GROUP	B
EXHIBIT	
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NATIONAL TRANSPORTATION SAFETY BOARD
Investigative Hearing
Washington Metropolitan Area Transit Authority Metrorail train 302 that encountered heavy smoke in the tunnel between the L'Enfant Plaza Station and the Potomac River Bridge on January 12, 2015

Agency / Organization

NTSB

Title

Signals, Traction Power, Track & Plant Systems Group Factual Report

Docket ID: **DCA 15 FR 004**

SIGNALS, TRACTION POWER, TRACK & PLANT SYSTEMS GROUP - FACTUAL REPORT OF INVESTIGATION

Smoke & Arcing near WMATA L'Enfant Plaza Station in Washington, DC on January 12, 2015

DCA-15-FR-004

NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF RAILROAD, PIPELINE &
HAZARDOUS MATERIALS INVESTIGATIONS
WASHINGTON, D.C. 20594

1 ACCIDENT

LOCATION:	Washington, DC - Yellow Line
TRAIN 1:	Metrorail Train Run 302
OPERATOR:	Washington Metropolitan Area Transit Authority
DATE:	January 12, 2015
TIME:	3:15 pm
NTSB #:	DCA-15-FR-004

2 SIGNALS, TRACTION POWER TRACK AND PLANT SYSTEMS GROUP

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3 SUMMARY

On January 12, 2015, about 3:15 pm, Eastern Standard Time, Washington Metropolitan Area Transit Authority (WMATA) Metrorail train 302 stopped after encountering an accumulation of heavy smoke while traveling southbound 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 Operation Control Center (OCC) and announced that the train was stopped due to heavy smoke.

A following train (train 510), stopped at the L'Enfant Plaza Station at about 3:25 p.m., and was also affected by the heavy smoke. This train stopped about 100 feet short of the south end of the platform. Passengers of both trains, as well as passengers on the station platforms, were exposed to the heavy smoke. Train 510 was evacuated while it was stopped at the station platform, where arriving police officers provided assistance in guiding passengers to the surface. Some passengers aboard train 302 began to self-evacuate as it remained in the tunnel. Emergency responders were dispatched to the scene and an evacuation of the train and station area ensued.

Both Metrorail trains involved in this incident consisted of six passenger cars and were about 450 feet in length. As a result of the smoke, 86 passengers were transported to local medical facilities for treatment. There was one passenger fatality. Initial damages were estimated by WMATA at $120,000.00.

4 DETAILS OF THE INVESTIGATION

4.1 Description of OCC Data Monitoring & Control

The rail operations control center (OCC) was equipped with monitoring, control, and communication facilities required to operate the transit system, subsystems and handle emergency situations necessary for the efficient movement of trains[1]. OCC utilized a central computer system supervised by human controllers to implement strategies that could be either automatically carried out by the central control mainframe computer or implemented manually by OCC line controllers.

Communication between the OCC computer system and field elements was accomplished through remote terminal units (RTU) and through monitored or controlled data "nodes" throughout all the rail lines and rail yards. Various sensors and subsystems positioned across the rail system collected data that reflected the status of operational parameters such as track circuit occupancies, switch positions, signal aspects, train-to-wayside communications, fire alarms, and fan shaft activation. In general, these data were first concentrated at a nearby RTU, usually located at a passenger station or in a rail yard. The OCC main computer system continually polled each RTU once per second. Each RTU responded to the poll by returning status data that was gathered by the sensors and subsystems.

RTUs are electronic data multiplexing systems. The RTUs on Metrorail had varying installation dates and consisted of either hardware-based devices using discrete logic chips or were microprocessor-based.

At OCC, software was used to manage the data transmitted from the RTUs in the field. At Metrorail, this software is referred to as the Advanced Information Management (AIM) system.

[1] These include power, ATC, automatic fare collection, and communications.

AIM data is then used by a graphics package called "Animator" to create the information that is displayed on the different monitors used by OCC line controllers.

4.2 Description of Signal & Train Control System

Train operations were governed by the Metrorail Safety Rules and Procedures Handbook (MSRPH). Train control and supervision for the entire transit system was conducted through OCC.

Train movements were governed by a train control system in both directions on two main tracks. The train control system used color-light signals located at interlockings. Interlocking locations were primarily operated automatically; but the operation of the interlocking could be requested remotely from OCC or from a local control panel in field ATC rooms. Audio frequency track circuits provided track occupancy detection and speed commands.

Train operations on mainline routes could be carried out in either automatic train control or manual control by a train operator. Automatic train control consisted of three control subsystems; automatic train protection, automatic train supervision, and automatic train operation. Manual control overrode automatic train supervision and automatic train operation but did not override automatic train protection.

The train-to-wayside communication (TWC) system provided two-way data communication between the carborne and wayside train control systems. The TWC system provided for automatic door operations at stations and for carborne passenger information displays. The wayside system transmitted signals to the train through track circuit transmitters. These signals were picked up by receiver coils mounted underneath the lead car of a train. A transmitter loop mounted under the front of the lead car transmitted information about the train to the wayside system.

4.3 Location and Site Description

4.3.1 Track

Tracks were owned, inspected, maintained, and operated by WMATA. The accident occurred on the Yellow Line, identified as the "L" line, of the Metrorail system at chain marker L2-70+50. The interlocking located south of the L'Enfant Plaza station designated the beginning of the "L" line which then continued towards the Potomac River Bridge and into Virginia. This portion of the Yellow line was located in Washington, DC.

The Gallery Place/Chinatown station (north of L'Enfant Plaza station) was designated as the beginning of the "F" line. The "F" line extended through the L'Enfant Plaza station and continued on the Green line towards the terminus Branch Avenue station.

The Yellow Line, in the vicinity of the accident, was oriented in a north/south direction and consisted of two main tracks with track 1 located to the east (inbound) and track 2 to the west (outbound). The track structure in the area of the accident was direct fixation or encased in concrete. The track structure did not have ballast or conventional crossties. The chain marker numbering increased in the southward direction.

The tracks through the accident site consisted of 115 pound RE rail. The main track consisted of continuous welded rail seated in Lord and Pandrol plates with special permanent fasteners that restrained the rails from lateral and longitudinal movement. The plate measurement varied depending upon the style of plate used but had an average spacing of 30 inches.

4.3.2 Tunnel Structure

The track section of the Yellow Line at the L'Enfant Plaza station and through the location of the incident was located in an underground tunnel in the southwest quadrant of Washington, DC. The tunnel construction of the "L" line, south of the interlocking was of circular design with a steel tunnel lining and equipped with raised concrete safety walkways located along both sides of each tunnel. Within the tunnel structure, just south of the accident location, a platform leading to fan shaft (FS-L01) was located. South of the platform, a concrete wall separated the two tracks.

4.3.3 Fan Shaft

Fan shaft FS-L01 was the closest fan shaft to the vicinity of the accident, and was designated as the first fan shaft on the L-line. Fan shaft FS-L01 was located south of the L'Enfant Plaza station. Two other fan shafts configured similarly to FS-L01 were located one to the north and the other to the east of the L'Enfant Plaza station. In addition, two vent shafts were located at the north and south ends of the L'Enfant Plaza station.

The fans at FS-L01 could operate in either exhaust mode or supply mode. FS-L01 was configured with four fans[2], equipped with a 480 vac, 25 horsepower motor and a capacity of 50,000 cfm in exhaust mode and 35,000 cfm in supply mode. In both exhaust or supply mode, fans could be requested to activate in either emergency or automatic. Emergency activation would immediately initiate fan activation. Automatic would initiate fan activation when a temperature sensor in the vent shaft indicated the temperature was above 95 degrees Fahrenheit.

Operation of the fans could be requested remotely from OCC or locally by maintenance personnel using a selector switch on the fan control panel located adjacent to the four fans within the fan shaft. Remote fan operations from OCC were through the Data Transmission System (DTS) cables to an RTU at the L'Enfant Plaza station. When OCC would send a control command, an initial status was reported back from the fan controls to the RTU that indicated the current status of the fans. A second status would then be sent back that confirmed the control command from OCC. Status and alarms were sent from the fan control cabinet to the RTU and then to OCC and logged by the AIM system.

4.4 Description of Traction Power System

Train propulsion power was supplied from an electrified contact rail with 750 volts (dc). The third rail was located parallel to the running rails. The third rail was located approximately 2-feet 2-inches (+/- ½-inch) from its centerline to the gage line of the nearest running rail; and 4 ½-inches (+/- 1-inch) higher than the nearest running rail. The third rail, also known as the contact rail, was typically shielded or covered but allowed for the contact rail shoes affixed to the rail cars to contact the top of the third rail as it moved. In the area of the incident, the third rail was located outside of the running rail, which in this case was between the east rail of the track structure and the east wall of the tunnel. Along the length of the platform area for the fan shaft, the third rail terminated at each end of the platform. Four jumper cables maintained third rail continuity from each end of the platform.

The train propulsion power system was monitored using a SCADA system that maintained a record of the status of the third rail traction power system. The SCADA log

[2] The four fans at FS-L01 were designated as SVF5, SVF6, SVF7 and SVF8.

recorded changes in parameters such as circuit breaker conditions. The train propulsion power system data was also managed by the AIM system at OCC.

4.5 System Data Logs

Signal and train control system data logs were downloaded from OCC for southbound train runs 301, 302 and 510, and northbound train runs 306 and 307. Track occupancy reports were provided for review.

Third rail power system logs were also downloaded from OCC. A complete timeline of recorded AIM system events was developed and included ATC data, Third rail data, OCC alarm logs and fan shaft status logs. Significant events were reviewed and incorporated into a timeline, (see Table 1).

Table 1. AIM data timeline

Time	Location	Event
2:54	L'Enfant Plaza	Train run 301 departs station
3:06:21	L'Enfant Plaza Track 2	Track circuits F2-32, F2-35 & F2-39 indicate temporary occupancy with no trains in area (bobbing)
3:06:32	L'Enfant Plaza South Tie Breaker	Indicates breaker 68 trips open (closes and trips a few times after this event)
3:06:40	L'Enfant Plaza South Tie Breaker	Indicates breaker 68 trips open and remains open
3:14:32	L'Enfant Plaza	Train run 302 accepts signal to depart station
3:14:45	L line, Track 2	Track circuit L2-55 indicates occupied by run 302
3:15:02	L line, Track 2	Track circuit L2-57 indicates occupied by run 302
3:16	L line, Track 2	Train run 302 stops
3:16:09	L'Enfant Plaza	OCC sends command to UPE Fan #2 for Emergency On – Exhaust mode (under-platform exhaust fans)
3:16:32	L'Enfant Plaza	OCC sends command to UPE Fan #1 for Emergency On – Exhaust mode (under-platform exhaust fans)
3:20:59	L'Enfant Plaza Fire Alarm #1	OCC receives active alarm indication
3:21:54	L'Enfant Plaza Fire Alarm #6	OCC receives active alarm indication
3:21:59	L line, Track 1	Track circuit L1-62 indicates occupied by run 306
3:24:26	L'Enfant Plaza	Train run 510 stopped at station
3:24:28	Fan Shaft – L1	OCC sends command for Emergency On – Exhaust mode Fan #6
3:26:20	L'Enfant Plaza	Train run 510 keyed down at station
3:26:49	Fan Shaft – D3 & Fan Shaft - D4	OCC sends command for Emergency On – Exhaust mode Fan #1
3:28	L line, Track 1	Track circuit L1-62 indicates occupied by run 307
3:30:06	L'Enfant Plaza Fire Alarm #4	OCC receives active alarm indication
3:40:21	Maryland Avenue Tie Breaker	OCC receives DC feeder tie breaker 43, 44, 45, 63, & 64 tripped indication
3:44:18	Fan Shaft - F2	OCC sends command for Emergency On – Exhaust mode Fan #5
3:44:47	Fan Shaft – F3	OCC sends command for Emergency On – Exhaust mode Fan #5
3:49:34	L'Enfant Plaza South Tie Breaker	OCC sends command for breaker 68 to trip
3:49:45	Ohio Drive Traction Power	OCC sends command for breaker 32 to trip

Time	Location	Event
3:49:55	L'Enfant Plaza South Tie Breaker	OCC sends command for breaker 69 to trip
3:50:11	Ohio Drive Traction Power	OCC sends command for breaker 11 to trip
3:50:23	Ohio Drive Traction Power	OCC sends command for breaker 34 to trip

4.6 Track Maintenance Records

The WMATA Track, Structures, and System Maintenance Division is responsible for inspecting and maintaining the Metrorail track. Track maintenance consisted of twice-weekly walking/visual track inspections. Track inspectors produced a "Track Walker Inspection Report" of their inspections, which were submitted for review by their supervisors. The reports included track defects, track maintenance items and updates on known issues. Specialized automated equipment was also used to conduct additional track geometry inspections and internal rail defects.

The last inspection on tracks L1 and L2 before the accident was on January 12, 2015. WMATA personnel conducted the track inspections from a train due to inclement weather and slippery conditions. No track defects were noted on the inspection record. Track inspection reports from January 4th, 5th, 7th, and 8th were reviewed. Nothing remarkable was noted regarding the track in the area of the accident.

The most recent automated track geometry inspection through the area of the accident was on November 7, 2014. The inspection included geometry, platform, signal, third rail and tunnel clearance. Nothing remarkable was noted during the inspection.

4.7 Postaccident Track & Third Rail Examination

A postaccident visual track examination was conducted on track L-2 in the vicinity of the accident. Nothing remarkable was noted with track geometry, including; gage, curve alignment, and cross elevation. An examination of the third rail did not identify any measurements that did not comply with Metrorail standards. In addition, there was no indication of dragging equipment or any other marks in the track in that area.

The track examination noted that 18 feet south of the arcing area was where the heaviest flow of water was coming in between the grout pads under the east rail. South of the water flow there were rocks and debris on three grout pads. The sediment south of the water flow gave indication that the water volume was heavier at some point. Rocks and debris were also noted on two grout pads north of the water flow, however less sediment was present on the north pads. No exception was taken to any track geometry in the subject location

4.8 Postaccident Fan Shaft, FS-L01 Examination

On January 19, 2015, a postaccident examination of the fan shaft system at FS-L01 commenced. The examination found that OCC was unable to remotely execute a command to switch fan operation modes from supply to exhaust. In addition, fans SVF5 and SVF7 (two of the four fans) were inoperable due to overload breakers being in the tripped position.

The OCC remote command failure was identified to be associated with a fault in the signal from the RTU to the local fan control panel. When OCC sent a command to place the fans at FS-L01 in exhaust mode, a command would be generated at OCC and sent to the RTU at L'Enfant Plaza. The RTU would then generate a 28 volt (dc) pulse signal that was transmitted through the DTS to the local fan control panel. At the fan control panel, the DTS signal triggered the relays in the control panel and changed the fan mode from supply to exhaust.

The investigation found that the command from OCC was generated and transmitted to the RTU at L'Enfant. The RTU however was not generating or transmitting the 28 volt pulse signal to the fan control panel at FS-L01. The investigation determined that the circuit board control card (slot A14-J3, Word 0, Frame 5, Bit 9) in the RTU at L'Enfant was defective. The RTU control card was replaced and all command and control functions for the fans at FS-L01 were exercised and determined to be functional. The defective RTU control card was retained by NTSB investigators.

During the examination at FS-L01, the overload breakers for SVF5 and SVF7 were reset and all four fans were tested and found to be operational using the fan local control panel. The fan shaft system was activated in both exhaust and supply modes using the fan local control panel and nothing remarkable was noted. However, during the OCC remote command functional tests of the fan system at FS-L01, fans SVF5 and SVF7 were found to have reverted to the overload tripped condition that was initially found at the start of the examination.

The tripped overload breakers for fans SVF5 and SVF7 were found to be associated with a low supply voltage (480 volts-ac) from the WMATA, Ohio Power Substation. WMATA personnel[3] conducted an electrical system assessment report for the FS-L01 fan shaft equipment.

The assessment report determined that the state of the electrical system was based on original designs and equipment installed from the 1980s. Deficiencies were identified regarding the automatic transfer switch (ATS[4]), the automatic voltage regulator (AVR[5]) and the motor control center (MCC[6]). The assessment found that the ATS were installed based on the factory default settings and were never adjusted to meet the operational constraints of the fan system. These settings caused the ATS to prematurely transfer the load to the emergency source during fan startup. The AVR was found to be in a bypass mode which permitted the AVR to maintain electrical connectivity to the load without providing voltage regulation after an internal failure occurred. A tripped thermal switch was found but the cause was not determined. The MCC, motor starter components were original and nearing the end of their service life. In addition, the assessment report determined that the fan motors freewheeled at significant speeds in any direction during peak rail traffic. This resulted in higher than usual motor currents if the fans were commanded to operate in the opposite direction and could cause the circuit breaker to trip and disable the fan motors.

The assessment report recommended that FS-L01 be reconfigured and upgraded to improve reliability. In the meantime, the ATS were adjusted to be more tolerant and to prevent unnecessary load transfers.

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[3] Assessment was conducted by WMATA, Chief Engineer Infrastructure (CENI) Power (dated April 6, 2015)

[4] Designed to automatically switch to a readily available emergency power source in the event that normal power source becomes unavailable.

[5] Designed to automatically correct the incoming voltage to the system and provide regulated output voltage within a +/- 3% margin of the nominal system voltage.

[6] Designed to electrically start four fan motors when commanded locally by maintenance personnel at the fan control panel, or remotely by personnel at OCC.

4.9 Fan Shaft Maintenance Records

The investigation attempted to determine when the RTU control card became defective and disabled the ability of OCC to command the fans at FS-L01 to switch from supply mode to exhaust mode. WMATA procedures required monthly preventive maintenance of the tunnel ventilation fans[7]. The checklist for the monthly maintenance contained 21 items that covered visual inspection and local operation of the fan and associated components, as well as the remote operation of fans by an OCC line controller. The fan shaft maintenance was usually performed by a crew of two mechanics during regular service hours. For remote operation of the fans, the maintenance crew was required to contact OCC and request the line controller to operate the fans in both exhaust and supply modes. The record of preventive maintenance work at FS-L01 were reviewed for September, October, November and December of 2014. The December preventive maintenance was the last performed prior to the arcing event. All records showed no issues on any of the task items including remote operation of fans.

AIM data regarding historical records of fan operations from the same time periods were also reviewed. The AIM data showed no evidence of remote fan commands from OCC on the dates of the preventive maintenance. WMATA was notified of this inconsistency and conducted an internal investigation, which determined that no remote testing of fans was actually performed for FS-L01 during preventive maintenance from September to December 2014.

Preventive maintenance records and AIM data logs of fan shafts FS-F02 and FS-F03 were requested and reviewed. Comparison of the maintenance records and data showed the same inconsistency between the preventive maintenance records and the AIM data logs as to what was found for FS-L01

END OF SIGNALS, TRACTION POWER, TRACK &
PLANT SYSTEMS GROUP FACTUAL REPORT OF INVESTIGATION

[7] Preventive maintenance was recorded on PLNT Form 209-1571 (10/2014)