National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: SEP 2 2 2009

In reply refer to: R-09-20 and -21 (Urgent)
R-09-22

The Honorable Joseph C. Szabo
Administrator
Federal Railroad Administration
1200 New Jersey Avenue, SE
East Building
Washington, D.C. 20590

The recommendations in this letter are derived from the National Transportation Safety Board's (NTSB's) ongoing investigation of the recent collision between two Washington Metropolitan Area Transit Authority (WMATA) Metrorail trains on the Red Line near the Fort Totten station in Washington, D.C. The NTSB would appreciate a response from you within 30 days addressing the actions you have taken or intend to take to implement our recommendations.

On Monday, June 22, 2009, about 4:58 p.m., eastern daylight time, southbound WMATA Metrorail train 112 was traveling in a curve when it struck the rear end of Metrorail train 214 before reaching the Fort Totten station. There was no communication between the train operators and the Metrorail Operations Control Center before the collision. During the collision, the lead car of train 112 telescoped and overrode the rear car of train 214 by about 50 feet. Examination of the track and wreckage indicated that the emergency brake on train 112 was applied before impact. The District of Columbia Fire and Emergency Medical Service reported 9 fatalities and transported 52 persons to local hospitals.

Although the investigation is ongoing, postaccident testing showed that the track circuit at the accident site lost detection of train 214 when it stopped at the location where the collision occurred. Because the automatic train protection (ATP) system was not detecting train 214's location, the following train (train 112) did not receive a command to slow or stop in order to maintain train separation. Maximum authorized speed in the accident area is 59 miles per hour.

Train operations on all Metrorail mainline routes can be carried out in either automatic train control (ATC) or manual control by a train operator. ATC consists of three control subsystems: ATP, automatic train supervision, and automatic train operation. On the Metrorail system, ATP is designed to provide protection against collisions and overspeed conditions in both automatic and manual train operations. The system detects trains and transmits speed commands

to maintain train separation. Train detection and transmission of speed commands are accomplished through the use of audio frequency track circuits. Each track circuit[1] uses two track circuit modules that communicate with each other. The modules are mounted on metal racks inside train control rooms at each station, and each module contains a track frequency transmitter and a track frequency receiver.

A track circuit signal is a coded, modulated audio frequency signal[2] generated in the train control room at each station by a track circuit module transmitter. A twisted-pair bond cable is used to send the modulated signal to a transmitter impedance bond, which is mounted between the rails and injects the signal into the rails. The modulated signal then travels through the rails to a receiver impedance bond, also mounted between the rails, at the other end of the track circuit. A twisted-pair bond cable connects the receiver impedance bond to a track circuit module receiver located in the same train control room. The module receiver filters, amplifies, and checks the level of the track circuit signal from the rail and outputs a signal to a track relay, which completes the track circuit. A track relay is an electromechanical switch that is normally in an energized state when no train is present in the circuit. Train occupancy deenergizes a track relay. A train is detected when its wheels shunt[3] the modulated signal, which deenergizes the corresponding track relay. When a train is detected, a coded, modulated train frequency signal is also transmitted providing speed commands when track and traffic conditions allow the train to move.

The investigation of this accident has raised concerns about the susceptibility of this audio frequency track circuit design to errant signals. Extensive postaccident testing conducted during the NTSB's investigation determined that an unintended signal path was created between track circuit modules that resulted in the associated track relay remaining energized even though train 214, the stopped accident train, was occupying the track circuit. Testing found that a spurious high-frequency modulated signal was being created by parasitic oscillation[4] from the power output transistors[5] in the track circuit module transmitter. This spurious signal propagated through the power transistor heat sink, through the metal rack structure, and through a shared power source into the associated module receiver, thus establishing an unintended signal path. The spurious signal mimicked a valid track circuit signal. The peak amplitude of the spurious signal appeared at the correct time interval and was large enough to be sensed by the module receiver as a valid track circuit signal, which energized the track relay. This combination—of an

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[1] Each *track circuit* coincides with a length of track, or track block. Mainline routes are divided into track blocks from one end of the terminal station to the other. There is generally one track circuit per block with impedance bonds located at both ends of each track circuit.

[2] Eight frequencies between 2100 hertz and 3900 hertz are available for use by the track circuit.

[3] *Shunting* occurs when a track circuit signal passes from rail to rail through the train's wheels and axles, which interrupts the track circuit and indicates the presence of a train.

[4] *Parasitic oscillation* is a spurious signal pulse generated by a power amplifier that is carried on the audio signal used by the track circuit. The parasitic oscillation was not continuous and only occurred at or near the positive peak and/or the negative peak of the audio signal; this oscillation occurred in pulses synchronized with the valid track circuit audio signal peaks.

[5] The *power output transistors* are part of a push-pull, emitter-follower power amplifier that drives the output transformer. Each half of the amplifier uses two transistors in parallel. Each pair of transistors is mounted on heat sinks using mica insulators that are attached to the rear panel of the module.

alternate signal path between track circuit modules and a spurious signal capable of exploiting that path—bypassed the rails, and the ability of the track circuit to detect the train was lost.

The results of postaccident testing and the ongoing investigation also have raised concerns about how routine track circuit adjustments and/or changes in the operating characteristics of electronic components in ATC systems may affect system performance. The modules at the Fort Totten station are original equipment that was manufactured by General Railway Signal[6] and installed when the Red Line was constructed in the 1970s. WMATA maintenance records show that an impedance bond for the track circuit where the accident occurred was replaced 5 days before the accident, which required the track circuit signal strength to be adjusted to accommodate the new equipment. Investigators are continuing to examine train control system circuitry to better understand how the train control system functioned prior to the accident.

The NTSB believes that all rail transit operators and railroads should be informed about the ATC system failure identified in the June 22, 2009, WMATA accident investigation. Further, the NTSB believes that transit operators and railroads that use audio frequency track circuits should examine their train control systems for evidence of parasitic oscillations and eliminate unintended signal paths that could cause a track circuit to fail to detect a train. Additionally, these transit operators and railroads should develop programs to periodically examine electronic components in their train control systems to ensure that they are performing within design tolerances.

Therefore, the National Transportation Safety Board makes the following safety recommendations to the Federal Railroad Administration:

> Advise all railroads that use audio frequency track circuits in their train control systems that postaccident testing following the June 22, 2009, collision between two rail transit trains near the Fort Totten station in Washington, D.C., identified that a spurious signal generated in a track circuit module transmitter by parasitic oscillation propagated from the transmitter through a metal rack to an adjacent track circuit module receiver, and through a shared power source, thus establishing an unintended signal path. The spurious signal mimicked a valid track circuit signal, bypassed the rails, and was sensed by the module receiver so that the ability of the track circuit to detect the train was lost. (R-09-20) (Urgent)
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> Require all railroads that use audio frequency track circuits in their train control systems to examine track circuits that may be susceptible to parasitic oscillation and spurious signals capable of exploiting unintended signal paths and eliminate those adverse conditions that could affect the safe performance of their train control systems. This work should be conducted in coordination with their signal and train control equipment manufacturers. (R-09-21) (Urgent)

[6] General Railway Signal has since been acquired by Alstom Signaling, Inc.

Require all railroads that use audio frequency track circuits in their train control systems to develop a program to periodically determine that electronic components in their train control systems are performing within design tolerances. (R-09-22)

The NTSB also issued safety recommendations to the Federal Transit Administration, the Washington Metropolitan Area Transit Authority, and Alstom Signaling, Inc.

In response to the recommendations in this letter, please refer to Safety Recommendations R-09-20 and -21 (Urgent) and R-09-22. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our secure mailbox. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

Chairman HERSMAN, Vice Chairman HART, and Member SUMWALT concurred in these recommendations.

By: Deborah A.P. Hersman
Chairman