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

GROUP	B
EXHIBIT	
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Agency / Organization

NTSB

Title

Mechanical Group Factual Report

Docket ID: **DCA 15 FR 004**

National Transportation Safety Board

Office of Railroad, Pipeline and Hazardous Materials Investigations

Washington, D.C. 20594

Smoke and Arcing at L'Enfant Plaza Subway Station

Washington D.C.

January 12, 2015

Mechanical Group Factual Report

Accident

NTSB Accident Number:	DCA15FR004
Date of Accident:	January 12, 2015
Time of Accident:	3:06 p.m. (EST[1])
Type of Trains:	WMATA Transit Railcars
Railroad Owner:	WMATA
Train Operator:	WMATA
Fatalities:	1
Number of passengers that visited local hospitals	86
Location of Accident:	L'Enfant Plaza, Washington D.C.

Mechanical Group Members

National Transportation Safety Board
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[1] Eastern standard time

Accident Synopsis

On January 12, 2015, about 3:15 p.m., 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 railcar 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 WMATA Transit police officers, Metrorail/L'Enfant Plaza Station Managers and WMATA Supervisor personnel 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 railcars 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.

Atmospheric conditions at the time of the incident were reported as rain/mist, calm winds and 37 degree ambient temperature. (Weather reported from Reagan National Airport, about 1 mile south of the tunnel portal near the Potomac River Bridge).

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

Train Consist 302

Southbound WMATA train 302 consisted of six railcars mechanically, electrically and pneumatically coupled together. Each railcar weighs about 80,000 lbs. and is 75 feet in length. The total estimated weight of an empty train is about 480,000 lbs. with a total estimated length of 450 feet.

The railcars in train 302 are designated as follows:

1. 6134 – lead railcar
2. 6135
3. 1285
4. 1284
5. 3030
6. 3031 – trailing railcar

All Metrorail revenue railcars operate in married pairs with an operating cab at each end. Each pair of railcars is electrically powered and fully automated. The railcars are equipped with a friction brake system, a low voltage system, automatic heating ventilation and air conditioning control and automatic couplers.[2] The railcars must operate in married pairs; no railcar can be operated as a single unit. Primary propulsion power is supplied by a 750 volt direct current (VDC) third rail system.

Accident Sequence

Railcars 6134, 6135, 3030 and 3031 were all equipped with onboard event recorders. The recorders continuously record several parametric parameters such as speed and braking when the train is being operated. The data was successfully downloaded, analyzed and plotted by NTSB's Recorder division and provided to the mechanical group.[3] The data was reviewed along with the data from the train propulsion power system which was monitored using a supervisory control and data acquisition system (SCADA) that maintained a record of the status of the third rail

[2] This list is not all inclusive.
[3] More information is available in the Event Recorder Specialist's factual report.

traction power system.[4] The SCADA log recorded changes in parameters such as circuit breaker conditions for the track at the L'Enfant Plaza station. Investigators also interviewed the train operator.

Event recorder data showed train 302 departing L'Enfant Plaza on track 2 moving south at 3:14:25 p.m. The train's speed increased to about 17 MPH and then slowed to 15 MPH. After traveling 182 feet, the battery voltage on the leading pair of railcars, 6035 and 6034, began to drop from a normal voltage of 37 VDC. At 3:14:42 p.m., 17-seconds after departing L'Enfant plaza, the battery voltage dropped to 32 VDC. As the train continued south, the trailing railcars battery voltage, 3030 and 3031, also dropped to about 32 volts. Event recorder data indicated train 302 came to a stop at 3:15:15 p.m. after traveling a distance of about 800 feet.

The grade of track 2 at L'Enfant Plaza station for southbound traffic is at -0.37 percent. South from the station for 283 feet, the grade continues to have a grade of -0.37 percent after which the grade decreases to -2.97 percent for the next 968 feet. The grade transitions to -0.50 percent 1400 feet south from L'Enfant plaza.

The operator of train 302 stated he observed heavy smoke after departing the L'Enfant Plaza station, stopped his train and notified the operations control center (OCC) that he was going to reverse ends in preparation to return to the platform.[5] Event recorder data shows the lead railcar, 6034, keyed down at 3:16:35 p.m. Event recorder data shows the battery voltages on the 6135/35 and 3030/31 both dropped below 32 VDC.

At 3:18:45 p.m., event recorder data shows the trailing railcar, 3031, was keyed up, indicating the train was now powered from the trailing end. Event recorder data shows the environmental control off trainlines from 6134, 6135 and 3030 and 3031 transitioned from a value of 0 to 1 when car 3031 was keyed up. The train operator stated he received permission to cut out, or disable, the ventilation systems on the train, he then said he did this by dropping [opening] the environmental control circuit breaker on railcar 3031.

[4] More information is available in the Railroad Signal & Train Control, Traction Power And Track Group factual report.

[5] Reversing ends is an operational term meaning train operator will physically move to the trailing railcar, activate the console and be prepared to move in the opposite direction.

At 15:20:40 p.m., event recorder data shows the white light relay on car 6134 transitioned from a value of 1 to 0. According to WMATA, there are two operations of the white light thus activating the relay. A solid white light is lit when the main reservoir pressure is below 90 psi. A white light flashes when the air spring pressure between front and rear truck or the brake cylinder pressure between front and rear truck differs by more than 25 psi.

If the white light is "ON" on both cars of a married pair, then it is most likely that main reservoir pressure is below 90 psi. This is an indication that brake pipe will dump soon when pressure drops to 70 psi.

If the white light is flashing on only one car, then it is most likely due to air bag or brake cylinder pressure difference between F and R truck.

At 3:21:30 p.m., the environmental control trainline transitioned to from 1 to value of 0.

At 3:22:40 p.m., event recorder data shows train speed increase from 0 mph to 2 mph in a time interval of one second and immediately returned to 0 mph. there was no recorded movement. This event coincided with a momentary transition of brake cylinder pressure from about 45 psi to 0 psi. the brake cylinder pressure transitioned several more times over a time interval of about 3 seconds however.

At 3:32:30 p.m., the brake pipe pressure switch on railcars 6135 and 6134 changed state indicating the brake pipe pressure dropped below 70 psi. When this occurs, the air is evacuated from the brake pipe affecting all the railcars in the consist and, the emergency brakes are applied on the entire train.

After notifying OCC his train dumped the brake pipe, the train operator was instructed to recharge the brake pipe and begin preparations to move the train. Event recorder data shows there were several attempts by the train operator to recharge the brake pipe beginning at 3:33:40 p.m. but, he was not successful. At 3:38:52 p.m. event recorder data shows railcar 3031 keyed down, the status of the door check relay indicated the side passenger doors on the train were still closed.

The data from the SCADA system shows the third rail tie breakers in the L'Enfant Plaza tripped at 3:40:21 p.m., de-energizing the third rail at L'Enfant Plaza platform.

At 3:47:50 p.m., event recorder data shows the brake cylinder pressures on railcars 6034 and 6035, all fell to 0 psi, an indication the train operator was isolating the brake system making preparations to move the train. At 3:48:42 p.m., event recorder data shows railcar 3030 (the 5th railcar in the train as it moved south) keyed up and the status of the door check relay indicated that the side passenger doors on the train were not closed. This indicated that at least one or more door panels in the train consist was open, however, the data does not indicate which. At 3:52:45 p.m., event recorder data shows railcar 3030 keyed down.

Pre-Departure Inspections

On January 16, 2015, investigators met with WMATA maintenance personnel and requested pre-departure inspection records for train 302 for January 12, 2015. WMATA said their pre-departure inspection consists of a Daily Safety Test (DST).

An onboard system is provided for use in yards where trains are being assembled for dispatch. No additional equipment, either hand carried or wayside, is required to conduct the test. Operator input to the Automatic Train Control (ATC) equipment for daily safety purposes is via the DST panel located in each of the operating cabs below the operator's console, on the sidewall of the cab. During the test, five ATC functions are checked:

1. Cab signal reception and decoding
2. Over speed protection
3. Rollback protection
4. Motion sensor failure protection
5. Door operations (passenger)

In addition to the DST, a brakes applied and released along with emergency application is tested. The radio installed in the train is also function tested. Records of the DST for 302 were reviewed by investigators with no discrepancies noted.

During his interview, the train operator from train 302 was questioned by investigators about the performance of his train. He indicated that there were no problems.

Equipment Post Accident Inspections

On January 16, 2015, investigators met WMATA personnel at their maintenance facility in Greenbelt, MD, to inspect train 302. The train was still in the original configuration in an undisturbed state upon initial examination. A general exterior and under railcar equipment examination was completed and no indications of fire damage or missing components were observed.

The train was powered up and all systems were brought back online. Investigators then completed a successful DST test on the leading railcar, 6134 and the trailing railcar 3031. The brake systems were evaluated with no defects observed.

Investigators then had WMATA maintenance personnel separate the train into the married pair units for closer examination. The following transit railcar systems were closely examined for signs of fire, damage or overheating:

A. Battery systems
B. Brake resistor grids
C. Auxiliary power supply systems
D. Ground fault power interrupter
E. Propulsion systems
F. High voltage panels
G. Main power switch
H. Traction motors & cables
I. Grounding systems
J. High voltage collection systems (collector assemblies)

No indications of damage or fire were observed.

On Wednesday March 17, 2015, the investigators again met with WMATA officials at the Greenbelt Shop in Greenbelt, MD, with the train (302) from the L'Enfant Plaza accident re-assembled for follow up testing and evaluation.

The train was positioned in a yard track number 2 on energized third rail. The team was dispersed through the train in a manner that allowed for the evaluation of all six railcar's HVAC systems. Railcar 3031 was keyed up, all HVAC systems were operational. The test operator, a

WMATA 10-year veteran, was asked to shut down the train's HVAC systems in a manner consistent with receiving permission from the operations control center during a smoke event. With the train stopped and the console keyed on, the test operator used a key to turn the environmental control (EC) switch off which is located on a panel on the right wall of the operator's cab. See figures 1 and 2.

Figure 1-Operator console of railcar 3031

Figure 2-Enviromental control (EC) switch

The test operator then opened an environmental control circuit breaker. See figure 3. At this time railcar 3031's environmental systems shut down. The team verified that all other environmental systems remained operational. That is, they did not shut down with the action performed by the test operator.

Figure 3-Circuit breaker panel of railcar 3031 with the environmental control circled

Investigators attempted the same test with the railcar in motion. The results were identical in that railcar 3031's environmental systems shut down and all other railcars remained operational.

WMATA officials were asked to demonstrate the shutdown of a train's environmental systems based on their response to NTSB staff stating they have a procedure. This procedure was not demonstrated by the WMATA test operator it was demonstrated by a WMATA vehicle engineer.

With railcar 3031 keyed on and all environmental control systems operational, the engineer keyed the console off. He then used a key to turn the EC switch on the right wall of the operator's cab to the off position. He then opened the environmental control circuit breaker on the panel and keyed the operator's console back up.

Investigators verified that all environmental systems in the consist (all railcars) shut down in less than four seconds after the WMATA engineer initiated the shutdown procedure. NTSB investigators requested a copy of the procedure and WMATA officials later provided an approved copy of the HVAC Emergency Shutdown Procedure, dated March 19, 2015.

According to WMATA internal email, the agency began developing the emergency shutdown procedure immediately after the January 12, 2015 incident. A working procedure was provided to WMATA's operations group on February 5, 2015. The provided procedure lacked only the agency's approval signatures; all other elements of the procedure were identical to the March 19, 2015 approved procedure provided to investigators.

Investigators questioned WMATA engineers about the effectiveness of the shutdown procedure on mixtures of railcars from different series, i.e., 1000, 2000, 5000, etc. Officials explained that there is a feature in the 5000 series railcar that will delay the immediate shutdown of the HVAC systems on this series. Currently the delay ranges between 1-2 minutes. WMATA officials stated they are taking immediate steps to modify this delay feature so the 5000 series will shut down immediately upon initiation of the HVAC Emergency Shutdown Procedure.

Investigators needed to further understand the characteristics and behavior of the train when it was on dead rail or, third rail that did not have 750 VDC. This environment was simulated by WMATA officials and the team monitored factors like battery voltage, emergency lighting, brake pipe pressure, main reservoir air, air conditioning systems and the time it took for the

train's brake pipe to 'dump'. A design function that activates when the brake pipe falls below 70 psi thus, putting the train into emergency braking.

The next phase of the follow-up testing focused on the third rail power systems. With third rail power removed, the train's HVAC systems stopped operating immediately along with each railcar's interior lights; emergency lights were on. Emergency lighting consists of fluorescent overhead lights above each doorway. During the time the third rail power was removed, investigators measured the amount of time for it took for the brake pipe to dump; about 17-minutes. Again, with the third rail power removed, the battery voltages on railcars 6135 and 3031 were measured at 31.0 VDC and 29.6 VDC respectively.

Lastly, investigators asked WMATA if they would demonstrate the ability of a single railcar, energized by 750 VDC, to move the remaining unpowered 5 railcars. This did not work. So investigators asked WMATA if they would energize one additional railcar to determine if two railcars could pull 4 railcars. This worked and the train was able to move.

Third Rail Voltage & Railcar Powered Systems

The nominal third rail voltage of WMATA's system is 700 VDC. According to WMATA's railcar design specifications, all equipment shall operate without damage for any duration at any voltage between 430 VDC and 860 VDC.

Third rail voltage shall be used for propulsion, via inverters for alternating current drive motors; heating (except for cab heater); and as input to the battery system power converter and the auxiliary power system inverter(s).

Each railcar contains its own auxiliary power system (APS). Each system consists of an DC-AC inverter, located under the railcar, operating on the third rail power and servicing all AC auxiliary loads on the railcar.

The APS is sized for continuous operation of the air compressor, air conditioning compressor, blower motors, and cab heater loads in addition to any other continuous auxiliary loads. The APS will shut down when the steady state input voltage is out range.

Each married pair of railcars is equipped with a low voltage power supply (LVPS) that includes battery charging, traction control, trainline control, all emergency loads, normal and emergency fluorescent lighting, and all other auxiliary railcar circuits connected to the battery supply. The converter has a constant voltage output capability of 37.5 VDC for any load demanded by a pair of railcars for all third rail voltages between 430-860 VDC.

Systems and components supplied with battery voltage include, but not limited to, are the headlights, tail lights, running lights, threshold lights, emergency lights, cab ceiling lights, instrument lights, temperature controls, destination sign controls and illumination, door operators and door controls, communications system, automatic train control, ATC power supply, and propulsion and braking controls. All subsystems or components supplied directly from the battery are capable of operation with subsystem or component input voltage at any and all values between 23 and 42 volts.

In the event of the loss of third rail power, the battery load is shed automatically, leaving the battery capacity able to meet emergency load requirements. Load shedding provides for the disconnection of all nonessential battery loads. During third rail power loss, battery system power is available to the select essential systems, which is not shed:

A. Door controls
B. Exterior marker lights
C. Emergency lighting
D. Emergency brake controls
E. Fault indicator lights
F. Friction brake
G. Radio
H. VMS VCU

END OF FACTUAL REPORT