Issued: January 29, 2025 Railroad Investigation Report: RIR-25-01

Chicago Transit Authority Yellow Line Train Collision with Snow Removal Machine

Chicago, Illinois
November 16, 2023

1 Factual Information

1.1 Accident Description

On November 16, 2023, about 10:30 a.m. local time, southbound Chicago Transit Authority (CTA) Yellow Line passenger train (train 593) collided with a stationary CTA snow removal machine (S-500) on south Skokie track 1 near Howard Yard and derailed.[1] (See figure 1.) The train was carrying 1 operator and 30 passengers; there were 6 CTA employees on board the snow removal machine. Sixteen people were transported to a hospital, treated, and released. Three people were critically injured, including the operator. There were no fatalities. The train remained upright following the collision. CTA estimated damages to equipment to be about $8.7 million. At the time of the accident, visibility conditions were daylight and clear; the weather was 61°F with no precipitation.

[1] (a) All times in this report are local. (b) The *snow removal machine (S-500)* was purchased by CTA from Mitsubishi International Corporation in 1981. The machine was designed to operate over track. (b) *Howard Yard* is CTA's rail yard located north of Howard Station. (c) Visit ntsb.gov to find additional information in the public docket for this NTSB accident investigation (RRD24MR002). (d) Use the CAROL Query to search safety recommendations and investigations.

Figure 1. Overview of the accident site. (Courtesy of Google Earth.)

1.2 Train Operations on the Yellow Line

Trains on the Yellow Line transported passengers between Dempster-Skokie, Illinois, and Howard, a neighborhood in the north of Chicago. The track at the accident site was double main track, Skokie track 1 (the accident track) and Skokie track 2. Skokie track 1 ran east toward Howard Station and then turned south as it approached Howard Yard. CTA's last inspection of Skokie track 1 occurred on the day of the accident, November 16, 2023. The inspection did not find any defects or note any unusual conditions.

Trains operating on the Yellow Line consisted of the 5000-series heavy rail transit vehicles (railcars) built by Bombardier Transportation in 2014. The railcars were designed to meet CTA's braking specifications. The railcars were equipped with three types of brake systems: dynamic brakes, friction brakes, and magnetic track brakes. The dynamic brakes used the railcar's traction motors to slow the wheels of the railcar; most braking applications above 5 mph used the dynamic brakes. The friction brakes used discs and calipers to brake the wheels. The track brakes applied braking force directly on the running rail. These brake systems could be activated individually or in combination by the train's operator or by the automatic train control (ATC) system if the operator did not respond appropriately to a signal indication.[2] The railcars were also equipped with a wheel slide protection system to prevent the wheels from locking up and sliding during braking by modulating (releasing and re-applying) the train's dynamic and friction brakes.[3]

Train movement on the Yellow Line were authorized by wayside and in-cab signal indications from an ATC system and coordinated from a rail operations control center. The ATC system used track circuits and signal blocks to detect trains on the track.[4] A Yellow Line southbound train approaching Howard Station would traverse through track circuit 26 (about 1373 feet long), track circuit 15 (about 525 feet long), and track circuit 9 (about 616 feet long) to reach Howard Station. The signal block at the accident site extended from the beginning of track circuit 26 to the end of track circuit 9. The ATC system was configured to allow only one train or rail equipment in a signal block. A train entering track circuit 26 would automatically get a zero-speed command from the ATC system if there was another train or rail equipment within the signal block and would stop within a distance of 1,780 feet or less in ideal conditions.[5] The maximum authorized speed for trains on the Yellow Line were set by CTA at 55 mph. Under normal operating conditions and when there were no other trains or rail equipment within the signal block, the operator of a southbound train entering track circuit 26 would receive a command to decelerate from 55 mph to 35 mph. As the train entered track circuit 9, the operator would receive another command to decelerate further to 15 mph. The operator would then manually reduce the train's speed while approaching the red signal indication at the entrance to Howard Station and stop the train at the station.[6] (See figure 2.)

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[2] An *automatic train control system* enforces speed limits and protects equipment and train separation by preventing movement through a signal or location that requires a stop. To stop a train, the automatic train control system transmits a 0 mph speed to the operator of the train. If the operator fails to respond to the 0 mph command, the automatic train control system applies the brakes to stop the train.

[3] *Wheel slide* typically occurs during aggressive braking or when the rails are slippery. Wheel slide can damage the wheels and increase the stopping distance.

[4] (a) A *track circuit* detects train movement on a section of the track. As a train enters a track circuit, the electrical current of the track circuit passes through the train's wheels and communicates the presence of the train to the signal system. (b) A *signal block* is a segment of the track which is configured to allow the movement of only one train or rail equipment within the signal black for the safe operation of trains.

[5] NTSB investigators calculated the stopping distance based on CTA's safe braking distance calculations in CTA's *Infrastructure Design Criteria Manual* (Chapter 11: Train Control, Section 15: ATP Safe Braking Distance Calculations). The dynamic tests conducted by NTSB on the Yellow Line on December 19, 2023, confirmed that the stopping distance is less than 1,780 feet under ideal conditions.

[6] A *red signal indication* is a signal requiring a train or rail equipment to come to a full stop.

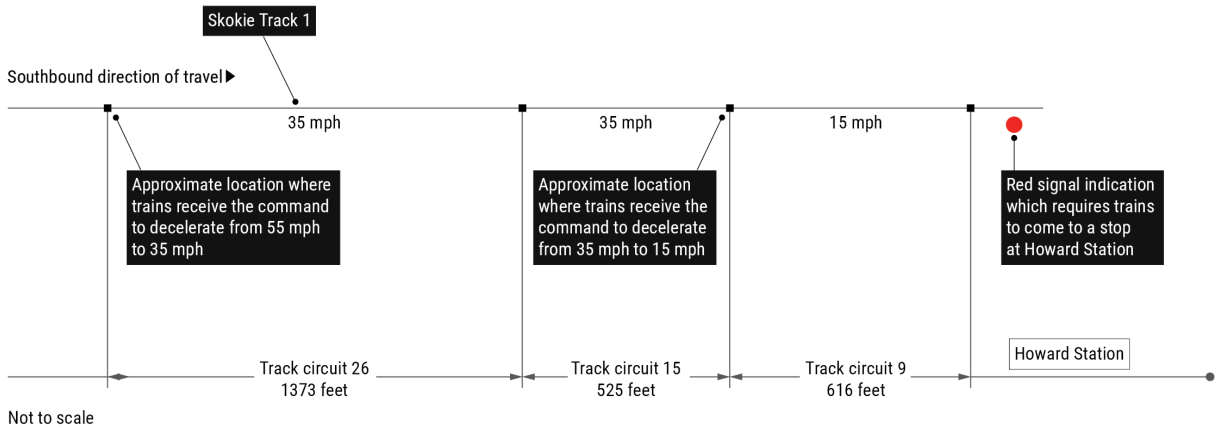

Figure 2. Movement of Trains on Skokie Track 1 during normal operations. (Courtesy of CTA).

1.3 Accident Sequence on November 16, 2023

On the morning of the accident, about 7:16 a.m., the operator reported for duty at Howard Yard and began operating Train 593 between Howard Station and Dempster-Skokie Station. Train 593 consisted of two 5000-series railcars. About 10:21 a.m., the operator departed Dempster-Skokie Station for a scheduled trip to Howard Station. This was the operator's third trip from Dempster-Skokie Station to Howard Station on the morning of the accident. When interviewed by the National Transportation Safety Board (NTSB), the operator of train 593 did not report anything unusual about these trips. On the same day, the snow removal machine secured permission to operate northbound and southbound between Dempster-Skokie Station and Howard Station from 9:00 a.m. until 2:00 p.m. as part of a training exercise. The operator of train 593 said in his interview that he was aware that the snow removal machine was operating on the Yellow Line but did not know its exact location.

Shortly before the collision, during a southbound movement, the snow removal machine had stopped in track circuit 9 about 370 feet north of a red signal indication before entering Howard Station. At this time, train 593 was traveling southbound toward Howard Station about 54 mph on the same track. At 10:30:22 a.m., as the train entered track circuit 26, the operator received an in-cab zero-speed command from the ATC system, because the snow removal machine was already present within the signal block.[7] The train received the zero-speed command about 2,150 feet from the stopped snow removal machine. The train operator initiated a full-service braking application about

[7] A *zero-speed command* is a command given by the ATC system to stop the train.

1 second later.[8] When interviewed by the NTSB, the operator said that he noticed that the train had started sliding and was not slowing down as much as it should have. The NTSB's subsequent review of event recorder data showed that the train's wheel slide protection system activated during the full-service braking application and modulated the train's dynamic and friction brakes. The operator saw the snow removal machine and initiated an emergency braking application at 10:30:41 a.m., which activated the train's dynamic, friction, and track brakes.[9] The train decelerated to about 23 mph before striking the snow removal machine at 10:30:50 a.m. (See figure 3 and figure 4.)

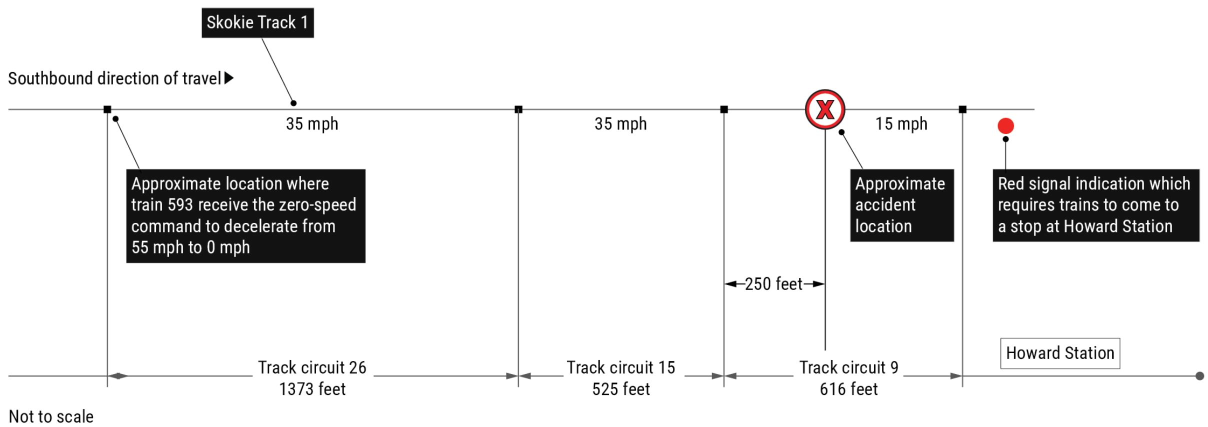

Figure 3. Movement of Train 593 on Skokie Track 1 on November 16, 2023. (Courtesy of CTA).

[8] A *full-service braking application* is the strongest application of a train's brakes under normal circumstances; on the railcars involved in this accident, a full-service braking application involves the dynamic and friction brakes.

[9] An *emergency braking application* uses the maximum braking force available and is designed to stop a train as quickly as possible; on the railcars involved in this accident, an emergency braking application involves the dynamic, friction, and track brakes.

Figure 4. Train 593 and the snow removal machine on the Yellow Line after the accident.

1.4 Postaccident Tests, Observations, and Examinations

1.4.1 Signals and Track

The NTSB tested the ATC system at the accident site and did not find any defects; the system functioned as designed.

The NTSB conducted a series of sight-distance observations and determined that the snow removal machine would have become visible to the train operator about 476 feet from the point of collision.

The NTSB found a slippery black substance on the top surface of the rails at the accident site and sent samples to the NTSB Materials Laboratory for testing and identification. Laboratory analysis found that this substance was organic and consisted of leaves and other plant matter, typical of leaves falling on the rails and being crushed beneath the wheels until they are compacted into a gel. CTA's rail maintenance procedures did not include monitoring for the build-up of material on the rails or regular cleanings.

1.4.2 Equipment

The NTSB tested the dynamic, friction, and track brakes of train 593 at the Skokie Maintenance Facility. The brakes functioned normally.

The NTSB's review of the train's event recorder showed that the wheel slide protection system activated during the full-service braking application and the emergency braking application. During the full-service braking application, the wheel slide protection system automatically activated the dynamic and friction brakes, but not the track brakes. The NTSB's review of CTA's wheel slide performance qualification testing conducted in 2009 confirmed that CTA had disabled the automatic application of the track brakes in the 5000-series railcar's wheel slide protection system. Wheel slide typically occurs during aggressive braking or when the rails are slippery (also known as low-adhesion conditions) and can cause damage to the wheels and increase the stopping distance.

During the 5000-series railcar tests leading up to a 2009 internal report, CTA found that the wheel slide protection system was effective at reducing the stopping distance under low-adhesion conditions, but the system tended to continuously deploy the track brakes, which could produce a high brake rate and discomfort to passengers.[10] Consequently, CTA decided to disable the automatic track brake application during wheel slide, leaving the application of the track brakes to the judgment of the operator.

The NTSB also conducted stopping distance tests on the Yellow Line on December 19, 2023, and found that the train could stop within 1,780 feet under ideal conditions, as designed. However, these tests could not perfectly replicate the conditions present at the time of the accident—the exact amount, location, and composition of the slippery substance (organic matter) identified on the rails—and direct comparison between ideal and relevant non-ideal conditions was not possible.

1.5 Toxicology Testing

Shortly after the crash, the train operator was transported to the emergency department and blood specimens obtained for toxicological testing. Hospital testing detected ethanol at 0.06 g/dL in the blood specimen. At the NTSB's request, the FAA Forensic Sciences Laboratory performed toxicological testing of the train operator's hospital blood specimens. Ethanol was detected at 0.043 g/dL in a specimen collected at 11:20 a.m. on the day of the accident and at 0.048 g/dL in a specimen collected at 11:36 a.m. on the same day. No other tested-for substances were detected.

A urine specimen was obtained from the train operator on November 17, 2023, at 7:10 p.m. Department of Transportation (DOT) postaccident drug testing of this

[10] CTA. 5000 Series Cars: Spin/Slide Performance Qualification Test Report. July 17, 2009.

specimen did not identify any tested-for substances.[11] The train operator did not undergo a DOT postaccident alcohol breath test because of his ongoing medical treatment in the hospital.

A urine specimen was obtained from the snow removal machine operator at 3:17 p.m. on the day of the accident. DOT postaccident drug testing of this specimen did not identify any tested-for substances. A DOT postaccident alcohol breath test conducted at 3:11 p.m. on the same day was negative.

1.6 Postaccident Actions

CTA reduced the maximum authorized speed on the Yellow Line from 55 mph to 35 mph to eliminate the possibility of a speed reduction from 55 mph to 0 mph and reduce the incidence of wheel slide and the subsequent activation of the wheel slide protection system. CTA enabled the automatic track brake application feature of the wheel slide protection system on its 5000-series railcars. CTA cleaned the Yellow Line track of debris and fallen leaves, removed material that had accumulated on the rails, and issued bulletins to remind employees of best practices for operating trains under slippery conditions to reduce the risk of a train sliding after the brakes are applied. Finally, CTA modified its track inspector certification training program to include information about the build-up of material on the rails. This program is intended to make track inspectors aware of the hazards of the build-up of material on the rails which makes the rails slippery and degrades the braking performance of trains.

2 Analysis

2.1 Accident Summary

In this accident, train 593 collided with a stationary snow removal machine when it failed to stop in time after receiving a zero-speed command from the ATC system. The train was traveling below the maximum authorized speed of 55 mph, and the operator promptly initiated a full-service braking application followed by an emergency braking application, but the train was still traveling about 23 mph at the point of collision.

2.2 Toxicology

[11] Tested-for substances included marijuana metabolites, cocaine metabolites, amphetamines, opioids, and phencyclidine, in accordance with Title 49 *Code of Federal Regulations* 40.82 and as detailed in Title 49 *Code of Federal Regulations* 40.85.

Although toxicology results show that the train operator had consumed ethanol and likely was experiencing some impairing effects of ethanol at the time of the collision, he responded to the zero-speed command quickly (within 1 second) and appropriately. It is unlikely that effects of ethanol contributed to the collision.

2.3 Aggressive Braking

Train 593 was traveling about 54 mph when it entered track circuit 26 and received a zero-speed command because the snow removal machine was occupying the signal block. The train had made two southbound trips through the area earlier in the day and had followed the normal deceleration commands from the ATC system (a reduction in speed from 55 mph to 35 mph and then another reduction in speed from 35 mph to 15 mph). The train had stopped at Howard Station without any incident and under similar conditions. (See figure 2.) However, under the aggressive braking required by the zero-speed command, the train began to experience wheel slide, which reduced the train's braking performance. The train was still travelling about 23 mph at the point of collision, when during normal deceleration, it had successfully slowed down to 15 mph or less at that same location earlier in the day. While other factors contributed to the collision—see below—the accident sequence began with this aggressive braking maneuver required by the ATC system.

Following the accident, CTA reconfigured its ATC systems to eliminate all 55 mph to 0 mph speed reductions to reduce the incidence of wheel slide.

2.4 Wheel-Slide

Braking on train 593 began about 2,150 feet from the collision—more than its stopping distance of 1,780 feet under ideal conditions—and occurred in two stages. In the first stage, the operator used only a full-service braking application because he could not yet see the snow removal machine stopped on the track ahead. The wheel slide protection system modulated the train's dynamic and friction brakes to minimize wheel slide during this stage, but it did not deploy the track brakes because CTA had disabled the automatic track brake application.

In the second stage, the operator saw the snow removal machine at a maximum distance of about 476 feet and initiated an emergency braking application, which applied the track brakes. This means that the track brakes were applied for only the last quarter of the total distance available before the collision. If the wheel slide protection system had been set to automatically apply the track brakes when wheel slide was first detected, the train likely would have decelerated more quickly, reducing the severity of the accident or preventing the collision altogether. CTA has since re-enabled this automatic track brake application feature on its 5000-series railcars.

2.5 Slippery Conditions

The NTSB found fallen leaves on the track and a black gel-like substance (organic matter) on the top surface of the rails near the accident site. This substance made the rails slippery and likely aggravated the wheel slide, reducing the train's braking performance and contributing to the severity of the collision. CTA's track inspections before the accident did not check for debris on the track, such as fallen leaves, or the accumulation of material on the rails, such as the gel-like substance that made the rails unusually slippery. CTA did not clean the rails or increase adhesion by applying sand or sandite to the rails.[12] If CTA had cleaned the rails or taken steps to increase rail adhesion, the train's wheel slide would have been less pronounced, likely preventing or reducing the severity of the collision.

Following the accident, CTA cleaned the rails at the site and modified its track inspector certification training program to cover material build-up on the rails and identify conditions like those that contributed to this accident.

3 Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision between Chicago Transit Authority (CTA) passenger train 593 and snow removal machine S-500 was a combination of three factors: (1) an aggressive speed reduction command that resulted in wheel slide and degraded the train's braking performance, (2) CTA's decision to disable the automatic track brake application feature of the train's wheel slide protection system, delaying application of the track brake and further reducing the train's braking performance, and (3) the presence of organic material on the rails that caused slippery conditions that worsened the wheel slide and further degraded the train's braking performance.

[12] *Sandite* is a mixture of sand, antifreeze, and metal particles commonly used to improve adhesion.

The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, "accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties … and are not conducted for the purpose of determining the rights or liabilities of any person" (Title 49 *Code of Federal Regulations* section 831.4). Assignment of fault or legal liability is not relevant to the NTSB's statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code* section 1154(b)).

For more detailed background information on this report, visit the NTSB Case Analysis and Reporting Online (CAROL) website and search for NTSB accident ID [RRD24MR002]. Recent publications are available in their entirety on the NTSB website. Other information about available publications also may be obtained from the website or by contacting –

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