NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

March 17, 2015

MATERIALS LABORATORY FACTUAL REPORT Report No. 15-018

A. ACCIDENT INFORMATION

Place	:	Lynchburg, Virginia
Date	:	April 30, 2014
Vehicle	:	CSX train KO8227
NTSB No.	:	DCA14FR008
Investigator	:	Paul Stancil, RPH-20

B. COMPONENTS EXAMINED

Two shell pieces from tank car CBTX 741712 and a piece of body bolster with attached body bolster pad and tank shell sections from tank car CBTX 741720.

C. DETAILS OF THE EXAMINATION

Tank cars CBTX 741712 and CBTX 741720 were initially examined on scene, and overall views of the tank cars are shown in figure 1. For reference, the ends of the tank cars are shown labeled A and B, where the B end was the end with the brake wheel. Right and left sides of the car are as viewed looking away from the B end toward the A end. The shell of tank car CBTX 741712 was fractured on the right side starting at the middle (lengthwise) of the tank and propagating toward the A end of the tank. The fracture extended approximately 8 feet along the middle and lower portion of the right side of the tank as indicated with a bracket in figure 1. On the right side of tank car CBTX 741720, the lower portion of the body bolster at the A end of the tank car was fractured from the upper portion of the body bolster web, and the body bolster was bent with the outboard end deflected toward the A end of the tank car.

Both tank cars were DOT specification 111S100W1 tank cars. According to build records for the tank cars, both tank cars were manufactured by American Railcar Industries, Inc., in July, 2012, under an Association of American Railroads (AAR) Certificate of Construction that was approved on May 11, 2012. According to the Certificate of Construction, the tank shell material for each car was AAR TC-128, Grade B, normalized steel with a nominal thickness of ½ inch.

Pieces were cut from each of the tank cars and shipped to the NTSB Materials Laboratory in Washington, DC, and to the NTSB Training Academy in Ashburn, Virginia for further examination and testing. Overall views of pieces cut from tank car CBTX 741712 are shown in figures 2 and 3. The larger piece shown in figures 2 and 3 contained the shell fracture, and the smaller piece (lower left image in figure 2) was cut from an intact portion of the tank that appeared undeformed and had paint on the surface. The intact shell piece was cut from the tank just above the larger piece containing the shell fracture and included a portion of the circumferential weld that intersected the B end of the shell fracture (see figure 4). Wall thickness was measured on the smaller intact shell piece at locations on either side of the circumferential weld, and the wall thickness at both locations measured 0.510 inch.

1. Fractured Shell Piece

Images of the shell fracture from various angles showing the external and internal faces of the shell piece are shown in figures 2 and 3. All fracture faces showed matte features on slant angles along with adjacent deformation and contact marks, features consistent with ductile overstress fracture from contact with another object. During the course of the fracture, pieces of the tank shell were deformed inward into a curled shape, leaving curled material attached to the tank wall at three locations labeled A through C as shown in figures 2 through 4.

Views of the fracture origin are shown in figure 4. The fracture initiated at a location just below the tank longitudinal centerline where a longitudinally-oriented sliding contact mark intersected the B side of the circumferential weld between shell segments 2 and 3. (The tank shell consisted of 6 cylindrical segments numbered starting at the B end of the shell.) The tank shell was creased inward at the location of the sliding contact mark, consistent with relatively heavy contact compared to other longitudinal sliding contact marks in the vicinity. The smeared surface features associated with the heavy sliding contact mark was approximately 2 inches wide at the location where the mark intersected the fracture.

Within a foot of the fracture origin, the fracture opened to a 6.75-inch-wide opening. The shell material from the opening curled inward to form curl A attached to the shell at the lower side of the fracture opening. A view of curl A viewed from the interior surface of the shell is shown in figure 5. Longitudinally-oriented sliding contact marks including one that emanated from the end of the curl with the fracture origin were observed on the exterior surface of the curl.

Within 6 inches past curl A, the fracture opened to a width of approximately 13 inches. Material from the opening in the portion of the fracture between curl A and curl B was deformed inward and curled to form curl B. The deformed material in curl B wrapped around itself approximately 3 times (see figure 3, lower image). A view of curl B as viewed looking upward from the interior side of the shell is shown in figure 6. A sliding contact mark was observed approximately midway between the fractures aligned approximately parallel to the fracture faces. Additional sliding contact marks were observed at an angle to the mark indicated in figure 6. The marks at an angle corresponded to angled marks observed on the shell exterior above and below the fracture, indicating that the angled marks were present prior to fracture.

For a 6-inch segment past curl B, mating faces of the fracture were on the shell exterior and not contained within a curl. The shell wall was generally deformed inward on the upper side of the fracture, and the upper fracture face was displaced inward and approximately 2 inches downward relative to the mating lower fracture face (*i.e.* the wall on the lower side overlapped the upper side by approximately 2 inches).

Past the overlapping fracture, the crack opened to a 7-inch-wide opening, and the material from the opening was deformed into curl C. The fracture on the lower side of the opening within this segment of the fracture was obliterated by post-fracture contact as indicated in figure 7. The fracture face was flattened consistent with heavy contact. A lip of deformed material was readily visible extending approximately 0.13 inches into the interior, and a small lip of deformed material was also visible upon close inspection at the exterior edge of the flattened fracture face.

At the B end of the fracture, the tank wall at the lower side of the fracture was bent outward as indicated in figure 7. The outward bend was associated with a fracture along 2 inches of the tank wall at the lower edge of the outward-bent material. A sharp change in the extent of deflection was observed near the upper edge of the outward-bent portion along with a change in the deformation lip at the edge of the fracture face, features consistent with contact with an edge or corner on the contacting object. An unlabeled arrow in the lower image in figure 7 points to this feature in the deformation of the shell wall, which was particularly evident when viewed looking inward toward the B end as in the lower image in figure 7.

A view of curl C as viewed from the interior side of the fractured shell piece is shown in figure 8. Heavy sliding contact marks were observed on the lower edge of the curl as indicated in figure 8. Secondary fractures were also present at the lower edge of curl C, and pieces of the lower edge were curled inward in the same direction as the main curl.

2. Body Bolster Piece

Views of the body bolster at the right side, A end of tank car CBTX 741720 as it was examined on-scene are shown in figures 9 and 10. The body bolster at the right side, B end of the tank car was intact and showed slight bending deformation with the outboard end deflecting toward the A end of the tank car. Oil was present on the exterior of the tank shell and head at the A end of the tank car.

The body bolster included an upper web section that was 2 inches thick. Thinner web and flange sections comprising the lower portion of the body bolster were welded to the lower side of the upper web piece. The lower web and flanges were fractured from the upper web piece and the web was bent such that the outboard end deflected toward the A end of the tank car. The upper web was also bent such that the outboard end was deflected toward the A end of the tank car.

The pad was fractured from the shell through a portion of the body bolster pad weld at the B side of the pad as shown in figure 10. The tank shell was intact, but was deformed slightly inward adjacent to the pad edge weld fracture. The pad was also deformed slightly outward between the ends of the edge weld fracture. An angled sliding contact mark was observed in the area of the tank shell deformation.

The upper web portion of the body bolster with attached pieces of the body bolster pad and tank shell was cut from tank car CBTX 741720. Views of the cut body bolster piece as-received at the NTSB Training Center are shown in figure 11. Relatively heavy sliding contact marks associated with deformed edges of the web were observed in multiple locations of the upper web piece as indicated with unlabeled brackets and arrows in figure 11. Sliding contact marks with deformed edges were observed at the edge formed by the intersection of the upper face and the B face (larger unlabeled bracket in figure 11) with contact marks continuing onto the B face. The outermost corner of the upper web on the B side (corner between the two brackets in figure 11) showed the greatest deformation and sliding contact damage. The edge between the lower face and the B face of the upper web (smaller unlabeled bracket in figure 11) was also deformed from sliding contact with another object. The inboard corner at the lower end of the web on the A side of the web was deformed (right unlabeled arrow in figure 11), and contact marks with deposited metal shavings were present on the B side near the upper end of the hoist hole (left unlabeled arrow in figure 11).

3. Damage Matching

To facilitate a better understanding of witness marks and damage patterns on the fractured shell piece and the bolster piece, the bolster piece was placed in close proximity to the shell fracture in several locations. Illustrations of the observations from the close placement of the objects are presented in figures 12 through 19. In these illustrations, arrows indicate the “up” and “A end” directions individually for each piece shown since the relative orientations are different for each piece, and the global orientation during the accident sequence is uncertain. These illustrations do not necessarily represent actual positions of these two objects during the course of the accident sequence. Deformation that occurred during the accident sequence and recovery and material that was removed to facilitate shipment and examination of the pieces could affect actual relative positions that would have been possible during the accident sequence versus what was possible with the examined pieces. In addition, precise relative positioning of the objects during the examination was challenging due to the weight of the objects and tools and time available for positioning the objects for photography.

Figure 12 shows two views with the bolster upper web from the bolster piece placed in close proximity to curl B on the fractured shell piece. An unlabeled bracket indicates a series of sliding contact marks that appeared to initiate near the base of curl B near the lower side. The sliding marks were aligned with the general direction of the shell fracture toward the A end and downward.

Figures 13 through 15 show the bolster piece in close proximity to the shell fracture in the area of the fracture between curl B and curl C. In figures 13 and 14, the A side inboard corner of the bolster upper web (right unlabeled arrow in figure 11) is shown contacting the obliterated fracture surface on the lower side of the shell fracture (bracketed are in figure 7). In figure 15, the bolster piece is shown closer to the fractured shell piece, where the area of the bolster web with deposited metal shavings on the B side near the upper end of the hoist hole (left unlabeled arrow in figure 11) is shown in close proximity to the obliterated fracture surface on the lower side of the shell fracture.

Figures 16 through 18 show images with the body bolster upper web placed in close proximity to curl C on the fractured shell piece. In figures 16 and 17, the bolster piece is shown closer to the fractured shell piece, where the area of the bolster web with deposited metal shavings is shown in close proximity to the obliterated fracture surface on the lower side of the shell fracture. In figures 18 and 19, the bolster piece is shown positioned slightly further from the fractured shell piece with the lower outboard end of the bolster upper web positioned within the area where the shell was deformed outward on the fractured shell piece.

4. Mechanical Testing and Chemical Analysis

Specimens for 3 tensile tests, 6 Charpy impact tests, and chemical analysis were cut from the smaller shell piece of tank shell from tank car CBTX 741712 (see figure 1, lower left image). The tensile specimens were full-thickness plate-type specimens with 8-inch gauge lengths fabricated with the weld located transverse across each specimen at the middle of the gauge section. The weld beads on each side of the tensile specimens were machined flat to the rest of the specimen surfaces prior to testing. Charpy impact tests[1] were conducted at room temperature and at -50º F (3 specimens at each temperature) in base material away from any welds or torch cut edges. Mechanical testing was conducted in accordance with ASTM A370-14.[2] Chemical composition was determined using optical emission spectroscopy coupled with combustion analysis of carbon, sulfur, and nitrogen conducted in accordance with the applicable requirements of ASTM A20-14.[3]

Results of the mechanical testing and chemical analysis are included in Appendix A. All three tensile specimens fractured in the base metal away from the weld. The yield strengths of the tensile specimens were 62 ksi for one specimen and 63 ksi for the other two specimens. The ultimate tensile strength was 86 ksi in each of the three tensile specimens. The total elongations within a 2-inch length in the three specimens were 32%, 36%, and 40%. The total elongations within an 8-inch length for the three specimens were 18%, 20%, and 21%. For reference, the AAR Manual of

[1] Charpy impact testing was conducted for information only. AAR TC128 material must meet minimum Charpy impact energy absorption requirements only in tank cars specified for low-temperature service. Tank car CBTX 741712 was not specified for low-temperature service.
[2] ASTM A370-14, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*, ASTM International, West Conshohocken, Pennsylvania (2014).
[3] ASTM A20-14, *Standard Specification for General Requirements for Steel Plates for Pressure Vessels*, ASTM International, West Conshohocken, Pennsylvania (2014).

Standards and Recommended Practices[4] specifies tensile properties for TC128 steel, grade B, including a minimum yield strength of 50 ksi, a minimum tensile strength of 81 ksi, a minimum elongation of 22% within a 2-inch length, and a minimum elongation of 16% within a 8-inch length.

All Charpy impact test specimens showed 100% shear behavior both at room temperature and at -50º F. At room temperature, one specimen had an impact energy of 140 ft-lb, and the other 2 specimens had impact energies of 142 ft-lb. At -50º F, the impact energies were 53 ft-lb, 59 ft-lb, and 92 ft-lb. For reference, the AAR Manual of Standards and Recommended Practices requires that when used in tank cars specified for low-temperature service, AAR TC128 steel must have a minimum Charpy impact energy of 15 ft-lb when tested at -50º F.

Results of the chemical analysis are presented in Appendix A. The chemical composition of all elements and combination of elements was within limits specified for the product analysis of AAR TC128 as listed in the AAR Manual of Standards and Recommended Practices.

Matthew R. Fox
Senior Materials Engineer

[4] AAR Manual of Standards and Recommended Practices, Specifications for Tank Cars, Appendix M, Specifications for Materials, Association of American Railroads, Washington, DC (2014).

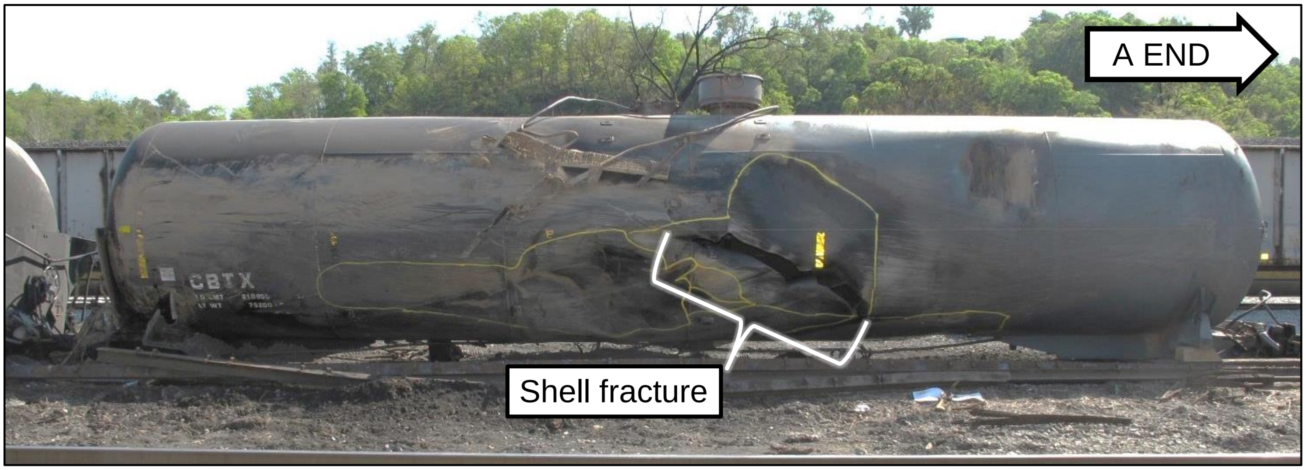


Figure 1. Overall views of the right side of tank car CBTX 741712 (upper image), and the A end and right side of tank car CBTX 741720 (lower image) as examined on scene.

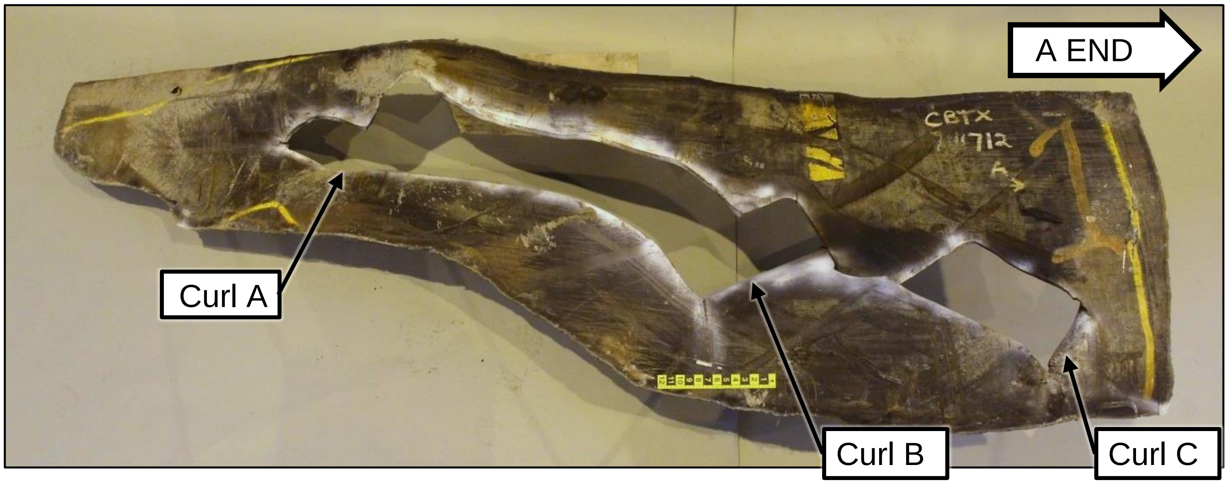
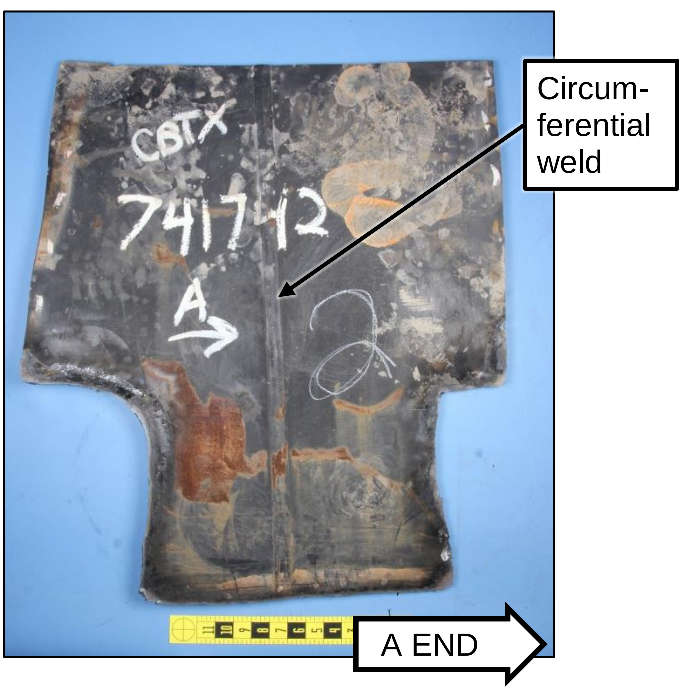


Figure 2. Overall views of the pieces cut from tank car CBTX 741712 including pieces containing the shell fracture (top, middle, and lower right images) and the piece cut for mechanical and chemical testing (lower left image).



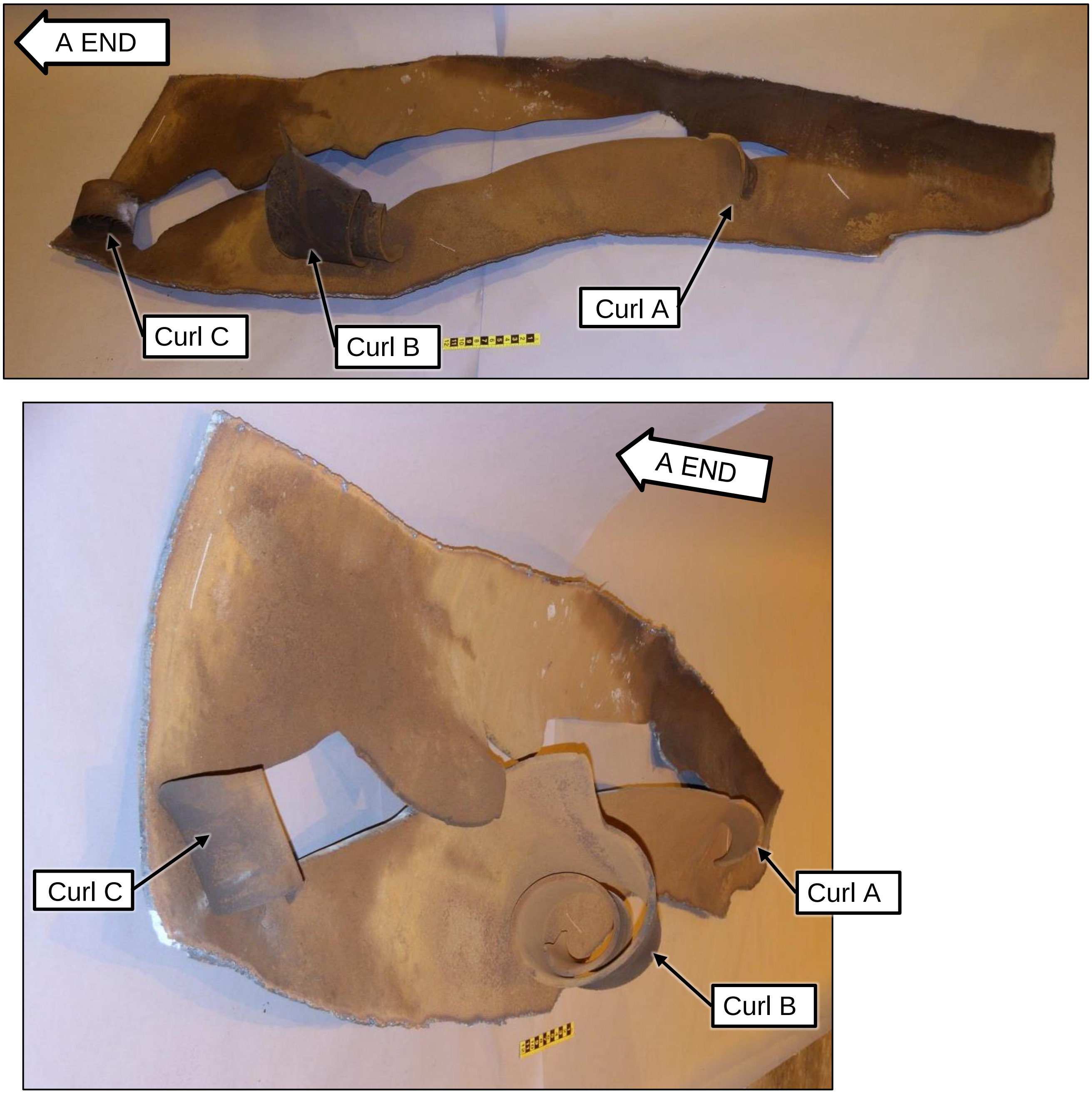


Figure 3. Views of the shell fracture showing the interior face of the shell piece.

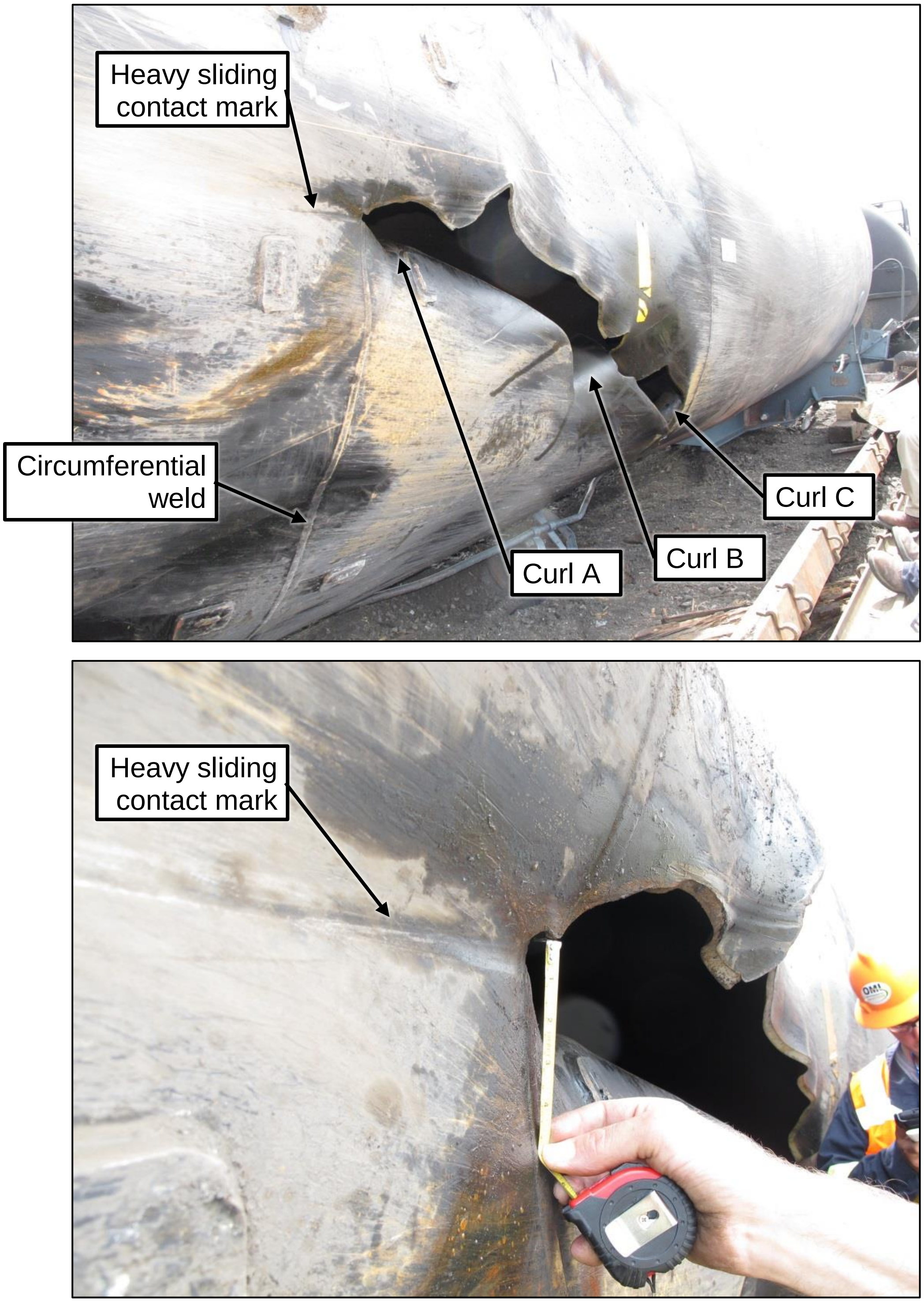


Figure 4. Views of the B end of the shell fracture (as viewed on scene) showing a longitudinally-oriented sliding contact mark and inward deformation at the fracture initiation.

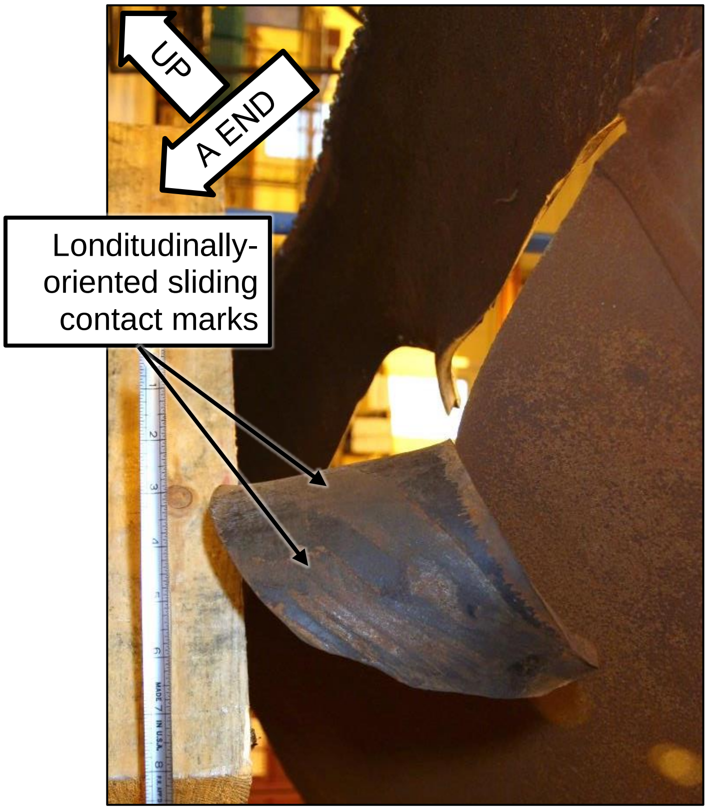


Figure 5. Interior face of the fractured shell piece at curl A showing longitudinally-oriented sliding contact marks on the exterior face of the curl.

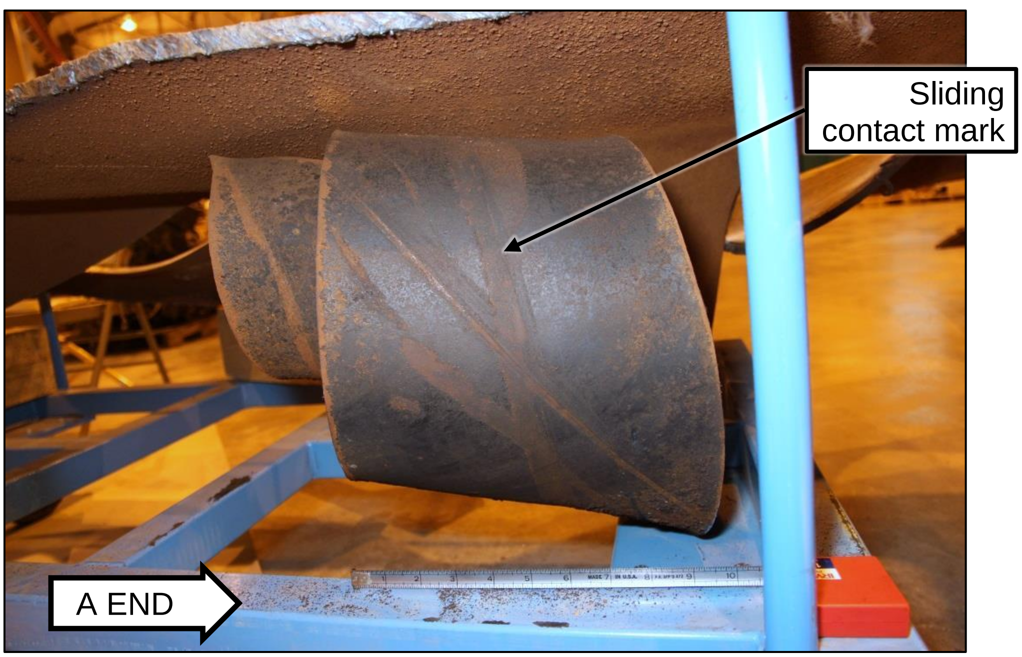


Figure 6. Interior face of the fractured shell piece looking upward showing a sliding contact mark on the exterior face of curl B approximately parallel to the fractures on either side of the curl.

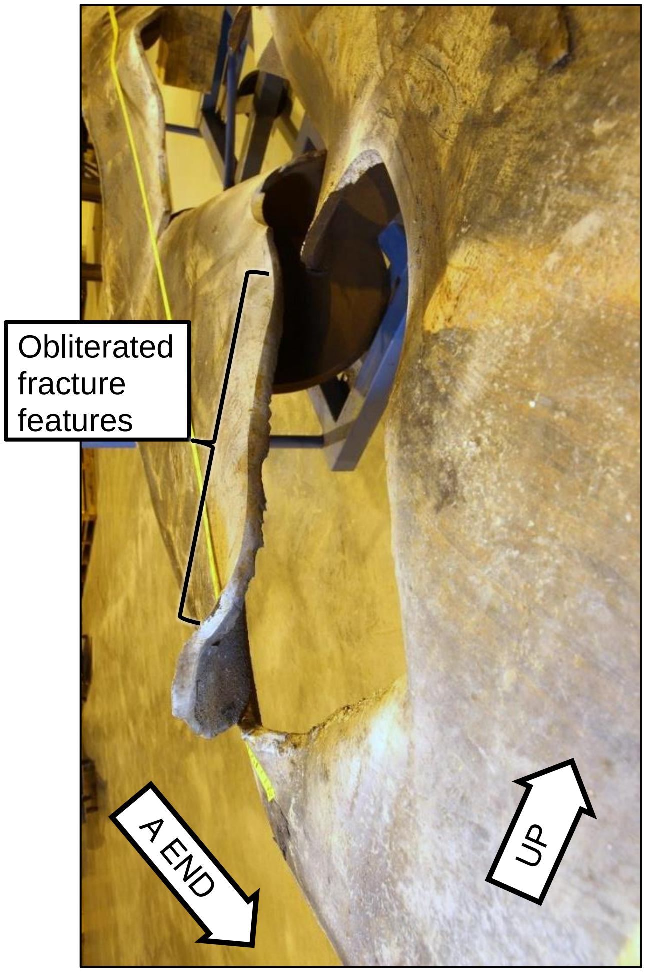
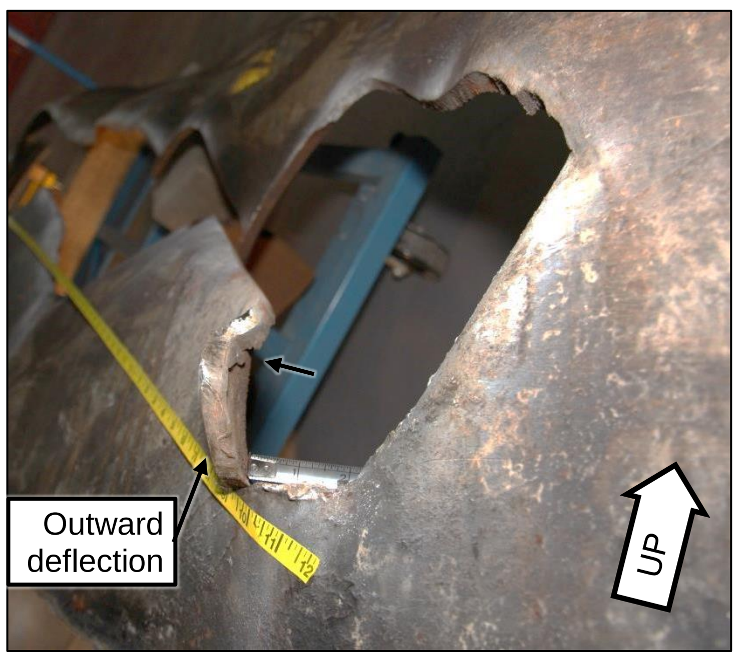


Figure 7. Views of the B end of the shell fracture showing the obliterated fracture features on the lower fracture face (left image) and outward deflection of the shell at the end of the fracture. An unlabeled arrow in the lower image indicates a sharp change in the deformation consistent with contact with an edge or corner on the contacting object.



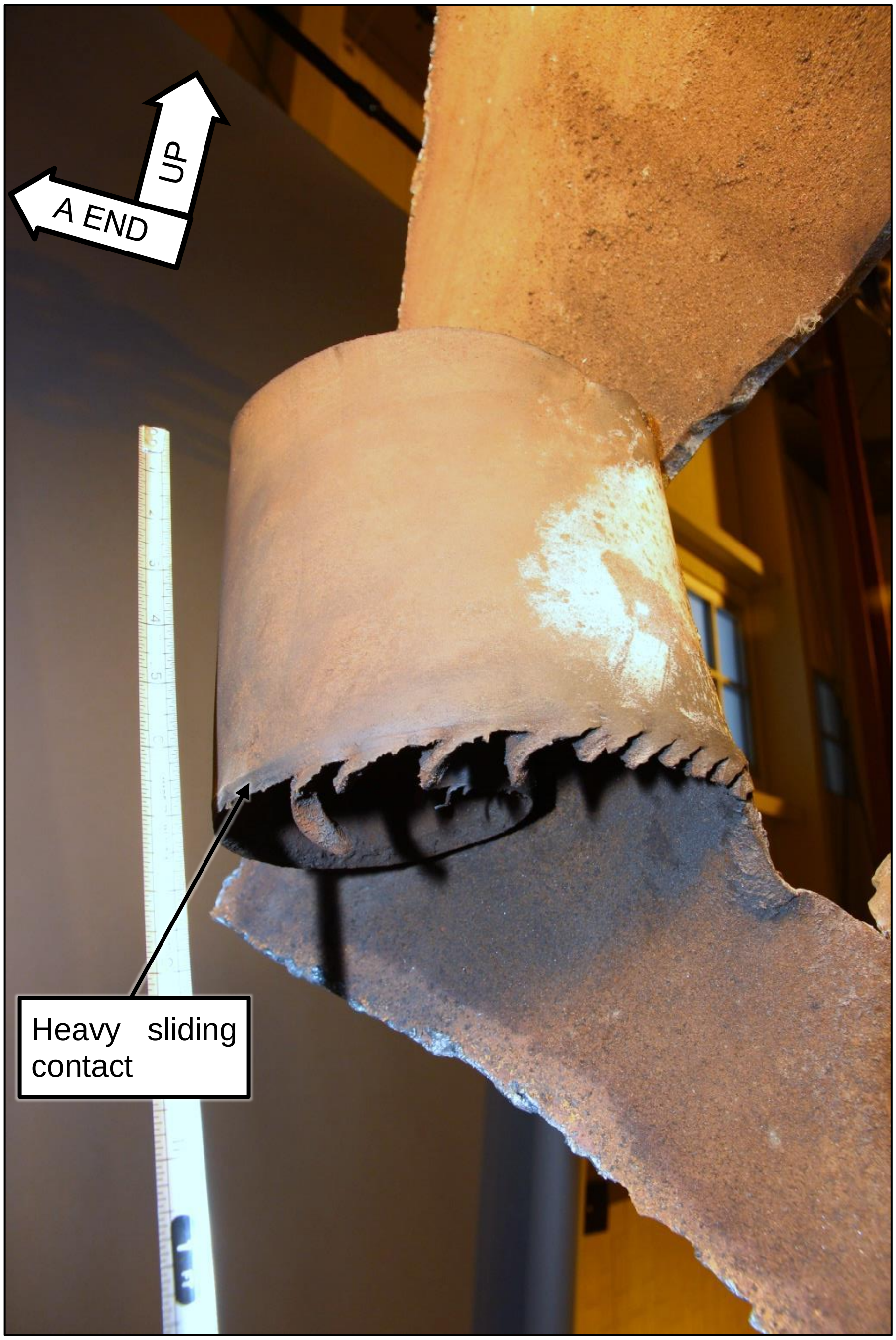


Figure 8. Interior of the fractured shell piece showing curl C at the A end of the fracture. Heavy sliding contact was observed at the lower edge of the curl as indicated.

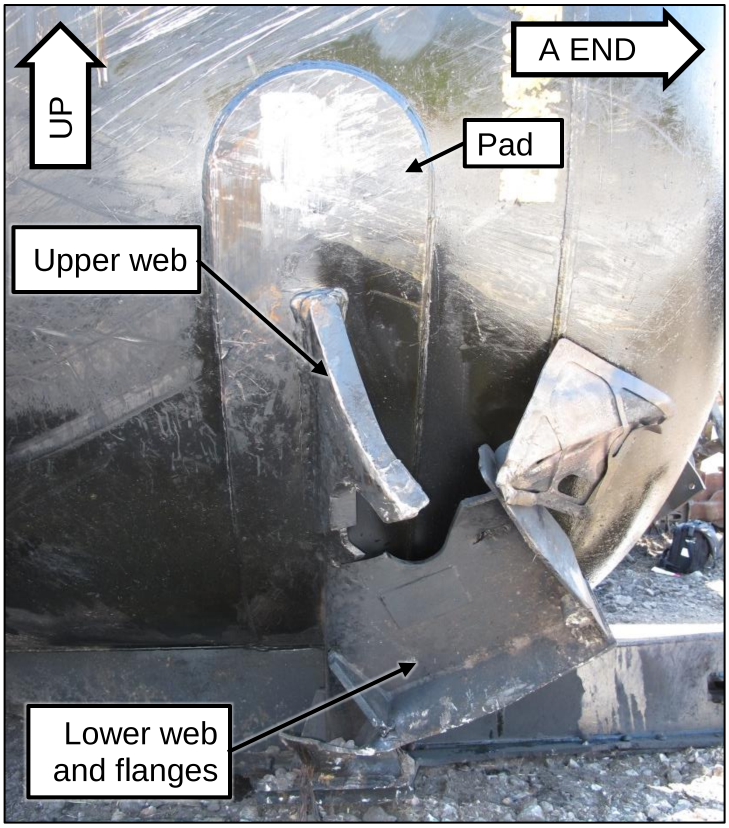


Figure 9. Overall view of the damage to the A-end body bolster on the right side of tank car CBTX 741720.

Figure 10. The weld at the B side of the body bolster pad was fractured in the area indicated with an unlabeled bracket.

Figure 11. Views of the piece cut from tank car CBTX 741720. Unlabeled arrows and brackets indicate locations of sliding contact marks with edge deformation.

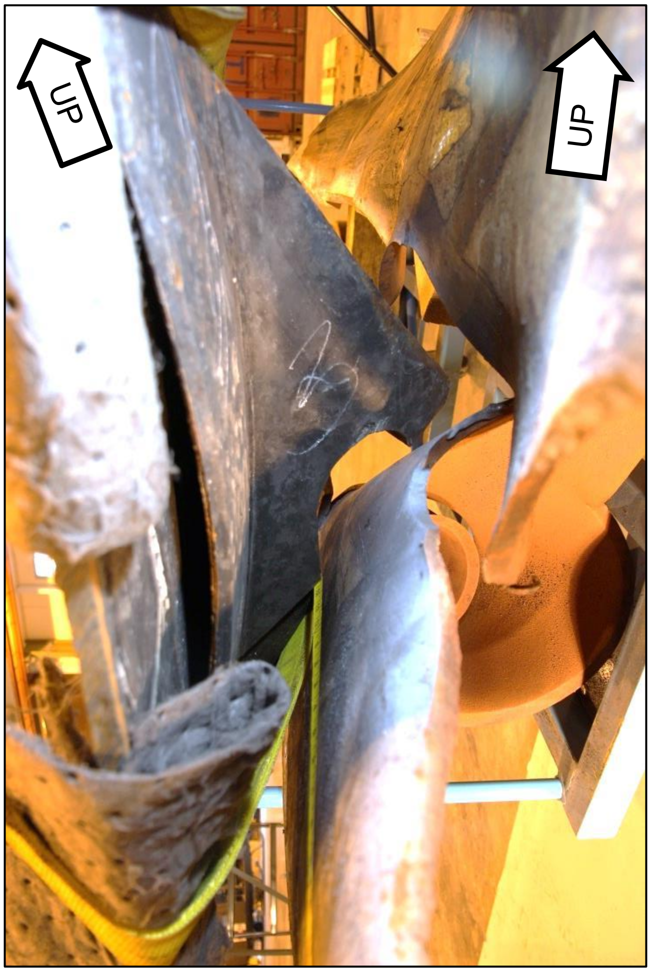
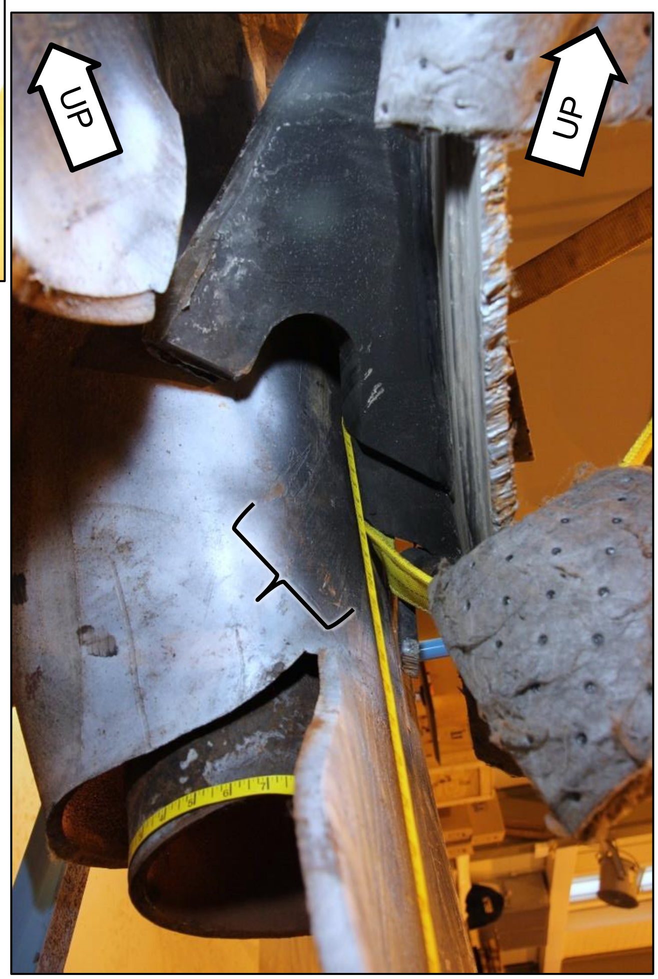


Figure 12. Views showing the bolster piece in close proximity to curl B in the shell fracture looking toward the B end of the fractured shell piece (upper image) and in the opposite direction looking downward and toward the A end of the fractured shell piece (image at the right). A bracket indicates sliding contact marks that appeared to initiate near the base of curl B.



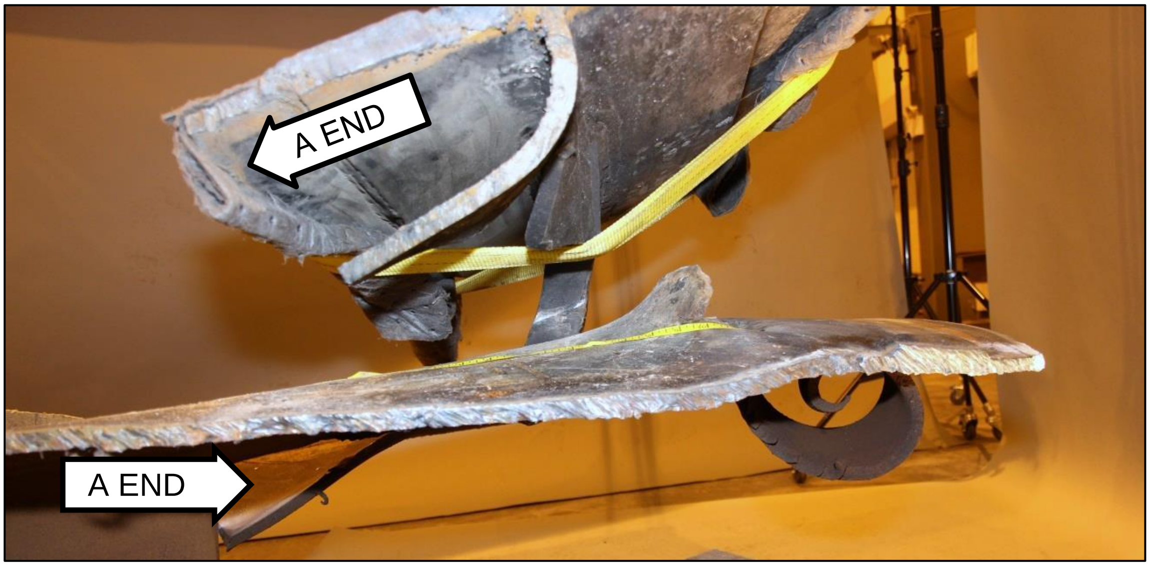


Figure 13. Tank car pieces shown in close proximity near the A end of the shell fracture.

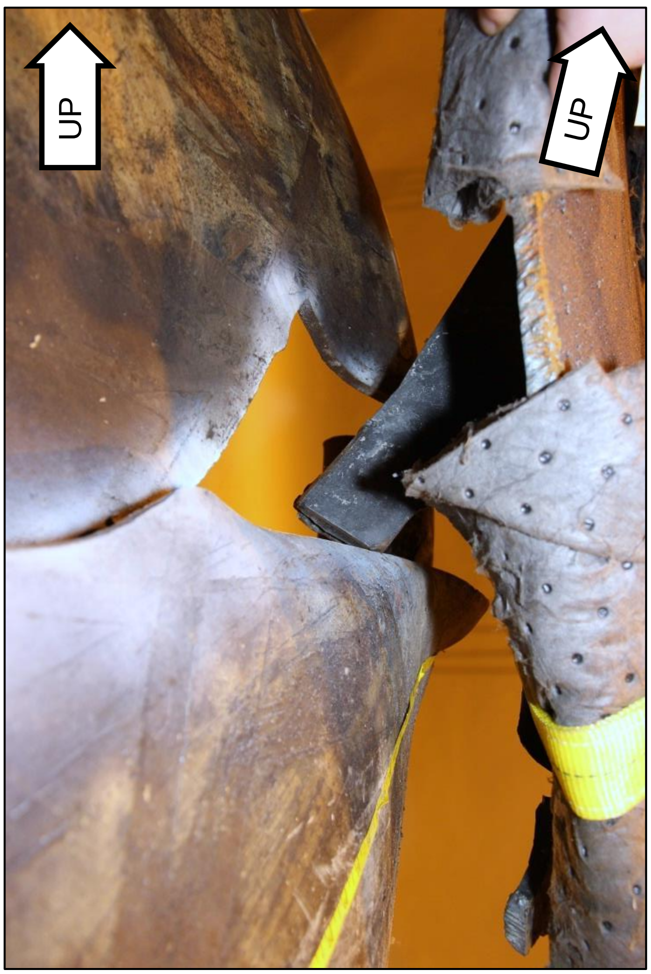


Figure 14. View looking toward the A end of the fractured shell piece and the B end of the bolster piece with the pieces shown in close proximity in the position shown in the previous figure.

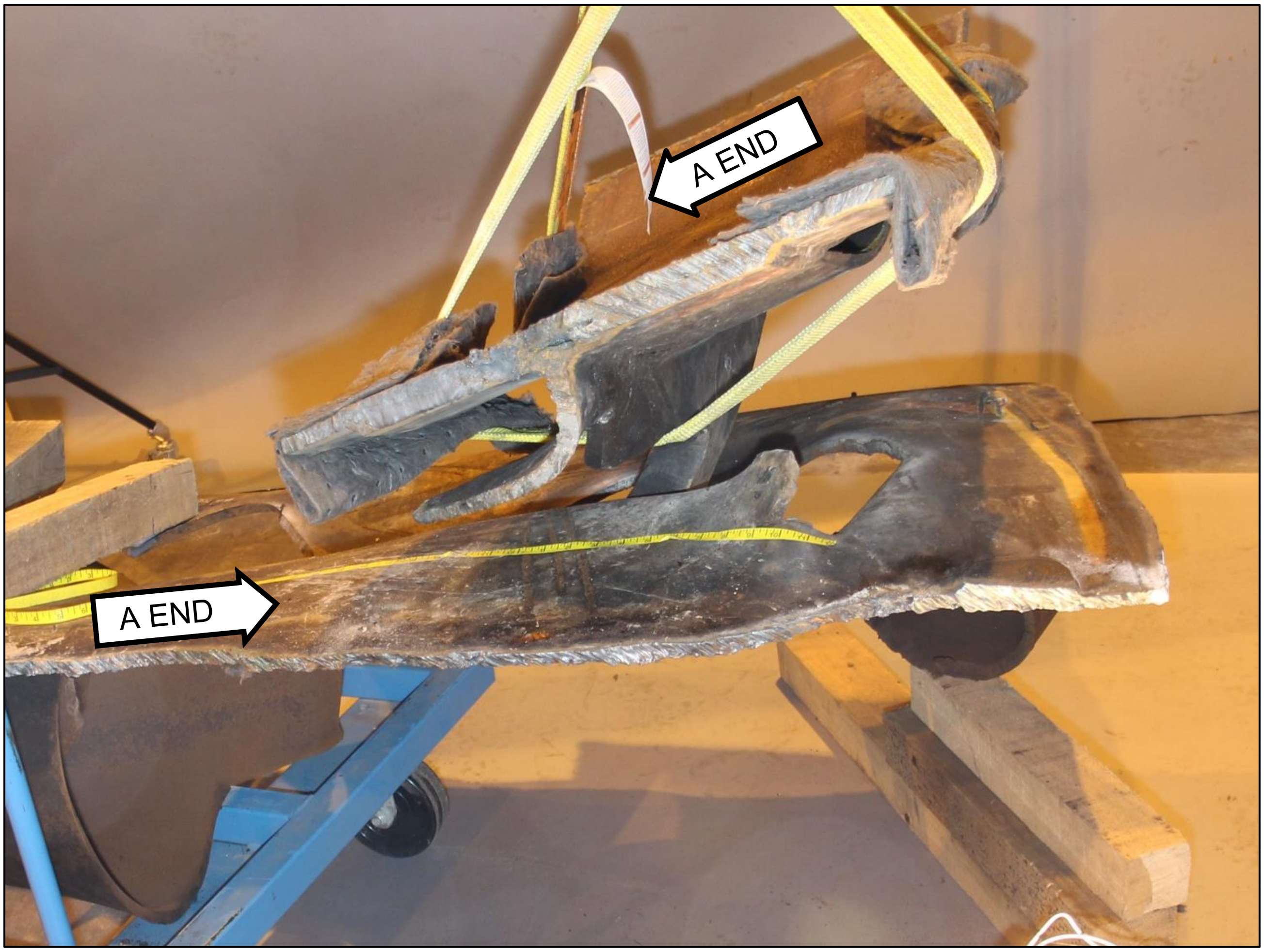
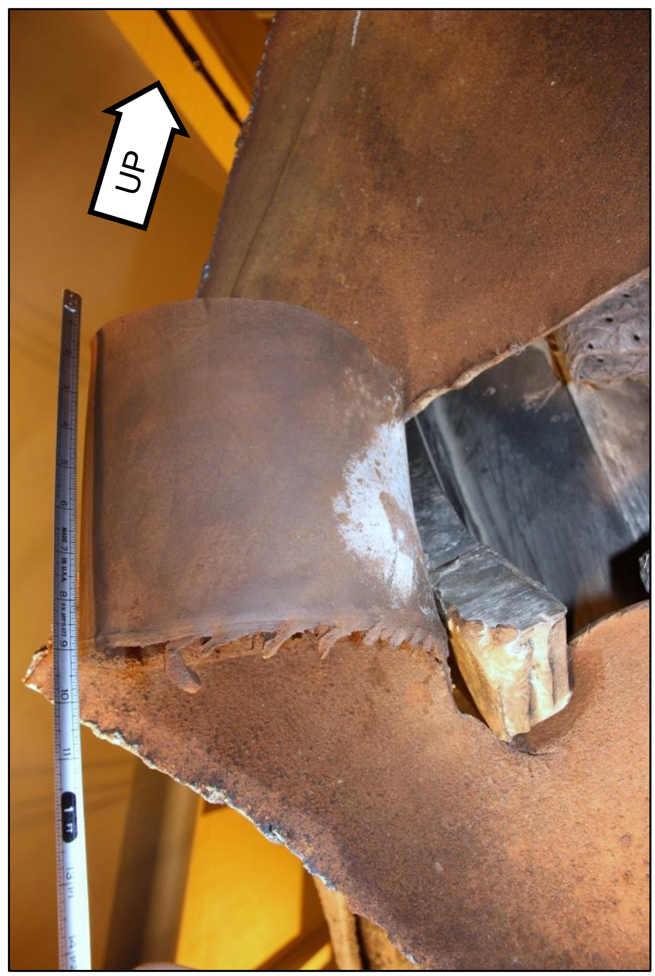


Figure 15. Another view looking upward showing the pieces in close proximity near the A end of the shell fracture with the bolster web piece positioned closer to the fractured shell piece.

Figure 16. Views of the fractured shell piece and the bolster piece in close proximity at the A end of the fracture as viewed from the exterior looking toward the B end of the fractured shell piece (image above) and from the interior looking toward the A end of the fractured shell piece (image to the right).



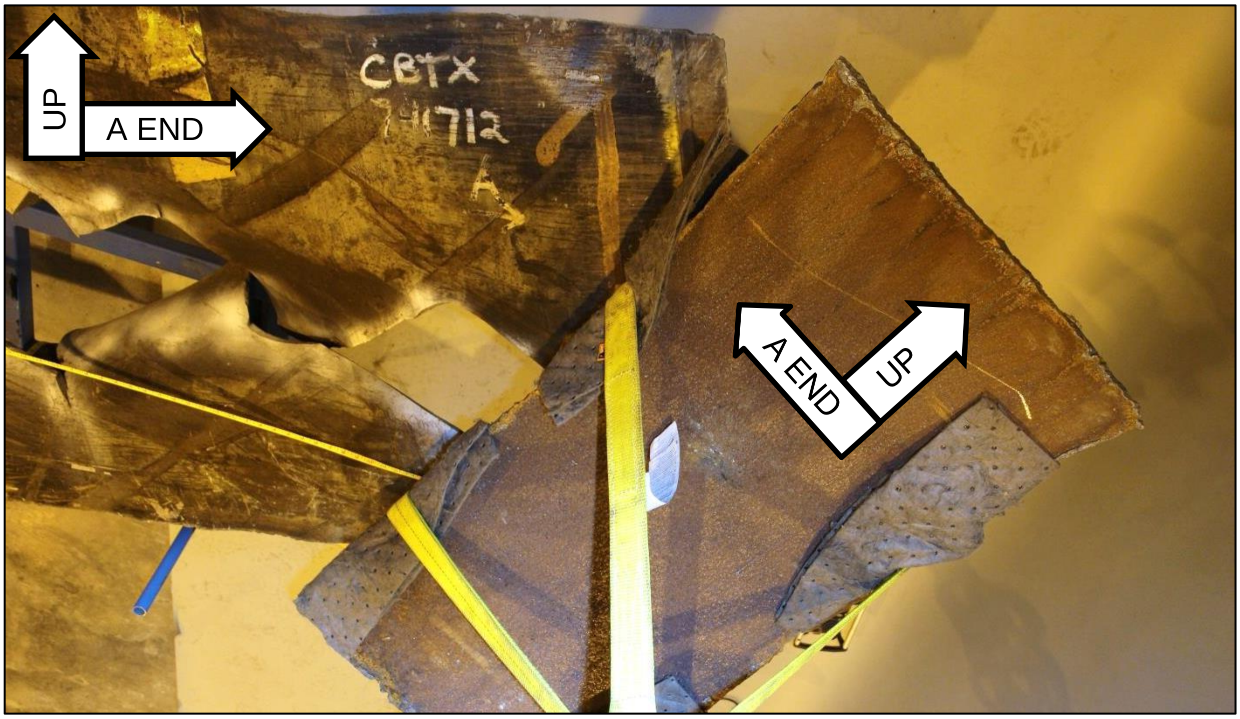


Figure 17. Overall view of the pieces in the positions shown in the previous figure showing the relative shell orientations.

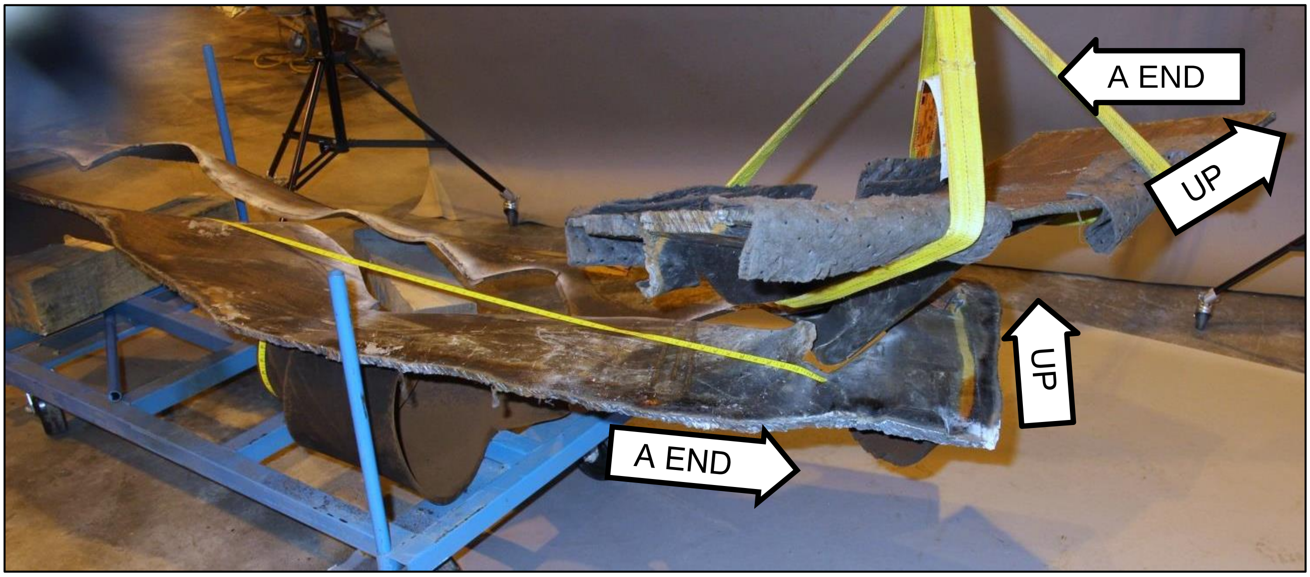


Figure 18. Views of the fractured shell piece and the bolster piece shown in close proximity with the bolster piece positioned near the A end of the shell fracture as viewed looking upward relative to the fractured shell piece.

Figure 19. Another image of the pieces in the position shown in the previous figure as viewed looking toward the A end of the fractured shell piece.

D. APPENDIX A: MECHANICAL TEST AND CHEMICAL ANALYSIS REPORTS

Lehigh Testing Laboratories, Inc.
A Subsidiary of THE MMR GROUP, INC.
308 WEST BASIN ROAD • P.O. BOX 903 • NEW CASTLE, DE 19720
(302) 328-0500 • FAX (302) 328-0417

TEST REPORT

NATIONAL TRANSPORTATION SAFETY BOARD
ATTENTION: MATTHEW FOX
490 L'ENFANT PLAZA EAST SW
WASHINGTON, DC 20594

DATE: January 23, 2015

PO NO: **VERBAL**

LEHIGH NO: **S-54-20**

MATERIAL: NORMALIZED TC 128 STEEL
SAMPLE DESIGNATION: (1) SAMPLE: PIECE FROM A RAIL TANK CAR SHELL WALL MARKED CBTX 741742

MECHANICAL PROPERTIES (Per ASTM A370-12a)

	A	B	C
Width (inches):	1.508	1.512	1.510
Thickness (inches):	0.509	0.505	0.502
Area (square inches):	0.7676	0.7636	0.7580
Yield Point (ksi): 0.5% EUL:	63	63	62
Yield Point (ksi): 0.2% offset:	63	63	62
Ultimate Tensile Strength (ksi):	86	86	86
Elongation (%) in 2":	32	36	40
Elongation (%) in 8":	20	18	21

Results are for information only.

Lehigh Testing Laboratories, Inc.

Kenneth M. Petito

Kenneth M. Petito, Supvr., Mechanical Testing

Lehigh Testing Laboratories, Inc.
A Subsidiary of THE MMR GROUP, INC.
308 WEST BASIN ROAD • P.O. BOX 903 • NEW CASTLE, DE 19720
(302) 328-0500 • FAX (302) 328-0417

TEST REPORT

REVISED: 1/26/15*

NATIONAL TRANSPORTATION SAFETY BOARD
ATTENTION: MATTHEW FOX
490 L'ENFANT PLAZA EAST SW
WASHINGTON, DC 20594

DATE: January 23, 2015

PO NO: **VERBAL**

LEHIGH NO: **S-54-20**

MATERIAL: NORMALIZED TC 128 STEEL
SAMPLE DESIGNATION: (1) SAMPLE: PIECE FROM A RAIL TANK CAR SHELL WALL MARKED CBTX 741742

IMPACT PROPERTIES (Per ASTM A370-12a)

Lehigh No.	Customer ID.	Test Temp.	Imp. Energy (Ft.-Lb.)	Lat. Exp. (Mils)	Shear (%)
S-54-20	CBTX 741742	Room Temp 70° F	140	92	100
		Room Temp 70° F	142	94	100
		Room Temp 70° F	142	91	100
		AVERAGE:	141	92	100
		-50° F	92	69	100
		-50° F	59	45	100
		-50° F	53	41	100
		AVERAGE:	68	52	100

Specimen Size: 10mm X 10mm

Results are for information only.

*Revised to correct values.

Lehigh Testing Laboratories, Inc.

Kenneth M. Petito

Kenneth M. Petito, Supvr., Mechanical Testing

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THE MMR GROUP, INC.
an ESOP Company

TEST REPORT

NATIONAL TRANSPORTATION SAFETY BOARD		DATE:	January 23, 2015
ATTENTION: MATTHEW FOX			
490 L'ENFANT PLAZA EAST SW		PO NO:	**VERBAL**
WASHINGTON, DC 20594			
		LEHIGH NO:	**S-54-20**
		PAGE:	1 of 1

MATERIAL: NORMALIZED TC 128 STEEL
SAMPLE DESIGNATION: (1) SAMPLE: PIECE FROM A RAIL TANK CAR SHELL WALL MARKED CBTX 741742

CHEMICAL ANALYSIS (%)

Carbon	0.16
Sulfur	0.006
Manganese	1.43
Phosphorus	0.008
Silicon	0.21
Vanadium	0.04
Copper	0.23
Nickel	0.13
Chromium	0.12
Molybdenum	0.05
Aluminum	0.02
Niobium	<0.001
Titanium	0.002
Boron	0.0003
Tin	0.01
Nitrogen	0.009

Results are for information only.

Procedure: *QA-CH-P-018 Rev 4 (OES)*
QA-CH-P-122 Rev 1 (Leco N)

Lehigh Testing Laboratories, Inc.

Deborah A. Hotra

Deborah A. Hotra, Senior Lab. Technician