NATIONAL TRANSPORTATION SAFETY BOARD

OFFICE OF RAILROAD, PIPELINE &

HAZARDOUS MATERIAL INVESTIGATIONS

WASHINGTON, D. C. 20594

DCA-11-FR-002

REAR END COLLISION / DERAILMENT OF BNSF C-BTMCNM0-26
STRIKING BNSF MAINTENANCE OF WAY EQUIPMENT TRAIN U-BRGCRI5-15

On BNSF Creston Subdivision, Line Segment No.1, Nebraska Division

Red Oak, Iowa

April 17, 2011

CRASHWORTHINESS FACTUAL

Prepared by: Michael E. Hiller, Crashworthiness Group Chairman

Contents

Accident Reference Information

NTSB Accident Number:	DCA-11-FR-002
Location of Accident:	Red Oak, Iowa
Date of Accident:	April 17, 2011
Time of Accident:	6:55 a.m. (CDT)[1]
NRC[2] Report No.	973202
Type of Incident	Rear End Collision of Two Trains
Railroad Property	BNSF Railway (BNSF)
Track Location	Creston Subdivision, MP 448.3

Train 1 (Striking Train)

Owner	BNSF
Train Number	C-BTMCNM0-26
Type	Coal Train
Consist	3 Locomotives (2 Pulling and 1 Pushing) and 130 Coal Cars.
Weight	18529 tons
Length	7122 feet
Operating Direction	eastbound
Equipment Manufacturer	
Locomotive (1)	Electro-Motive Diesel Inc. (EMD) SD70ACe (BNSF 9159)
Locomotive (2)	GE Locomotive ES44AC (BNSF 6133)
Locomotive (3)	Electro-Motive Diesel Inc. (EMD) SD70ACe (BNSF 9226)
Train Operator:	BNSF
Injuries	0
Fatalities	2

Train 2 (Struck Train)

Owner	BNSF
Train Number	U-BRGCRI5-15
Type	Maintenance of Way Equipment Train
Consist	1 Locomotive, 21 loaded cars and 13 empty cars.
Weight	2635 tons
Length	3170 feet
Operating Direction	eastbound (stopped)
Equipment Manufacturer	
Locomotive	Electro-Motive Diesel Inc. (EMD)
Clip Car	Herzog
Flat Car	Bethlehem Steel
Train Operator:	BNSF

[1] All time referenced in this report are Central Daylight Time unless noted otherwise.
[2] National Response Center, a function of USCG, provides initial notification to specific USDOT / FRA and NTSB offices, of transportation related incidents that meet certain pre-established criteria. See http://www.nrc.uscg.mil for report.

Injuries	0
Fatalities	0

Crashworthiness Group

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In addition to the Group Members, the following Group Participants supported the crashworthiness examination:

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Synopsis

On Sunday April 17, 2011 at approximately 6:55 a.m. (CDT) an eastbound BNSF coal train collided with the rear end of a standing BNSF maintenance of way equipment train near Red Oak, Iowa. The accident occurred at milepost 448.3 on main track number two on the Creston Subdivision of the BNSF Nebraska Division.

The coal train was designated as C-BTMCNM0-26, BNSF 9159 East. It consisted of 130 loaded coal cars, 18,529 tons, and was 7,122 feet long with two locomotives on the head end (BNSF 9159 leading with BNSF 6133 trailing) and one locomotive on the rear end. The maintenance of way equipment train was designated as U-BRGCRI5-15, BNSF 9470 East and consisted of 21 loaded cars and 13 empty cars, 2,635 tons and was 3,170 feet long with one locomotive on the head end.

As a result of the collision, the two head end coal train locomotives derailed along with the head two coal cars. The leading locomotive crew cab of the striking train was damaged and involved in a subsequent diesel fuel fire. The following locomotive's, BNSF-6133, fuel tank was compromised and the unit caught fire. Seven additional coal cars were also damaged but not derailed. Ten cars of the standing maintenance of way equipment train were derailed. Both the engineer and conductor on the coal train were fatally injured. The two crew members on the locomotive of the maintenance of way equipment train were not injured. Preliminary damage estimates are $8 million. The weather at the time of the accident was reported as 5 miles visibility with mist at Red Oak airport which is about two and one half miles east of the accident location.

Parties to the investigation include BNSF, Federal Railroad Administration (FRA), Brotherhood of Locomotive Engineers and Trainmen (BLET), United Transportation Union (UTU) and Electro-Motive Diesel Inc. (EMD).

Railroad Equipment Involved in the Collision

BNSF 9159

The lead locomotive of the striking train, unit number BNSF 9159, is an Electro-Motive Diesel Inc. (EMD) SD70ACe manufactured in March of 2008. Production of this model began in 2005. This unit is a six-axle / two-truck, 4300 THP[3], 'road switcher' type, diesel-electric locomotive. It is equipped with an EMD two cycle 16 cylinder turbocharged, diesel engine, model 16-710G3C-T2, that is mechanically coupled to an EMD [produced] model TA17/CA9 alternator

[3] Tractive Horse Power

(which functions as an auxiliary power supply producing alternating current). The locomotive unit features six alternating current (AC) traction motors (one fitted to each axle). See Exhibit 1.

The SD70ACe locomotive is arranged and equipped so that the shorthood or cab end is considered the front or forward end. The SD70ACe is equipped with an isolated or "Quiet" cab that is designed to improve crew comfort by reducing both vibration and sound levels. EMD documentation states[4] that although the locomotive operates equally well in either direction, when the locomotive operates alone, or when it leads a train, it is preferable that the cab end should lead. When operating in trail or leading a remote consist in the train, it can face in either direction.

The Quiet cab is a modular self contained assembly that is mounted atop the deck of the locomotive. It measures approximately 9 feet 3 inches in height, 9 feet 6 inches in length and 10 feet wide, weighing about 10,000 lbs. The cab is bolted in place at its rear floor underside on two cylindrical hollow posts welded to the top plate of the locomotive. The two rear cab mounting points are fitted with torsional bushings that establish a pivot point about rear floor axis of the cab.

The front of the cab rests on two coil springs located behind the shorthood approximately 5 feet 10 inches from the top plate behind the shorthood. Adjustment cups at each spring are used to control clearance from cab to underframe and to equalize spring compression. Adjacent each spring are hydraulic shock absorbers designed to dampen vibrations.

On the underside of the cab at its front are two double shear pin joints. This system includes two brackets welded to the top plate and two brackets welded to the underside of the cab floor. These joints are not an interference fit; in fact the one inch diameter hardened steel pin passes through a wide (2 inch) hole in the deck mounted bracket. When questioned, EMD stated this design acted as a loosely coupled fastening system.

BNSF currently has 200 EMD SD70ACe locomotives with the Quiet cab running in their operation. When questioned, EMD stated that a total of 562 SD70ACe with the Quiet cab units operate in USA, Canada and Mexico.

The locomotive unit measures approximately 74 ft (length), by 10 ft (width), by 16 ft (height), and weighs (fully loaded with fuel, traction sand, etc.) about 420,000 lbs. The design incorporates an Operator's Cab (where the crew normally is located during operation of the unit) at the front end of the unit, and utilizes a fabricated steel underframe platform that extends the length of the unit, upon which the diesel engine / alternator components are mounted (aft of the cab location).

A fuel tank, having a capacity of about 5,000 gallons, is located (suspended from the

[4] Locomotive Operator's Manual Burlington Northern Santé Fe Railway Order number: 20086021

underside of the underframe) between a pair of three-axle power truck assemblies. The locomotive unit can incorporate (as a customer selected option) an on-board Digital Video Recorder System, which is fitted inside the Operator's Cab, to observe the view [through the windshield] forward of the 'shorthood' of the unit (immediately preceding the Operator's Cab).

The locomotive involved in this Accident was manufactured in March of 2008. According to EMD, Locomotive BNSF 9159 was constructed to meet crashworthiness standards as prescribed in Association of American Railroads, AAR, Manual of Standards and Recommended Practices, Standard S-580, revision 2005, "Locomotive Crashworthiness Requirements", which is a standard incorporated by reference in the Code of Federal regulations, Title 49, Part 229[5] for all locomotives built after January 2009. See Exhibit 2. AAR Standard S-580, revision date 2005, as further described in this report incorporates the following crashworthiness features:

- Impact resistant fuel tank
- Underframe designed to withstand a longitudinal load of 1,000,000 lbs
- Collision posts
- Anti-climbers designed to withstand a vertical force of 100,000 lbs.

Additionally, locomotive BNSF 9159 was constructed to meet fuel tank performance standards as prescribed in Association of American Railroads, AAR, Manual of Standards and Recommended Practices, Standard S-5506, revision 2001, "Performance Requirements for Diesel Electric Locomotive Fuel Tanks", which is a standard incorporated by reference in the Code of Federal regulations, Title 49, Part 229. See Exhibit 3.

The AAR S-5506 Standard provides performance design criteria for all locomotives equipped with external fuel tanks requiring specific features to be incorporated into the design, such as structural strength requirements in consideration of minor derailments, jackknifed locomotive, side impact, penetration resistance, sideswipes and spill controls.

Locomotive Crashworthiness

In 1997 the Federal Railroad Association (FRA) tasked[6] the Railroad Safety Advisory Committee (RSAC)[7] to investigate and develop, if necessary, crashworthiness specifications to ensure the integrity of the locomotive cab in accidents from collisions such as highway rail crossing accidents, sideswipes and shifted loads.

[5] EMD Confirmed in correspondence with NTSB Investigators' BNSF 9159 was design was to meet AAR S-580, 2005 with an exception to the emergency interior lighting requirement.
[6] FRA RSAC Task 97-1
[7] In 1996 FRA established the RSAC, which provides a forum for consensus rulemaking. Representatives include; railroads, labor organizations, suppliers, state agencies, manufacturers. More information is available at www.fra.dot.gov

At the request of the FRA, the RSAC reviewed accident data from 1995 to 1996 and resolved the data pool into 23 types of accidents. From these 23, five accident scenarios were determined to be the range intended to encompass collisions in so far as to develop locomotive crashworthiness standards. The scenarios included:

1. In-line collision of two locomotive-led trains with trailing locomotive overriding leading locomotive
2. In-line collision of two locomotive-led trains with one colliding locomotive overriding the other
3. Locomotive grade crossing with highway vehicle hauling logs, with principle impact on locomotive window area
4. Oblique collision, locomotive with intermodal trailer
5. Oblique collision, locomotive with freight car

Many design modifications were investigated, tested and compared with the baseline designs. The modifications included shelf couplers, anti-climbers, modified collision posts, increased window structure strength, and increased shorthood strength. According to the results, improvement would come from strengthened window structures, collision posts and shorthoods for particular scenarios.

The AAR S-580 Standard provides crashworthiness design criteria for all new locomotives used in occupied service requiring specific features to be incorporated into the equipment, such as underframe strength, collision post strength, anti-climbers on each end, emergency egress and emergency lighting and interior requirements.

BNSF 6133

The second locomotive of the striking train, unit number BNSF 6133, General Electric model ES44AC (Evolution Series 4400 HP AC Traction Control) built in November 2006. This unit is a six-axle / two-truck, 4400 THP diesel-electric locomotive. It is equipped with a GE four stroke 12 cylinder turbocharged, diesel engine. The locomotive unit features six alternating current (AC) traction motors (one fitted to each axle).

The locomotive unit measures approximately 73 ft (length), by 10 ft (width), by 15.5 ft (height), and weighs (fully loaded with fuel, traction sand, etc.) about 416,000 lbs. A fuel tank, having a capacity of about 5,000 gallons, is located (suspended from the underside of the underframe) between a pair of three-axle power truck assemblies.

According to GE, Locomotive BNSF 6133 was constructed to meet crashworthiness standards as prescribed in Association of American Railroads, AAR, Manual of Standards and Recommended Practices, Standard S-580, revision 2001, “Locomotive Crashworthiness Requirements”.

Additionally, locomotive BNSF 6133 was constructed to meet fuel tank performance standards as prescribed in Association of American Railroads, AAR, Manual of Standards and Recommended Practices, Standard S-5506, revision 2001, "Performance Requirements for Diesel Electric Locomotive Fuel Tanks", which is a standard incorporated by reference in the Code of Federal regulations, Title 49, Part 229. See Exhibit 3.

HZGX-150

The last car, Line 34[8], in struck train U-BRGCRI5-15 was HZGX-150 maintenance of way Clip Car[9]. This was the first car stuck in the collision by locomotive BNSF 9159. This car was manufactured by Herzog Railroad Services Inc in 1995. HZGX-150 was constructed by altering a gondola car originally purchased from BNSF. The car is constructed from mild steel, weighs 177,000 lbs and is 54 feet in length[10]. See Exhibit 4. The HZGX-150 is a self propelled maintenance of way unit. The hydrostatically driven unit has one power driven axle set and has a 350 gallon fuel tank that was mounted atop the deck.

BNSF 927022

The second to the last car, Line 33, in struck train U-BRGCRI5-15 was BNSF 927022. This is an 89 foot flat car with a Kershaw designed, folding loading ramp attached to the end of the car. See Exhibits 5 and 6. BNSF 927022 was originally designed and manufactured by Bethlehem Steel in 1974; this flat car weighs 155,400 lbs. This car was loaded with a Swingmaster 181-TC, Crane Loader weighing 22,500 lbs.

When retracted and stored for travel, the Scorpion[11] ramp fits within "C" plate clearance dimensions. Optional bridging bar systems are available that allow movement from one flat car to another. A self-contained diesel power plant drives hydraulic pumps to provide power for the hydraulic cylinders and winch. The engine is housed in a lockable enclosure with controls and instrumentation. A hydraulic fluid tank and diesel fuel tank share a separate enclosure.

The ramp is powered by a John Deere 3012DF 27 horse power diesel engine. The fuel tank holds 11.5 gallons and the hydraulic fluid tank has a 25 gallon capacity.

[8] The term Line is a railroad industry term meaning where, in the line of cars, the vehicle is located. Thus, line 34 refers to the 34th car in the train.
[9] HZGX-150 is maintenance of way equipment that installs clips on the rail. The clips secure the rails to the railroad ties. This type of vehicle is commonly referred to as a 'clip car'.
[10] This information is referenced from the Universal Machine Language Equipment Register (UMLER)
[11] The Kershaw loading ramp is also known as the "Scorpion Ramp".

Lines 32 through 25

Line numbers 32 through 25 of struck train U-BRCGRI5-15 were all flat cars of similar design to BNSF 927022 with the exception of the loading ramp. These cars were loaded with maintenance of way equipment.

The Investigation made efforts to indentify the maintenance of way equipment loaded on Lines 32-25 based on available information. The cars in struck train UBRCGRI5-15 were loaded with the following maintenance of way equipment[12]:

Line Number	MFG	Model	Description	Weight
Line 32	Tamper	MBCA	Production Clip Machine	14,000 lbs.
			Toilet Car	Unk.
Line 31	John Deere	TCM-120C	Scrap Crane	19,500 lbs.
Line 30	Kershaw	38-6	Adzer Cribber w/ADC &FS	29,000 lbs.
	Nordco	NETP-BBH	Tie Plugger w/BBH Attachment	29,500 lbs.
Line 29	Teleweld	RM-1/RM-2	Rail Heater w/Trailer Cart	21,200 lbs
	Nordco	CX-NG	Auto Spiker	29,000 lbs.
Line 28	Nordco	BAAM	Auto Anchor Machine	35,000 lbs.
	Nordco	BAAM	Auto Anchor Machine	35,000 lbs.
Line 27	Nordco	CX-NG	Auto Spiker	29,000 lbs.
Line 26	Racine	Unk.	Clip Machine	10,000 lbs.
	Racine	Unk.	Clip Machine	10,000 lbs.
Line 25	Swingmaster	181-TC	Crane Loader	33,5000 lbs.

[12] This list is not inclusive and in some cases does not represent all of the loaded equipment.

Post Accident Observations

Information from the event recorder in locomotive BNSF 6133, second locomotive in the striking train, was downloaded on site. See Exhibit 7. The data showed the train was traveling at a speed of 23 MPH prior to the point of collision. Further, the data also shows the throttle position on the lead locomotive was in power position 4. The data also shows the train was not in a braking mode prior to the point of collision. The following are observations made during the on-scene phase of the investigation:

1. Line 34 (HZGX-150, Clip Car) of train UBRGCRI5-15 was the first car struck by the cab end of locomotive BNSF 9159.
2. The collision occurred at or about MP 448.3 on a 0.09% grade in 1° of curvature. HZGX-150 was ejected near the point of collision, from train UBRGCR15-15 to the north side of main track number two and caught fire.
3. As a result of the collision, HZGX-150 was folded roughly in half, between the first and second saddle assemblies[13], with the bottom of the car inside the fold and the end sills in close proximity to each other. See Exhibits 8, 9 and 10.
4. Line 33 (BNSF-927022, Flatcar featuring a Kershaw 'Scorpion Ramp' roll-up loading ramp) was the second car struck. See Exhibit 5.
5. The struck end of Line 33 overrode and came to rest atop of BNSF 9159 with the Scorpion ramp extended from engine hood slip joint to the rear of the car (Approximately 24'). See Exhibit 11.
6. Line 33 was partially bent lengthwise, top toward the bottom, 20 feet from the 'A' end of the car.
7. One bogie assembly from BNSF-927022 came to rest atop the shorthood assembly of BNSF 9159, positioned predominantly to the left side of the locomotive. See Exhibit 12.
8. The other bogie assembly from BNSF-927022, along with other identified wreckage, came to rest in front of BNSF 9159. See Exhibit 13.
9. Lines 32-29 were ejected from U-BRGCR15-15 to the north side of the main track number two in the area near the bridge. See Exhibit 14.
10. The west facing side of the bridge showed signs of recent damage. The damage appeared along the concrete face and the I-Beam directly above the centerline of main track number two. The overpass height was measured at 22' from the top of rail to the bottom of the I-Beam. (The measurement was completed after the track section was replaced) See Exhibits 15 and 16.
11. The east facing side of the overpass underframe I-Beam was deformed consistent with a west to east force directly above the centerline of main track number two. The I-Beam flange was partially sheared and rolled upward toward the overpass surface. See Exhibit 17.

[13] Saddle Assemblies are illustrated in Crashworthiness Exhibit 10.

12. Lines 26-28 (cars only) and 33 came to rest pitched against each other in an overriding fashion. Bogie assemblies were scattered along the north and south sides of the tracks.
13. The distance traveled by C-BTMCNM0-26 from the point of collision to the final resting position is estimated to be 690 feet.
14. Positioned in front of the snowplow of BNSF 9159 from east to west are:
    a. One powered axle assembly,
    b. One bogie frame,
    c. One axle with wheels attached
    d. A bogie assembly from BNSF 927022, Line 33.

    See Exhibit 18.
15. BNSF 9159 derailed both bogie assemblies however, the unit stayed upright.
16. Approximately 16 feet of the front end of BNSF 9159 was compromised as a result of the collision. See Exhibit 19.
17. The coupler assembly from locomotive BNSF 9159 was sheared off just aft of the knuckle. (The shear took place in an area known as the barrel) See Exhibit 20.
18. The shorthood and collision posts of locomotive BNSF 9159, normally positioned perpendicular to the deck, were pushed and deformed at an angle of approximately 35°-40° in the direction of the cab. See Exhibit 21.
19. The cab assembly was separated from the deck of the locomotive and the bottom half of the operating cab rotated up just over 90 degrees. The left rear corner was crushed inward toward the interior. The windshield area was pushed back relative to the platform, but rotated forward, relative to the lower portion of the cab. The roof moved forward, relative to the lower portion of the cab, and also rotated back somewhat more than 90 degrees, relative to the platform. See Exhibit 21.
20. The interior of the cab was severely damaged by fire apparently fed by fuel leaking down from damaged MOW equipment which overrode over the locomotive.
21. Recovery operations resulted in the removal of the cab from BNSF 9159 wherein recovery operations personnel used extrication equipment to access the victims.
22. The diesel fuel tank on BNSF 6133, the second locomotive in the striking train was compromised on the right rear corner of the sidewall / end plate and caught fire. See Exhibit 21A.

Post Accident Inspections

A Crashworthiness Working Group was formed on April 21, 2011. It should be noted this occurred during the closeout meeting of the on-scene phase this investigation. Representatives from the NTSB, FRA, BNSF, UTU and BLET were present at the accident site during the on-scene phase of the investigation however, not all the members of the Crashworthiness Working Group were present. EMD accepted party status after the data collection phase and were not present at the accident site.

Principals of the Crashworthiness Working Group inspected and examined locomotive BNSF 9159, HZGX-150 Clip Car and BNSF 927022 during the week of June 27th at BNSF's Havelock maintenance facilities in Havelock, NE. For this examination, the damaged equipment was removed from the accident site and transported to the facility in Havelock, NE. Thus an examination by the Working Group of the original at-rest state of the equipment after the accident was not completed.

With regard to the damage of BNSF 6133, this Investigation collected design documentation from GE to confirm their fuel tank was constructed to meet the requirements of AAR S-5506, revision 2001. Further, this Investigation also received confirmation of independent engineering analysis from GE that validated their design met the requirements associated with penetration resistance. Close examination of the damage showed the tank was compromised on the right rear corner of the sidewall approximately 12 inches from the bottom of the tank. The opening was elliptical in appearance with a major axis of approximately 2 inches.

It should be emphasized; the railroad equipment was relocated prior to evaluation by the Crashworthiness Working Group, wherein accordingly, no pre-recovery technical examination was performed on that equipment. In an effort to document the pre-recovery locations, and physical conditions (to a certain degree) of the disturbed equipment prior to relocation, the Investigation made use of several map graphics and photographs that were constructed in the Investigation.

Movement of the damaged equipment either during recovery or transport to Havelock shops resulted in alteration of its post accident condition. As a result, the exhibits examined for this Investigation contained replacement equipment that otherwise were damaged during the accident. One such example is the coupler assembly on BNSF 9159. A replacement unit was installed to facilitate movement from the accident location.

The Crashworthiness Working Group participants were able to conduct a full examination of the artifacts involved in the accident. As mentioned above, three artifacts were examined. They included locomotive BNSF 9159, HZGX-150 and BNSF 927022. In addition, locomotive BNSF 9293 was stationed adjacent to BNSF 9159 for reference purposes during the examination which is an SD70ACe manufactured from the same production order. (Identical to BNSF 9159) The results of this examination are detailed below.

Locomotive BNSF 9159

As a result of the rear end collision, the lead locomotive of train C-BTMCNM0-26, BNSF 9159, sustained extensive frontal damage. The locomotive was occupied by an engineer and conductor wherein the cab portion of the locomotive sustained a substantial loss of occupied space.

The post recovery examination efforts focused on the end plate, anti-climber, shorthood, collision posts, underframe, operating cab, electrical locker and fuel tank.

The location reference used for these examination results is defined such that the right side of the locomotive is understood to be the engineer's side or operating side, facing front, as one would when operating the unit.

End plate

The End Plate consists of a mild steel plate, 1 inch thick oriented in the perpendicular plane of the locomotive. The locomotive has two, each attached at the deck line on the ends of the unit. The front End Plate is positioned just behind the coupler and snowplow assembly. It measures approximately 8 feet 8 inches wide and 5 feet 2 inches tall.

The general condition of the End Plate indicates it was subjected to a severe longitudinal load. A gouge is visible above the coupler and an impression consistent with coupler impact was visible in the end plate below the anti-climber. See Exhibit 20.

The lower right portion of the End Plate was bent at its outboard edge approximately 23 inches in the longitudinal plane toward the rear of the locomotive. The right side of the plate has a 16 inch, primarily vertical, shear located 9½ inches from the draft pocket. See Exhibit 22.

The lower left portion of the End plate was bent at its outboard edge approximately 12 inches in the longitudinal plane toward the rear of the locomotive. The left side of the plate has a small shear located at the lower corner of the draft pocket.

Anti-Climber

The Anti-Climber is formed from a low alloy high tensile steel (LAHT) ½ inch thick plate consisting of a front apron and gussets. The front apron is a continuous 6 inch piece originating from the right front end sill of the locomotive, bent and formed to a circular arc, rejoining the left end sill. Four gussets at equal spacing are welded to the end sill and end plate joining the back portion of the apron to make up the web of this structure thus providing the strength requirements as detailed in AAR S-580. See Exhibit 23. Side plates are welded to the end sill and front apron for added strength.

The general condition of the Anti-Climber indicates it was subjected to a severe longitudinal load, crushing the structure inward and to the right toward the end sill. The right side of the apron was sheared at the first bend wherein the forward section buckled longitudinally inward. See Exhibit 23-A.

Gusset number one was bent inward and to the right toward the end sill at an angle of 43 degrees along its horizontal center and showed indications of heavy gouging. Wedged between gusset number one and gusset number two was a Brenco®[14] bearing end cap, model number AAR 5A, 6x11. See Exhibit 24. Gussets two and three were bent inward toward the end sill and to the right at an angle of 30 degrees along their horizontal center also showing signs of heavy gouging. The lower portion of gusset number three was torn near the joining point on the end plate.

Gusset number four showed signs of slight damage and was relatively intact. The left side of the apron was bent to the right at an angle of 12 degrees.

Shorthood

The Shorthood is a wedge shaped structure that is mounted on the forward deck of the locomotive in front of the cab. The structure contains an entryway into the engineer's cab with a reinforced door, located on the right side. It is constructed of structural plates designed to meet strength requirements in AAR S-580 that form the nose of the locomotive. The shorthood is 6 feet 3 inches tall, just below the window line of the Operating Cab, and 10 feet wide.

The general condition of the Shorthood indicated it was subjected to a severe longitudinal load resulting in deflection of the entire hood toward the rear of the locomotive. The doorway also showed indication of severe longitudinal loading resulting in separation of its frame thus, separating the Shorthood into a right and left half. Examination of post accident Investigation photos reveal the door was separated from its hinges and came to rest laying on top of the deck positioned in the compromised entryway. See Exhibit 25.

Measurements made during the examination show the right side of the Shorthood resulted in a 22 degree deflection to the rear of the locomotive as measured from the perpendicular reference plane on the outside of the locomotive. The lower right section of the Shorthood, where it is integrated with the right side Collision Post, was torn 28 inches along the longitudinal axis above the Centersill web. The right side front section had indications of an impact load 27 inches above the deck. See Exhibits 26, 27 and 30.

The left side of the Shorthood was measured and found to have deflected 42 degrees as measured from the perpendicular reference plane. The left side of the Shorthood had indications of an impact load 39 inches above the deck and the center of the Shorthood, just adjacent of the doorway, was bent inward toward the rear of the locomotive. See Exhibits 28 and 29.

[14] BRENCO® was founded in 1949 to manufacture bronze journal bearings for railroad freight cars. In 1959, Brenco® received conditional AAR approval for the product it is known for today throughout the worldwide railroad industry — the tapered roller bearing. (Source: www.amsteadrail.com)

Collision Posts

The Collision Posts, which are "the primary crash energy absorbing feature on a locomotive features on a locomotive involved in an in-line train-to-train collision or impact with a large motor vehicle"[15], are constructed of low alloy high tensile steel (LAHT) plate, extending vertically from the deck approximately 6 feet three inches in height (Equal to the height of the Shorthood). They are integrated into the Shorthood assembly, welded to the top plate, approximately 36 inches off the centerline on each side.

The general condition of the collision posts indicate they were subjected to a severe longitudinal load, wherein the left side deflected more than the right but, overall behaved similarly to the Shorthood. The collision posts were deflected rearward due to the bending of the top plate resulting in partial failure of the welds securing the top plate to the webs of the underframe.

The left Collision post showed signs of an impact 39 inches above the deck and was deflected rearward to an angle of 42 degrees and approximately 6 inches to the right side of the locomotive at its uppermost point. The right Collision post was deflected reward to an angle of 29 degrees and tore away 28 inches along the top plate above the Centersill web. See Exhibit 30.

Underframe

The underframe is a structural assembly fabricated from mild steel and low alloy high tensile steel (LAHT) that extends the length of the locomotive, upon which the diesel engine and alternator assemblies are mounted. It is assembled from two centersill webs, two top plates and a bottom plate.

The general condition of the underframe indicates it was subjected to a severe longitudinal load. The underframe was impacted and bent upward approximately 1.75 inches at its maximum as referenced from its original horizontal position. See Exhibit 31. The top plate separated from the side walls of the centersill webs at the weld a distance of approximately 52 inches on the right side and 31 inches on the left as referenced from the front sill. See Exhibit 32.

Operating Cab Attachment Fixtures

The rear Operating Cab attachment fixtures consist of two steel hollow cylindrical posts, approximately 10 inches in diameter welded to the deck. Welded atop these sections are square plates, or flanges, on which the rear section of the cab is bolted.

[15] Federal Register / Vol. 71, No. 124 / Wednesday, June 28, 2006 / Rules and Regulations, pp. 36906

The front Operating Cab attachment fixtures are integrated with the shorthood. The cab rests on two coil springs located behind the shorthood approximately 5 feet 10 inches from the top plate behind the shorthood. Adjustment cups at each spring are used to control clearance from cab to underframe and to equalize spring compression. Adjacent each spring are hydraulic shock absorbers designed to dampen vibrations.

Two brackets welded to the deck of the locomotive support the bottom side front attachment of the Operating Cab. These brackets are part of a pin joint design for the cab attachment. One inch diameter hardened steel pins pass through the wide (2 inch) holes in the deck mounted brackets.

Other fixtures include stinger assemblies or, oversized turnbuckles, and dampers. These additional fixtures limit the lateral motion of the Operating Cab assembly sitting atop the deck of the locomotive.

The general condition of the Operating Cab attachment fixtures indicate they were subjected to severe vertical loading and shear. The rear posts were broken along the circumference welds that hold the cylindrical posts to the deck. The forward mounted floor brackets had indications of deep scoring on the inboard sides in a manner consistent with vertical loading. See Exhibits 33 and 34. A hardened steel through pin was found sheared adjacent the area of the forward mounted floor bracket on the right side.

Operating Cab

The operating Cab is a modular self contained assembly that is mounted atop the deck of the locomotive. It measures approximately 9 feet 3 inches in height, 9 feet 6 inches in length and 10 feet wide, weighing about 10,000 lbs. The cab is bolted in place at its rear on two flanges welded on cylindrical posts which are welded to the top plate of the locomotive. The two Operating Cab rear mounting points are fitted with torsional bushings that establish a pivot point about the rear axis of the cab.

The front of the cab rests on two coil springs located behind the shorthood approximately 5 feet 10 inches from the top plate, or just below the window line on the front. Adjustment cups at each spring are used to control clearance from cab to underframe and to equalize spring compression. Adjacent each spring are hydraulic shock absorbers designed to dampen vibrations.

On the underside of the cab at its front are two double shear pin joints. This system includes two brackets welded to the top plate and two brackets welded to the underside of the cab floor. These joints are not an interference fit; in fact the one inch diameter hardened steel pin passes

through a wide (2 inch) hole in the deck mounted bracket. When questioned, EMD stated this design acted as a loosely coupled fastening system.

The general condition of the Operating Cab assembly indicated it was subjected to a severe upward lifting longitudinal load resulting in rotation toward the rear of the locomotive, shearing and separating from the front lower double shear pin joints and separating from the circumference welds that hold the cylindrical posts to the deck. The rear posts remained bolted to the cab. See Exhibit 35.

The cab was crushed at the rooftop in a manner consistent with rolling into a large fixed mass (Electrical Locker) and the forward facing window frame was folded forward over top of the cab in the same plane as the roof. The side walls remained intact to the point of the window line, which is approximately 4 feet from the roof. The underside was relatively intact and undamaged. The entire cab had extensive fire exposure and damage.

Recovery operations required fire department personnel to dismantle the wrecked equipment from the at rest position to gain access to the operating crew. As the wreckage was removed the cab was lifted off of the locomotive and placed on the ground at the south side of main track number two near the east side of the overpass. Additional operations were needed to access and remove the event recorder thus further disturbance of the cab was done.

The examination of the assembly conducted for this Investigation revealed an estimated remaining volume of survivable space was 65 cubic feet. Both the engineer's and conductor's side of the cab was severely damaged and burned. The engineer's seat was sheared from the floor mounts and the control panel was bent downward and inward. See Exhibit 36. The conductor's seat remained attached and the desk area was crushed toward the floor. See Exhibit 37.

A major impact area was identified on the front doorway frame of the Operating Cab. The frame was found to be split at the top right. The inner doorway, or vestibule, floor area had indications of severe loading and was bent rearward and upward. See Exhibits 38 and 39.

Examination of the cab door revealed the door was subjected to severe loading on the right side (hinged side) at the mid-point of the door. The door also showed signs of extensive fire exposure. See Exhibit 40.

Electrical Locker

The Electrical Locker is positioned just aft of the Operating Cab assembly. The locker houses the high voltage electrical inverter system and batteries for the locomotive. It measures 8 feet in length, 10 feet in width and is 9 feet 8 inches tall.

The general condition of the Electrical Locker indicated it was subjected to severe longitudinal loading and was crushed at the upper right side. The locker became separated from the floor mounting system and slid rearward 25½ inches. See Exhibit 40-A.

The damage was present more on the upper right side of the locker and the crush was measured to be 28 inches in the longitudinal direction. The left side crush was measured at 13 inches. See Exhibit 41.

The batteries were not compromised during the collision. The battery locker assembly remained intact. The exterior right side door has indications of impact however, the door remained attached.

Fuel Tank

The fuel tank is a 5000 gallon tank mounted to the underframe at the bottom plate. It is mounted approximately 23 feet from the front of the locomotive and spans a total of 24 feet. The tank was not compromised (No leaks). The left side had minor scraping along the sidewall and the sight gauge. The filler cap adaptor was broken off. The underside had minor dents near the filler cap. See Exhibit 42.

HZGX-150 Clip Car

BNSF 9159 struck HZGX-150 Clip Car at the end nearest its operating cab[16]. As a result of the collision, HZGX-150 was folded roughly in half, between the first and second saddle assemblies[17], with the bottom of the car inside the fold and the end sills in close proximity to each other. See Exhibits 8, 9 and 10. The bend occurred between the first and second saddle assemblies approximately 20 feet from the operating end of the unit and came to rest on its side near the point of impact.

For the post examination the Clip Car was in two pieces. The cars became separated as a result of the on scene recovery effort and transport to the Havelock shops. The diesel engine that is mounted on the rear deck on the Clip Car was not available for the post examination. The engine mounting threaded holes all showed signs of recent elongation and severe deformation. See Exhibit 43-A. The post examination effort focused on the end sill, draft gear and pocket, centersill, side sill and the powered wheel axle assembly. See Exhibit 43.

[16] For this assessment, this will be referred to as the front of the Clip Car.
[17] Saddle Assemblies are illustrated in Crashworthiness Exhibit 10.

End Sill

The End Sill consists of a mild steel cross members located at each end of the rectangular shaped car.

The End Sill and Draft Pocket of the struck end of HZGX-150 was subjected to a severe longitudinal load and pushed rearward 6 ½ inches and upward 15 inches. The hand brake mechanism was still attached to the stand with the chain connected. Examination of the wreckage showed the loading was more prominent at the center of the end sill. See Exhibit 44.

Draft Pocket

The Draft Pocket, located at each end of the car, is a receiver designed to hold the draft gear constructed of mild steel.

The draft Pocket was longitudinally loaded and pushed rearward. The pocket was spread apart approximately 6 inches but remained intact. The knuckle block was found jammed into the shank. See Exhibit 45.

Draft Gear

The draft gear is designed to absorb energy between railcars to prevent damage to the car or lading. The draft gear remained intact and was found in a compressed state. The lug castings were found in place. See Exhibit 46.

Centersill

The Centersill is a fabricated structural assembly that extends the length of the Clip Car, upon which the diesel engine, hoppers and control cab are mounted.

The centersill examination began at the front half of the car. The front half or the section forward of the body bolster[18] was buckled on the sides and bent upward 15 inches. The center sill was severed 11 feet 6 inches from the front of the Clip Car. [This was a result of recovery and/or transport] The centersill at this point was bent at a 90 degree angle toward the bottom of the car, 32 inches from the separation point. See Exhibit 47

The rear half of the center sill at the break point was bent and twisted downward and to the left for a distance of 11 feet. See Exhibit 48.

[18] Body bolster refers to the perpendicular frame structure that supports the bogie assembly. There are two body bolsters on this vehicle.

Three feet of the center sill at the rear of the Clip Car was crushed, twisted and buckled. See Exhibit 49.

Side Sill

The side sill consists of the right and left outboard frame assembly that make up the rectangular shaped car. They are constructed of mild steel. This unit's side sills rise up at unique angles to form the unique shape of this car.

The general condition of both right and left side sills indicate they were subjected to a compressive load that bent the sill in a downward direction. See Exhibit 50.

Saddle Assemblies

The Saddle assemblies are underframe structural beams forming U-shaped assemblies in the perpendicular plane that are welded and fastened with gussets to the side sill and centersill of the car. See Exhibit 10. Their primary function is to support the undercar equipment used to install the tie clips on the rails. On the Clip Car there are three saddles. Number one is referenced from the front end of the car.

Saddle assembly one and three were relatively undamaged. Assembly number two was intact but folded in the same manner as the side sill. See Exhibit 51.

Powered Wheel Axle Assembly

The HZGX-150 is a self propelled maintenance of way unit. The hydrostatically driven unit has one power driven axle set and has a 350 gallon fuel tank that was mounted atop the deck. See Exhibit 52.

The powered wheel axle assembly was examined and compared to the post accident Investigation photos in an undisturbed state. Through examination of photographs of the post accident condition, this Investigation concluded this powered axle assembly came to rest in front of BNSF 9159's snow plow[19]. See Exhibit 53.

BNSF 927022 Flat Car

BNSF 9159 struck BNSF 927022 Flat Car after HZGX-150 Clip Car was ejected from the struck train consist. As a result of the collision BNSF 927022 was struck on the A-End and

[19] The snow plow on BNSF 9159 was not available for this examination.

overrode BNSF 9159 coming to rest with the Scorpion ramp extended from engine hood slip joint to the rear of the car (Approximately 24'). See Exhibit 11. BNSF 927022 was partially bent lengthwise, top toward the bottom, 20 feet from the A-End of the car.

For the post examination BNSF 927022 was positioned upside down without bogie assemblies. The engine enclosure or the hydraulic fluid and diesel fuel tank enclosure was not available for the post examination.

The Scorpion Ramp was removed from BNSF 927022 during the recovery and transport operation. The Scorpion Ramp was also available for examination. The post examination effort focused on the end sill, draft gear, mechanical coupler, centersill, side sill and the Scorpion Ramp.

End Sill

The End Sill consists of a mild steel cross members located at each end of the rectangular shaped car. The End Sill of A-End was slightly bent and sheared in the area below the coupler. See Exhibit 54. The B-End Sill was bent inboard and torn. See Exhibit 55.

Draft Gear

The draft gear is designed to absorb energy between railcars to prevent damage to the car or lading. Both draft gears on BNSF 927022 were undamaged.

Mechanical Coupler

The mechanical coupler is designed to mechanically join train cars. The A-End coupler was intact relatively undamaged however the knuckle was missing. The B-End coupler was mildly damaged and the knuckle was missing.

Centersill

Centersill is a fabricated structural assembly that extends the length of the Flat Car. The A-End of the centersill was bent and scraped at point of 21 feet 2 inches from the End Sill at the gooseneck[20]. See Exhibits 56 and 57. The gooseneck transition point was missing a 24 inch section of the top plate.

The mid section of the centersill was relatively undamaged but did have indication of scraping and fire exposure. The fire exposure was located just aft of the A-End gooseneck between

[20] The gooseneck is a transition zone of the bottom plate underneath the centersill.

right side cross bearers 11 through 14. See Exhibits 58 through 61. The B-End of the centersill was relatively undamaged however; there was slight damage at the B-End body bolster.

In addition to the Centersill damage, there was extensive damage to the cross bearers on both the right and left side of the car. See Exhibits 62 and 63.

Side Sill

The Side Sill consists of the right and left outboard frame assembly that make up the rectangular shaped car. The A-End left and right sides were bent and buckled along the length of the car between cross bearers 11 through 15. See Exhibit 64. The B-End was bent inboard of on the right side a distance of 4 feet. See Exhibit 65.

Scorpion Ramp

The Scorpion Ramp consists of six segments tied together with pin joints and hydraulic rams. In its stored position, the ramp takes the shape of a square. When the ramp is fully open and extended it is 52 feet 8 inches long. See Exhibit 6.

For this examination the ramp was in two sections. Section one contained segments one through three and section two contained segments four through six. Section one was laying on the ground and section two was on a flat car. Segments were numbered one through six such that number one section is the segment attached to BNSF 927022 and number six the end segment, or the segment designed to rest on the rails; otherwise known as the bitter end. See Exhibit 66.

The ramp sections showed indications of fire exposure with many of the hydraulic rams being severely overloaded with their attaching points compromised. See Exhibit 67.

END OF FACTUAL REPORT

List of Exhibits

Exhibit 1	SD70ACe Locomotive Outline
Exhibit 2	AAR Manual of Recommended Practices, Standard S-580, Revision 2005, "Locomotive Crashworthiness Requirements"
Exhibit 3	AAR Manual of Recommended Practices, Standard S-5506, Revision 2001, "Performance Requirements for Locomotive Fuel Tanks"
Exhibit 4	HZGX Series Clip Car Manufactured by Herzog Railroad Services Inc.
Exhibit 5	BNSF 89 feet Flat Car with Kershaw Loading Ramp
Exhibit 6	Kershaw 'Scorpion' Loading Ramp
Exhibit 7	Train Performance Data from BNSF 6133, 2nd Locomotive in the Striking Train
Exhibit 8	Accident Layout
Exhibit 9	Photo Showing HZGX-150, Post Collision, on the North Side of Main Track Number Two
Exhibit 10	Photo Showing Saddle Fixture on HZGX Series Clip Car
Exhibit 11	Photo Showing BNSF 927022 Overriding BNSF 9159 with Loading Ramp Extended Overtop of Locomotive
Exhibit 12	Photo Showing Bogie Assembly from BNSF 927022 On Top of BNSF 9159's Shorthood
Exhibit 13	Photo Showing Bogie Assembly from BNSF 927022 in Front of BNSF 9159
Exhibit 14	Photo Showing Lines 32-29 Laying on Their Side on the North Side of Main Track Number Two
Exhibit 15	Photo Showing West Face of Overpass with Damage to Concrete Span and I-Beam above Centerline of Main Track Number Two
Exhibit 16	Photo Showing West Face of Overpass with Damage to Concrete Span and I-Beam above Centerline of Main Track Number Two
Exhibit 17	Photo Showing East Face of Overpass with Damage to the I-Beam
Exhibit 18	Photo of Wreckage Positioned in Front of BNSF 9159
Exhibit 19	Photo Showing Compromised Front End on Locomotive BNSF 9159
Exhibit 20	Photo Showing Sheared Coupler Assembly on Locomotive BNSF 9159
Exhibit 21	Photo Showing Shorthood Deflection and Cab Assembly Separation of BNSF 9159
Exhibit 21-A	Photo Showing Compromised Fuel Tank on BNSF 6133
Exhibit 22	Photo Showing Damage to the End Plate on BNSF 9159
Exhibit 23	Photo of Undamaged Anti-Climber Assembly on EMD SD70ACe Series Locomotive
Exhibit 23-A	Photo Showing General Condition of Damaged Anti-Climber of BNSF 9159
Exhibit 24	Photo Showing Right Side Damage to Anti-Climber Assembly of BNSF 9159
Exhibit 25	Photo Showing Damage to Shorthood and Separation of Doorframe (Door Laying on Top of Deck) BNSF 9159
Exhibit 26	Photo Showing Right Side Shorthood Deflection of BNSF 9159
Exhibit 27	Photo Showing Right Side Shorthood Impact Damage of BNSF 9159
Exhibit 28	Photo Showing Left Side Shorthood Deflection of BNSF 9159
Exhibit 29	Photo Showing left Side Shorthood Impact Damage of BNSF 9159
Exhibit 30	Photo Showing Right Side Collision Post Torn Away from Top Plate on BNSF 9159
Exhibit 31	Photo Showing Underframe Deflection on BNSF 9159
Exhibit 32	Photo Showing Left Side Underframe Separation from the Top Plate on BNSF 9159