National Transportation Safety Board
Office of Railroad, Pipeline and Hazardous Materials Investigations
Washington, D.C. 20594

Amtrak Passenger Train 89 Collision with Maintenance of Way Equipment

Chester, Pennsylvania - April 3, 2016

Mechanical Group Factual Report

Accident

NTSB Accident Number:	DCA16FR007
Date of Accident:	April 3, 2016
Time of Accident:	7:40 a.m. (EDT[1])
Type of Trains:	Amtrak Passenger Train 89
Railroad Owner:	Amtrak
Train Operator:	Amtrak
Fatalities:	2
Injuries:	30
Location of Accident:	Chester, PA

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[1] Eastern daylight time

Accident Summary

For a summary of the accident, refer to the *Accident Summary* report, within this docket.

Train Consist

Passenger train 89 consisted of one controlling locomotive and 8 passenger coaches, 1 café car, and 1 baggage car. The train weighed approximately 1,172,000 lbs. and was about 912 feet in length. The consist is shown in table 1.

Table 1-Train 89 consist

Sequence	**Car Type**	**Number**	**Capacity**
1	Locomotive	627	2 (+ 1 jump seat)
2	Business Coach	82993	72
3	Passenger Coach	82524	70
4	Passenger Coach	82781	72
5	Passenger Coach	25034	59
6	Passenger Coach	25040	59
7	Passenger Coach	25013	59
8	Passenger Coach	25088	59
9	Café Car	43364	0
10	Business Class Car	81543	62
11	Baggage Car	61028	0

Railroad Equipment Involved in the Derailment

The lead locomotive, 627, is an ACS-64 Siemens locomotive. The ACS-64 locomotive consists of a front and rear cab, joined in the center by the locomotive machinery room. The front and rear cabs are identical, unless otherwise noted. The locomotive unit measures 67 ft. (length), by 10 ft. (width), by 12.5 ft. (height), and weighs about 210,000 lbs.

The ACS-64 is powered by a network of 25 kVac (60 Hz), 12.5 kVac (60 Hz), and 12 kVac (25 Hz) supplies, depending upon locomotive location in the North East Corridor (NEC). These catenary power sources are accessed through the front and rear pantographs, mounted on roof panel number 1 and roof panel number 3. A tap changer switch on the transformer connects the windings for the proper input configuration. The power then goes through a series of electrical and electronic components contained in the traction converters to provide Variable Voltage Variable Frequency (VVVF) power to the traction motors and also power the Head End Power (HEP) 480 Vac three-phase system.

The ACS-64 features two sets of two-axle trucks, one each under the front and rear cabs. Each truck is powered by two transversely-mounted AC traction motors, each of which drives an axle by means of a dedicated gearbox. The four traction motors are classified as M1 or M2 for the leading and trailing axles of the F truck respectively, and M4 and M3 for the leading and trailing axles of the R truck respectively. Each of the traction motors produces 1480 kW (2,012 hp) of tractive effort for a total of 6400kW.

The operating cab features an engineer's console that contains all of the controls and indicators necessary for the operation and driving of the locomotive, including three full-screen monitors, designated as Train Operator Display (TOD) 1, 2, and 3 (F Cab) and TOD 4, 5 and 6 (R Cab). Also located in the operating cab are the windshield and wiper assembly, and the seats for the engineer and assistant engineer.

The ACS-64 is an integral wide-body, double-cab design, suited for push-pull operation. The car body is comprised of four major elements: underfloor, side walls, front and rear cabs, and three detachable roof sections (roof panel numbers 1, 2, and 3). It is designed to allow compression forces of 800,000 lb. (400 ton) of buff load and is equipped with an Association of American Railroads (AAR) F-type coupler with a push-back mechanism to achieve full anti-climber engagement. Crash energy management (CEM) systems are incorporated into the design of the ACS-64.

The locomotive engineer is protected by a safety cage comprised of different structural members such as side sill, collision posts, corner post, structural shelf, roof rail, top cross member, door posts and front sheathing. In front of the safety cage, crash boxes are designed to deform in a controlled manner to absorb collision energy. In case of an accident with another railroad vehicle the coupler pushes back and the anti-climber interlocks. The arrangement of anti-climber and coupler complies with current AAR S-580 section 6.1.

Lighting for the ACS-64 consists of an exterior and interior system. The exterior lights include headlights, marker lights, ditch lights, and step lights. The interior lights are made up of cab lights, machinery room lights, and console lights.

Monitoring of the locomotive is done with three separate networks of cameras: the left- and right- rear view cameras, the roof catenary monitoring system, and a forward facing camera. Images from the side view cameras are broadcast through the side-camera display unit, located on the right side of the engineer's console. Data collected by the catenary monitoring system and the forward facing camera via the Locomotive Digital Video Recorder (LDVR) is recorded and stored. The LDVR also includes a front-mounted microphone that picks up sounds in the direction of travel from the exterior of the locomotive. There are inward facing cameras -- the Locomotive Digital Recording System (LDRS) records video and audio of the control cab.

The Locomotive Cab Radio (LCR) is mounted on the engineer's console and allows the engineer several methods of communication, 'push to talk' or via handset. Cab speakers are located on the rear cab wall.

Amtrak passenger cars involved in the accident are designated as Amfleet I and II cars, built by the Budd Company (Philadelphia, PA) except for the baggage car. They were placed into regular mainline service on the Northeast Corridor on in 1975 (baggage car in 2015), they have served as the backbone of the Amtrak passenger rail car fleet. Ordered in three batches in 1973, 1974 and 1975, they were delivered continuously during 1975 through 1977. The first batch of cars cost $405,000 each but with change orders and escalation latter cars were at $558,425 each for a total contract value of $266M. Of the 492 Amfleet I cars delivered, 464 remain in service. They primarily serve the densely populated Northeast Corridor between Boston, New York and Washington on Regional branded trains. There were 150 Amfleet II cars delivered in 1982 – 145 cars remain in service.

The Amfleet car body structure, with the exception of the end underframe which is a High-strength low-alloy steel (HSLA), is constructed entirely of stainless steel. The exterior skin is formed in corrugations for strength and appearance. Only in the window areas are flat formed panels used. The stainless steel structure with curved sides is designed as a modified beam, using the roof and the floor as chord members, connected by the sides which carry the shear load. At the time they were built the car body's strength exceeded all applicable AAR and FRA requirements, including the full 800,000 lb. compression strength applied at the draft gear and lateral anti-climbers. Additionally to improve the strength of the cars, the end collision post assemblies were made stronger than AAR requirements of the day by designing these assemblies for an ultimate horizontal load of 300,000 lbs. applied 18" from the floor and at a 15 degree angle. The vertical end collision posts are constructed of stainless steel and are located on either side of the end door openings. They are fastened securely into a horizontal end plate at the top and are welded to LAHT steel stubs extending up from, and welded to the end underframe at the bottom.

Each passenger car is equipped with a 26-C Control Valve is a pneumatic device designed for use on passenger carrying rail vehicles in equipment arrangements where the air pressure does not exceed 150 psig. It functions to direct a flow of air under pressure into or exhausts air from the brake cylinder pipe, or directs a flow of air under pressure to an intermediate brake cylinder relay valve in response to changes in brake pipe pressure at the control valve itself.

The truck assemblies on the Amfleet I cars are Budd Pioneer type III, especially designed for this high-speed service. The Pioneer III truck is a fabricated, all welded, H-frame, single center pivot, articulated frame truck that uses inboard journal bearings and a lower yaw pivot. They use a combination steel-coil-and-air springs and ride on in-board bearings. The inside bearing design is extremely rigid and true at high speed. The side frames are rectangular tubes and fabricated in two matching halves. A triangular structure integral with each side frame, is terminated in a half bearing at the central pivot that is attached to the bolster. This arrangement provides independent pitch motion of the two side frames in that the wheels can negotiate cross level irregularities with satisfactory load equalization. The frame assembly supports a bolster through the center pivot. Amfleet II cars were built with similar Pioneer II truck systems.

The primary suspension is a unique arrangement that uses an unbounded rubber ring between the axle bearings and their housings. Dampers are not used. Rubber pads are also used between the truck side frames and the bolster side bearers. Both rubber sections also provide some degree of damping. The secondary suspension uses a series arrangement of coil and air springs. Four hydraulic shock absorbers are mounted; two on each end of the truck bolster and connected to the car body, to provide lateral and vertical damping. Additionally, two radius rods are mounted, one on each side of the truck and connected to the car body, to absorb acceleration and deceleration forces. The truck bolster, also serving as an air reservoir, supports the car body by means of two combination air spring and mechanical coil spring assemblies. In the event of failure of an air spring, the other air spring will deflate to prevent car lean, and the mechanical coil springs resiliently support the car. The car body rests on two combination air and coil springs which rest on the truck bolster. Laterally spaced anchor rods provide the longitudinal connection between the bolster and the car body. Secondary lateral and vertical dampers are situated in parallel with the coil/air spring unit. Each truck assembly contains two axles with four tread brake units and four inboard disc brake systems. The baggage cars are constructed of stainless steel meeting the 800,000 lb. crush requirements and are equipped with GSI double equalizer truck systems.

Wreckage

Preliminary equipment damage is estimated by Amtrak at $2.1M. The damage is summarized in table 2 below.

Disposition	Car Type	Number	Estimated damage
Damaged	Locomotive	627	$2.1 Mil
Damaged	Passenger Coach	82993	$350,000.00
Damaged	Passenger Coach	82524	$50,000.00
Damaged	Passenger Coach	82781	$10,000.00
Damaged	Café Car	43364	$1000.00

Table 2

Equipment Pre-Accident Inspection

Amtrak passenger train 89, which was train 89 upon departing New York Penn Station, originated in New York City, NY. The consist, equipped with locomotive 627, passed a Class I air brake test by qualified inspectors at 4:52 a.m. on April 03, 2016. While in New York City, locomotive 627 was inspected by a qualified mechanical person and passed all FRA required pre-departure tests. Supporting documents are included as attachments.

On its trip to Savannah, GA the train made scheduled station stops at Newark, NJ; Metro Park, NJ; New Brunswick, NJ; Princeton, NJ, Trenton, NJ; and Philadelphia, PA with no reported problems by the train crew with the brake system.

Equipment Post Accident Inspections

NTSB investigators formed a mechanical group of qualified inspectors to evaluate the mechanical condition of the equipment involved in this derailment.

Investigators assembled at the Amtrak 30th Street Station, Philadelphia Pa. The complete consist was towed to the 30th street station coach yard for inspection. Investigators documented all post-accident damage. Locomotive 627 had extensive front or F end damage and testing could not be completed from the F end. The engineer screens would not power up due to collision damage. Brake tests were conducted using the R or rear end. A class 1 brake test was performed by a Carman under the observation of NTSB and FRA. A leakage test was conducted prior to initiating the test and the train had no leakage. The train was walked on both sides and confirmed the application and release of tread brakes (TBU) and the inboard disc brakes. The locomotive suffered extensive front end damage during the collision. The following list describes all post-accident damage to the consist.

Consist list

Locomotive # 627 ACS64	Extensive front end damage
(1) 82993 Quiet car	Right side damage to outer shell #3, #4, #9 windows
	A/L corner post and vertical handhold
	Damage to interior portion of car.
(2) 82524 Am Fleet 1 Coach	HVAC rack
	480 volt electrical cabinet
	Left rear step
	# 3 Left side window
	Left side Main reservoir drain handle
(3) 82781 Am fleet 1 coach	480 volt electric cabinet
	HVAC rack
(4) 25034 Am fleet 2 coach	No damage
(5) 25040 Am fleet 2 coach	No damage

(6) 25013 Am fleet 2 coach No damage

(7) 25088 Am fleet 2 coach No damage

(8) 43364 Café car Left rear step and corner post

(9) 81543 Business class car No damage

(10) 61028 Baggage car No damage

The event recorder download was performed post-accident and it appeared that the event recorder lost power at the time of the collision and no data was stored after the actual strike with the backhoe. Siemens representatives met with the group at the 30th street station in Philadelphia in an attempt to determine a cause for the failure. Research by Siemens to find a fix is on-going. The event recorder download is included in the file as an attachment.

A post-accident test of the horn, bell, and lights was conducted from the F end of the locomotive and the results are as follows:

The horn was fully functional.

The bell was fully functional even though the bell on the F end was missing the bottom sound diffuser portion due to the collision.

The top mounted headlamps were both fully functional.

The red marker lamps were both fully functional.

The auxiliary or ditch lights were not operational.

The Locomotive #627 was placed on the pit at Race Street and the underside was inspected by the team. Damage to the traction motors could be observed and it appears that the damage was caused by the rail and traction motor interference when the locomotive derailed. It also appears debris from striking the backhoe travelled under the locomotive causing damage. Several pieces of the backhoe were located within the coupler pocket area. The transformer over pressure device was activated.

Investigators observed all wheels on the equipment had full flanges and normal wheel tread wear. All cars showed no evidence of wheel flats, or flat marks on the wheel's tread. All brake rigging appeared normal and all brake pads and discs were within their tolerance.

Each Amtrak passenger car is equipped with low level floor emergency lighting. The Amfleet DC system consists of a combination Low Voltage Power Supply (LVPS)/Battery Charger and a set of nickel-cadmium batteries (50 cells in series) with a nominal voltage of 64Vdc. When the LVPS is powered on from the 480Vac system, the voltage is raised to 74Vdc. The output is divided into 2 parts: the primary voltage bus and the load shed bus (secondary voltage bus).

When an Amfleet car loses power from the 480 Volt systems, the LVPS also loses power, and the only voltage source left is the battery bank. Upon loss of 480 Volt power, the Emergency Relay de-energizes, and the emergency lights are activated. The EM Relay is located in the Amfleet Electric Locker on the left-center wall. The function of the EM Relay can be seen on Schematic diagram.

In order to extend battery life as long as possible, a load shed circuit driven by battery voltage, de-energizes when the battery voltage drops below a threshold of 56Vdc. When that occurs, a load shed relay disconnects the secondary bus, with all non-essential loads, from the batteries leaving only the emergency devices on the primary voltage bus.

Battery capacity must be sufficient to provide emergency lighting and PA functions for a period of 90 minutes upon loss of 480 Volt power as defined by 49 CFR 238.

In addition to emergency lighting, the FRA has mandated a Low-Level Exit Path Markings (LLEPM) system. Amfleet coach cars have an active (powered) LLEPM system that operates from the 72Vdc primary voltage bus. It consists of a small power supply that converts the 72Vdc from the vehicle, to a 12Vdc output that operates an LED strip on the floor. Light energy from the LEDs is absorbed by a photo luminescent strip, which will 'glow in the dark', for a period of up to 60 minutes to provide additional lighting during extreme emergencies when battery voltage is depleted. The Amfleet café car employs a strictly passive system that consists of a series of photo luminescent strips along the length of the center aisle attached to the sides of the seating and the walls. The photo luminescent strips will operate in a similar fashion to the active system when emergency lighting is exhausted.

The team met with representatives from Siemens to discuss follows up testing on locomotive 627. Investigators wanted to confirm proper operation of the following systems:

Friction brake
Event recorder
Propulsion
Alerter

Friction Brake

The CCBII Passenger Brake System, hereafter referred to as CCBII-P, is a network-based, electro-pneumatic air brake system designed for AAR compliant main line freight and passenger locomotives and cab cars. The CCBII Passenger Brake System utilizes a Line-Replaceable Unit (LRU) design approach based on a distributed architecture. Several LRU modules contain embedded self-diagnostic capabilities. CCBII Passenger Brake System diagnostic fault codes are reported to the operator on the EBVs LCD display screen. The three digit fault codes will be displayed as part of an air brake crew message. Fault codes are displayed at the end of a crew message.

CCBII Passenger Brake System is capable of running a PTU based self-test for the CCBII Passenger Brake System. The CCBII Passenger Brake System Self-test failure codes that are reported to the operator in the Portable Test Unit (PTU) Tool on the Laptop computer can be found in New York Air Brake's IP document. The four digit failure codes may be seen on the laptop's Self-test Display Screen in the "Last Self-Test Failure" drop down box. NYAB's IP document describes each of the failure codes and its corrective action.

Propulsion System

The locomotive is equipped with a traction system that applies tractive force based on the master controller handle and the drives' individual tractive capability. The following main components are contributing to generate the traction needed to move the locomotive.

<u>Master controller driving/braking:</u>

Driving position is used for the generation of traction set values. The own loco's internal set value is generated notch-free and linearly from the handle position (0 – 100 %).

<u>Central Control Unit (CCU):</u>

Reads the master controller handle position and generates an according traction set value. Receives the actual tractive force and available tractive force from the TCU and controls the set value accordingly.

A resulting traction set value (processed and limited) in kN for each axle is transmitted to the Traction Control Unit (TCU).

The locomotive traction set value, binary coded to a corresponding notched handle position (idle, 1 thru 8), is transmitted via train line to any trailing locos or cab car. The train line values are not used to generate traction when the train is configured as a lead locomotive such as it was during the derailment. If it is configured as a push pull or double header configuration, the train line values would be used for traction.

Traction Control Unit (TCU):

Generates the torque force set value from the CCU's traction set values. Monitors the motors and inverters and regulates the tractive capacity. Reports each axle's actual and available tractive force to the CCU. See figure 3.

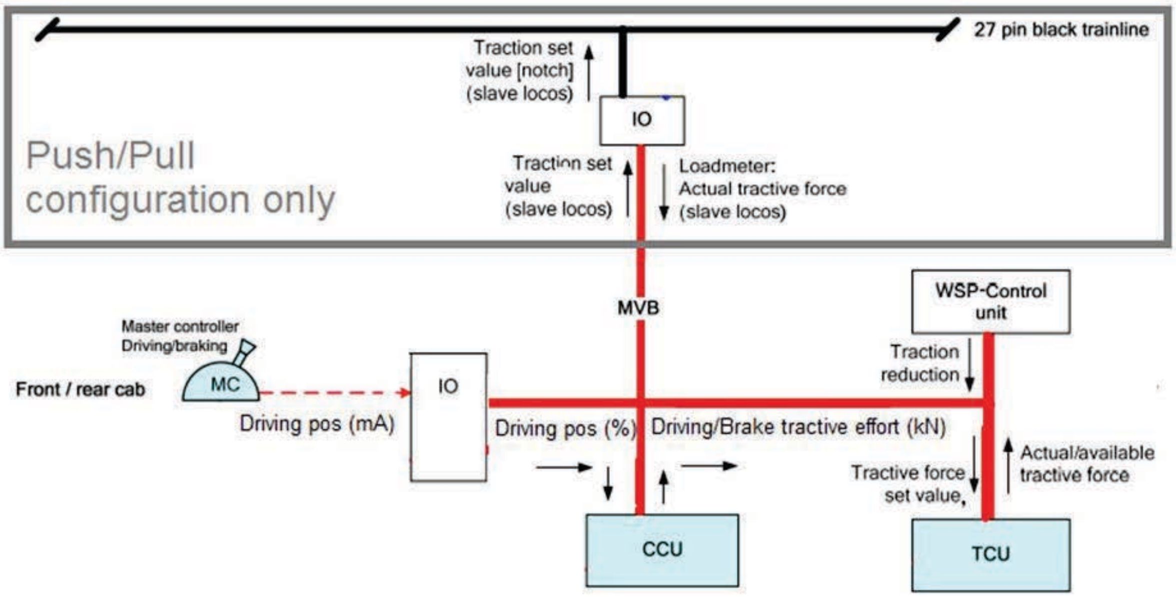

Figure 1-ACS64 Traction control principle

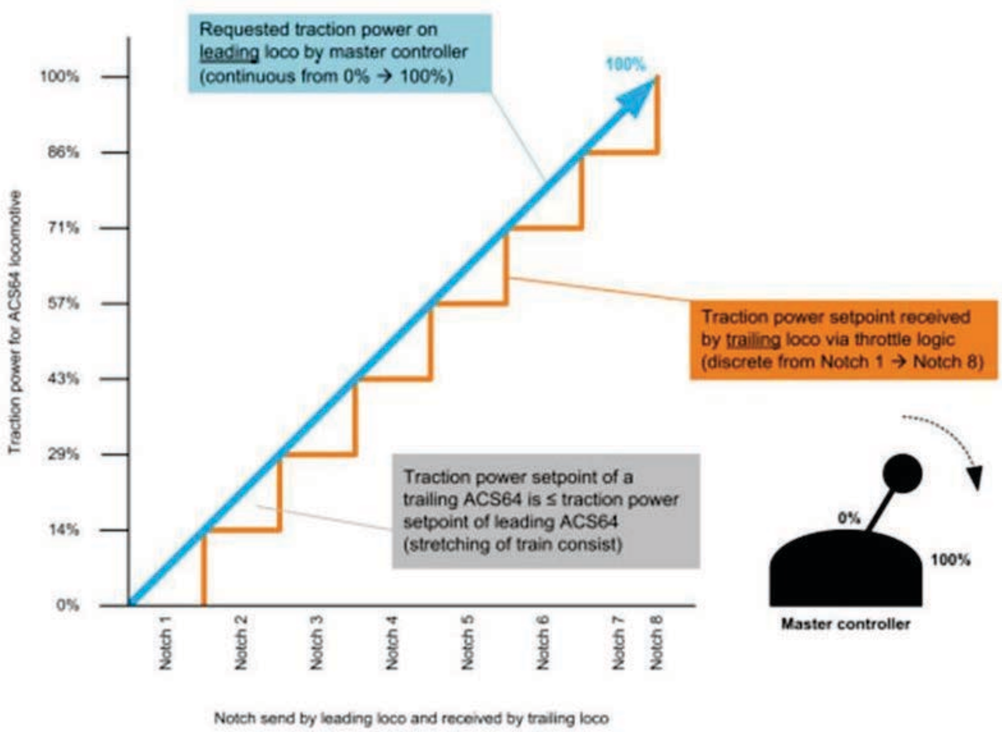

Figure 2-ACS-64 master controller relationship between tractive efforts

The diagram above depicts the relation between the requested tractive effort of the master controller in the lead locomotive (read by CCU as a percentage value) and its representation (not used for traction/braking in single locomotive leading a consist) into notches on the MU black train lines for push/pull configuration trailing vehicles only. Those notches are also recorded in the event recorder of the locomotive and depict a translated (from actual percent to notches binary states) representation of the state of the master controller.

Cab Signal & Advanced Civil Speed Enforcement System

The ACS-64 locomotive is equipped with an automatic train control (ATC) system. The system is a combined 9-Aspect ATC and Advanced Civil Speed Enforcement System (ACSES) configuration that ensures safe operation of the locomotive.

The ATC portion of the system includes Automatic Speed Control (ASC) and Automatic Train Supervision (ATS) capabilities. The ASC feature protects the locomotive from exceeding speed limits established by track signals. The ATS feature ensures that the locomotive engineer recognizes and acknowledges track signal (aspect) downgrades.

The ACSES portion of the system includes civil speed enforcement and Positive Train Stop (PTS) enforcement capabilities. The civil speed enforcement feature of ACSES protects the locomotive from exceeding civil speed limits. Civil speed limits are established by the presence of permanent and temporary wayside transponders. The PTS enforcement feature ensures that the locomotive stops at home signals when an absolute stop aspect is present.

Daily ATC and ACSES departure tests are required by the Federal Railroad Administration (FRA) no later than every 24-hours. Each test must be conducted or verified by the locomotive engineer prior to the day's initial service run.[2] The departure tests are a sequence of functions that verify the operational integrity of the equipment. Any identified equipment malfunction must be corrected prior to the locomotive's service run.

Departure test prerequisites are:

- Locomotive is stopped or at velocity zero (VZ),
- Either the F Cab or the R Cab is active,
- Independent Brake is applied (ATC departure test only),
- Permanent Suppression is released,
- ATC Restricted aspect is present,
- ATC is cut-in,
- ACSES is cut-in (ACSES departure test only) and;
- Electronic Brake System (EBS) magnet valve cut-out cock is engaged.

The following steps detail the procedures for conducting the ATC departure test.

[2] This can be verified by review of Amtrak form MAP-100, Maintenance Analysis Program Equipment Condition Report.

- Select the ATC Test soft key on the Engineer's Display Screen. All ATC-related ADU indicators illuminate for 5 seconds, and then the test automatically proceeds to the next step.
- With no signal (0 Code, 0 Hz carrier); simulate a restricted aspect (20 mph). Increase speed to 23 mph. Observe alarm.
- With a high-level signal (Single 75 Code, 100 Hz carrier); simulate an Approach aspect (30 mph). Increase speed to 33 mph. Observe alarm.
- With a high-level signal (Dual 75 Code, 100/250 Hz carrier); simulate an Approach Medium aspect (30 mph). Increase speed to 33 mph. Observe alarm.
- With a high-level signal (Single 120 Code, 100 Hz carrier); simulate an Approach Medium aspect (45 mph). Increase speed to 47 mph. Observe alarm.
- With a high-level signal (Single 270 Code, 100 Hz carrier); simulate a Cab Speed 60 aspect (60 mph). Increase speed to 63 mph. Observe alarm.
- With a high-level signal (Dual 120 Code, 100/250 Hz carrier); simulate a Cab Speed 80 aspect (80 mph). Increase speed to 83 mph. Observe alarm.
- With a high-level signal (Dual 270 Code, 100/250 Hz carrier); simulate a Clear 100 aspect (100 mph). Increase speed to 103 mph. Observe alarm.
- With a high-level signal (Single 180 Code, 100 Hz carrier); simulate a Clear 125 aspect (125 mph). Increase speed to 128 mph. Observe alarm.
- With a high-level signal (Dual 180 Code, 100/250 Hz carrier); simulate a Clear 150 aspect (150 mph). Increase speed to 153 mph. Observe alarm.
- Place brake handle in suppression (SUPP) position. Test will continue once brakes are recovered.
- With a high-level signal (Single 180 Code, 100 Hz carrier), simulate a Clear 125 aspect. Observe alarm and acknowledge downgrade.
- With a high-level signal (Dual 270 Code, 100/250 Hz carrier), simulate a Clear 100 aspect. Observe alarm and acknowledge downgrade.
- With a high-level signal (Dual 120 Code, 100/250 Hz carrier); simulate a Cab Speed 80 aspect. Observe alarm and acknowledge downgrade.
- With a high-level signal (Single 270 Code, 100 Hz carrier); simulate a Cab Speed 60 aspect. Observe alarm and acknowledge downgrade.
- With a high-level signal (Single 120 Code, 100 Hz carrier), simulate an Approach Medium aspect. Observe alarm and acknowledge downgrade.
- With a high-level signal (Dual 75 Code, 100/250 Hz carrier), simulate an Approach Medium aspect. Observe alarm and acknowledge downgrade.
- With a high-level signal (Single 75 Code, 100 Hz carrier), simulate an Approach aspect. Observe alarm and acknowledge downgrade.

The team collected data from the following systems:

- TCUs,
- CCU,
- Event recorder data from follow up tests.

- RDA data

Documentation & Data Collected[3]

ACS-64 Locomotive Technical Manuals	Locomotive Daily Inspection Report (MAP-100)
ACS-64 Locomotive inspection procedures	Locomotive Maintenance History
ACS-64 Locomotive Daily, 92, 184 and annual inspection procedures	Expert Downloads (CCU data)
As Delivered Budd Car Drawings	Consist and Weight Report
Pioneer Car Arrangement Drawings	LDSL baggage car documentation
Passenger Car Overhaul Reports	
Passenger car periodic maintenance reports	
Class I Inspections prior to 89 April 3, 2016	
Wheel drawings; passenger cars and locomotives	
Passenger car calendar day inspection	

End of Report

[3] This list in not all inclusive