Issued: November 10, 2021 Railroad Accident Brief: RAB-21/08

Southeastern Pennsylvania Transportation Authority Light Rail Vehicle Collision

Upper Darby, PA
August 22, 2017

1. Factual Information

1.1 The Accident

On August 22, 2017, about 12:11 a.m. local time, a southbound Southeastern Pennsylvania Transportation Authority (SEPTA) single light-rail passenger car (car 155) carrying 42 passengers on the Norristown High Speed Line (NHSL) collided with another SEPTA single light-rail passenger car (car 148), which was unoccupied and stopped at passenger platform 1 of the 69th Street Transportation Center station (69th Street station) in Upper Darby, Pennsylvania.[1] The 43 persons on board car 155, including the operator, suffered non-life-threatening injuries and were transported to local medical facilities. Both cars remained on the rails and upright. (See figure 1.) SEPTA estimated the damage to the equipment to be $331,680. The weather at the time of the accident was 79°F with light rain.

[1] (a) All times in this report are local time unless otherwise indicated. (b) Visit ntsb.gov to find additional information in the public docket for this NTSB accident investigation (case number DCA17FR012). Use the CAROL Query to search safety recommendations and investigations. (c) Federal Transit Administration provides federal regulatory oversight and Pennsylvania Department of Transportation provides state safety oversight of SEPTA's rail transit division.

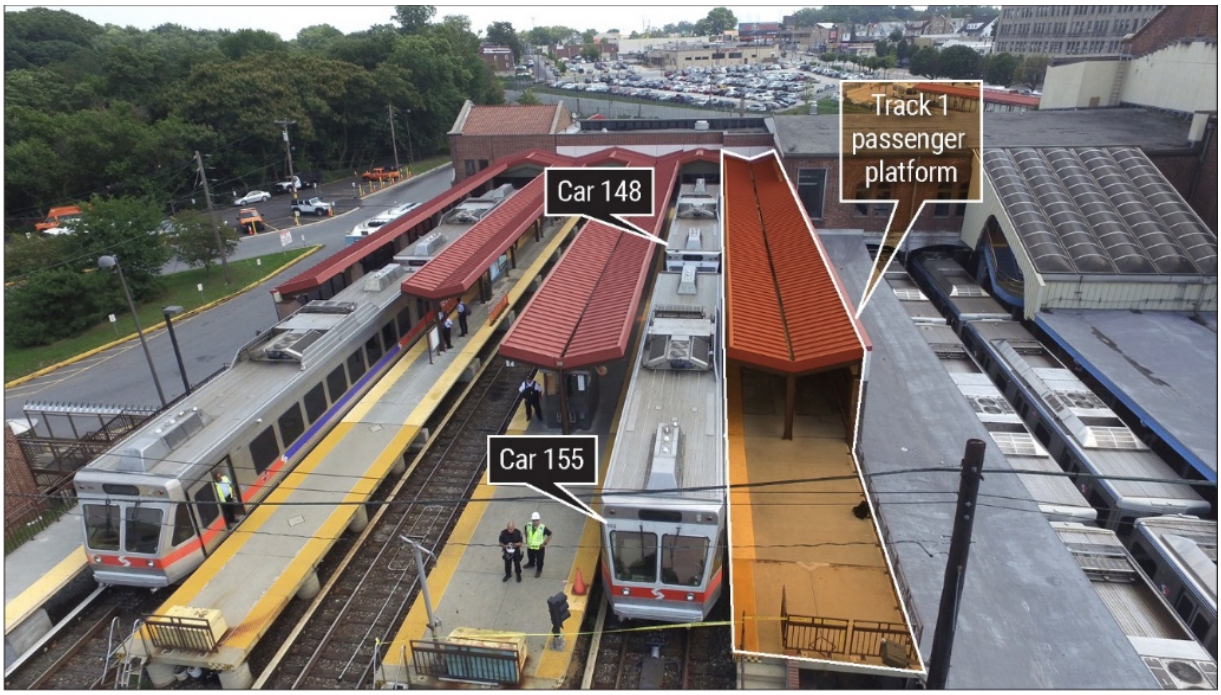

Figure 1. Aerial view of accident location looking southeast on the morning after the collision. (Source: SEPTA)

The NHSL is a grade-separated, transit line operating mostly with single cars on two main tracks in a north-south direction. Passenger service is provided at 22 stations between the Norristown Transportation Center (northern terminal) in Norristown, Pennsylvania, and the 69th Street Transportation Center (southern terminal) in Upper Darby.

About 11:32 p.m., car 155 departed southbound from Norristown station on the accident trip. The car's event recorder documented occasional wheel spins while accelerating and wheel slides while decelerating. There was a marked increase in both wheel spins and slides during the final accident movement between Township Line Road and 69th Street stations.

At 12:10:26 a.m., after departing Township Line Road station, car 155 reached signal 2S, the first of three wayside signals, along the approach into the 69th Street station. (See figure 2.) Car 155 passed signal 2S traveling at 53 mph even though the onboard cab signal indicated a maximum allowable speed of 30 mph.[2] The operator

[2] The *cab signal system* indicates the local speed limit, which is displayed in the speedometer/cab signal display unit located on the operator's control console.

applied service braking, but car speed did not decrease as expected.[3] The operator then applied maximum service braking, decreasing car speed to 51 mph. About 1,800 feet from the collision, the operator applied the car's emergency brakes.

At 12:10:49 a.m., car 155 passed signal 4S at 48 mph while the onboard cab signal indicated a maximum allowable speed of 15 mph. At 12:10:59 a.m., car 155 passed signal 6S at 29 mph as the onboard cab signal indicated a maximum allowable speed of 0 mph. At 12:11:21 a.m., traveling at 23 mph, car 155 struck the rear of car 148 on station track 1.

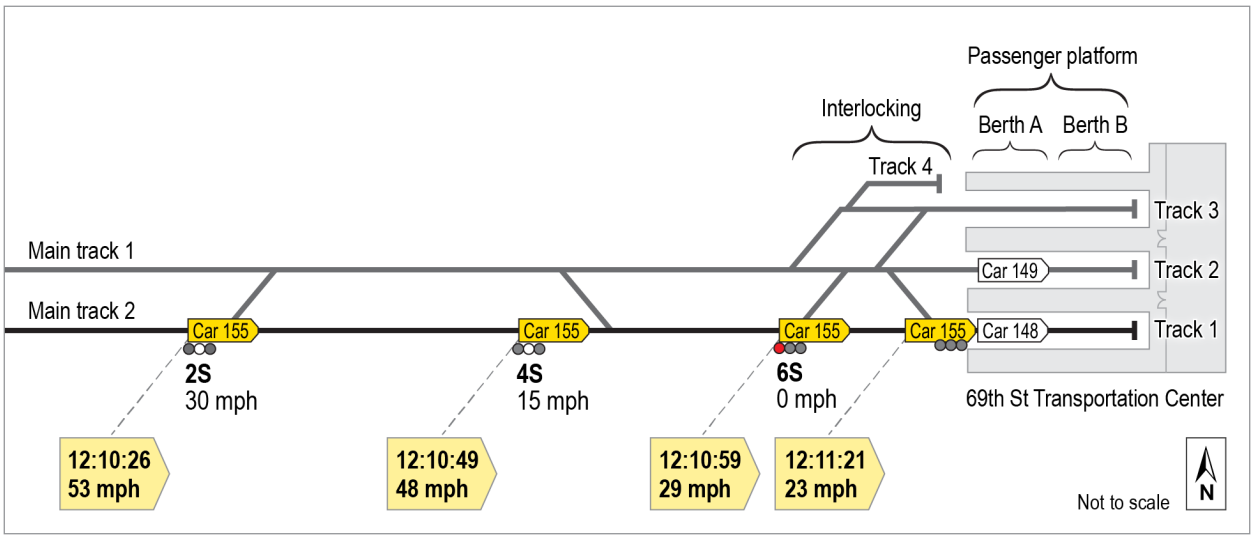

Figure 2. Diagram of car 155's approach to the 69th Street Transportation Center.

[3] (a) The automatic train control system did not initiate a penalty brake application, indicating this was a timely and adequate braking request. (b) The *automatic train control system* comprises the wayside and cab signal systems to maintain a safe distance between cars, prevent speeding over authorized limits, and enforce stop signals.

Figure 3. Postaccident collision damage to car 155.

Car 155 sustained exterior damage on the striking end of the coupler and front bulkhead panel and adjacent sidewall structure.[4] (See figure 3.) On car 148's exterior, the struck end coupler, front bulkhead, and adjacent sidewall structure were damaged. The collision damage on both cars did not extend into the interior occupant space; only localized minor frame buckling was found. In addition, minor floor panel buckling, a broken door panel window, wall and ceiling panel cracks, dislodged seat cushions, and a misaligned door panel were noted on each car.

1.2 Before the Accident

The operator of car 155 went on duty at 2:22 p.m. and was scheduled to operate car 155 between Norristown and 69th Street terminals. He told National Transportation Safety Board (NTSB) investigators that he felt very alert at the start of his shift. Before departing on his first trip, the operator completed required tests on the brakes, the cab signal system, and the speedometer; he did not report any problems with the car. He made eight roundtrips that day before the accident trip. He described these trips as "nothing out of the ordinary" to NTSB investigators.

Cars 148 and 149 had arrived at the 69th Street station terminal at 11:33 p.m. and 11:52 p.m., respectively, and were stopped at the passenger platform tracks as car 155 approached.

1.3 Meteorological Information

During the time of the accident, National Weather Service data indicated scattered clouds with a 10-mile visibility.[5] The temperature was 79°F with periods of precipitation over the NHSL. Heavy rain fell over the southern half of the NHSL for about 30 minutes, transitioning around midnight to light rain. Event recorder and meteorological data showed that car 155 operated southbound in light rain during the

[4] (a) A *coupler* is a metal device used to connect one car to another. (b) The ends of the car are designated as the *A-end* and the *B-end*.

[5] Weather observations were provided from the closest National Weather Service reporting location at Philadelphia International Airport, about 5.5 miles south of the accident site.

accident trip between Gulph Mills and 69th Street stations. The light rain ended about 4 minutes after the collision.

1.4 Equipment

The passenger equipment that operates on the NHSL consists entirely of the N-5, interurban-type car. The fleet comprises 26 cars, numbered 130 to 155, that were designed and manufactured by ASEA Brown Boveri/Bombardier Transportation in the early 1990s.[6]

The N-5 car prioritizes dynamic braking for all service brake settings at speeds above 3 mph and friction (pneumatic disc) braking for emergency braking and speeds below 3 mph.[7] The system can use blended (dynamic and friction) braking to achieve the requested deceleration for both service and emergency braking.[8] Once emergency braking is applied, it remains in effect until the car comes to a stop.

The wheel spin/slide protection system is designed to control tractive or braking effort on a per truck (A-truck or B-truck) basis to improve performance and prevent wheel spins or slides under all power, service brake, and emergency brake configurations.[9] The car sanding system enhances wheel-rail adhesion by automatically dispensing sand when a wheel spin or slide is detected.

In preparation for N-5 car operations, SEPTA determined that a minimum deceleration capability of 1.6 miles per hour per second (mph/s) would allow operators to stop the car across a range of passenger loading, speed, track grade, and weather conditions.[10] SEPTA used the 1.6 mph/s deceleration to design its signal block system, the authorized speed codes, and the service schedule on the NHSL.

SEPTA tested the N-5 car wheel spin/slide protection system in September 1993 using maximum service braking in natural low-adhesion conditions (excluding rainfall) on

[6] In 2001, ASEA Brown Boveri's (ABB) rail engineering unit merged with Bombardier Transportation.

[7] *Dynamic braking* is a method of slowing the train by using the traction motors as generators to convert vehicle momentum to electric current. The current generated by the motors is dissipated through fan-cooled grids. *Friction brakes* consist of discs and brake pads mounted on each axle of each truck. A *truck* is the frame assembly under the cars that contain the axles, wheels, suspension, and traction motors.

[8] The master controller on the operator's control console can be shifted into 13 positions: from P1 to P4 to accelerate (level 4 represents the highest power), COAST for neutral, from B1 to B7 to brake (level 7 represents the highest braking rate), and EM to apply the emergency brakes.

[9] Minimizing wheel spins/slides improves car acceleration/braking and reduces wheel tread damage.

[10] This braking rate reflects a safety margin of 20 percent (an industry standard) relative to demonstrated deceleration of 2.0 mph/s for a B5 brake application on dry rail with two operative trucks.

the NHSL.[11] Testing verified that the system functioned as designed but test results also demonstrated an average deceleration of 0.88 mph/s, about half the deceleration SEPTA assumed in the design of the NHSL system.[12] Two years later, the car manufacturer's failure mode and effects analysis of the wheel spin/slide protection system identified more than one failure mode (software, hardware, electrical, or mechanical) on the car that could result in a 50 percent loss of braking effort.[13]

In a separate 1995 report, the car manufacturer recommended that SEPTA operators be trained to use the parking brake during emergency situations when service brake and emergency brake cannot safely slow or stop the car. The car manufacturer also recommended that SEPTA equip cars with placards to remind operators that the parking brake can be used for emergency stops.[14] At the time of the accident, the N-5 car fleet was not equipped with the recommended parking brake emergency use placards.

1.5 Car Performance

Performance data from car 155 showed that on August 18, 2017, 4 days before the accident, when traveling southbound between Township Line Road and 69th Street station in similar weather conditions as the accident day, the operator made two service brake requests and car 155 decelerated at 2.2 mph/s, consistent with expected performance. However, immediately afterward, car 155 exhibited substantially degraded deceleration performance accompanied by 21 wheel slide indications. The average car deceleration during this period dropped to 0.42 mph/s. On departure from 69th Street station on the northbound trip, car 155 again demonstrated expected performance, accelerating at 2.1 mph/s and decelerating at 2.2 mph/s.

Performance data from car 155 showed that on August 22, 2017, during the accident trip while approaching the stop at Gulph Mills station (coincident with the arrival of the leading edge of a precipitation front), the operator of car 155 experienced two wheel slides when he applied the brakes on a descending grade, first with maximum service braking and then with emergency braking. Car 155 slid past the Gulph Mills station by two car-lengths (130 feet). After this and for most of the remainder of the trip, he operated the car at less than the maximum authorized speed, experiencing

[11] Low (or poor) adhesion was attributed to leaves combined with humidity, rendering the rails slippery. No sand was applied to the rail because the test car was not equipped with a sanding system.

[12] ASEA Brown Boveri, *Technical Specification,* "Spin/Slide Test Procedure for Norristown High Speed Line N-5 Cars," Section 1.6.3.3, November 24, 1993 (Vasteras, Sweden: ASEA Brown Boveri, 1993).

[13] ASEA Brown Boveri, *SEPTA NHSL: Failure Mode and Effects Analysis for the Slide Protection System*. TR-RT9508, August 30, 1995 (Vasteras, Sweden: ASEA Brown Boveri, 1995).

[14] ASEA Brown Boveri, *SEPTA NHSL: Safety Analysis of the Brake System*. TR-RT9502, (Vasteras, Sweden: ASEA Brown Boveri, 1995).

infrequent wheel slips and slides north of Township Line Road station. During this period, car 155 was repeatedly able to accelerate to and decelerate from 55 mph on wet rail, as expected, on both ascending and descending grades.

After car 155 departed Township Line Road station, performance data showed 17 wheel spins within a 95-second interval when accelerating. Performance data further showed car 155 responded as expected to a service brake request on the 0.5-percent descending grade, with no wheel slide indications, before entering the steeper 2.5-percent descending grade. At signal 2S, traveling at 53 mph, the operator applied service brakes; however, car speed continued to increase to 55 mph. The operator then applied maximum service brakes, which reduced the car speed to 51 mph.

Near signal 4S, the operator applied the emergency brakes, but car deceleration did not improve. Car 155 continued through the stop signal at signal 6S and struck car 148 at the station platform. Performance data showed ten wheel slides during the 45 seconds before the accident.

Based on NTSB's calculations, car 155 needed to decelerate about 1.1 mph/s to stop without collision when the emergency brake was applied. Data from car 155's event recorder indicated the average deceleration for the car, beginning near signal 4S after emergency brake application, was 0.83 mph/s. This deceleration is comparable to the average deceleration of 0.88 mph/s demonstrated during SEPTA's 1993 testing. However, unlike the N-5 test car used in 1993, car 155 was equipped with a car sanding system to improve wheel/rail adhesion response to wheel spin or slide events.

NTSB evaluated car 149's performance as it traveled directly through heavy rain on the accident track about 17 minutes before car 155 departed Township Line Road station. The operator of car 149 indicated he did not experience any acceleration or deceleration problems during his southbound trip, and car 149 was able to make a full stop prior to signal 6S and at 69th Street station.

On departing 69th Street station northbound on the adjacent main track about 12 minutes after the accident, performance data showed that car 149 accelerated and decelerated at near dry rail performance levels, indicating adequate wheel/rail adhesion in wet rail conditions like the car 155 accident movement.

1.6 Wheel/Rail Adhesion

The NTSB found no evidence of contamination sources that could have negatively affected the adhesion between the steel wheels and rails from the Township Line Road

to 69th Street stations.[15] At the time of the accident, no wheel or track lubrication system was installed anywhere along the NHSL.

According to technical studies and research publications examining wheel/rail adhesion reviewed by NTSB, the risk of low wheel/rail adhesion is highest during the early onset phase of light moisture, including mist or dew, following a dry or an extended dry period.[16] In contrast, the studies provided no evidence that the accident conditions of light rain following heavy rain presented a risk of low wheel/rail adhesion.

NTSB's evaluation of the acceleration and deceleration performance for cars 155 and 149 also confirmed that wheel/rail adhesion was adequate to stop an N-5 car on the night of the accident. However, both 4 days before the accident and on the night of the accident in wet weather, car 155 exhibited sudden intermittent and frequent wheel spin/slide events accompanied by substantial and unexplained reductions in acceleration and deceleration, while weather, operator, track, and equipment were unchanged.

1.7 Examination of Car 155

Investigators and SEPTA mechanical personnel conducted a postaccident examination of car 155. After repair of the damaged brake pipe near the A-end coupler, static testing confirmed that the friction brakes were functional. The examination did not identify any problems with the air brake valve, brake pads and discs, cab signal equipment, or master controller. The NTSB requested SEPTA prepare car 155 for track testing to help evaluate vehicle braking performance. SEPTA determined that track testing would not be safe because of accident damage to the B truck so brake performance testing was not completed.

The manual sanding system on car 155 was tested and functioned properly. When activated during static testing, the sand dispensed freely from the applicators.

Examination of car 155's eight wheels confirmed there were no flat spots.[17] Each wheel was measured and confirmed to have a diameter of 28 inches. However, the postaccident wheel calibration status differed between the car's two computers,

[15] (a) Twenty-four swab samples from the wheels of cars involved in the accident were examined. The results indicated no hydrocarbon substance at detectable levels. The analysis of the particulates found primarily iron, aluminum, and silicon—elements consistent with train component materials and soil. (b) Cars 155 and 148 were parked and stored in the car barn after the accident.

[16] This weather scenario of dry-to-light-rain conditions excludes the fall and winter periods when such seasonal conditions as falling leaves and frozen precipitation, respectively, heighten the risk of low wheel/rail adhesion.

[17] A *flat spot*, or *wheel flat*, is a fault in the wheel shape. Flat spots are usually caused by use of the emergency brake, or spin/slide conditions that cause wheels to lock up while the train is still moving, or by mechanical failures.

indicating that the wheel sizes had not been calibrated: the A-computer was set at 27 inches, and the B-computer at 28 inches. If the actual wheel sizes differ from what has been programmed into the computer, perceived wheel speed changes can result in an unwarranted wheel spin or slide indication. Due to accident damage, NTSB was unable to test car 155 on the tracks at speed to assess how uncalibrated wheel sizes would have affected the wheel spin/slide protection system.

1.8 Operator

The operator of car 155 had 6 years of operating experience and met SEPTA's qualifications to operate the car. His SEPTA medical records contain a single medical examination report on January 26, 2011. He had 20/20 vision, normal hearing, and no sleep disorders documented.

In accordance with Title 49 *Code of Federal Regulations* Part 655, Subpart E, the operator provided a urine specimen and took a breathalyzer test 5 hours 1 minute after the accident to detect the presence of alcohol and other drugs, respectively.[18] The results of both tests were negative.

1.9 Postaccident Actions

As a result of the accident, SEPTA implemented several procedures and proposed various changes for improving operational safety on the NHSL. These developments were provided to the NTSB on February 16, 2018, in a plan called the "Operational Safety Improvement Program Summary." SEPTA grouped these efforts into three categories - technology, rules and procedures, and training enhancements and are, in part, explained below.

Technology: SEPTA changed speed restrictions immediately after the accident. The maximum authorized speed on the NHSL was reduced from 70 to 55 mph. In addition, trains passing through a station are limited to 45 mph. Track speeds were also reduced between the approach to Township Line Road and 69th Street stations. All vehicles are required to stop at Township Line Road station.

Rules and Procedures: SEPTA updated its standard operating procedures for reporting slippery rail conditions. Once an operator makes the report, the control center will share this information with all their rail operations.

Training Enhancements: Rail operators received refresher training on brake procedures that included scenarios for brake failure, slippery rails, and emergency stops.

[18] Federal Transit Administration regulations specify that safety-sensitive employees may not use any of the five prohibited substances (or their metabolites): marijuana; cocaine; opiates (such as heroin, morphine, codeine); amphetamines (such as, racemic, amphetamine, extroamphetamine, and methamphetamine); or phencyclidine.

New hires will be assigned a particular mode (bus, Media–Sharon Hill Line, and NHSL) to gain familiarity with a specific mode and improve their technical competency. Once training is completed, they would remain with that mode for 7 months or up to 1 year.

SEPTA acquired rail transit simulators in December 2020. SEPTA began using these simulators during training for new operators starting in October 2021. SEPTA also intends to use these simulators when they conduct refresher and remedial training.

2. Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was an intermittent anomaly in the braking system of car 155 that degraded its stopping performance on approach to the 69th Street Transportation Center station, resulting in the collision with car 148.