virginia was registered with the AAR as a Class F and G tank car facility.[32]Axiall's registration expired on June 7, 2016, and the company states that at the time of the incident it was in the process of seeking M-1002 certification for removal and replacement of tank car service equipment, including removing and replacing valves.[33]

The MSRP M-1002, Appendix D retest and qualification requirements also specify that structural integrity inspections and tests for fatigue-critical structural elements must include all transverse fillet welds greater than 0.25 inch, and the termination of longitudinal fillet welds greater than 0.25 inch within 4 feet of the bottom longitudinal centerline. Tank car facilities must inspect such elements using approved nondestructive examination methods. Appendix D specifies a 10-year maximum interval for structural integrity inspection of stub draft sills, sill pads, and sill attachment welds inboard of the bolsters, and for qualification and inspection of load-carrying members as required by AAR Field Manual Rule 88.B.2.

Requirements for postweld heat treating are found in M-1002, Appendix R and W. Postweld heat treatment is usually required for general purpose cars and is mandatory for pressure tank cars after welded repairs to defective areas and repair of attachment fillet welds. Local postweld heat treatment (LPWHT) must use a heating soak band that extends past the ends of each weld a distance of at least six times the plate thickness surrounding the weld repair. The rate of heating and cooling, and temperature distribution must be controlled in accordance with AAR specifications to prevent damage to the material. The variation in temperature throughout the heated area of the tank must not exceed 250 °F, nor should any portion of the tank exceed 1,250 °F.

Relevant Association of American Railroad casualty prevention circulars include the following:

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[31] Companies may voluntarily participate in the AAR M-1003 Quality Assurance Program and must meet all the requirements for acquiring and maintaining certification.

[32] Registration as a Class F and G tank car facility is an acknowledgment from the AAR that a tank car facility has stated and submitted checklists indicating that the facility meets all the applicable requirements of AAR M-1002, Appendix B for facilities that manufacture, recondition, repair, retest, or qualify tank car service equipment or change gaskets.

[33] Tank car service equipment includes pressure relief devices, valves, closures and fittings, devices used for loading and unloading, venting, sampling, vacuum relief, measuring lading volume or temperature, or flow restriction.

- AAR Maintenance Advisory MA-0123 (CPC-1218). On October 1, 2010, in response to an increasing number of stub sill-related defects found on tank cars in transportation, the AAR issued MA-0123 advising tank car owners, repair shops, and railroads to inspect stub sills when personnel are performing maintenance or during normal inspection events. Among several items, railroad operating and mechanical personnel were asked to visually inspect critical locations, including the bottom of the tank at the inboard end of the cradle pad for buckling in excess of ½ inch. Defects should be communicated to car owners for a maintenance determination.
- AAR Casualty Prevention Circular CPC-1114. The circular requires stub sills to be inspected at each HM-201 tank car qualification event and any defects or cracks are to be repaired. Tank car owners may use an alternate AAR Tank Car Committee-approved inspection protocol based on a damage tolerance analysis or other analytic tool. Car owners, or their designee, must record the results of stub sill inspections, as well as alterations, conversions, corrosion repairs, crack repairs, non-accident buckles, and tank repairs in the web-based Tank Car Integrated Database (TCID). The qualification decal applied to AXLX1702 indicated that the stub sill was inspected in 2010 and was due for re-inspection in 2020.
- Attached to CPC-1114 is the AAR Interim Stub Sill Inspection Program.[34] An earlier AAR Circular letter, CPC-1082, stipulated that, effective July 1, 1999, each tank car stub sill would be inspected in accordance with a plan based on a damage tolerance analysis (DTA), or at a default inspection interval of five years or 75,000 miles. However, because the DTA method was not providing reliable or consistent results, an alternate inspection plan provides a stub sill SS-3 inspection frequency not to exceed 10 years or 200,000 miles, whichever occurs first.[35]

***Axiall Corporation Tank Car Maintenance Program***

In accordance with 49 CFR Part 180 Subpart F, Axiall Corporation developed a maintenance manual and maintenance-specific requirements for its chlorine tank car fleet.[36] The manual contains requirements applicable to all Axiall railcars undergoing scheduled or non-scheduled maintenance and repair, as well as requirements applicable to 17,500-gallon capacity chlorine tank cars. The Axiall maintenance manual contained the applicable owner's instructions for the 2016 inspections and corrosion repairs to AXLX1702. Detailed methods for conducting the inspections, repairs, and tank qualification are found in AllTranstek fleet maintenance shop procedures.

Axiall established the commodity-specific inspection interval for chlorine at 10 years for tank qualification inspection. Axiall told NTSB investigators that it sought advice and input

[34] *AAR Manual of Standards and Recommended Practices, Specifications for Tank Cars,* Section C, Part III (M-1002), Appendix Y, selected AAR Circular letters (November 2014).

[35] When the actual mileage of the tank car is not known, mileage may be estimated using an assumed 20,000 miles per year as established in AAR O&M Circular No. 1.

[36] *Axiall Corporation Chlor Alkali and Derivatives SBU Tank and Hopper Rail Car Maintenance Manual*, Version 7.0 – Issued August 2015.

from AllTranstek in selecting the inspection interval. Axiall company-specific requirements state that Axiall has no limitations or additional requirements pertaining to reliability performance or analysis frequency. According to the procedure, this inspection interval had been adjusted to account for special product requirements and in-service history concerns.

The Axiall maintenance manual refers to AllTranstek fleet maintenance procedures for stub sill reinforcement pad structural weld inspections.[37] The procedure requires the last 6 inches of the inboard longitudinal sill pad weld to receive magnetic particle examination or liquid penetrant inspection. The maintenance manual states that if the inboard pad has a wrap-around weld (such as shown in Area 1 of Figure 5), the last 6 inches of the longitudinal weld and entire wrap-around should be inspected.

The Axiall acceptance criteria states that the tank car successfully passes the structural integrity inspection when no abrasion, cracks, dents, or distortions have been identified.

The Axiall maintenance manual includes provisions for interim inspections with the following conditions:

- Leased and owned chlorine tank cars are on a 5-year cleaning inspection cycle, at and in between tank qualifications. The 5-year cleaning inspection includes a check for internal corrosion and shell thickness measurements to verify integrity.
- Tank cars with ACF-200 underframes shall be modified to include a head brace when the car is scheduled to be relined. Until a car with an ACF-200 stub sill has been modified, the stub sill shall have an SS-3 inspection performed every 5 years.[38] [39]
- For tank car AXLX1702 and similar build tank cars, Axiall has established a minimum allowable service life shell thickness of 0.7595 inch for the 5-year inspection interval, minimum allowable thickness of 0.7438 inch, and localized corrosion allowance of 0.6813 inch. [40]

The FRA maintains that defining critical flaw sizes for various rail car components, especially in fracture critical locations such as fillet weld longitudinal terminations, is essential for the application of damage tolerance analysis for determining component

[37] *Structural Weld Inspection*, Fleet Maintenance Procedure FM-214, AllTranstek LLC (February 2016).

[38] Axiall states that it intended this section to apply to general service tank cars in sodium hydroxide service, and not pressure tank cars in chlorine service. Axiall notes that technical writers intended to consolidate all stub sill requirements into a single general section of the Axiall maintenance manual, however the language failed to differentiate the unique stub sill requirements based on the product specification requirements contained elsewhere in the manual.

[39] Axiall also notes that the SS-3 inspection is of the outboard portion of the stub sill (closer to the coupler), and not the inboard part of the stub sill. The inboard portion would be covered under a Rule 88B.2. inspection, and AllTranstek procedure FM-214.

[40] *Company Specific Requirements, Axiall,* AllTranstek LLC (February 2016). The thickness allowances apply to AXLX1666 through AXLX1718.

service life and NDT acceptance criteria.[41] The 2016 FRA report on Probability of Detection Evaluation Results for Railroad Tank Car Nondestructive Testing suggests that Title 49 CFR Part 179.7 is a mandate for tank car owners to evaluate and consider the relationship between critical flaw size, crack growth rate, the capabilities of particular NDT methods to detect a crack, and inspection intervals when developing the owner's qualification program. The Axiall Tank & Hopper Railcar Maintenance Manual does not describe the criteria the company used to determine chlorine tank car service and inspection intervals.

Axiall Corporation has contracted AllTranstek, L.L.C. as its maintenance administration contractor. Among other obligations, AllTranstek is responsible for rail car shop maintenance logistics, monitoring repair shop throughput, final rail car disposition, monitoring and receiving all necessary maintenance documents and repair estimates, and for receiving and auditing invoices for payment.

Post-incident modification and enhancement to the Axiall tank car maintenance program is discussed in Section M of this report.

***Former Owner PPG Industries, Inc. Tank Car Maintenance Program***

PPG Industries, Inc. owned AXLX1702 when it was last subjected to a qualification inspection and weld crack repairs in June 2010. The tank car reporting mark was PPGX1702 at that time. The PPG qualification procedures that were applicable during the 2010 qualification and maintenance work were set forth in the *PPG Industries, Inc. Tank Car Qualification Manual* issued July 2001, (rev. September 2008), and *PPG Industries, Inc. Rail Fleet Maintenance Manual*, Version 4. The PPG qualification manual provided that all defects in the structural welds and base metal must be repaired in accordance with AAR Specification M-1002 Appendices R and W. The maintenance instructions were consistent with AAR Casualty Prevention Circular CPC-1114 for requiring stub sill (SS-3) inspection at the time of tank qualification.

At the time AXLX1702 was qualified in 2010, the PPG Maintenance Manual V.4 generally set its chlorine fleet tank qualification and thickness inspection interval at ten years, unless otherwise directed. However, a reduced qualification cycle would have been required if the car traveled more than 200,000 miles prior to the next qualification due date. The PPG Industries, Inc. specific repair procedures required an SS-3 stub sill inspection (outboard of the body bolster) to be performed every 5 years on tank cars equipped with ACF-200 style stub sills. The instructions further stated that the stub sill inspection due date on the car stencil qualification marking area should not be changed following the 5-year inspection.

[41] *Probability of Detection Evaluation Results for Railroad Tank Car Nondestructive Testing*, DOT/FRA/ORD-16-35 (Washington, DC: U.S. Department of Transportation, Federal Railroad Administration, 2016).

The PPG Maintenance Manual V.4 stated that for jacketed tank cars with a stub sill design, such as AXLX1702, the initial NDT method for inspection of external fillet welds should be either direct or remote visual examination. The instructions stated that a tank shell successfully passed the structural integrity visual inspection when it showed no structural defect such as abrasion, corrosion, cracks, dents, distortion, or any other unsafe condition that would require repairs in accordance with the AAR MSRP.

The PPG Maintenance Manual V.4 further stated that a tank car successfully passed a structural integrity inspection and test when the weld showed no structural defect that may initiate cracks or propagate cracks and cause failure of the tank. Examples provided of structural defects that might initiate or propagate cracks included weld undercut and cracks at the termination of the inboard sill pad.

### *Tank Car Facility Maintenance and Repair Procedures*

The car owner's maintenance instructions are supplemented by Rescar Companies shop procedures and AllTranstek LLC fleet maintenance procedures. To the extent that a company-specific requirement imposes limitations or additional requirements to the Rescar and AllTranstek procedures, the owner's requirements take precedence. Rescar's car file for AXLX1702 contained the owner's qualification and maintenance manuals.

#### Rescar Companies Shop Procedures

Rescar procedures call for mapping any defects or corrosion noted during a tank car interior shell inspection. Technicians are supposed to grind any corrosion to sound metal and record ultrasonic thickness measurements to identify areas needing weld buildup repair and postweld heat treatment. Rescar then makes a repair recommendation and submits a repair cost estimate to the tank car owner for approval.

The tank shell repairs begin once the owner approves the repair and the repairmen review the work order forms and understand the scope of the work. Rescar shop procedures for tank welding and TC-128 Gr. B welding and weld buildup provide general welding specifications and welder qualification requirements. Technicians conduct non-destructive testing after the tank shell is repaired. A technician then verifies the areas to be LPWHT and communicates the proposed plan to a postweld heat treatment contractor as described in Section G of this report.

After LPWHT is completed, shop procedures call for Rescar technicians to perform non-destructive testing of the repaired areas in accordance with the tank car owner's requirements.

#### AllTranstek Fleet Maintenance Procedures

PPG began using AllTranstek maintenance procedures on April 1, 2011. When Axiall Corporation purchased the tank car fleet in 2013, it continued using AllTranstek as its maintenance administrator. AllTranstek reviewed and approved Axiall Corporation company specific requirements that governed the 2016 repairs to AXLX1702, including qualification and inspection intervals established for the fleet.

The designated intervals for thickness inspection, service equipment inspection, and tank qualification are each 10 years. AllTranstek company specific requirements for the Axiall fleet do not note any adjustment to the federal maximum 10-year inspection intervals for tank cars in chlorine service or for any in-service history concerns. AllTranstek procedures further call for stub sill inspections to be performed at the earliest of the tank qualification due date, or the mileage limits based on the design of the stub sill as specified in the AAR, MSRP, Section C, Part III, Specifications for Tank Cars, Appendix D.

***Nondestructive Testing Technique Sensitivity***

AllTranstek fleet maintenance procedures describe the reliability and sensitivity of NDT methods its inspectors use to assess the structural integrity of tank cars. The probability of detecting (POD) fillet weld and butt weld cracks during the pre-repair and post repair examinations of AXLX1702 using direct visual examination and magnetic particle examinations are quantified in Tables 1 and 2.

*Table 1: AllTranstek Evaluation of Visual Test Reliability and Sensitivity.*

| | **Fillet Welds** | **Butt Welds** | |
|---|---|---|---|
| **Flaw Size (inches)** | POD | POD | Confidence |
| **0.25** | 34% | 34% | 95% |
| **1.5** | | 46% | 95% |
| **3** | 57% | 50% | 95% |
| **6** | 62% | | 95% |

*Table 2: AllTranstek Evaluation of Magnetic Particle Test Reliability and Sensitivity.*

| | **Fillet Welds** | **Butt Welds** | |
|---|---|---|---|
| **Flaw Size (inches)** | POD | POD | Confidence |
| **0.25** | 50% | 28% | 95% |
| **3** | 75% | 62% | 95% |
| **6** | 78% | 74% | 95% |

AllTranstek states that its reliability and sensitivity data are averages obtained from qualification of its inspection procedures using the probability of detection approach from historical data, NDT studies conducted by the Transportation Technology Center, Inc., published NDT industry data, and American Society for Mechanical Engineers and American Society for Nondestructive Testing publications and specifications.

## G. AXLX1702 Pre-accident Maintenance and Repair

*2010 Maintenance Events*

In 2010 tank car AXLX1702 (formerly PPGX1702) was subjected to an HM-201 tank car qualification cycle at the Rescar DuBois, Pennsylvania tank car facility.[42] Rescar technicians noted that the tank decal indicated Rescar had conducted the previous tank qualification in 2000 and the previous stub sill and Rule 88.B2 inspections in 2006.

The shop records indicated that Rescar cleaned and inspected the interior of the tank car finding no indications of interior corrosion. Rescar technicians collected ultrasonic thickness measurements and further noted no evidence of interior corrosion or mechanical damage.

On May 19, 2010, Rescar technicians conducted stub sill and structural integrity inspections using direct visual inspection (VT) to inspect for weld defects. Technicians reported the longitudinal cradle pad-to-tank fillet weld terminations failed the inspection. The defects noted included cracks in the A-end and B-end left and right pad-to-tank weld terminations. Technicians also inspected the bottom four feet of tank girth welds by ultrasonic examination, finding no reportable indications.

The Rescar repair work order indicated that the defective cradle pad termination welds were removed by grinding and rewelded. The work order indicates that the applicable Rescar shop procedure was followed for repair of pressure tank car TC-128 Gr. B carbon steel tank shells or attachments directly to the tank shell.

Shop records indicated that post-repair and post LPWHT visual and dye penetrant inspections found the longitudinal pad-to-tank fillet welds in acceptable condition.

On June 18, 2010, the repair welds were subjected to local postweld heat treatment. Dye penetrant inspection was performed again after the stress relief process with acceptable results.

Also on June 18, 2010, Rescar completed AAR Form R-2, Report of Nonaccident-Related Buckles, Corrosion, and Crack Repairs, which indicated that the length of the cracks were 3 inches at each of the four cradle pad weld terminations.

On June 24, 2010, a Rescar technician performed a final quality audit and found no defects. The technician certified that work performed met Rescar, customer, industry, and regulatory requirements and standards.

Because of external surface corrosion induced by moisture collecting in the urethane foam insulation on tank cars of this design in the PPG fleet, in July 2010, PPG shipped

[42] Maintenance records indicate the car was stenciled with reporting mark PPGX1702 during the 2010 shopping event because PPG Industries owned the tank car at that time.

AXLX1702 (formerly PPGX1702) to Texana Tank Car Mfg. Ltd for rejacketing. Texana Tank removed the jacket and urethane insulation then sand blasted the exterior tank surface. Texana reported finding pitting corrosion at seven locations on the top surface of the tank, which were repaired by weld buildup.[43] A combination of 2 inches of ceramic wool and 2 inches of fiberglass insulation over the ceramic wool, a new jacket and ½ inch thick full headshields were installed to complete the conversion.

***2016 Maintenance Events***

On December 16, 2015, Axiall scheduled AXLX1702 for a 5-year interim inspection to check for interior corrosion and shell thickness in accordance with Axiall's fleet-specific requirements. The tank car was not yet due for its 10-year HM-201 qualification inspection and testing event. Therefore, AXLX1702 did not receive a structural integrity inspection of the stub sill underframe weld terminations. Both the AllTranstek tank car final inspection and test report dated July 25, 2016, and the Rescar service request form indicated "n/a" for Rule 88.B2 and SS-3 inspections. The service request form did not report any pre-existing railroad damage. The car mileage report indicates AXLX1702 logged about 55,000 miles since its 2010 qualification inspection and repair; about 24,400 of these were loaded miles.

In January 2016, AXLX1702 arrived at the Rescar DuBois, Pennsylvania tank car facility. The work process began with cleaning the tank interior. Inspectors noted the presence of a scale and "heavy rust throughout the tank." The tank was cleaned with a water rinse, steam cleaning, then interior hand cleaning with sodium bicarbonate. About 25 pounds of rust and/or sludge was removed from the tank. Following the initial cleaning, interior blasting was necessary to sufficiently remove scale from tank surfaces to complete the inspection.

The visual inspection found evidence of corrosion damage to the shell and manway nozzle flange (Figure 6). Inspectors mapped areas of metal loss between 2 feet each side of the bottom centerline using ultrasonic thickness tests (UTT). The inspector found corrosion spots in the bottom of the tank in each of the five tank rings that resulted in shell thickness below Axiall's designated minimum for AXLX1702 of 0.7438 inch. The area of the tank where the crack occurred in Ring #4 had a measured thickness as low as 0.709 inch at one location. The inspector did not note any shell buckling in the area inboard of the A-end cradle pad. The inspector completed a structural integrity defect record and reported that the tank failed inspection.

[43] Weld buildup is the application of a weld layer or layers to the tank surface to restore the thickness of areas that have been thinned by corrosion.

*Figure 6: AXLX1702 internal corrosion and ultrasonic thickness measurement locations in Ring 2, Rescar inspection March 21, 2016.*

On March 28, 2016, the Rescar inspector notified the AllTranstek fleet maintenance manager of the inspection results, noting that the tank car was built in "1981" and had severe corrosion in Rings 3 and 4.[44] On April 19, 2016, the AllTranstek fleet maintenance manager responded with approval to perform all identified repairs on the tank car.

The billing repair card summarized the repairs Rescar made to the tank and service equipment, including weld corrosion repair to a total of 6,912 square inches (48 square feet) of interior surface along with post weld heat treating. Rescar technicians removed corrosion by grinding prior to using weld buildup to repair shell locations that were determined to be below minimum required thickness, including a segment of girth weld in Ring #4.[45] Technicians blended the weld buildup spots into the adjacent parent metal using hand held grinders.

On May 24, 2016, Rescar performed post-repair UTT to confirm minimum thickness at each repair spot. Technicians did not identify any exceptions.

Rescar technicians also used magnetic particle inspection methods to examine areas with weld buildup repairs for evidence of cracks.[46] Examination surfaces met the acceptance criteria and technicians noted no exceptions. This crack examination did not include any cradle pad welds, which were not reworked during this shopping. Rescar told NTSB investigators that the cradle pad welds were not examined because the corrosion repairs were to the interior of the railcar only.

[44] The tank car was actually built in 1979, but was erroneously stenciled with a build date of 1981.

[45] Rescar Shop Procedure RSP-041, Rev. J, *WPS-FCAW Pressure and Non-Pressure Tank Welding, E81T1-NI1 Filler Metal, TC128 Gr. B Welding and Weld Buildup* (April 24, 2013). Weld buildup, or overlay, is used to restore the thickness when sound metal is less than the minimum allowable thickness.

[46] *Magnetic Particle Examination*, Fleet Maintenance Procedure FM-230, AllTranstek LLC (rev. March 2015).

Rescar attempted to conduct local post-weld heat treatment in accordance with Rescar Shop Procedure RSP-014 for electrically controlled heating pads.[47] The shop procedure calls for all repairs to be completed in the heat treatment zone prior to heat treating. The shop procedure cautions that multiple LPWHT in the same area should be avoided because multiple heat treating cycles could damage the material and compromise tank integrity. However, Rescar told investigators that equipment problems caused them to abort and rerun several of the heat treatment cycles. The procedure calls for using ceramic fiber insulation over the heating elements as well as insulating the opposite surface of the material to be treated. In such cases tank jacket cutouts are necessary to provide access to the area to be insulated. The procedure states that insulation must be 2 inches thick and extend a minimum of 12 inches past the heating elements.

Rescar subcontracted Superheat FGH of Aston Mills, Pennsylvania to provide internet-based remote LPWHT operation and monitoring. The Rescar LPWHT procedure states that for heat treatment jobs that exceed equipment capacity or complexity, technicians should contact Superheat for direction. After receiving a map of the weld-repaired areas on the tank car, Superheat provided Rescar with a general layout plan indicating the locations for ceramic resistance-pad heaters along with the thermocouple attachment points. The heating pads and thermocouple leads were attached to heater control units to regulate the rate, intensity, and duration of the heating process. Superheat also provided the locations for exterior insulation for controlling the work piece temperature.

Because numerous areas required local post-weld heat treatment (LPWHT), Rescar performed the treatment with 26 heater circuits on six different dates between May 27, 2016, and June 9, 2016 as shown in Figure 7. This sketch depicts the shell repair locations and the chronological order of the successful LPWHT runs with 8-inch by 14-inch heating elements that were used to cover the weld repair spots. Rescar told NTSB investigators the purpose for these multiple LPWHT stages was to better control the heat treatment process.

Other applicable shop procedures included heat treating an area at least the width of six times the plate thickness on each side of the weld repairs. Controlling elements on different material thicknesses such as over the tank only and over the tank and a support pad must be controlled separately. Additionally, heat sinks such as pads, brackets, and flanges in the heating area must be heavily insulated to prevent false temperature readings to the controller.

[47] The procedure is intended for repairs and alterations in involving welding where there is an absence of customer specific instructions. AAR M-1002, Appendix R, Table R.2 (November 2014) provides requirements for PWHT and Appendix W, paragraph 16.2 provides temperature and time requirements for PWHT.

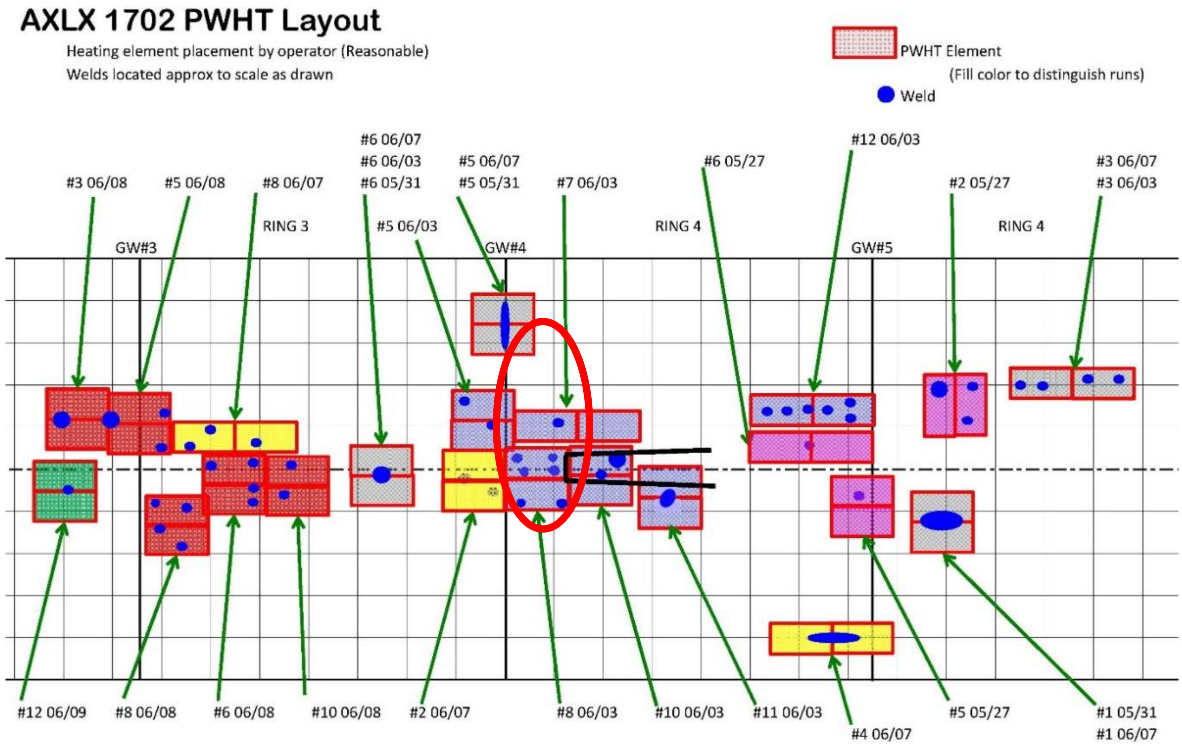


*Figure 7: Rescar post weld heat treatment map for AXLX1702. Area of the shell crack is circled in red nearest heating elements 7 and 8.*

Rescar technicians made five rectangular jacket cutouts along the bottom of the car to insulate exterior surfaces for maintaining sufficient heat stress relief temperature during LPWHT. The Rescar jacket cutout mapping record indicated that the cutouts measured about 20 to 30 inches wide, and 30 to 40 inches long. The specific heat treat parameters were 1,012°F ±12 for a minimum hold time of 3 hours. The AAR PWHT temperature requirement for carbon steel tanks for 3 hour holding time is 1,000 °F.[48]

The Superheat remote facility monitored and controlled the temperature of each heating element to ensure that temperature ramp up limits, soak temperature and time, and cool down rates were within the limits of the procedure and in compliance with AAR requirements. Rescar retained a temperature versus time chart recording for each successful LPWHT run.

AAR M-1002 Appendix R, Figure R.4 and the Rescar shop procedure require each circuit to have a controlling and spare thermocouple. The controlling thermocouple is used and the spare is not connected unless there is a failure of the controlling thermocouple. In that event the spare becomes the controlling thermocouple. Superheat's remote controlling systems connect to both the controlling thermocouple and the spare thermocouple. This allows the remote monitoring technician to monitor two heat signatures for each heating

[48] Table W16, AAR MSRP C-III Appendix W (11/2014) provides permissible PWHT time-temperature combinations.

zone. Although the monitoring technician can print charts for all thermocouples, the final report only requires data from one thermocouple. For example, circuit 7A & 7B would be the same heat zone.

Superheat can abort heat treatment cycles if communication is lost with thermocouples or heating pads do not reach or maintain the target temperature. Superheat records indicate that the area of the tank car where the shell crack occurred received LPWHT as part of a 6-circuit run on May 31, 2016, but the run was aborted (see elements 7 and 8 in Figure 8). Superheat records indicate that LPWHT was successfully completed on this same area of the tank on June 3, 2016 (Figure 9).

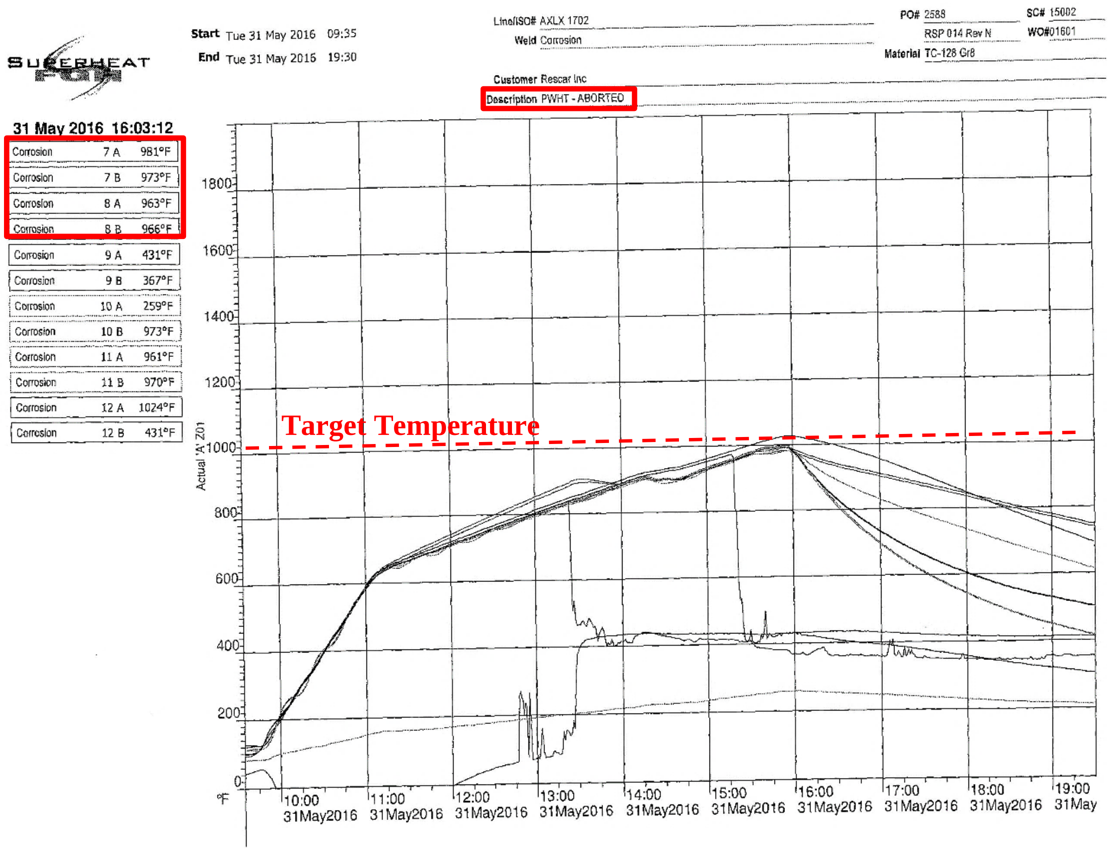


*Figure 8: Aborted post-weld heat treatment run, Superheat chart of May 31, 2016. Channels 7 and 8 are highlighted in the red box. The chart traces show thermocouple temperatures that failed to reach the target temperature of 1012 ±12 °F (indicated by the dashed line) for 3 hours.*

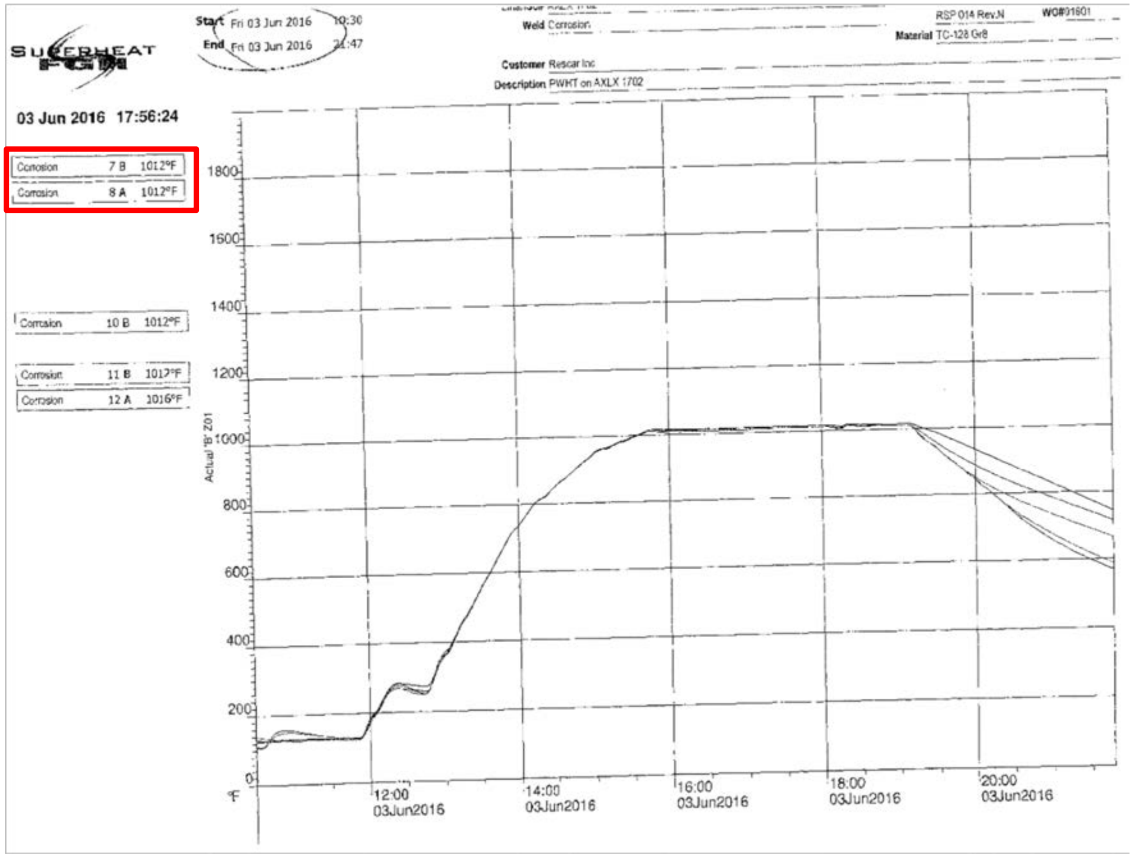


*Figure 9: Successful post-weld heat treatment run, Superheat chart of June 3, 2016. Channels 7 and 8 are highlighted in the red box.*

Rescar shop procedures and the AAR M-1002, Appendix R 8.0 require that girth weld repairs in pressure tank cars manufactured of TC-128 Gr. B carbon steel plate must be hardness tested after post weld heat treatment to verify that heat treatment has been performed correctly. There is no record in the AXLX1702 tank car file that Rescar technicians performed PWHT hardness testing on the tank during the 2016 shop work.[49]

Although the shop procedure states that a Rescar shop supervisor, level II visual inspector, or quality assurance manager will review and approve the PWHT documentation, the same Rescar technician signed the shop record as both the LPWHT set-up technician and the approving official. FRA inspectors examined Rescar files for a total of 83 tank cars on which it conducted PWHT work during 2016 and found that set-up technicians had signed off on their own work in violation of the shop procedure 63 percent of the time.

On June 20, 2016, Rescar inspectors conducted direct visual inspection and magnetic particle examination of the tank interior following the LPWHT procedure. The inspectors did not note any exceptions.

[49] AAR M-1002, Appendix R (November 2014) contains no specific hardness testing requirement or exception for corrosion repair weld buildup crossing a girth weld.

On July 20, 2016, an AllTranstek inspector reviewed applicable documentation for tank car AXLX1702, inspected the service equipment and mechanical repairs that Rescar performed, and witnessed the final bubble leak test. The inspection noted that all repairs were done with "good quality" and no visual defects were observed at the time of the inspection.

On July 20, 2016, an AllTranstek inspector performed a final inspection of AXLX1702 and finding no exceptions. The inspector concluded that AXLX1702 was in acceptable condition for return to Axiall chlorine service and was ready to be loaded. The inspector only noted the condition of paint and stenciling, service equipment, trucks, wheels, and bearings.

Axiall maintenance records indicate that six other tank cars constructed under Certificate of Construction A791013, in the sequence of AXLX1666 to AXLX1718, had also received crack repairs in the stub sill or cradle pad area.

The accident occurred after the AXLX1702 received its first chlorine loading following the corrosion repairs.

### *Shell Thickness Measurements*

The Axiall company specific requirements for AXLX1702 minimum tank head and shell bottom/sump thicknesses are 0.7595-inch 5-year inspection interval; 0.7438-inch minimum allowable thickness; 0.6813-inch minimum allowable shell thickness for areas with localized corrosion.[50]

In May 2010 and March 2016, Rescar technicians collected benchmark pre-repair thickness measurements at several locations, including the 6:00 (bottom center line) as presented in Table 3.

*Table 3: AXLX1702 Thickness Measurement Benchmarks at Bottom Centerline (inches)*

| Date | B Head | Ring 1 | Ring 2 | Ring 3 | Ring 4 | Ring 5 | A Head |
|---|---|---|---|---|---|---|---|
| **May 2010** | 0.872 | B: 0.761<br>A: 0.788 | B: 0.774<br>A: 0.767 | B: 0.762<br>A: 0.761 | B: 0.777<br>A: 0.785 | B: 0.789<br>A: 0.786 | 0.809 |
| **March 2016** | 0.830 | B: 0.748<br>A: 0.754 | B: 0.747<br>A: 0.746 | B: 0.744<br>A: 0.745 | B: 0.759<br>A: 0.755 | B: 0.760<br>A: 0.742* | 0.775 |

* below minimum allowable shell thickness of 0.7438 inch

On March 21, 2016, Rescar technicians collected more detailed measurements in a 32-location grid pattern within each barrel section, 24-inches to each side of the bottom center line. Rescar's ultrasonic thickness measurements found 40 of the 160 locations tested, or 25 percent, were below the Axiall minimum shell thickness requirements.

[50] 49 CFR 180.509(f) specifies a general corrosion allowance, or condemning limit, of 1/32-inch top and bottom for tanks with a test pressure greater than 200 psig.

On May 24, 2016, Rescar technicians collected post repair measurement at each location where they removed corrosion and conducted weld buildup. No exceptions on shell thickness were noted.

***Tank Car History – Transportation Incidents***

AllTranstek reviewed billing repair card (BRC) data specific to AXLX1702 and found no evidence of repairs made as a result of railroad damage.[51] AllTranstek also checked Railinc records for any damaged defective car tracking (DDCT) incidents and found none.[52]

## H. Other Pre-accident Events

***Transfer from Rescar, DuBois, PA to Axiall, New Martinsville, WV***

On July 28, 2016, about 9:31 p.m., AXLX1702 departed the Rescar tank car facility in DuBois, Pennsylvania destined for the Axiall Corporation facility in New Martinsville, West Virginia. The initial transporting railroad was Buffalo and Pittsburgh Railroad. The tank car was interchanged to CSXT in Newcastle, Pennsylvania on July 30, 2016. The waybill recorded the route from Newcastle, Pennsylvania, which included Wilwest, Ohio; Lima, Ohio; Cincinnati, Ohio; Russell, Kentucky; Parkersburg, West Virginia; Brojunction, West Virginia; and finally, Natrium, West Virginia. No transportation incidents were recorded during this movement. The tank car arrived at the Axiall facility on August 6, 2016, at 4:37 p.m.

***Tank Car Loading***

The process of loading a chlorine tank car at the Axiall loading facility typically requires about 6 to 8 hours. The procedures followed for filling AXLX1702 generally occurred in three stages.

The first stage involved the following inspections:

- Verify tare weight
- Inspect for signs of tampering, general defects, or damage
- Verify the condition of the top fittings
- Check currency of tank car qualification inspection dates stenciled on the tank
- Check the tank car for a defect card noting any outstanding problems
- Confirm the tank car is DOT Specification 105J500W

[51] The Car Repair Billing internet billing repair card module allows repair shops and railroads to report repair data directly to the Railinc data exchange to promote business exchanges between rail car owners, freight car repair companies and railroads.

[52] DDCT is a web-based application that provides a centralized system for railroads, car owners, and repair facilities to identify and track damaged and defective rail equipment.

The second stage is called “prep,” where the top fittings were cleaned and the tank car was purged of any product from the previous load.[53] Because AXLX1702 was returned from a tank car shop with about 30 psig of nitrogen, the loader opened a liquid valve to test the tank for the presence of moisture, finding none. The tank liquid valve was left open, releasing the nitrogen to the atmosphere to reduce the pressure to about 10 psig prior to beginning the chlorine loading.

The tank car was moved onto a track scale and loading lines were connected for the third and final stage. The inspection and loading process involved two chlorine loader personnel; one loader was responsible for items accessible at the ground level while the other loader managed the top fittings and loading lines from an elevated stand.

The Axiall loading shed contains three tracks (Tracks 8, 10, and 11) on which tank cars are loaded. Between 2:00 and 3:00 a.m. on August 27, the night shift began filling AXLX1702 on the middle track (Track 10). One other tank car was being simultaneously loaded on Track 8. The tank car weight was recorded hourly. Axiall controls tank car loading amount using a set point calculation to determine the amount of liquid chlorine to load. Loading personnel must monitor scale readings and system flow rates as the cars are filled. When the quantity loaded reaches the calculated amount, the loader manually shuts off the loading process. Axiall loading personnel told NTSB investigators they typically load chlorine tank cars to gross weight between 260,000 and 263,000 pounds.[54]

About 6:30 a.m. the morning shift loading personnel arrived and finished loading the tank car at about 8:15 a.m. Three chlorine loaders interviewed told NTSB investigators that no leaks were detected and no unusual events occurred during the loading process.

The tank car was loaded to a pressure of 65 psig and the product loading temperature was -9 °F. Loading records indicate the gross weight for AXLX1702 was 261,950 pounds. The tare weight of AXLX1702 was 83,550 pounds and the amount of liquefied compressed chlorine loaded into the rail car before the incident was 178,400 pounds. The stenciled maximum load authorized for AXLX1702 was 178,400 pounds. Axiall quality control testing showed the chlorine was within specification and contained traces of other halogens and halogenated hydrocarbons, and a moisture content of 6 parts-per-million.

PHMSA regulations at 49 CFR 173.314(c) allow a maximum filling density for chlorine of 125 percent the tank car water weight capacity, or a maximum of 180,000 pounds. However, the maximum allowable load is restricted by the AAR maximum allowable weight on rails of 263,000 pounds or a maximum load of 179,500 pounds.

[53] In the case of AXLX1702, the tank car was in the as-received condition from the Rescar tank car shop and did not contain any residual chlorine.

[54] The Axiall tank car loading procedure requires the gross weight set point to be between 260,000 and 263,000 pounds.

Axiall typically loads its tank cars to a pressure between 50 and 108 psig.[55] One chlorine loader told NTSB investigators that he prefers to keep the pressure of a loaded tank car below 80 psig by removing excess vapor from the tank as necessary. Another chlorine loader told NTSB investigators Axiall had determined that a loading pressure at or below 108 psig prevents the possibility of pressure relief devices opening under conditions normal to transportation. The Chlorine Institute recommends that tank car loading must consider the increase in vapor pressure as the temperature increases, such that the chlorine pressure in the tank should be maintained below about 80 percent of the pressure relief device start-to-discharge setting of 375 psig.[56] For example, the Chlorine Institute recommends a shipping pressure of 54 psig at a product temperature of -10°F. According to this guidance, an initial shipping pressure of 65 psig would be appropriate for a product temperature of about 0 °F.

The temperature of the liquefied chlorine loaded in Axiall's tank cars is related to the process of condensing and blending chlorine from primary and secondary liquefaction systems. The loading temperature can range from -10°F to +10°F depending on liquefaction operating parameters. Current procedures have been in place since 1984 and there have been no changes in typical loading temperatures for tank cars.

After AXLX1702 was loaded, the chlorine loaders tested valves and fittings for leaks with ammonia solution spray.[57] Any leakage could also be detected by odor or by a network of chlorine gas sensors and alarms near the loading shed and throughout the plant. Typical minor leaks are caused by faulty gaskets, O-rings on fittings, or valves. However, chlorine loaders told NTSB investigators that it is rare for any leak to occur while loading tank cars. Because AXLX1702 had just returned from a tank car facility, it was equipped with new valves and new pressure relief device, which were not leaking.[58]

## I. Chlorine Release

When the loading was finished, Axiall loading personnel removed the loading lines and sealed the valves and fittings. Axiall personnel used a trackmobile to move the tank car at about a walking pace forward from the loading shed about 30 to 40 yards. They then set the brake and chocked the wheels. AXLX1702 was not coupled to any other rail cars at the time of the incident.

On August 27 about 8:26 a.m., while the next tank car was being loaded, one chlorine loader prepared another tank car in the line and weighed it for loading. Ten minutes after AXLX1702 had been moved out of the loading shed the chlorine loader heard a loud bang

[55] The total pressure in the tank car is the combination of the partial pressure of the liquefied chlorine and the partial pressure of non-condensable gases.

[56] The Chlorine Institute, Pamphlet 66, 5th ed.

[57] Ammonia mist reacts with a chlorine leak to produce a visible white cloud, and is a technique used by loading personnel to trace and remediate leaks.

[58] Axiall replaces the liquid and vapor valves after 18 trips as a routine maintenance procedure. Pressure relief valves are replaced at shopping.

from the tank car. The chlorine loader then observed a green chlorine gas cloud engulfing the tank car on Track 10 north of the loading shed.

About 8:26 a.m., while AXLX1702 was not in direct view of any security camera, Axiall security video recorded the first images of a rapidly expanding green gas cloud emerging from the rail car staging area outside of the chlorine loading rack where the tank car was stationed.

Upon observing the chlorine gas cloud growing around the tank car, one chlorine loader who just finished loading AXLX1702, entered the loading shed and telephoned the guard station to initiate a chlorine release alarm.[59] Both chlorine loaders shut down other rail car loading equipment and evacuated the area towards the south. All non-essential employees and contractors immediately evacuated to the guard station or to the dispensary for exposure treatment.

Chlorine gas sensors that are positioned at several locations within the plant first detected the release and went into alarm about 8:28 a.m.[60] Between 8:29 a.m. and about 11:07 a.m., several in-plant gas sensors near the point of release and near the south plant perimeter (downwind of the release) recorded chlorine concentrations above the OSHA immediately dangerous to life and health (IDLH) concentration (see Figure 10).[61]

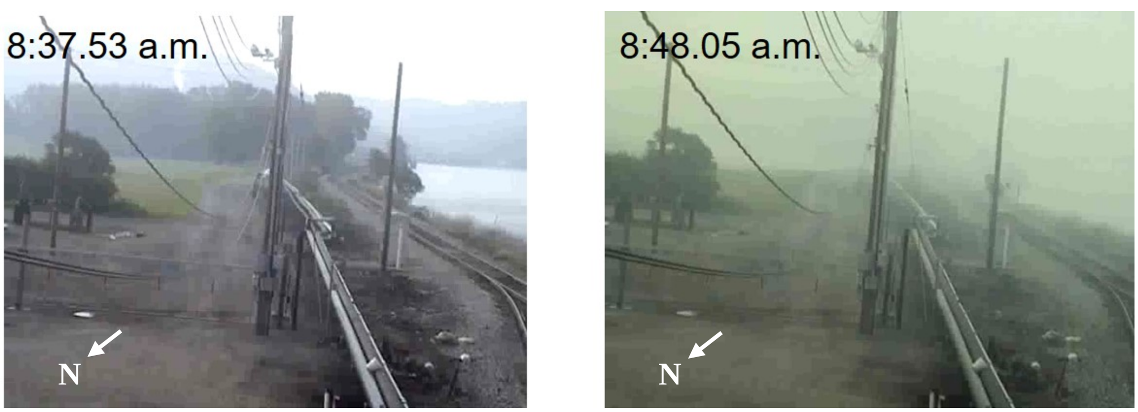


*Figure 10: Axiall security camera views looking south beyond perimeter fence, August 27, 2016. The tree line visible in the left image, but obscured by the chlorine cloud in the right image, is about 6,100 feet southeast of the incident location.*

[59] The chlorine loader who first observed the gas cloud is also a volunteer firefighter and hazmat technician.

[60] The Natrium plant is monitored by an array of 51 chlorine gas sensors that are set to alarm at 1.0 ppm, which is the OSHA short term exposure limit, or the average concentration above which a worker should not be exposed over a 15-minute time period.

[61] Most the gas sensors were stationed around the plant perimeter. One of the gas sensors near the point of release recorded intermittent IDLH levels until about 12:51 p.m.

On August 31, 2016, NTSB investigators observed evidence of vegetation damage near Axiall's perimeter about 4,000 feet south of the incident location (Figure 11), and in a forest about 2 miles south of Axiall, east of West Virginia Route 2.


*Figure 11: Damaged (brown) vegetation near Axiall Corporation south perimeter, August 31, 2016.*

Photographs taken from the Ohio side of the river after the chlorine release at a distance of about ¼ mile are provided in Figures 12 and 13. The images show water vapor from a cooling tower rising nearly vertical with a slight tilt to the south. The green to yellowish lower cloud was the visible indication of the chlorine release, being about 2.5 times heavier than air remained closer to the ground and propagated towards the south.


*Figure 12: Axiall Corporation as seen from Rt. 7 (Ohio River Scenic Byway) to the west opposite bank of the Ohio River, August 27, 2016, (courtesy West Virginia Division of Homeland Security and Emergency Management)*


*Figure 13: Water vapor from a cooling tower rises nearly vertical with a slight tilt to the south. The green to yellowish lower cloud is the visible indication of the chlorine release. August 27, 2016 (courtesy West Virginia Division of Homeland Security and Emergency Management)*

The closest weather reporting station to the incident site was from an Ohio Department of Transportation station located about 5 ½ miles to the south near Hannibal, Ohio. The observation at 8:05 a.m. on August 27, 2016, reported a wind from the north at 1 mph, visibility 1 ¼ miles in mist, temperature 72 °F, dew point temperature 67°F, with relative humidity of 83 percent, and road conditions dry. The NTSB Office of Aviation Safety Meteorology Factual Report provides additional details about weather data derived from the National Weather Service and other sources.

## J. <u>Emergency Response</u>

Following the release of chlorine, the State of West Virginia, Department of Environmental Protection (WV DEP) reported that the Marshall County, West Virginia, Office of Emergency Services (OES), Wetzel County, West Virginia OES, and Monroe County, Ohio OES had activated their respective incident command posts. The Marshall County OES command post was situated about 4 miles north of the Axiall facility on State Route 2.

WV DEP reported that the communities of Kent (Marshall County), Proctor (Wetzel County) and Clarington (Monroe County), and the northern portion of New Martinsville were ordered to evacuate via the reverse 911 system or by door-to-door notification by public safety personnel. About 1,864 households are located within a 5-mile radius of the Axiall facility.[62]

Adjacent industrial facilities, including BlueRacer Midstream Natural Gas and Covestro activated shelter-in-place procedures. Traffic was halted on State Route 2, State Route 7, the CSXT rail line, all running parallel to the Ohio River. Additionally, the Coast Guard halted commercial river traffic on the Ohio River.

Between 1:37 and 2:19 p.m., Axiall personnel used portable air monitoring devices to test several intersections and business locations along State Route 2 south of the Axiall plant in New Martinsville. The Axiall personnel measured no concentrations of chlorine during that time.

Additionally, between 1:40 p.m. and 2:15 p.m., the WV DEP Homeland Security and Environmental Response group (HSER) conducted air monitoring for chlorine at several stations along State Route 2 from New Martinsville south of the Axiall plant to the Marshall County command post north of the facility. The HSER found no detectable chlorine concentrations. Similarly, between 3:40 p.m. and 4:14 p.m., HSER personnel checked several locations along Rt. 7 on the Ohio side of the river finding no detectable chlorine levels. These monitoring results prompted emergency management officials to lift the community evacuations.

Axiall told NTSB investigators that its formal gas detection team protocol was not activated on the day of the incident because other Axiall individuals and outside agencies were already taking gas detection readings in potentially impacted areas.

A chronology of emergency response events is contained in Appendix A to this report.

The Axiall Corporation, Natrium Plant Emergency Response Plan details notifications and warnings, plant and community evacuation, incident command and emergency response framework, resource management, communications, and emergency operations for transportation and non-transportation chemical release scenarios.

Under the provisions of 40 CFR Part 68, the Environmental Protection Agency (EPA) conducted a Risk Management Program (RMP) inspection of the Axiall Corporation facility in follow up to the chlorine release. Chemical manufacturers such as Axiall that are subject to RMP regulations must submit a plan to the EPA that includes an off-site consequence analysis, prevention program, and an emergency response program. The information required from facilities under the RMP rule is intended to help emergency response officials prepare for and respond to chemical emergencies.

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[62] A demographic profile of the Axiall Corporation Chlor-Alkali plant is provided on the Environmental Protection Agency Enforcement and Compliance History Online, https://echo.epa.gov/detailed-facility-report?fid=110000875367, accessed on March 29, 2017.

## K. Injuries and Damages

### *Exposure Injuries*

Following the chlorine release, 5 Axiall employees and 18 contractors reported to the Axiall medical dispensary for first aid or precautionary evaluation.[63] The first arrived about 8:40 a.m. and all were discharged by 1:40 p.m. Following initial oxygen treatment, one Axiall chlorine loader and one painting contractor were transported to Reynolds Memorial Hospital where they were treated and released that day. Ten employees and contractors were given oxygen at the dispensary. The remainder were either not treated or were given over-the-counter medications. Three contractor employees and five Axiall employees sustained OSHA-recordable injuries.[64]

### *Property Damage*

Axiall investigated property damage claims and the consequences of the August 27, 2016, chlorine release. The Covestro facility directly south of the Natrium plant reported damage to stainless steel piping, tanks, and operating equipment. In addition, Covestro employees have raised claims of impacts to their vehicles in the parking lot at the time of the release. Residents in Proctor and New Martinsville have filed eight lawsuits claiming property damage. Total monetary damages have not been determined as of the date of this report.

## L. Tank Car AXLX1702 Postaccident Examinations

### *NTSB Materials Laboratory Examination*

The following discussion summarizes on-scene observations and laboratory examination findings. Details of the laboratory examination are contained in the NTSB Materials Laboratory Factual Report.[65]

On September 1, 2016, NTSB investigators examined tank car AXLX1702 at the Axiall Natrium Plant. The car was further examined and shell material samples were removed the following week. Examinations and testing of the removed samples began September 20, 2016, in the NTSB Materials Laboratory.

Investigators found an approximately 42-inch-long, mostly circumferential crack in the 4th ring of the tank near the inboard end of the A end stub sill (Figure 14). The crack was located about 0.25 to 0.5-inch inboard of the A end stub sill cradle pad and ran

[63] The Axiall medical dispensary was staffed by a nurse and 5 assistants. Non-Axiall personnel reporting to the dispensary included 2 landscaping, 3 general construction, 4 paving, and 9 painting contractors.

[64] Generally, a recordable injury under OSHA is one that requires medical treatment beyond first aid, as well as one that causes death, days away from work, restricted work or transfer to another job, or loss of consciousness.

[65] *Materials Laboratory Factual Report No. 17-001*, AXLX1702 Liquid Chlorine Tank Car DOT105J500W component examination, Docket DCA16SH002 (Washington DC: National Transportation Safety Board, 2017).

circumferentially across the bottom of the tank. The crack ended near the right corner of the cradle pad and showed local yielding of the tank material.[66] To the left, the crack ran partially up the side of the tank and split into two legs. One leg continued circumferentially about 13 inches before arresting and the other leg turned horizontally toward the B end. This leg terminated at the girth weld between the 4th and 3th barrel section rings. The crack faces were gapped apart about 0.25 inch at the bottom of the tank. However, the only visible yielding deformation was at the right end of the crack.

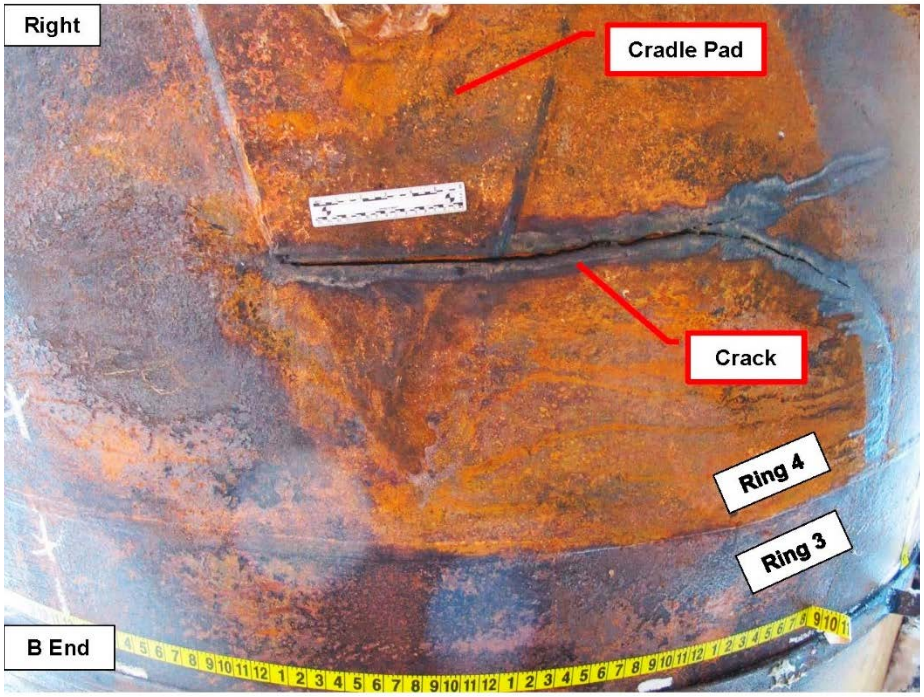


*Figure 14: Exterior surface of tank car AXLX1702 showing a circumferential crack inboard of the cradle pad, September 1, 2016.*

Different appearing welds were apparent at the inboard terminations of both right and left cradle pad-to-tank fillet welds. The different welds were consistent with manually applied repair welds as documented in the Rescar 2010 crack repairs. The cradle pad repair weld was about 2.5 inches long on the right side, and about 2 inches long on the left side.

The distance between the cradle pad inboard weld terminations was about 8.5 inches. These welds did not encroach into an 8-inch "no-weld zone" noted in the manufacturer's drawing for the end of the cradle pads (Figure 15).

[66] All orientations noted in this report are as viewed looking from the B end (brake wheel end) of the tank car towards the A end.

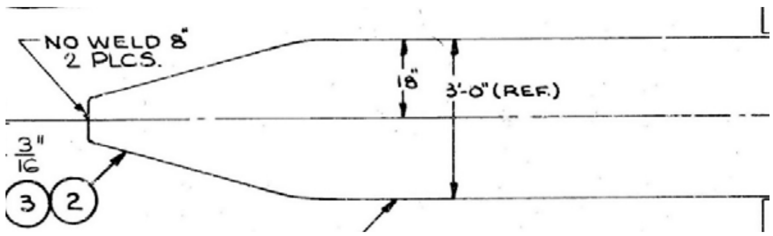


*Figure 15: Excerpt of tank car manufacturer drawing showing "no-weld zone "at inboard end of cradle pad.*[67]

The configuration of the welds had not been modified to the configuration of the "Inboard Cradle Pad Termination Detail" of ACF Maintenance Bulletin TC-200.

The tank outer surface surrounding the crack displayed general surface corrosion and numerous pits. The corrosion and pitting were also noted in locations remote to the crack. Some of the corrosion appeared as deep pitting.

Multiple weld repairs were found on internal tank shell surfaces, along with locations where the surface had been abrasively ground. The interior surface exhibited no evidence of corrosion pitting. A portion of the third and fourth ring shell material encompassing the entire crack area that was removed for further examination had 13 visible weld repairs. Of these, eight welds and 11 ground spots were noted in Ring #4 and five repair welds and two ground spots were found in ring 3. Two weld repair areas were just inboard of, but did not intersect the crack (see Figure 16).

The shell material in Ring #4 was buckled between the crack at the cradle pad plate and the ring 3 to 4 girth weld joint. In the approximate 11-inch distance, the interior surface was deformed downward approximately ½ inch. The circumferential extent of the deformation was not established.

[67] ACF Industries drawing "Attachments Welded Stub Sill U.F." 2-C-2118, 9-3-86 last revision date.

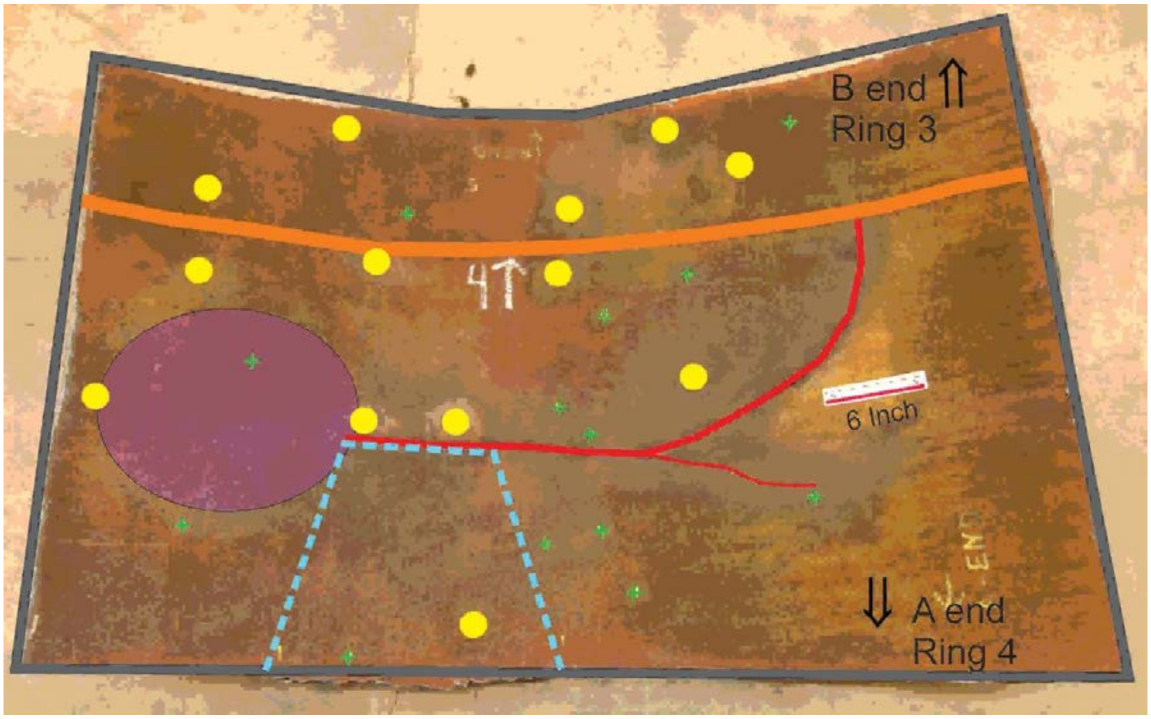


*Figure 16. Annotated interior surface of the tank shell section showing the shell crack (red line), corrosion weld repairs (yellow circles), inboard cradle pad termination on exterior/opposite surface (dashed blue line), girth weld between ring 3 and ring 4 (orange line). The purple oval on the left indicates the area with visible interior surface scaling. Ground spots are identified with a green + mark.*

Investigators removed the entire area of the crack including portions of both the 3rd and 4th rings from the tank for further examination. In addition, a plate an approximate 20 inch by 26-inch uncracked area was removed from the right side of the 4th ring for mechanical tests of the material.

The end of the cradle pad at the B end of the tank was also examined on-scene. Visual inspections did not reveal any cracks. However, repair welds, like those noted at the A end, were found at the inboard 2 to 3 inches of the cradle pad-to-tank fillet weld terminations. The entire end of the pad along with the surrounding tank material were removed for further examination. Two weld repair locations and three ground spots were visible on the interior surface of the removed piece.

Inspections of the interior tank surface at the NTSB laboratory also uncovered an area of heavy surface oxidization (scale) near the right corner of the cradle pad that investigators measured to be about 0.03 inches thick. The boundaries of the scaling were indistinct but the area was estimated to be at least 12 inches in diameter and included the right-side termination of the crack. Shell thickness measurements, 0.725-inch and 0.705-inch, within the scaled area with the scale removed were below the minimum allowed.[68] A

[68] The minimum allowable thickness for AXLX1702 tank shell bottom is 0.7438-inch as specified in AllTranstek, LLC Customer Specific Requirements (August 8, 2014).

metallographic section from the scaled area also showed decarburization 0.006 inches deep and scaling on both the interior and exterior surfaces. When the hardness of the tank material was measured, the scaled area measured somewhat softer than the surrounding material.

When the crack was opened, NTSB investigators found that the crack was consistent with brittle fracture propagation for the entire length. Chevron markings on the crack faces demonstrated that the crack initiated near the toe of the left-hand repair weld bead.

Propagation was circumferentially away from the left weld (see Figure 17). Progression to the right side arrested near the right cradle pad repair weld, but did not intersect the weld or its apparent heat affected zone. The left crack propagation continued to propagate circumferentially before splitting into two legs with the longer portion turning toward the B end of the car and arresting in the fusion weld connecting rings 3 and 4. The shorter leg of the crack continued for a distance and arrested in the middle of the plate.

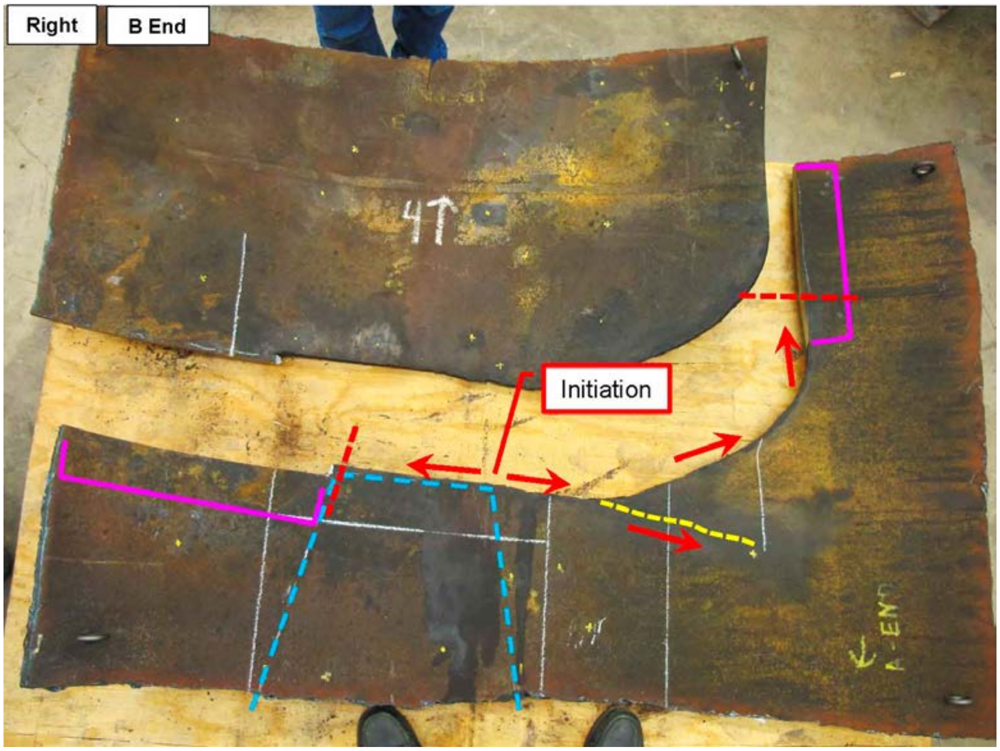

*Figure 17: Opened crack with saw cuts indicated by purple brackets, crack propagation is indicated by red arrows, the dashed blue line indicates location of cradle pad on opposite side of the shell.*

The NTSB Materials Laboratory factual report details the inspection of the crack initiation area, which identified a darker-colored elliptically-shaped region at the repair weld toe that appeared consistent with an oxide layer.[69] The elliptical region was oriented at about 45

[69] *Materials Laboratory Factual Report*, New Martinsville, West Virginia, Report No. 17-001 (Washington DC: National Transportation Safety Board, 2017).

degrees to the plate surface approximately bisecting the angle between the surfaces of the weld bead and the surface of the plate. The dark region was estimated to be about 0.7-inch wide by about 0.2-inch deep. The crack initiation region roughly followed the curved shape of the toe of the repair weld, which projected past the inboard end of the cradle pad by almost 0.30-inch. Three additional cracks found under the repair weld bead measured 0.037-inch, 0.094-inch, and 0.109-inch.

The right repair weld partially wrapped around the inboard corner of the cradle pad and its configuration was not symmetric to the left side weld. The right terminus of the crack arrested further inboard and did not intersect weld. The right weld was undercut and was made of several beads that did not blend smoothly together. The examination also identified an oxide-covered preexisting crack in the material of the tank at the right repair weld measured 0.6-inch wide and 0.3-inch deep.

Mechanical testing of Ring #4 material showed the material met the minimum requirements for AAR TC-128 grade B steel for ultimate, and yield strengths, and elongation.[70] Chemical analysis of the material identified minor deviations in the percentages of sulfur, aluminum, and boron compared to current requirements for AAR TC-128 grade B steel.[71]

Although not required at the time of original tank car manufacture, Charpy impact tests of the tank materials from Ring #4 were also conducted at temperatures between -100°F and +200°F. For a shell temperature equal to the loading temperature of -9°F, as was the case in this incident, the Charpy impact test result transverse to the rolling direction was about 8 ft-lb and in the longitudinal direction was about 12 ft-lb. The material from AXLX1702 Ring #4 would not have met the present requirements of 15 ft-lb at -30º F for pressure tank cars ordered after August 1, 2005.[72]

Investigators also examined the B end inboard end of the cradle pad and found two to three-inch-long repair welds similar to those observed at the A end on both sides of the inboard end of the cradle pad. The repair welds on both sides of the cradle pad slightly turned the inboard corners of the pad. There was slightly less than 7 inches between the two weld terminations in nonconformance with 8-inch separation called for in the manufacturer's cradle pad detail drawing (Figure 15). Metallographic specimens found 4 cracks at the toe or root of the repair welds that were wholly contained within the heat affected zone (HAZ) and did not extend into the unaffected base metal. The repair welds also exhibited areas with lack of fusion, undercutting, and slag inclusions.

The Materials Laboratory factual report provides further detail of scanning electron microscope examinations, metallographic section examinations of both the A and B end

[70] Table M.3 of AAR Manual M-1002 (November 2014).
[71] Table M.2 of AAR Manual M-1002 (November 2014).
[72] Section 2.2.1.2 of AAR M-1002 states that the test coupons tested transverse to the rolling direction must meet the minimum requirement of 15 ft-lb average for three specimens at -30°F, with no single value below 10 ft-lb and no two values below 15 ft-lb.

cradle pad welds, surface hardness, tank thickness, mechanical tests, and material chemistry.

### *FRA Follow-up Inspection*

On September 29, 2016, FRA investigators returned to Axiall Corporation to inspect the interior tank shell of AXLX1702 and collect ultrasonic thickness measurements. Investigators found seven areas below minimum shell thickness of 0.7438 inch in tank rings three and four. Investigators noted that the below minimum readings were in the grinding regions at the edges of the weld overlays where the repair technicians attempted to blend the toe of the welds into the shell.

As described in the Rescar 2016 repair records, FRA investigators found only five tank jacket patches along the bottom centerline of the car where jacket cutouts were made to access post weld heat treatment locations for applying external insulation. FRA investigators expressed concern that repair records indicate girth weld repairs had been made in the 2 and 10 o'clock positions that would also have required local post-weld heat treating, however investigators observed no exterior jacket patchwork near the repairs or interior signs of heat treatment such as discoloration in that area.

FRA investigators estimated the amount of weld repair overlay to be about 405 square inches, or about 2.78 square feet. However, Rescar reported repairing a total of 6,912-square inches of corrosion on the billing repair card for the 2016 repairs.[73]

### *Pressure Relief Device Function Test*

Tank car AXLX1702 was equipped with an Emmerson Crosby-style JQ pressure relief valve, Model H-50155-JQ-375-RD, O-ring seat with rupture disc assembly (Figure 18). The valve was originally assembled in October 2003 and Midland Manufacturing repaired the valve in May of 2016.

On September 8, 2016, a Midland engineer examined the pressure relief device to evaluate the valve condition and function. The engineer reported that the valve as received appeared in good condition with some rust around the mounting flange and on the upper lead diaphragm and identification tags.

[73] FRA investigators measured the amount of repair after metallurgical samples had been extracted from the tank, and therefore were not able to measure the entire surface repaired.

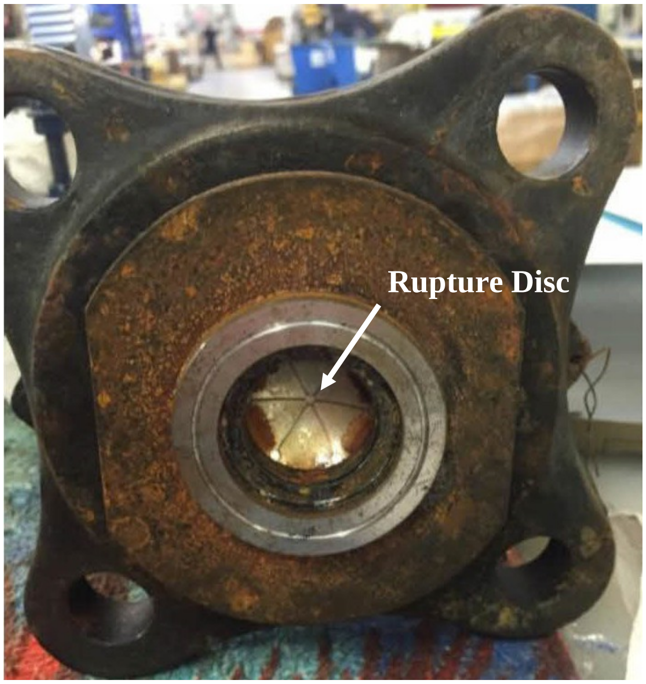


*Figure 18. Bottom view of the pressure relief device removed from AXLX1702 for examination, showing the intact rupture disc. Midland Manufacturing photograph, September 8, 2016.*

The rupture disc assembly was subjected to an initial pressure test of about 50 percent of its rated burst pressure of 375 psig. The pressure test found no evidence of leakage, indicating that the rupture disc had not been compromised. The rupture disc burst pressure was then measured to be 410 psig. The Midland engineer reported that acceptable burst pressure limit was 319 to 375 psig, and therefore the disc failed the pressure test.[74]

The pressure relief valve start-to-discharge pressure was measured to be 360 psig and the valve resealed at 330 psig. The acceptable start-to-discharge limit was 360 ±10.8 psi.

The Midland engineer then disassembled the valve and inspected each component for damage, rust, or scratches. The engineer reported that all components were in good, reusable condition.

Midland told NTSB investigators that because of the rupture disc pressure test failure, Midland subsequently contacted two tank car manufacturers who use this pressure relief device to discuss the risks associated with higher rupture disc pressures.[75] Because tank cars that use this particular valve have a test pressure of 500 psig and a burst pressure of 1,250 psig, Midland does not believe existing non-specification rupture discs that are in service present a significant risk for tank failures. Midland pointed out Title 49 CFR 179.15(b)(2) establishes that the start-to-discharge pressure of a pressure relief device may not exceed 33 percent of the tank car minimum burst pressure, which for AXLX1702 would

[74] This limit is from AAR M-1002, Appendix A (November 2014): Tank Car Valves and Fittings, Section 4.2.2 stating that the permissible tolerance for the burst pressure of a rupture disc must be 0% to -15%.

[75] Telephone conversation K. Hall and P. Stancil, April 5, 2017.

have been 412.5 psig. Although the rupture disc pressure did not comply with AAR specifications, it did comply with the federal regulatory requirement. Midland told NTSB investigators that it is advising customers to change out the rupture disc at the next scheduled tank car maintenance activity.

***Nondestructive Testing Method Comparison***

Investigators examined the B end cradle pad right side A6 inboard end fillet weld using a variety of NDT techniques. The testing included radiography, magnetic particle inspection wet and dry, dye penetrant, and angle beam ultrasonic testing. The examination included the original manufacturing cradle pad to tank fillet weld, and the 2010 repair weld at its inboard termination. The testing was performed to normal shop practices, but not to any specific tank car standards and not optimized for the conditions.

Radiography

Three film exposures were made with an iridium 192 radioactive source at incident angle between 5 and 10 degrees from normal to the plates. The repair weld showed undercutting on the tank side at the inboard end, with evidence of porosity. No positive indications of cracks were apparent. The original weld was unremarkable.

Magnetic Particle Testing

Using wet particles, the original manufacturer's weld showed a tank side toe linear indication along most of its length. The repair weld showed a ¼ to ½ inch crack-like indication in the tank material at the inboard toe of the weld (Figure 19).

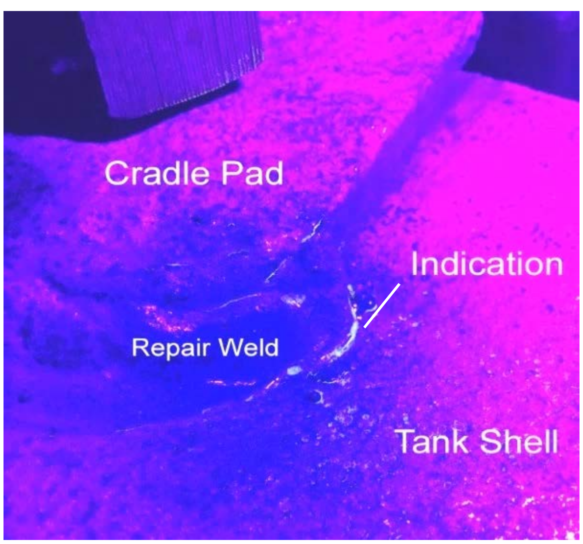


*Figure 18: Wet magnetic particle examination at termination of right B end cradle pad (A6) fillet weld, with indication at toe of the weld, November 9, 2016.*

Using dry particles, the original weld showed fewer indications. The repair weld showed the same indications as using wet magnetic particles.

Dye Penetrant

The dye penetrant examination did not reproduce the linear magnetic particle indications in the original manufacturer's weld, but did expose a previously undetected pit indication. The repair weld did not show any indications.

Ultrasonic Shearwave Testing

The existing surface of the tank was too rough to reliably couple the ultrasonic beam, therefore an area inboard of the repaired fillet weld termination was abrasively ground smooth, leaving approximately 1-inch band of unground surface remaining adjacent to the weld. Tests were limited to the repair weld (Figure 20). Using a 60-degree angle beam probe, scanning was performed in both the first and second leg of the ultrasonic beam. An indication was observed in the second leg of the beam, about 0.750 inch in length and about 0.100 inch in depth. The indication was determined to be an undercut at the toe of the fillet weld to tank shell. This indication was in the same location as the previously noted magnetic particle test crack-like indication.

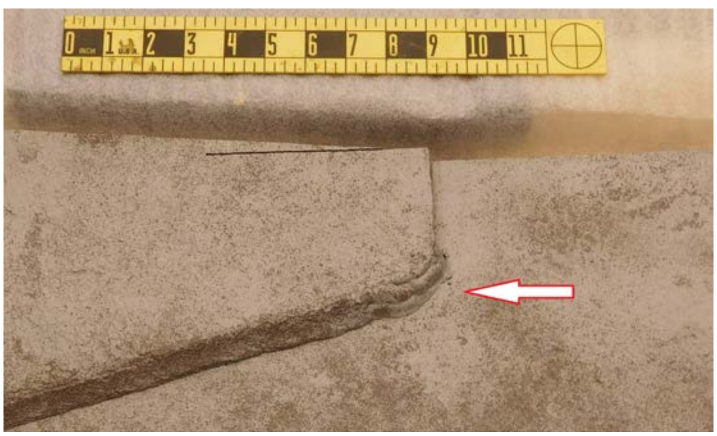


*Figure 19: AXLX1702 B-end stub sill weld termination ultrasonic testing scan area, November 9, 2016.*

## M. Pre-1989 Tank Cars Constructed of Non-normalized Steel

In accordance with industry standards, all class 105 tank cars built after January 1, 1989, must have heads and shells constructed of normalized steel plate material.[76] Normalized steel is subjected to a heat treatment process that relieves stress and improves fracture resistance. It produces more uniform plate properties to reduce the possibility of brittle and low-energy fracture propagation. Non-normalized steel has a higher ductile to brittle

[76] AAR M-1002, Chapter 2.2.1 (November 2014), general requirements for pressure tank cars.

transition temperature and lower fracture toughness at all operating temperatures when compared to normalized steel.[77]

The majority of pressure tank cars that were constructed before 1989 were fabricated from non-normalized steel. PHMSA estimates there were about 3,000 chlorine tank cars built prior to 1989 from non-normalized steel.[78] At the time of this incident, Axiall operated a fleet of 1,027 owned or leased pressure tank cars in chlorine transportation. About 350 of these tank cars, or 34 percent of the Axiall fleet, were constructed before 1989. Axiall told NTSB investigators that about 250 of its chlorine tank cars were constructed of non-normalized steel.

According to AAR figures, there are about 75,400 annual shipments of PIH materials in a pressure tank car fleet of about 11,900 cars.[79] The North American chlorine fleet consists of about 5,108 tank cars, of which 1,542 cars are compliant with federal interim PIH tank car design standards that have been established by final rule HM-246 pending completion of advanced tank car design research and development of a new crashworthiness performance standard.[80] In its final rule, PHMSA stated that adoption of this interim standard for PIH tank cars would ensure the availability of tank cars while FRA and PHMSA completed and validated the research.[81]

The interim design requirements include commodity-specific enhancements, such as increased shell and/or jacket thickness, full head shields where not already required, enhanced top fittings protection systems and nozzle arrangements. The interim PIH tank cars are all constructed from normalized steel. In accordance with 49 CFR 173.314(c), chlorine tank cars built on or after March 16, 2009, must meet the interim specification designated as105J600I.[82]

In addition, the HM-246 final rule added 49 CFR 173.31(e)(2)(iv), which requires tank car owners to prioritize retirement or replacement of pre-1989 non-normalized steel tank cars when retiring or removing cars from PIH materials service.

Railroad freight cars, including tank cars constructed after July 1, 1974, have a federally mandated service life limit of 50 years from the date of construction as long as the tank meets qualification requirements.[83] In the case of AXLX1702, the tank car could have

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[77] The ductile to brittle transition temperature is the minimum material temperature at which it has the ability to absorb a certain amount of energy on impact without fracturing.

[78] Final Rule Regulatory Impact Analysis*: Improving the Safety of Railroad Tank Car Transportation of Hazardous Materials,* Docket No. FRA-2006-25169 (Pipeline and Hazardous Materials Safety Administration, 2008).

[79] K. Dorsey, Association of American Railroads, e-mail ("TIH Statistics") to P. Stancil, National Transportation Safety Board, December 8, 2016.

[80] *Petition for Final Specification for Tank Cars Used to Transport TIH Materials*, submitted to the Pipeline and Hazardous Materials Safety Administration by The Chlorine Institute, American Chemistry Council, The Fertilizer Institute, Association of American Railroads, and Railway Supply Institute (December 16, 2016).

[81] 74 FR 1770, January 13, 2009

[82] The delimiter "I" in the specification signifies the tank car has been built to interim performance standards to meet the requirements of 49 CFR 173.244(a)(2) or (3) or 173.314(c) or (d).

[83] See 49 CFR 215.203.

remained in revenue service until 2029. Federal regulations at 49 CFR 173.31(e)(2)(iii) mandate that tank cars constructed to interim performance specifications are authorized for the transportation of PIH materials for a period of only 20 years after the date of original construction. PHMSA stated that it intended the 20-year authorized service life to guarantee tank car owners a reasonable service life for these cars, even if a new tank car standard were developed in the years immediately following the 2009 rule.[84] In the rule preamble, PHMSA stated that it would not require a phaseout schedule for legacy PIH tank cars until the conclusion of the research and adoption of a final rule incorporating a new specification.

### ***Petitions for Rulemaking and Other Actions***

*Chlorine Institute P-1646*

On June 30, 2016, PHMSA published a Notice of Proposed Rulemaking (NPRM) under docket PHMSA-2015-0102 (HM-219A) titled *Hazardous Materials: Petitions for Rulemaking*.[85] Among the petitions considered in the NPRM is a proposal to extend the service life of interim compliant PIH tank cars to the full 50-year service life of all other tank cars allowed in 49 CFR 215.203. Petition P-1646 submitted by the Chlorine Institute argues that the extension is necessary because of an expected delay of at least 8-10 years before a permanent PIH design standard and specification would be available from the Advanced Tank Car Collaborative Research Project.[86] The NPRM proposes to revise §173.31(e)(2)(iii) to eliminate the interim tank car 20-year service life restriction.

*Association of American Railroads*

On December 16, 2016, the AAR submitted a petition to PHMSA seeking to amend 49 CFR 173.31 to convert current interim PIH tank cars constructed pursuant to final rule HM-246 to a permanent specification for all PIH materials. The petition requests PHMSA to phase out the use of legacy tank cars not meeting the HM-246 standard over a six-year period to mirror the original timeframe PHMSA proposed in its 2008 notice of proposed rulemaking.[87]

On April 7, 2017, the AAR Tank Car Committee (TCC) published Casualty Prevention Circular CPC-1325, titled: *Final Action, Revision to MSRP Section C Part III, M-1002, Specifications for Tank Cars, Chapter 2*. The revisions address interchange requirements for tank cars used for the transportation of TIH materials, and state:

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[84] HM-246 Final Rule, *Improving the Safety of Railroad Tank Car Transportation of Hazardous Materials*, *Federal Register*, Vol. 74, No. 8 (January 13, 2009), P. 1770.

[85] 81 FR 42069 (June 30, 2016)

[86] The Advanced Tank Car Collaborative Research Project (ATCCRP) is a joint effort of industry and government to develop a new generation tank car for PIH commodities. ATCCRP participants include Federal Railroad Administration, Transportation Security Administration, Department of Homeland Security, Transport Canada, the Association of American Railroads, the Chlorine Institute, the Fertilizer Institute, and The American Chemistry Council.

[87] 73 FR 17818 (April 1, 2008)

- After July 1, 2023, tank cars used to transport products classified as TIH must comply with the requirements for tank cars built on or after March 16, 2009 as provided in 49 CFR 173.244a(2), 173.314c (Note 12), 179.16c(1) and 179.102-3 for cars marked DOT, or TP-14877 section 10.5.1.2 for car marked TC, and
- After July 1, 2019, tank cars used to transport products classified as TIH, manufactured from carbon steel plate, must have tank heads and shells constructed of normalized material.

*Advanced Tank Car Collaborative Research Program Industry Coalition*

On December 16, 2016, an industry coalition including the Chlorine Institute, the American Chemistry Council, the Fertilizer Institute, the Association of American Railroads, and the Railway Supply Institute in cooperation under the Advanced Tank Car Collaborative Research Program (ATCCRP), submitted a Petition for Final Specification for Tank Cars Used to Transport TIH Materials to PHMSA.[88] The petition requests PHMSA to consider the interim PIH/TIH tank cars constructed under final rule HM-246 as a final tank car specification.

The industry coalition pointed out that for the last seven years, the ATCCRP has commissioned projects to study impact scenarios and performance of various tank car design concepts and materials. The ATCCRP concluded that no design feature or material was identified that would provide a significantly greater level of improvement, or would be a reasonable alternative, from an economic and manufacturability standpoint. The petition cited modeling and service experience of fourteen derailed HM-246-compliant tank cars in which no PIH/TIH materials were released, to support its conclusion that the interim design standard provides significant improvement in accident survivability over former legacy specifications.

*Transport Canada Actions*

Transport Canada is currently in the final development stage for updating its regulatory standard TP14877E, "*Containers for Transport of Dangerous Goods by Rail*." On March 31, 2017, Transport Canada published a notice for a 30-day public consultation on the updated standard. The updated tank car standard includes provisions to:

- Extend the service life of tank cars designed to interim PIH standards to the full 50-year maximum service life, and
- Phase out over a 2-year period from the date of publication all pressure tank cars in PIH service fabricated of non-normalized steel.[89]

Transport Canada expects the revised TP14877 standard to be published in the *Canada Gazette*, Part 1 in 2017.

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[88] The term "toxic inhalation hazard" (TIH) is synonymous with "poison inhalation hazard" (PIH).

[89] S. Singh, "Transport Canada Update," oral report to the Association of American Railroads Tank Car Committee, April 19, 2017. Atlanta, Georgia.

## N. Association of American Railroads Quality Assurance Program Audit

Between November 15-17, 2016, as part of its recertification process AAR-BOE Quality Assurance Program inspectors and AAR TCC staff conducted a comprehensive audit of the Rescar Companies DuBois, Pennsylvania tank car repair facility under the provisions of the AAR Specification M-1003 for Quality Assurance.[90] The auditors reviewed the Rescar facility procedures for welding, post weld heat treatment processes, weld build-up processes, NDT processes, use of car owner instructions, and facility validation processes to ensure that tank cars conform to specification requirements and to AAR standards.

The auditors noted that Rescar compliance with the AAR MSRP and Quality Assurance Program were satisfactory except for the following adverse findings:

- Tank car bubble leak test completed without leak testing all possible leak paths;
- UT technicians did not perform complete weld inspections in accordance with the applicable Rescar procedure;
- Tank jacket patches being applied without interior protective coating;
- Bottom outlet valve bench tested without all valve closures as required;
- A local postweld heat treatment chart and documentation form were not reviewed and signed as approved by the shop supervisor, level II visual inspector, or QA manager to ensure the requirements have been met.

The auditor noted that Rescar's corrective action responses to the adverse findings were acceptable. The audit report cited "no key issues or concerns requiring top management attention."

## O. Previous NTSB Findings and Safety Recommendations

### *Tank Car Inspection and Testing*

Two 1992 accidents involving the structural failures of a dual diameter tank car and a non-pressure tank car transporting hazardous materials prompted the NTSB to issue a Special Investigation Report on the inspection and testing of railroad tank cars.[91] The failures resulted from preexisting cracks that had gone undetected. The NTSB investigation also addressed stub sill failures on various types of tank cars that resulted from undetected cracks at welds. The NTSB concluded, among other things, that tests and visual inspections at arbitrary intervals do not effectively detect defects at high stress areas where stub sills or other components are attached to tanks before sudden and complete failure. The NTSB also concluded that the use of nondestructive testing methods, if applied at appropriate intervals based on damage-tolerance concepts, could detect existing cracks prior to catastrophic failure of rail tank cars; however, more research was needed to determine the best methods to be used under given conditions and appropriate inspection intervals.

[90] Quality Assurance Program compliance audits are conducted to provide confidence that a contractor effectively meets AAR program requirements.

[91] *Inspection and Testing of Railroad Tank Cars*, Special Investigation Report, SIR-92/05 (Washington DC: National Transportation Safety Board, 1992).

The NTSB made the following safety recommendations to the Federal Railroad Administration:

> Evaluate with the cooperation and assistance of the Association of American Railroads, the Railway Progress Institute, and the Chlorine Institute, nondestructive testing techniques and determine how such techniques can best be applied for periodic testing and inspection of all tank cars that transport hazardous materials. (R-92-21) Closed – Acceptable Action
>
> Develop and promulgate with, with the Research and Special Programs Administration, requirements for the periodic testing and inspection of rail tank cars that help to ensure the detection of cracks before they propagate to critical length by establishing inspection intervals that are based on defect size detectable by the inspection method used, the stress level, and the crack propagation characteristics of the structural component (requirements based on a damage tolerance approach). (R-92-22) Closed – Unacceptable Action
>
> Companion recommendation R-92-23 was issued to the Research and Special Programs Administration. Closed – Acceptable Action

Safety Recommendation R-92-21 was closed with acceptable action in 1996 after RSPA issued regulations that require the use of NDT techniques to inspect tank car welds. The FRA noted that it was continuing research that included stub sill fatigue crack growth and stresses in tank cars that can lead to crack initiation, and the interval between crack initiation and catastrophic failure.

In 2011, the NTSB classified Safety Recommendation R-92-22 as closed with unacceptable action because after two research projects and more than 17 years, the FRA had not progressed beyond the research phase in addressing this recommendation. The NTSB stated that it saw little progress being made to develop and implement regulations for the periodic testing and inspection of rail tank cars establishing inspection interval requirements based on a damage-tolerance approach.

In 2013, the NTSB classified Safety Recommendation R-92-23 as closed with acceptable action after PHMSA published final rule HM-216B.[92] The rule amended the Hazardous Materials Regulations to incorporate provisions contained in widely used or longstanding special permits as well as amending 49 CFR Part 180 to require tank car owners to develop written procedures for a qualification program with inspection procedures, intervals, and acceptance criteria. The acceptance criteria must be based on service reliability data or analytical evaluation of the tank car and its components. Regarding crack detection, the program allows an owner to develop an alternative qualification program suited to the tank

[92] See 77 FR 37961, June 25, 2012.

car design and use by permitting an alternative inspection and test program or interval based on a damage-tolerance analysis, contingent on FRA approval.

***Minot, North Dakota***

Among the findings relevant to tank car construction cited in the NTSB report on the January 18, 2002, Minot, North Dakota train derailment that resulted in the release of more than 146,000 gallons of anhydrous ammonia leading to one death, 11 serious injuries, and 322 minor injuries are the following:

- The low fracture toughness of the non-normalized steels used for the tank shells of the five tank cars that catastrophically failed in this accident contributed to the cars' complete fracture and separation.
- Using tank cars built before 1989 and fabricated from non-normalized steel to transport U.S. Department of Transportation Class 2 hazardous materials under current operating practices poses an unquantified but real risk to the public.[93]

The NTSB made the following safety recommendations to the FRA specific to the impact resistance and fracture toughness of steels used to construct pressure tank cars:

> Conduct a comprehensive analysis to determine the impact resistance of the steels in the shells of pressure tank cars constructed before 1989. At a minimum, the safety analysis should include the results of dynamic fracture toughness tests and/or the results of nondestructive testing techniques that provide information on material ductility and fracture toughness. The data should come from samples of steel from the tank shells from original manufacturing or from a statistically representative sampling of the shells of the pre-1989 pressure tank car fleet. (R-04-4) Closed – Unacceptable Action
>
> Based on the results of the Federal Railroad Administration's comprehensive analysis to determine the impact resistance of the steels in the shells of pressure tank cars constructed before 1989, as addressed in Safety Recommendation R-04-4, establish a program to rank those cars according to their risk of catastrophic fracture and separation and implement measures to eliminate or mitigate this risk. This ranking should take into consideration operating temperatures, pressures, and maximum train speeds. (R-04-5) Closed – Unacceptable Action
>
> Develop and implement tank car design-specific fracture toughness standards, such as a minimum average Charpy value, for steels and other materials of construction for pressure tank cars used for the transportation of U.S. Department of Transportation Class 2 hazardous materials, including those in low-temperature service. The performance criteria must

[93] National Transportation Safety Board, *Derailment of Canadian Pacific Railway Freight Train 292—16 and Subsequent Release of Anhydrous Ammonia Near Minot, North Dakota, January 18, 2002*, RAR-04/01 (Washington DC: National Transportation Safety Board, 2004).

apply to the material orientation with the minimum impact resistance and take into account the entire range of operating temperatures of the tank car. (R-04-7) Open – Acceptable Response

The NTSB closed Safety Recommendations R-04-4 and -05 and classified them as unacceptable action because the tank car steel sampling method used for testing in connection with a study on the mechanical properties of pre-1989 tank cars was not sufficiently random or representative of the pressure tank car fleet. While the NTSB anticipated that under the provisions of final rule HM-246, pre-1989 tank cars that transport PIH materials may be retired earlier than other PIH tank cars, the Safety Board did not consider this an acceptable alternative to the recommended actions.

On March 17, 2015, the NTSB classified Safety Recommendation R-04-7 as open with acceptable action while the FRA and PHMSA are working on rulemaking that will incorporate by reference the 2014 edition of the AAR's Specification for Tank Cars M-1002 into the Hazardous Materials Regulations, and while FRA publishes a report detailing a series of tests and subsequent materials analyses to determine whether rulemaking is needed to change material property criteria for tank car design standards.

## ***P*.** **Post Incident Actions**

### *Axiall Corporation Actions*

On October 5, 2016, Axiall Corporation issued enhanced inspection instructions (revised on February 16, 2017) effective immediately for its company-owned chlorine tank cars equipped with ACF-200 stub sills, that are either in a shop or arriving in a shop for maintenance.[94] Among the new structural weld inspection protocols are instructions for radiographic examination (RT) of the termination of the longitudinal welds in accordance with AllTranstek fleet maintenance procedures or an acceptable alternative. The enhanced instructions call for a complete stub sill inspection in accordance with ACF Maintenance Bulletin TC-200 Revision B, dated May 16, 2016, and AllTranstek tank qualification procedures. The inspector must also note if the inboard cradle pad longitudinal weld wraps around the corner radius of the 45-degree mark on the pad such that the weld becomes transverse, and photograph the condition prior to weld removal. The instructions call for RT examination of the inboard cradle pad A6 longitudinal weld terminations.

If radiographs show a defect at the toe of the weld or in weld metal, the inspector must perform a liquid penetrant examination and obtain the dimensions of any surface indication. The surface indication must be removed by grinding or air arcing the weld in accordance with the ACF maintenance bulletin. For subsurface indications that generally start at the root of the fillet weld, the fillet weld must be removed to expose the indication, the dimensions recorded, and the indication removed in accordance with the ACF maintenance bulletin.

[94] The enhanced instructions are added to the AllTranstek Company Specific Requirements, February 16, 2017 revision.

The enhanced instructions require 36 shell thickness measurements to be taken within a 24-inch square grid at the inboard end of the cradle pad. If any tank car requires weld build-up or other welded repairs (internal or external) within a 2-foot radius of the inboard terminations of the longitudinal sill-pad welds, the shop must send an estimate to AllTranstek and await further instruction and approval prior to proceeding with the work. The enhanced instructions further state that the P-470 angle brace retrofit is not a proper repair because the repair would protrude through the tank head shield. The instructions state that if there is a need to retrofit the stub sill underframe with head braces or inboard sill pad extensions, Axiall will coordinate with the tank builder to provide appropriate instructions.

On January 27, 2017, Axiall Corporation notified NTSB investigators that it had begun to receive information related to the enhanced inspections of its 264 tank cars equipped with ACF-200 stub sills. Axiall Corporation reported that AllTranstek had identified 82 tank cars where some welding had been performed on the tank in or around stub sills, including AXLX1702. Of these tank cars, further analysis identified 16 tank cars with repairs of special interest because of the following characteristics:

- A description in the “Axiall Data Request Weld” spreadsheet that indicated a repair of interest
- AAR Form R-2 data that indicated a crack repair at:
    - “A1” Pad-to-tank weld, transverse;
    - “A2” Pad-to-tank weld, longitudinal;
    - “J” Tank reinforcing pad, inboard of bolster;
    - Or the repair records for these cars indicate a repair associated with the outboard (near the tank head) end of the stub sill/reinforcement plate/tank attachment welds.

Axiall decided to remove these 16 cars from service pending an above-described enhanced inspection procedure as they are scheduled for maintenance. Four of the tank cars either have been or are being scrapped. Two of the tank cars did not have the ACF-200 stub sill design and have been returned to service. The remaining tank cars are to be subjected to the enhanced inspection process described above. Axiall will notify the FRA and NTSB if it intends to repair any of these tank cars and return them to service.

As of February 2, 2017, 54 Axiall-owned tank cars with the ACF-200-stub sill design had been delivered to the Texana Tank Car Mfg. shop in Texarkana, Texas for the enhanced inspection procedure. An additional 40 tank cars, for a total of 94 are scheduled to undergo the enhanced inspection procedure during 2017. Axiall has compiled a spreadsheet of its inspection findings and continues to report progress on the status of its fleet of 264 tank cars equipped with ACF-200 stub sills.

*Paul L. Stancil*
*Sr. Hazmat Accident Investigator*

# Appendix A

## New Martinsville, West Virginia (DCA-16-SH-002)
## Chronology of Events

| Date | Time | Source | Safety Significant Event |
|---|---|---|---|
| 27-Aug | 8:26 | security video | Gas cloud emerges from rail car in chlorine loading area |
| 27-Aug | 8:28 | chlorine monitor | First chlorine monitor alarm |
| 27-Aug | 8:29 | Axiall chronology | Chlorine loader reports release to guard station |
| 27-Aug | 8:30 | Axiall chronology | Axiall E-crew activation to respond to chlorine release |
| 27-Aug | 8:33 | Axiall chronology | Non-essential employee evacuation sounded on plant sirens |
| 27-Aug | 8:33 | Axiall chronology | Axiall incident command established, level 2 evacuation |
| 27-Aug | 8:36 | Axiall chronology | Axiall call to Blue Racer Midstream to block Route 2 |
| 27-Aug | 8:41 | Axiall chronology | Notified Marshall County, WV Dispatch 911 |
| 27-Aug | 8:45 | Axiall chronology | Called Bayer Material Science to shut down Rt. 2-south (no answer) |
| 27-Aug | 8:46 | Axiall chronology | All non-essential employees are out of the plant |
| 27-Aug | 8:47 | Axiall chronology | Called for Bayer ambulance - no - they are sheltered in place |
| 27-Aug | 8:50 | Axiall chronology | Notified Monroe County, OH Dispatch |
| 27-Aug | 8:55 | Axiall chronology | Called for Tri-State Ambulance |
| 27-Aug | 8:55 | Axiall chronology | Plant nurse arrives at dispensary |
| 27-Aug | 8:58 | Axiall chronology | Marshall County, WV - several calls discussion of roadblocks and evacuations |
| 27-Aug | 9:00 | Axiall chronology | All Axiall employees acounted for |
| 27-Aug | 9:08 - 9:11 | Axiall chronology | Three communications with Marshall County, WV |
| 27-Aug | 9:12 | Axiall chronology | Communication with WV Dept. Homeland Security |
| 27-Aug | 9:18 | Axiall chronology | Tri-State ambulance arrived |
| 27-Aug | 9:27 | Axiall chronology | Communication with WV Dept. Environmental Protection (DEP) |
| 27-Aug | 9:30 | Axiall chronology | Notified Reynolds Hospital they would receive two employees, faxed SDS |
| 27-Aug | 9:30 | Axiall chronology | Communicated with Coast Guard |
| 27-Aug | 9:41 | Axiall chronology | National Response Center notified |
| 27-Aug | 9:45 | Axiall chronology | Marshall County Office of Emergency Management notified |
| 27-Aug | 9:46 | SPSI chronology | SPSI dispatched for chlorine emergency response from Washington, PA |

| | | | |
|---|---|---|---|
| 27-Aug | 9:53 | Axiall chronology | Communicated with Coast Guard |
| 27-Aug | 10:07 | Axiall chronology | Communicated with EPA Region II |
| 27-Aug | 10:19 | Axiall chronology | Axiall hazmat team level A entry |
| 27-Aug | 10:20 | Axiall chronology | Contacted State Emergency Response Commission (SERC) |
| 27-Aug | 10:30 | Axiall chronology | Hazmat team observed no further release from tank car |
| 27-Aug | 10:42 | Axiall chronology | Hazmat team prepares lines to unload car |
| 27-Aug | 10:56 | Axiall chronology | Communicated with Monroe County, OH LEPC |
| 27-Aug | 11:00 | Axiall chronology | Leak stopped, no ice remaining on the tank car |
| 27-Aug | 11:19 | Axiall chronology | Communicated with Monroe County, OH LEPC |
| 27-Aug | 11:20 | WV DEP report | WV DEP environmental inspector supervisor arrived at Marshall County OES command post, SR2 and CR29, 4 miles north of Axiall facility |
| 27-Aug | 11:22 | Axiall chronology | Communication with West Virginia DEP |
| 27-Aug | 11:27 | Axiall chronology | Communication with West Virginia DEP |
| 27-Aug | 11:31 | Axiall chronology | Communication with West Virginia DEP |
| 27-Aug | 11:38 | Axiall chronology | Communication with Wetzel County, WV 911 |
| 27-Aug | 11:39 | Axiall chronology | Contacted Director, Wetzel County, WV Office of Emergency Services |
| 27-Aug | 11:50 | SPSI chronology | SPSI personnel arrive at incident command post on WV Rte 2 |
| 27-Aug | 12:20 | Axiall chronology | Faxed safety data sheet and information on inhalation to Wetzel County Hospital |
| 27-Aug | 12:29 | Axiall chronology | Communication with Monroe County, OH |
| 27-Aug | 12:30 | Axiall chronology | Plant personnel begin monitoring Rte 2 South to New Martinsville |
| 27-Aug | 12:32 | Axiall chronology | Communicaiton with Monroe County, OH |
| 27-Aug | 12:49 | Axiall chronology | Communicaiton with NTSB, requesting information |
| 27-Aug | 12:50 | Axiall chronology | Communicaiton with Assoc. of American Railroads, requesting information |
| 27-Aug | 13:00 | Axiall chronology | Faxed safety data sheet and information on inhalation to Ohio Valley Medical Center |
| 27-Aug | 13:08 | Axiall chronology | Notified Federal Railroad Administration |
| 27-Aug | 13:10 | Axiall chronology | Faxed safety data sheet and information on inhalation to Wheeling Hospital |
| 27-Aug | 13:11 | SPSI chronology | SPSI personnel stage for entry to the Axiall facility |
| 27-Aug | 14:07 | Axiall chronology | Axiall personnel collect 27 air readings inside of |
| 27-Aug | 14:19 | Axiall chronology | Axiall personnel completed monitoring of Rte 2 south of plant to New Martinsville, 30 readings of |
| 27-Aug | 14:55 | Axiall chronology | Communication with Monroe County, OH |
| 27-Aug | 15:55 | Axiall chronology | Axiall employee and contractor released from Morgantown hospital |
| 27-Aug | 16:35 | Axiall chronology | All clear declared on Rte 2 and Rte 7 |
| 27-Aug | 16:44 | SPSI chronology | A receiving tank car was prepared for offloading AXLX1702 |
| 27-Aug | 16:59 | Axiall chronology | TSA Freedom Center notified |

| | | | |
|---|---|---|---|
| 27-Aug | 18:15 | SPSI chronology | Receiving tank car positioned and ready for connection to AXLX1702 |
| 27-Aug | 18:55 | Axiall chronology | Notified OSHA |
| 27-Aug | 19:55 | SPSI chronology | Vacuum placed on AXLX1702, no liquid to transfer, pressure remained at 0 psig |
| 27-Aug | 22:15 | SPSI chronology | Changed connection to alternate liquid line, attempted to maintain vacuum |
| 28-Aug | 1:00 | SPSI chronology | Crews began tank car jacket removal |
| 28-Aug | 3:15 | SPSI chronology | 1/4-inch crack was observed infront of A-end stub sill reinforcement pad |
| 28-Aug | 4:15 | SPSI chronology | Crews used wooden wedges and plug n dike to patch 95% of crack to achieve vacuum on car |
| 28-Aug | 16:40 | SPSI chronology | Water flush fittings connected to vapor and liquid line. |
| 28-Aug | 20:00 | SPSI chronology | Moved tank car slowly to wash rack |
| 28-Aug | 20:45 | SPSI chronology | Water flush on AXLX1702 began, pH of 7 achieved by 21:15. Flushing continued |
| 29-Aug | 20:45 | SPSI chronology | Water flush terminated, wooden wedges removed |
| 29-Aug | 23:36 | SPSI chronology | AXLX1702 empty |
| 30-Aug | 12:55 | SPSI chronology | Pressure plate removed from AXLX1702 |
| 30-Aug | 14:05 | SPSI chronology | AXLX1702 vented for about 1 hour, air monitoring confirmed no residual Cl2 |
| 31-Aug | 9:05 | SPSI chronology | SPSI entered the tank for photo documentation and measurements |
| 31-Aug | 13:10 | | NTSB Arrival |