NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

September 1, 2011

MATERIALS LABORATORY FACTUAL REPORT Report No. 11-096

A. ACCIDENT INFORMATION

Place	:	Red Oak, Iowa
Date	:	April 17, 2011
Vehicle	:	BNSF 9159 East (coal train) and BNSF 9470 East (maintenance of way equipment train)
NTSB No.	:	DCA11FR002
Investigator	:	Michael Hiller, RPH-10

B. COMPONENTS EXAMINED

Forward cab retention pins and center sill area at the base of the collision posts.

C. DETAILS OF THE EXAMINATION

The lead locomotive of the striking train, 9159, was an Electro-Motive Diesel, Inc., (EMD) SD70ACe locomotive. The SD70ACe is equipped with an isolated or "Quiet" cab that is designed to improve crew comfort by reducing both vibration and sound levels. A system of springs, bushings, and dampeners help isolate the entire cab from vibrations.

The lead locomotive of the striking train was examined during the Crashworthiness Group meeting at a BNSF facility in Havelock, Nebraska on June 28 through 30, 2011. The examination included a visual examination and photographic documentation of fracture surfaces and deformation patterns in the vicinity of the striking locomotive collision posts. In addition, fractured pieces of the two cab forward retention pins were retained and hand-carried to the NTSB Materials Laboratory in Washington, DC, for further examination and testing.

1. Collision Post Attachment Area

A transverse cross-section of the primary structure under the collision posts of the EMD SD70ACe locomotive consists of a horizontally-oriented bottom plate, two vertically-oriented center sill plates welded to the upper surface of the bottom plate near the outboard edges of the bottom plate, two horizontally-oriented top plates welded to the upper edges of the center sills, and two vertically-oriented side sills welded to the outboard edges of the top plates. The top plates are 1.5 inches thick, and the 1-inch thick center sills are welded to the lower sides of the top plates 2.38 inches away from the inboard edges of the top plates. A thinner center plate is welded to the inboard edges of the left and right top plates.[1] According to the engineering drawing for the locomotive, the center sills are welded to the top plates with a 0.38-inch fillet weld on each side of each center sill. The top plates are welded to the center plate with a bevel weld, and according to an EMD representative, the size of the bevel on the outboard edges of the center plate is 3/8 inch.

The short hood of the EMD SD70ACe locomotive includes two collision posts. The collision posts are 1-inch thick steel plates that are welded to the top plates directly above the center sills.

Overall views of the short hood of the accident striking locomotive are shown in figure 1. The short hood including the collision posts were deflected rearward. The collision posts remained attached to the top plates. Deflection of the collision posts occurred as the top plates fractured, welds between the top plates and the center sills and center plate fractured, and the top plate and side sills bent upward. Arrows in figure 1 indicate locations where the side sills and top plates bent upward. Figures 2 and 3 show closer views of the fractures and deformation at the lower end of the right collision post. Figures 4 and 5 show closer views of the fractures and deformation at the lower end of the left collision post.

The right top plate was fractured near the forward end of the collision post as shown in figure 2. The fracture surface showed matte gray fracture features with areas of orange-colored post-fracture oxidation. Radial features emanated from an area near the forward end of the collision post consistent with fracture propagating front to rear. The fracture propagated nearly in the short transverse plane directly under the collision post from the upper side to the lower side of the top plate along a length of 11 inches. A secondary fracture curving from the longitudinal to the transverse plane emanated from the fracture under the collision post and turned back toward the front edge of the top plate approximately 6 inches outboard of the collision post.

The fillet welds between the right top plate and the right center sill were fractured near the original surface plane of the center sill as shown in figure 2. Fracture features showed smeared patterns consistent with shear fracture with no indications of weld anomalies. The weld sizes as measured on the fracture surfaces were 5/8 and 1/2 inch for the outboard and inboard fillet welds, respectively.

A view of the fracture surface of the weld between the right top plate and the center plate is shown in figure 3. The fracture features were covered with orange oxide, consistent with post-fracture oxidation. The fracture surface was rough and irregular consistent with overstress fracture. The weld depth as measured on the fracture surface was somewhat variable measuring approximately 7/16 inch deep with a variation of approximately ± 1/16 inch.

The left top plate was fractured in a plane nearly perpendicular to the longitudinal direction at the forward end of the left collision post as shown in figure 4. Fracture

[1] Left and right are defined as when facing forward looking out the front of the locomotive.

features were rough with orange-colored post-fracture oxidation, features consistent with overstress fracture. Radial marks emanated from the upper side of the top plate, indicating the fracture propagated through the top plate starting from the top surface.

The fillet welds between the right top plate and the right center sill were fractured near the original surface plane of the center sill as shown in figure 4. Fracture features showed smeared patterns consistent with shear overstress fracture with no indications of weld anomalies. The weld sizes as measured on the fracture surfaces were 3/4 and 3/8 inch for the outboard and inboard fillet welds, respectively.

A view of the fracture surface of the weld between the left top plate and the center plate is shown in figure 5. The fracture surface and surrounding surfaces were covered with black sooty deposits, and portions of the fracture surface were covered with orange oxide, consistent with exposure to fire and post-fracture oxidation. The fracture surface had smeared features consistent with overstress shear fracture. The weld depth as measured on the fracture surface was somewhat variable measuring approximately 1/4 to 3/8 inch deep.

2. Cab Retention Pins

The forward end of the cab rests on springs aligned in parallel with hydraulic vibration dampeners. At the lower side of the cab, two double-shear pin joints connect the front of the cab to the top plate of the underlying structure. The 1-inch diameter, 7.56-inch long forward retention pin from each double-shear pin joint is inserted through a 2-inch diameter hole in the lug on the deck, allowing clearance for the cab vibration isolation system.

The two forward cab retention pins were fractured, and overall views of the fractured retention pins are shown in figure 6. The pins were arbitrarily labeled “A” and “B” as shown in figure 6. The original position of the pins relative to the left or right side of the cab was not determined. A view of the right lug through which the right pin was inserted is shown in figure 7.

Both pins had part number “8146747” and manufacturer mark “GB” formed on the head. Pin A had paint visible on parts of the head. Portions of the original gray ground surface was visible around ¾ of the circumference of the shank within 1.1 inches of the head. The remainder of pin A had black and orange oxides and sooty deposits on the remainder of the surfaces. On pin B, painted areas were visible on the head, and the paint appeared heat tinted to a reddish brown color. The remainder of the surfaces showed orange and black oxides and sooty deposits.

The shank diameter of pins A and B measured 0.999 inch and 1.001 inch, respectively, both within the range of allowable dimensions specified in the engineering drawing for EMD part number 8146747 bolts. Pins A and B were fractured in the shank at 2.66 inches and 3.18 inches from the underside of the head, respectively. Views of the fracture surfaces are shown in figure 6. Fracture features on both pins were similar. The fracture surfaces were relatively smooth around the edges and rough in the middle.

Small shear lips were visible around the edges, and an overall change in fracture plane was observed at one side of the fracture. All features were consistent with overstress fracture of surface-hardened steel under a bending load.

Pins A and B were sectioned in the shank region to facilitate measurement of core hardness and case depth. The average core hardnesses of pins A and B were 96.4 HRB and 98.1 HRB, respectively. Knoop hardness using a 500 kgf load was measured on the cross-sections from 0.070 inches from the surface toward the core. At 0.070 inches deep, the hardness measured 56 HRC (658 HK_{500})[2] on pin A and 54 HRC (612 HK_{500}) on pin B. Case depth, as determined by the depth at which hardness measured 50 HRC (541 HK_{500}), was approximately 0.127 inch for pin A and 0.119 inch for pin B, both within the specified range for an EMD part number 8146747 1-inch diameter bolt.

Deposits and oxidation on the surfaces of the sectioned pieces of pins A and B were removed using a wire brush and surfaces were polished with 600-grit abrasive paper. Surface hardness was measured in the cleaned areas using a Rockwell superficial hardness diamond indenter with a 15 kgf load. Surface hardness measured 60.0 HRC (79.1 HR15N) and 54.7 HRC (76.6 HR15N) on pins A and B, respectively. The specified minimum surface hardness for an EMD part number 8146747 bolt is 58 HRC.

Composition of the pins was determined using a Thermo Scientific Niton XL3t-980 x-ray fluorescence (XRF) alloy analyzer. The material was identified as carbon steel, and manganese levels were within compositional ranges of the carbon steels specified for the EMD part number 814747 bolt.

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[2] Knoop and Rockwell N hardness values were converted to the Rockwell C scale in accordance with ASTM Standard E140.

Figure 1. Overall views of the front of the striking locomotive showing short hood and collision post deflection with bending deformation to the top plates and side sills.

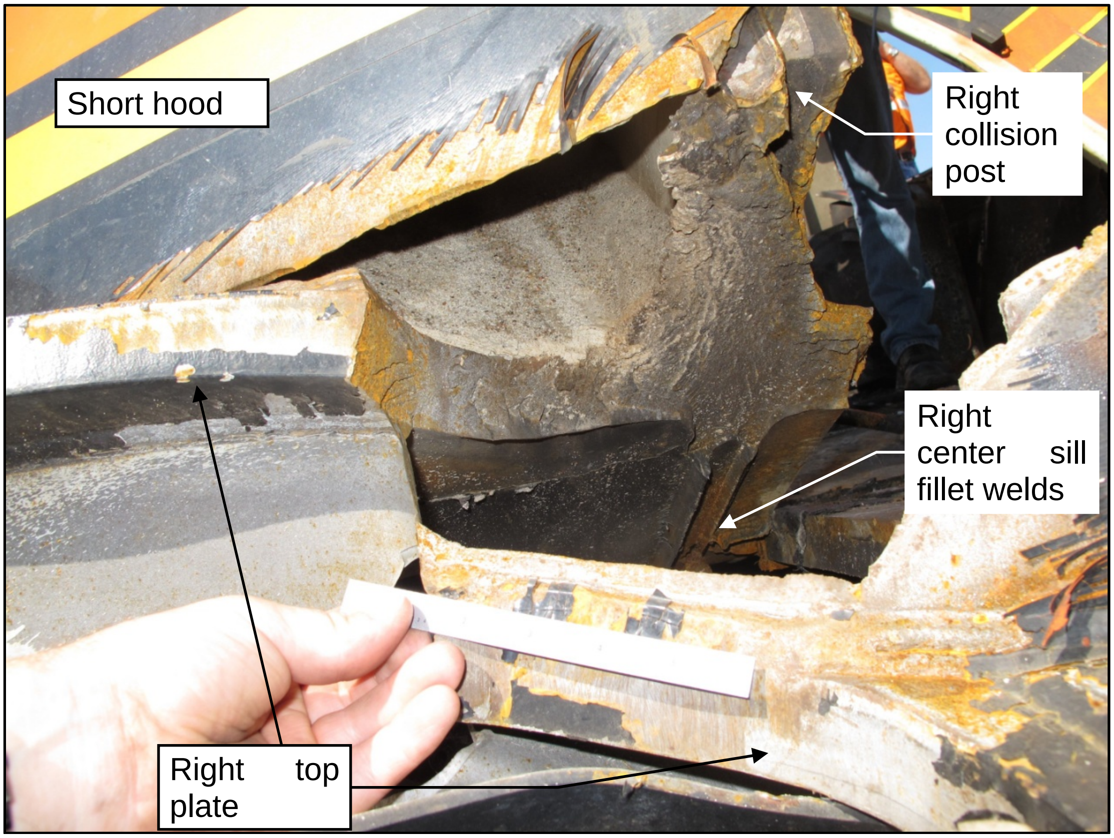

Figure 2. Close view of fractures at the lower end of the right collision post.

Figure 3. Side view of the lower end of the right collision post looking outward.

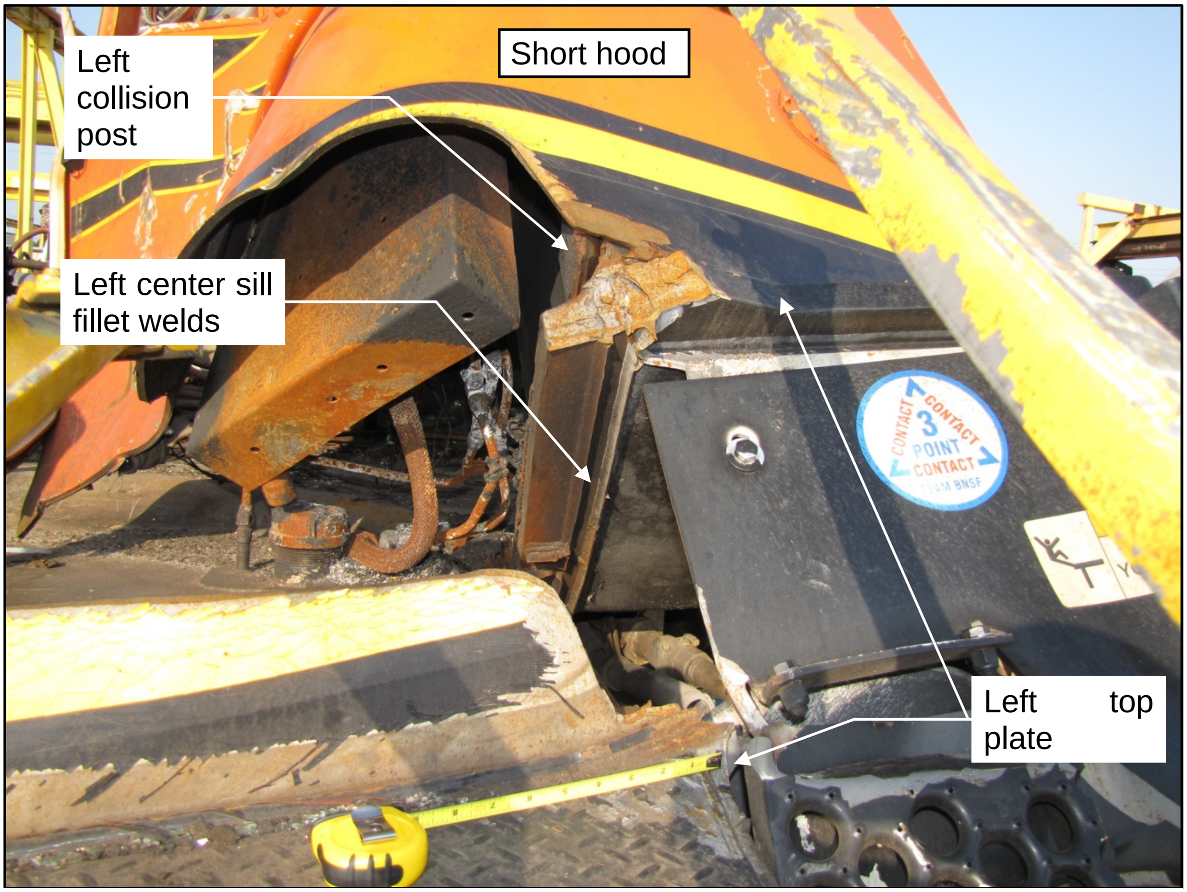

Figure 4. Close view of fractures at the lower end of the left collision post.

Figure 5. Side view of the lower end of the left collision post looking outward.

Figure 6. Side view and views of the fracture surfaces of the two fractured retaining pins arbitrarily labeled “A” and “B”.

Figure 7. Lug attached to the top plate at the right forward cab retention joint.