National Transportation Safety Board

Washington, DC 20594

Safety Recommendation

Date: June 8, 2015

In reply refer to: R-15-25

Mr. Jack Requa
Interim General Manager and Chief
Executive Officer
Washington Metropolitan Area Transit
Authority
600 5th St. NW
Washington, DC 20001

The National Transportation Safety Board (NTSB) is an independent federal agency charged by Congress with investigating every civil aviation accident in the United States and significant accidents in other modes of transportation—railroad, highway, marine, and pipeline. We determine the probable cause of the accidents and issue safety recommendations aimed at preventing future accidents. In addition, we carry out special studies concerning transportation safety and coordinate the resources of the federal government and other organizations to provide assistance to victims and their family members affected by major transportation disasters.

We urge the Washington Metropolitan Area Transit Authority (WMATA) to take action on the safety recommendation issued in this letter. This recommendation is derived from our ongoing investigation of the electrical arcing and smoke accident near the WMATA L'Enfant Plaza station in Washington, D.C., on January 12, 2015, and supported by evidence from the February 11, 2015, electrical arcing and smoke incident at the Court House station. Although our investigation is not yet completed, this recommendation addresses a safety issue requiring immediate action. Information supporting this recommendation is discussed below.

Background

On January 12, 2015, at 3:15 p.m., eastern standard time, southbound WMATA Metrorail Yellow Line train 302 stopped after encountering heavy smoke in a tunnel between the L'Enfant Plaza station and the Potomac River Bridge. After stopping, the rear car of the train was about 386 feet from the south end of the L'Enfant Plaza station platform. The train operator contacted the WMATA Operations Control Center to announce that the train was stopped due to heavy smoke.

A following train (train 510), which was stopped at the L'Enfant Plaza station at 3:25 p.m., also was affected by the heavy smoke. This train stopped about 100 feet short of the south end of the platform, but its cars were entirely within the station. Train 510 was evacuated while it was stopped at the station platform.

Police officers provided assistance in guiding passengers from the underground platform to the surface. Some of the passengers on board train 302 self-evacuated. Emergency responders were dispatched to the scene and assisted with evacuating passengers from both trains, as well as the station.

Both Metrorail trains had six passenger cars. The length of each train was about 450 feet. As a result of the smoke, 86 passengers were transported to local medical facilities for treatment. One passenger died. WMATA estimated initial damages were $120,000.

The parties to the investigation include WMATA; the Federal Transit Administration; the Tri-State Oversight Committee; the Bureau of Alcohol, Tobacco, Firearms and Explosives; the Amalgamated Transit Union, Local 689; the International Association of Fire Fighters, Local 36; the District of Columbia Fire and Emergency Medical Services Department; and the District of Columbia Metropolitan Police Department.

Discussion

The on-scene investigation and the laboratory evaluation of evidence recovered from the L'Enfant Plaza accident location revealed that the event was due to a short circuit between the electrical power cables and the steel wall of the tunnel. The smoke in the tunnel was generated by thermal damage to about 16 feet of electrical power cables and insulation, portions of 4 fiberglass cable connector covers, and about 5 feet of the fiberglass third rail cover.

The damage to the electrical power cables is consistent with a short circuit to ground, possibly due to electrical arc tracking.[1] The Federal Aviation Administration has studied this phenomenon extensively for aircraft applications.[2] NTSB investigators have found that electrical arc tracking at a cable connector assembly can occur if the power cable terminal lugs are not sealed in a weather tight connector, which provides access between the bare lugs inside the connector and the external environment.[3] Under these conditions, electrical arc tracking can then occur when contamination extends between the terminal lugs and ground, creating an electrically conductive path along the outside surface of the cable. Over time, cumulative degradation of the insulating material caused by this electrical arc tracking process can produce a low resistance

[1] *Electrical arc tracking* occurs on insulating surfaces when contaminants and moisture accumulate in a manner such that leakage currents can flow along the insulating surface, allowing a short circuit to develop. See Transport Canada, *Enhanced Zonal Analysis Procedures*, September 30, 2005, TP 14331, 6. Definitions, https://www.tc.gc.ca/eng/civilaviation/publications/tp14331-section6-3248.htm.

[2] Patricia L. Cahill and James H. Daily, *Aircraft Electrical Wet-Wire Arc Tracking*, DOT/FAA/CT-88/4 (Atlantic City, NJ: US Department of Transportation, Federal Aviation Administration Technical Center, August 1988).

[3] A *weather tight* enclosure resists moisture and particulate infiltration and accumulation that can exist in tunnel environments.

path between the lugs and ground, creating a short circuit that can generate fire and smoke in tunnels.

Extensive thermal damage to the electrical power cables and connector covers in the L'Enfant Plaza accident consumed evidence in the area of the short circuit. The investigation is ongoing and additional analysis is needed before the cause can be determined. However, the investigation of this accident and evidence from another recent WMATA incident indicate a safety issue concerning improperly constructed power cable connector assemblies.

On February 11, 2015, at 1:39 p.m., the operator of a WMATA Orange Line train, traveling from Court House station to Rosslyn station, reported smoke in the tunnel as it approached Rosslyn station. The train operator was instructed to reverse ends and move the train back to Court House station, which did occur. All smoke was cleared by 2:50 p.m., and normal train service resumed. There were no injuries as a result of the incident. NTSB investigators conducted a series of on-scene examinations and collected electrical power cables and cable connector assemblies for laboratory evaluation.

The laboratory evaluation of evidence recovered from the Court House station incident revealed that smoke in the tunnel was generated by thermal damage to about 11 inches of power cable insulation and a portion of the fiberglass cable connector cover. The signatures on the damaged power cable were consistent with a short circuit due to electrical arc tracking. The arc tracking occurred between a terminal lug inside a cable connector assembly and extended along the surface of a section of the pigtail cable leading to the third rail.[4] The terminal lug was inside a connector cover at the time of the arc tracking, and the cable was lying on the tunnel floor. Inspection revealed no evidence of cable insulation chafing or direct contact between the lug and a grounding medium.

Figure 1 shows the typical arrangement of a supply power cable connected to a pigtail cable, which is welded to the third rail (a cable connector assembly protects the bolted terminal lugs).[5] The supply power cable is brought to the surface of the tunnel through a stub-up conduit.[6] In figure 2, the two upper images show the thermally damaged connector cover from the Court House station incident; in the lower image, the thermal damage is identified along the length of the pigtail cable.

[4] A *pigtail cable* is a short length of electrical power cable with a terminal lug at one end and often welded or bolted to the third rail at the other end.

[5] A *supply power cable* energizes the third rail from the electrical power substation, and normally extends through a conduit below the floor of the tunnel. A conduit is a metal tube through which electrical power cables are placed for protection and ease of replacement.

[6] The term *stub-up conduit* describes a 90° bend transition in the electrical power cable conduit from under the tunnel floor to above the surface.

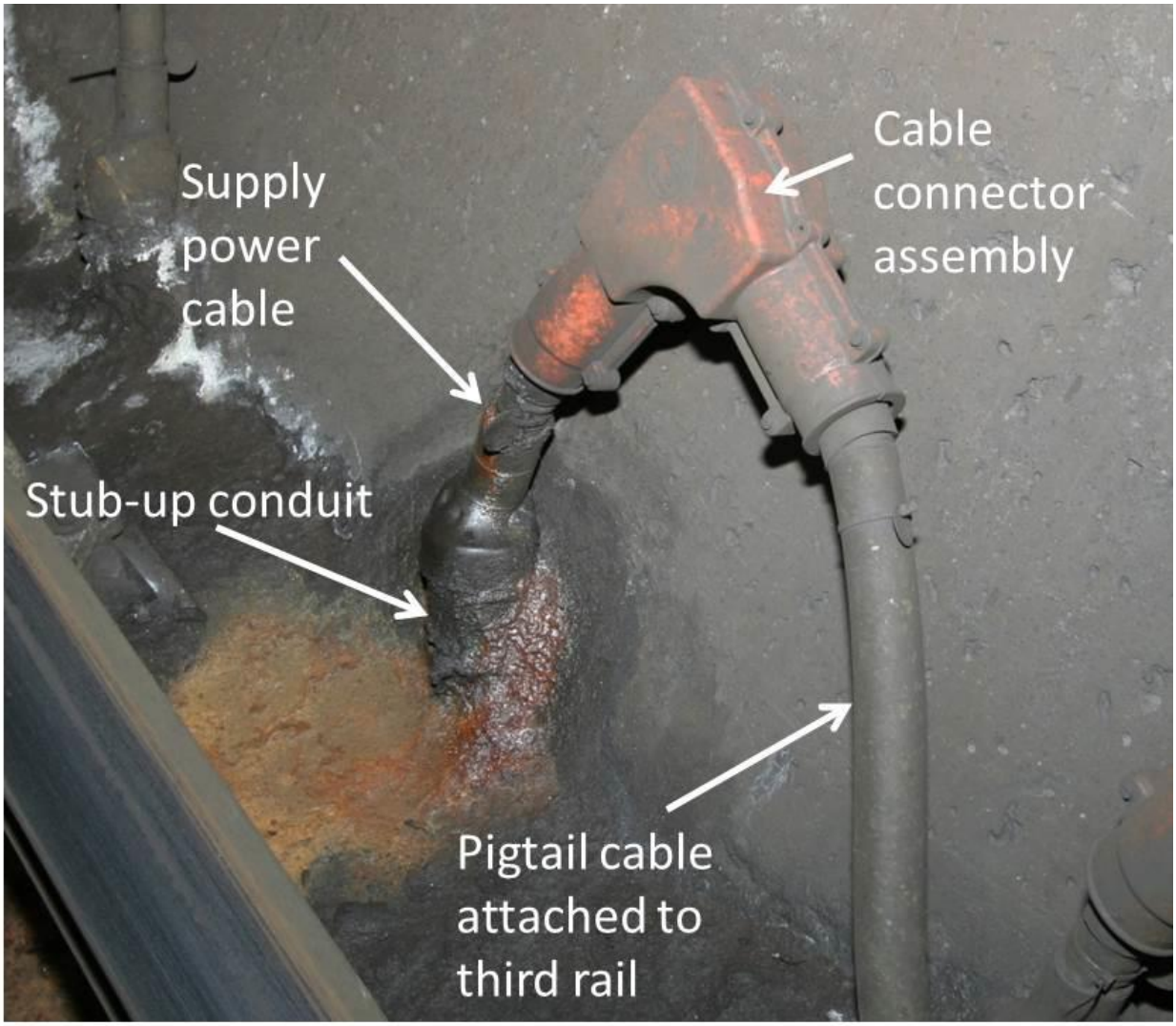

Figure 1. A typical stub-up conduit with supply power cable, cable connector assembly, and pigtail cable.

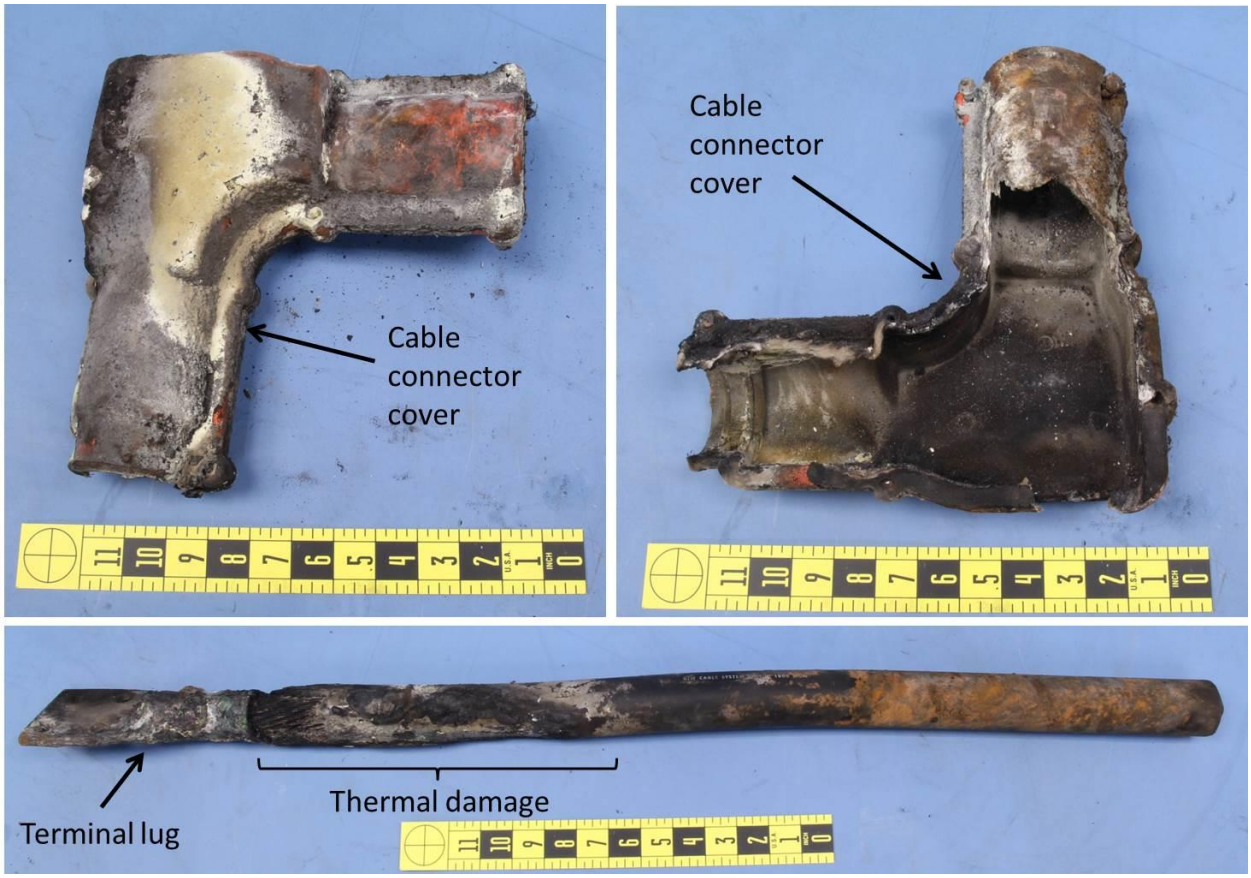

Figure 2. Section of electrical power cable from Court House station incident exhibiting thermal damage. The two upper images show the connector cover from the Court House station incident; in the lower image, the thermal damage is identified on the cable insulation.

Figure 3 shows the correct cable connector assembly in accordance with WMATA's engineering design specifications. According to WMATA engineering and procurement documents and discussions with engineering personnel, the power cable connector covers are designed to be weather tight when installed with all sealing sleeves (see figure 3).[7] However, investigators found that the failed power cable connector assembly at the Court House station incident location was missing its sealing sleeves. Figure 4 shows an in-service assembly without the sealing sleeves. NTSB investigators have found a number of other power cable connector assemblies throughout the WMATA Metrorail system constructed without sealing sleeves; often with heat shrink tubing or electrical tape used in place of the sealing sleeves; and with different types of terminal lugs, some of which are not specified for use with their connector covers.[8]

[7] (a) Engineering document—MAC Products, Inc., Engineering Drawing Number B-9180, Cable Connector Assembly, Kearny, NJ: April 15, 1988. (b) Procurement document—Washington Metropolitan Area Transit Authority, *Invitation For Bid, Install Six (6) DC Switchgear Lineups*, IFB No. FQ15074/MDG, Volume 1, Book 3 of 3, Technical Specifications, October 17, 2014, p. 120.

[8] *Heat shrink tubing* refers to an electrically insulating plastic tube that may be placed over an exposed terminal lug barrel and shrunk in place using heat.

These power cable connector assemblies were not in accordance with WMATA's engineering design specifications.

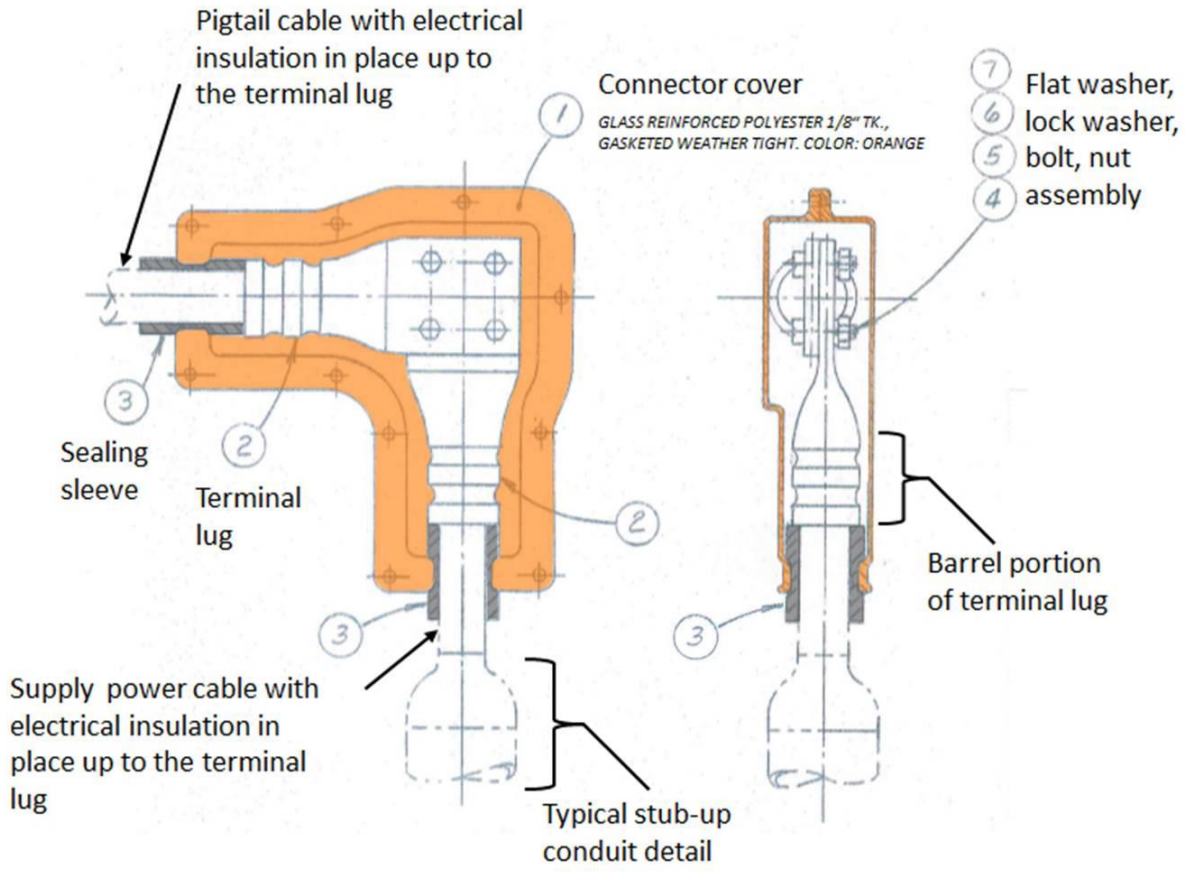

Figure 3. Cable connector assembly showing the correct arrangement of the terminal lugs, connector cover, and sealing sleeves. The typical arrangement of electrical power cables is identified.

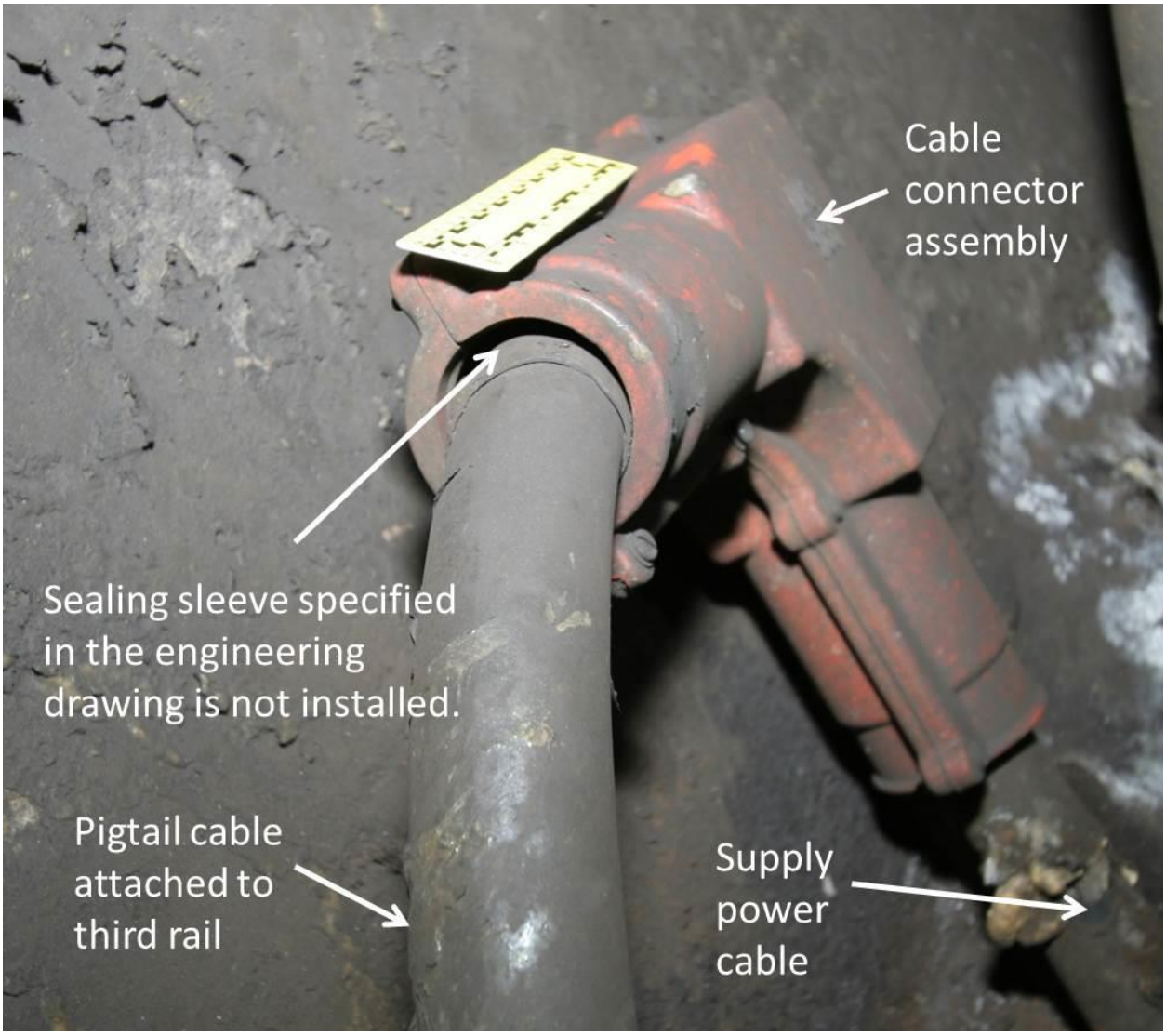

Figure 4. Installed cable connector assembly without required sealing sleeve.

There are many transit systems operating in the United States where the trains are powered by a third rail that is supported on electrical isolation insulators.[9] Figure 5 shows components of the third rail power distribution system at the L'Enfant Plaza accident location. There are three primary areas where electrical arc tracking can occur:

[9] Arun Vohra, *Cleaning Device for Electrified Third Rail Insulators*, Final Report for Transit IDEA Project 36, (Bethesda, MD: Transportation Research Board of the National Academies, October 2004).

1. Along the surface of the third rail support insulators, between the third rail and the floor of the tunnel.
2. Along the insulated surface of the pigtail cable, between the terminal lug in the connector assembly and the floor of the tunnel (or along the insulated surface of the cable, between the third rail end of the pigtail cable and the floor of the tunnel).
3. Along the insulated surface of the supply power cable, between the terminal lug in the connector assembly and the floor of the tunnel.

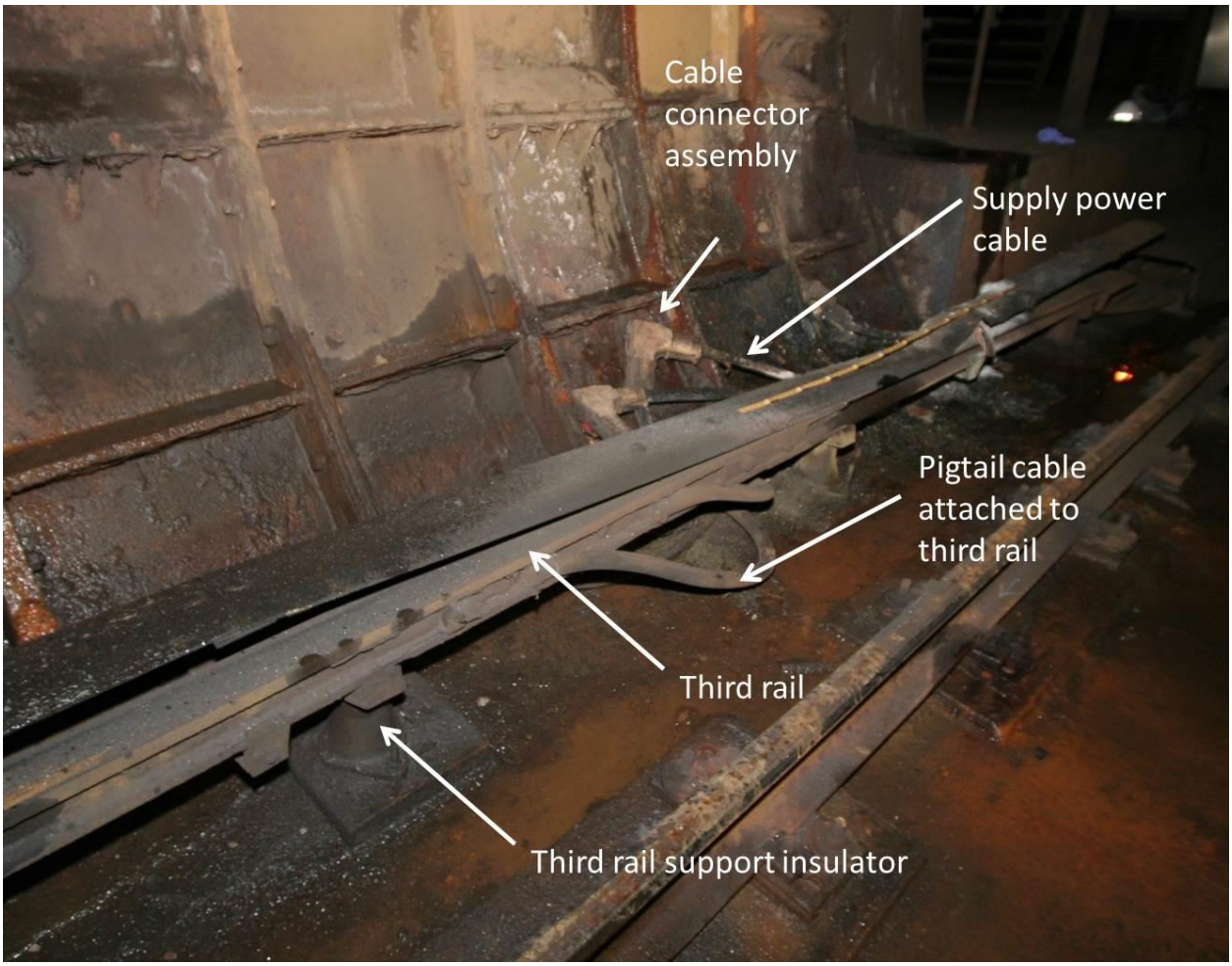

Figure 5. Third rail components with insulating surfaces susceptible to electrical arc tracking at L'Enfant Plaza accident location.

WMATA surveys revealed that the vast majority of the third rail support insulators that annually experienced electrical arc tracking occurred within tunnels.[10] Tunnels have particulate contaminants such as brake dust; rust particles; rail grinding swarf; rail and wheel wear debris; carbon motor brush dust; deicing salt dust; dirt particles; and calcareous deposits from minerals from ground water, which leaks or drips in tunnels.[11] Unlike open track, train tunnels can concentrate particulate contaminates, which can coat all surfaces, including support insulators and electrical power cable insulation. For these reasons, power cable connector assemblies need to be sealed to prevent moisture or contaminants from entering the assemblies and creating the path to ground necessary for electrical arc tracking to occur.

According to discussions with WMATA, it does not have a program to ensure that power cable connector assemblies are installed in accordance with its engineering design specifications. The specified cable connector covers are installed; however, WMATA has allowed maintenance crews and contractors to use various types of terminal lugs and sealing methods. In what should be identical assemblies throughout the system, NTSB investigators have found numerous power cable connector assemblies that are not in accordance with WMATA's engineering design specifications. These assemblies are frequently missing sealing sleeves and use a variety of different terminal lugs. Even the postaccident repairs made to the power cable connector assembly at L'Enfant Plaza did not include the sealing sleeves indicated in the WMATA engineering design specifications. Although the investigation of the L'Enfant Plaza accident is ongoing and additional analysis is needed before the cause can be determined, the damaged power cable in the Court House station incident is consistent with electrical arc tracking due to contaminants and moisture on the power cable surface. The NTSB concludes that WMATA's third rail electrical power cable systems are susceptible to electrical arc tracking at improperly constructed power cable connector assemblies, which can lead to short circuits that can generate fire and smoke in tunnels.

Therefore, the National Transportation Safety Board recommends that the Washington Metropolitan Area Transit Authority:

> Promptly develop and implement a program to ensure that all power cable connector assemblies are properly constructed and installed in accordance with your engineering design specifications, including the weather tight seals that prevent intrusion by contaminants and moisture. (R-15-25)

The NTSB notes there are other components in the third rail power distribution system that can be susceptible to electrical arc tracking and short circuits, and WMATA's programs and maintenance procedures to address these issues are being examined as part of the ongoing L'Enfant Plaza accident investigation.

Chairman HART, Vice Chairman DINH-ZARR, and Members SUMWALT and WEENER concurred in this recommendation.

---

[10] Vohra, *Cleaning Device for Electrified Third Rail Insulators*, October 2004.

[11] The term *swarf* refers to shavings, turnings, filings, chips, and particulate matter created by material removal processes such as grinding.

We are vitally interested in this recommendation because it is designed to prevent accidents and save lives. We would appreciate receiving a response from you within 90 days detailing the actions you have taken or intend to take to implement it. When replying, please refer to the safety recommendation by number. We encourage you to submit your response electronically to correspondence@ntsb.gov. If your response exceeds 10 megabytes, including attachments, please e-mail us at the same address for instructions. Please do not submit both an electronic copy and a hard copy of the same response.

[Original Signed]

By:Christopher A. Hart,
Chairman