PB82-916306

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

DERAILMENT OF WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY TRAIN NO. 410 AT SMITHSONIAN INTERLOCKING JANUARY 13, 1982

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UNITED STATES GOVERNMENT

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16. Abstract About 1630, e.s.t., on January 13, 1982, Washington Metropolitan Area Transit Authority (WMATA) Blue/Orange Line train No. 410 derailed at the Smithsonian Interlocking on the "downtown" subway line. While being operated manually, train No. 410 had been unintentionally routed into a crossover track at the interlocking. Without requiring a supervisor, who was at the location, or the train operator to ascertain that it was safe to do so, the WMATA Operations Control Center (OCC) allowed the supervisor to back the train out of the crossover track. As this was being done, the rear car derailed and struck the end of a reinforced concrete barrier wall separating the two main tracks in the subway tube. The aluminum sidewall of the car was severed and the main passenger compartment was breached. Of the approximately 220 passengers on the car, 3 were killed and 25 were injured. Damage to property was estimated to be $1,325,000.

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the Metrorail Operations Control Center (OCC) to stop movement of trains through the Smithsonian Interlocking until it ascertained the nature of and corrected the switch misalignment; the failure of the OCC over a 3-day period to note discrepancy reports concerning a wayside control failure in the Smithsonian Interlocking and to order repairs; the failure of the onscene rail transportation supervisor to check conditions at the original lead end of train No. 410 before initiating the reverse movement of the train; and the failure of the train operator to timely recognize the train had derailed and to apply the brakes in emergency. Contributing to the accident was WMATA management's failure to put into place an adequate program of initial and recurrent training for OCC and Metrorail operating personnel and its failure to adopt adequate rules and procedures for safe operation of trains in the manual mode.

17. Key Words WMATA, Metrorail, Smithsonian Interlocking, wayside control failure, switch misalignment, crossover move, Operations Control Center, snow, aluminum sidewall, inadequate training, Automatic Train Control system, emergency train evacuation, reverse movement, absolute block, derailment detector device, low-speed side impact, single track runaround operation.	18. Distribution Statement This document is available to the public through the National Technical Information Service Springfield, Virginia 22161

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SYNOPSIS

About 1630, e.s.t., on January 13, 1982, Washington Metropolitan Area Transit Authority (WMATA) Blue/Orange Line train No. 410 derailed at the Smithsonian Interlocking on the "downtown" subway line. While being operated manually, train No. 410 had been unintentionally routed into a crossover track at the interlocking. Without requiring a supervisor, who was at the location, or the train operator to ascertain that it was safe to do so, the WMATA Operations Control Center (OCC) allowed the supervisor to back the train out of the crossover track. As this was being done, the rear car derailed and struck the end of a reinforced concrete barrier wall separating the two main tracks in the subway tube. The aluminum sidewall of the car was severed and the main passenger compartment was breached. Of the approximately 220 passengers on the car, 3 were killed and 25 were injured. Damage to property was estimated to be $1,325,000.

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INVESTIGATION

Events Preceding the Accident

On January 13, 1982, the rapid transit lines of the Washington Metropolitan Area Transit Authority (WMATA) (see figure 1) experienced extensive delays in moving the commuter rush during the morning peak period. 1/ Twenty-one scheduled trains on the Blue/Orange Line and 6 scheduled trains on the Red Line were cancelled because of mechanical problems aggravated by the weather. Normal train operations resumed following the morning rush and continued during the offpeak period. About 1000, light to

1/ According to WMATA personnel, the morning and evening peak periods were from 0600 to 0900 and from 1500 to 1830, respectively. All times herein are eastern standard time, based on the 24-hour clock.

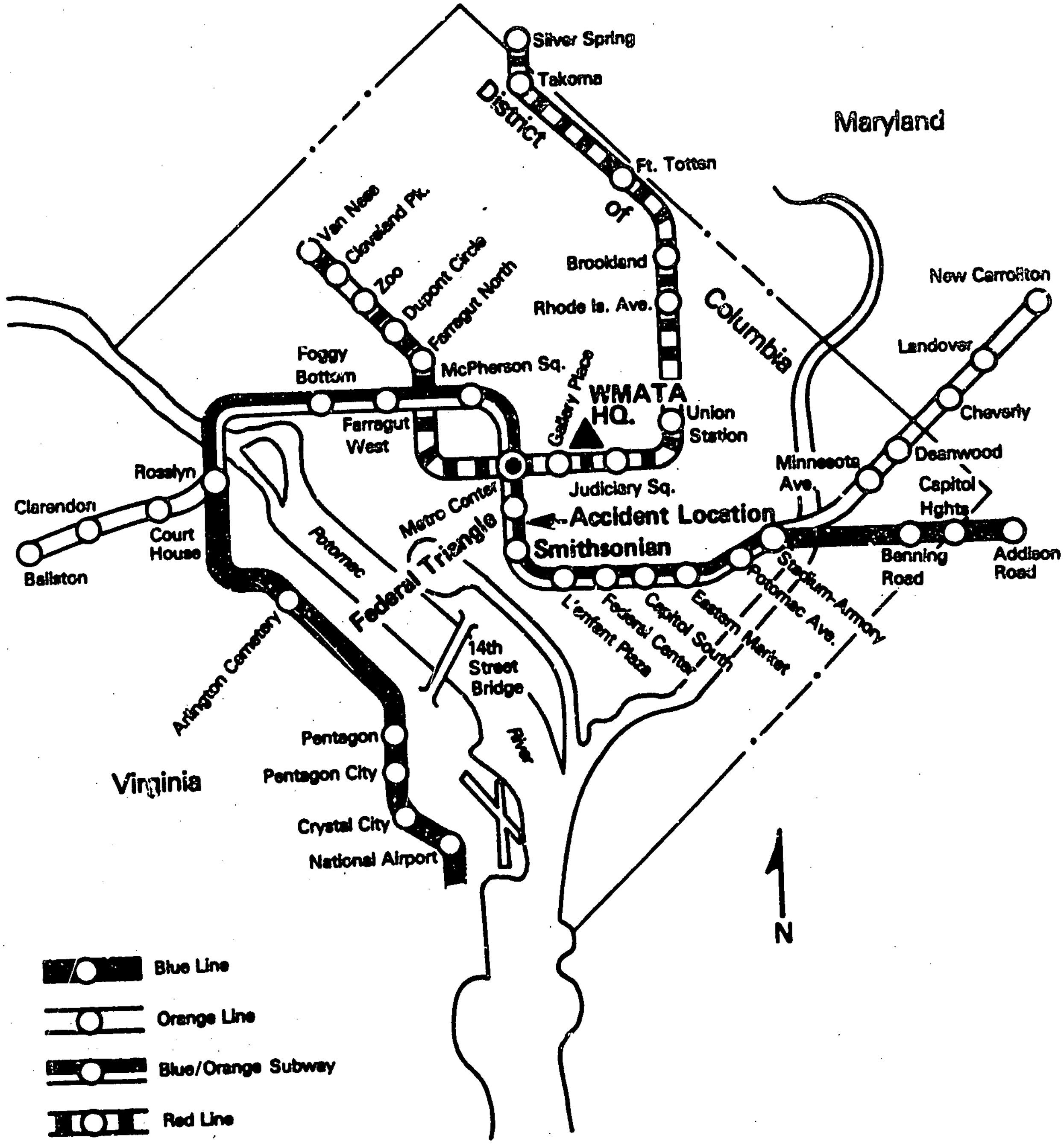

Figure 1.—Map of the Washington Metropolitan Area Transit Authority Metrorail lines in operation on January 13, 1982.

moderate snow began to fall in the Washington Metropolitan area, and when an 8-inch accumulation of snow by nightfall was forecast for the area, business firms and federal agencies released their employees in the early afternoon, resulting in the evening peak period beginning about 30 minutes earlier than normal. Although WMATA was aware of the increased accumulation of snow and knew that the Federal Office of Personnel Management (OPM) intended to allow the early release of office workers in the downtown area on the day of the accident, WMATA never activated its storm alert procedure which provided for operating a substantial number of additional trains during the midday offpeak period. Because of the train mechanical problems and because of large crowds at station platforms resulting in offloading/loading problems, both Metrorail lines began to experience serious delays during the earlier than normal evening peak period.

About 1545, Blue/Orange Line train No. 403, en route from New Carrollton, Maryland, to National Airport at Alexandria, Virginia, stopped at the Federal Triangle Station on the downtown subway in Washington, D.C. The train operator was unable to move the train forward from the station because of a propulsion power problem, and at approximately 1550, he was ordered by WMATA's Operations Control Center (OCC) to off-load the passengers from the train. Road Transportation Supervisor No. 31 2/ was at the Federal Triangle Station and subsequently boarded the train to assist the operator. After changing the operating end of the train, they established that the train could be moved backwards towards the Smithsonian Station. The OCC then decided that it could return train No. 403 to the New Carrollton Station by crossing it over to the D-1 southbound 3/ main track at the Smithsonian Interlocking double crossover located 534 feet south of the Federal Triangle Station platform. (See figure 2.)

Before routing train No. 403 to the D-1 track to return it to New Carrollton, the OCC decided to detour six National Airport-bound trains that had been stopped behind train No. 403 to the D-1 track against the current of traffic to the next double crossover at the McPherson Square Interlocking where the six trains would be returned to the D-2 track. Because the four crossover switches at the Smithsonian Interlocking were aligned for normal main track movement, the OCC remotely aligned switches 1A and 1B for the crossover movement of the six trains. (See figure 3.) Switches 1A and 1B were remotely aligned without any problems and the runaround detour operation of the six trains was completed without incident.

According to the WMATA computer log, the last time switch 1A had been thrown from reverse to normal position before January 13 was at 1339 on January 9. The log also showed that the fusetron that controlled the remote throwing of switch 1A from reverse to normal position had failed at 1423 on January 10. This failure in the Automatic Train Control (ATC) system, which did not prevent the OCC from remotely throwing the switch from normal to reverse, had generated a "Class 1" visual alarm on the Cathode Ray Tube (CRT) video display alarm screen in the OCC. The visual alarm included the time, date, and location of the failure, and the words, "Train Control Fail." There was no audible feature in the alarm alerting system. However, a supervisory controller was responsible

2/ A roving rail transportation supervisor who was designated No. 31 for radio communications purposes throughout his tour of duty and who was located at Smithsonian Interlocking before and after the accident. Hereafter, he is referred to in the report as "the supervisor."

3/ WMATA designates the Blue/Orange Line D-1 main track as northbound and the D-2 main track as southbound. Normal operation is right-hand and trains originating at the Virginia terminals are designated northbound and those originating in Maryland as southbound. However, between Federal Triangle and Smithsonian Stations trains operating over the D-1 northbound track are actually moving south and vice-versa. Actual compass direction at the accident location area is used throughout this report.

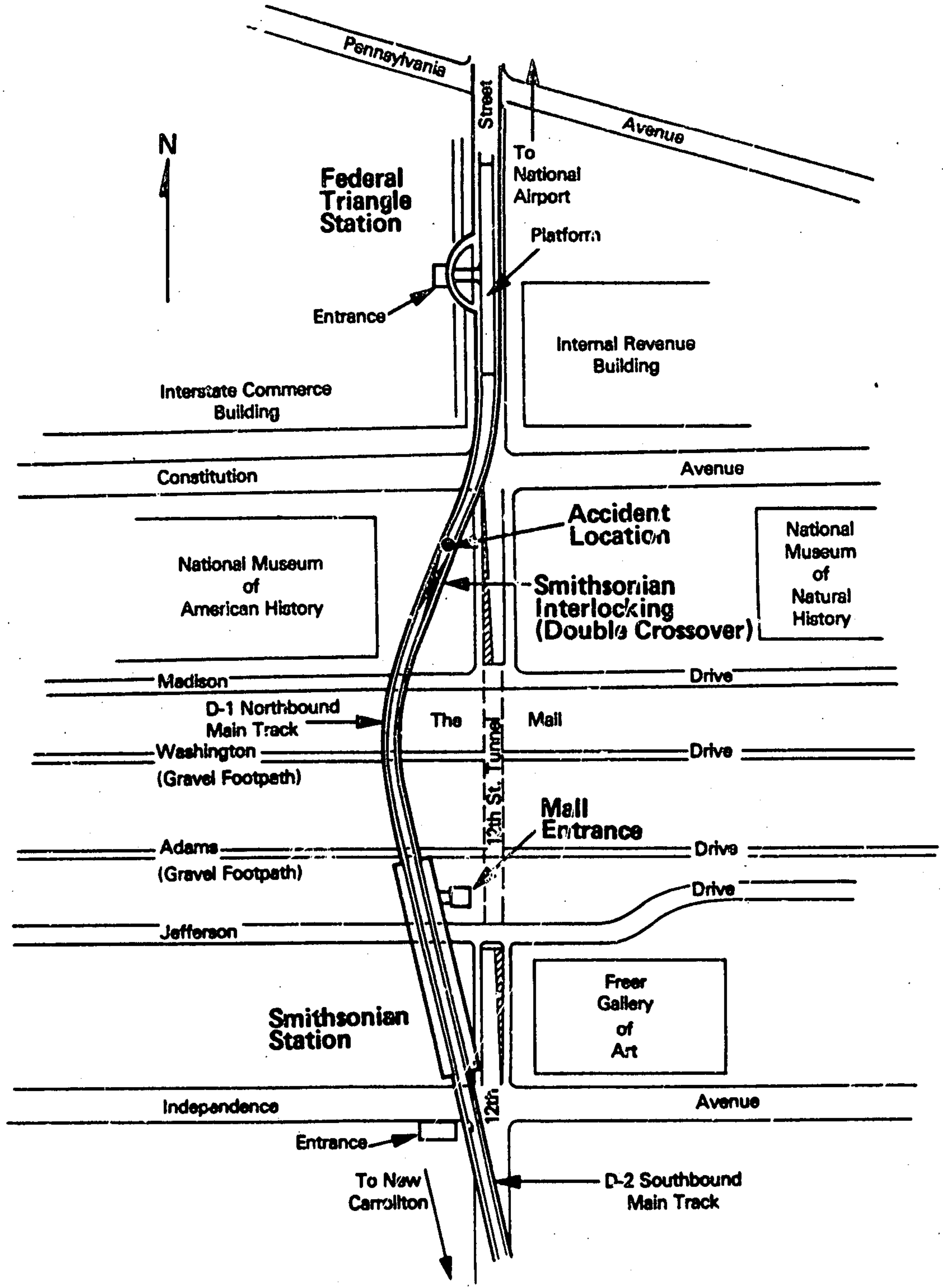

Figure 2.—Plan view of the Metro Blue/Orange Line subway between Federal Triangle and Smithsonian Stations.

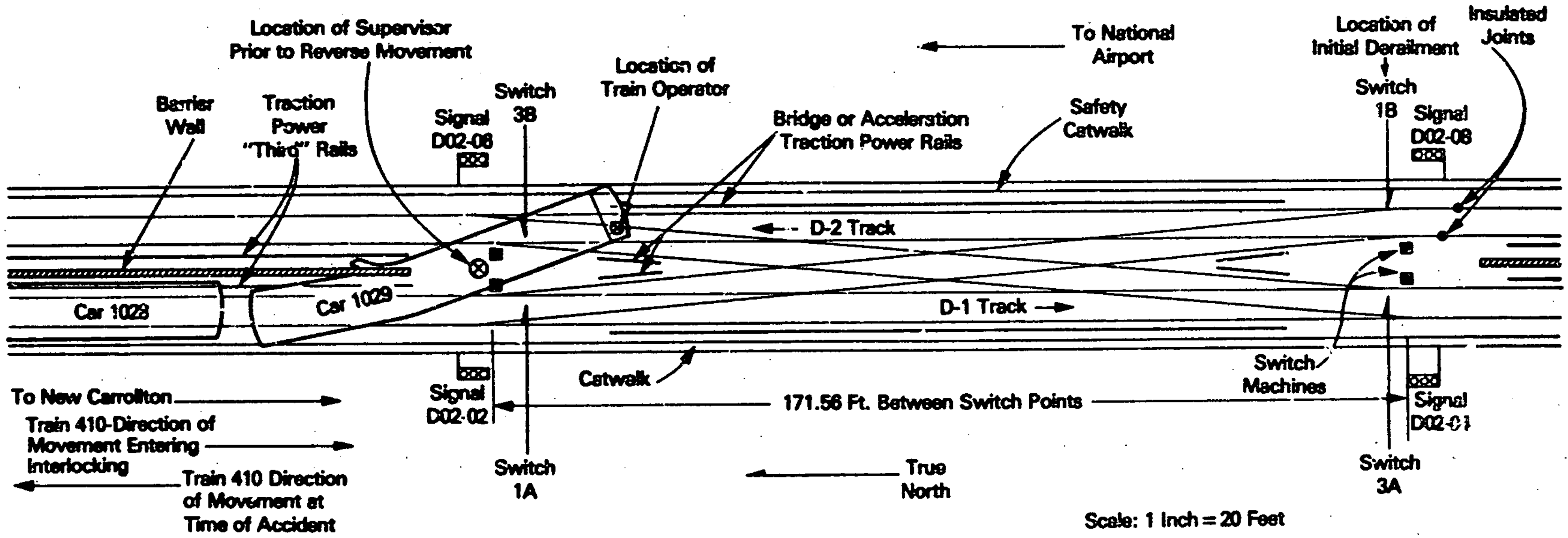

Figure 3.—Plan view of Smithsonian Interlocking showing location of car No. 1029 after the accident.

for monitoring the alarm screen. Only 15 alarms could be displayed on the screen simultaneously, and since there were numerous other alarms, mostly of the less-serious, train-oriented "Class 2" type being displayed, the switch 1A alarm was displayed only briefly before rolling off the screen. The investigation developed, however, that although this alarm was printed on the computer log 10 times after the failure occurred, it was never acknowledged nor reported to WMATA's Maintenance Control by the OCC. 4/

After the last of the detouring trains had cleared the Smithsonian Interlocking, the OCC at 1606 attempted to remotely realign switches 1A and 1B for normal main track movement, after which it planned to align switches 3A and 3B for the crossover movement of train No. 403. (See table 1.) Switch 1B at the Smithsonian end of the crossover returned to normal as commanded, but because of the failure of the control fuse, switch 1A at the Federal Triangle end of the crossover remained aligned in reverse for crossover movement. From their location, the OCC controllers and their superiors had no way of determining which of the switches had failed to throw or what had caused the problem. The CRT screen video display in the OCC was so designed that it could only indicate that the positions of the two switches did not correspond as required. Because the switches were not correspondingly aligned, the interlocking signals displayed a red "stop" aspect and could not be cleared. As a result, all trains could only be manually operated through the interlocking.

On authorization from the OCC, the operator of train No. 403 manually moved the train against the current of traffic to the Smithsonian Interlocking and stopped the train short of signal D02-06 and the facing point crossover switch (3B) at approximately 1612. Since the failure of the wayside control fuse did not affect switches 3B and 3A through which train No. 403 had to pass to reach the D-1 track, the OCC was able to remotely reverse these switches. At 1612:28, the OCC instructed the supervisor who was still on train No. 403, to block 5/ switches 3B and 3A in reverse position because the OCC could not clear signal D02-06. The OCC did not tell the supervisor why the signal could not be cleared and did not ask him to observe and report the positions of switches 1A and 1B. At 1614:39, the supervisor reported to the OCC that the switches were blocked in reverse. The OCC then authorized train No. 403 to proceed at "restricted speed" past the red "stop" aspect displayed by signal D02-06. Train No. 403 crossed over to the D-1 track without incident.

At 1615:21, the OCC instructed the supervisor to stay at the Smithsonian Interlocking until a signal maintenance employee arrived and that "we have trouble with it." The OCC gave no further information to the supervisor about the trouble. The OCC then instructed the supervisor to "unblock No. 3 switch," and at 1616:21 informed him that, "What we want to do is normal that interlocking so that we can operate normal traffic. We can't normal No. 1 switch." The OCC also told the supervisor that "In cranking, you can crank to block both sides." 6/ Between 1618:36 and 1619:22, the supervisor reported in a series of radio communications that he was unable to crank switch 3B to normal position and that switches 3B and 3A were unblocked but still in the reverse position. Subsequently, the OCC was able to remotely command the switches to

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4/ It was also learned that maintenance personnel were at the fusetron location on six occasions following the failure but apparently failed to observe that the popup failure indicator was in the up, or failed position.

5/ WMATA kept 2-inch tapered wood blocks about 18 inches long and 6 inches wide at Smithsonian and other interlockings for insertion between the open switch point and its mated stock rail to prevent gapping or an opening between the other, closed switch point and its stock rail. The blocks were painted yellow and stenciled "WMATA" in black.

6/ "Cranking" referred to manually throwing the switches with a hand crank kept in a box at the interlocking.

Table 1.—Chronology of events preceding and following derailment of train No. 410.

1546:35	Operator of train No. 403 reports explosion under train and loss of power at Federal Triangle.
1606:01	Supervisor No. 31 advises OCC he is on train No. 403. OCC unsuccessfully attempts to align switches 1A and 1B at Smithsonian Interlocking to normal position.
1612:28	OCC instructs supervisor to block switches 3A and 3B at the interlocking so that train No. 403 can cross over to the D-1 track.
1614:39	Supervisor informs OCC that No. 3 switches are blocked in reverse position, following which OCC authorizes train No. 403 to proceed through Smithsonian Interlocking.
1615:21	OCC tells supervisor to stay at the interlocking because "we have trouble with it."
1616:10	OCC instructs supervisor to unblock No. 3 switches, then tells him they want to restore normal operations through the interlocking but they can't "normal No. 1 switch." The supervisor is also told he can "crank to block both sides."
1619:43	The supervisor is instructed to block the switches on the D-2 track first so that OCC can resume running trains on this track.
1621:39	Supervisor informs OCC that switches 1B and 3B are blocked and OCC instructs the supervisor to block the switches on the "other side" (D-1 track).
1624:07	Supervisor reports that all switches are blocked and is instructed by OCC to stay at the interlocking and wave the trains through.
1626:32	Train No. 410 leaves the Federal Triangle Station.
1626:43	OCC instructs trains Nos. 410 and 906 to operate on instructions from the supervisor at Smithsonian Interlocking. Train No. 906 leaves Smithsonian Station.
1627:34	Train No. 410 enters crossover track at Switch 1A after the supervisor instructed the train's operator to proceed.
1627:50	Train No. 410 is stopped with lead end trailed through switch 1B into the D-2 track after supervisor ordered operator to hold up.
1629:07	Supervisor tells OCC they can't run trains on the D-2 track until he pulls train No. 410 back. OCC immediately responds, "All Right."

1630:00 Train No. 410 begins reverse movement, rear car derails and strikes barrier wall.

1631:56 Transit policeman on board derailed car reports the derailment to the WMATA police dispatcher.

1633:47 Supervisor advises OCC there is a derailment blocking both main tracks.

1634:18 OCC asks Fire Department Communications Center to send ambulance to Smithsonian Interlocking.

1640:56 First Fire Department engine company is dispatched to Federal Triangle.

1642:19 OCC tells Fire Department they may need equipment to free passengers pinned against barrier wall.

1646:44 Transit policeman is given permission to evacuate derailed car.

1648:44 Fire Department dispatches rescue squad with extrication tools.

1657:57 Fire Department dispatches ambulances.

1750:00 Evacuation of all ambulatory passengers completed.

1826:00 Last injured passenger removed from derailed car.

normal position and at 1619:41, the supervisor confirmed that switch 3B was in normal position. The OCC then instructed him to block both switches on the D-2 track first (3B and 1B) and told him to, "Make sure they are laying normal, please." Immediately afterward, at 1620:08, the assistant superintendent at the OCC addressed the supervisor by name and instructed him to, "Make sure the switch points are tucked under on switch one." 7/ The supervisor acknowledged both instructions and at 1621:21 reported that the switches were blocked and tucked under. The OCC determined that the supervisor was referring only to the switches on track D-2, and therefore instructed him to go to the other track and to also block the switches there.

National Airport-bound trains Nos. 904 and 415 were stopped and held south of the Smithsonian Interlocking during the time the OCC was attempting to have the supervisor align the interlocking for normal main track movement. Because the interlocking signals were still displaying red "stop" aspects, trains would have to be manually operated through the interlocking.

About 1622, the OCC authorized train No. 904 to pass signal D02-08, displaying a "stop" aspect, providing the rail alignment was correct for a "straight-through move" on the D-2 track. About 2 minutes later, train No. 415 was told, "O.K. 415. If you have correct rail alignment for a straight through move, you have permission to pass 02 red." The transcript of the voice recording indicates that the operator of this train did not acknowledge the instruction and that the OCC made no further attempt to contact the operator although required to do so by the rules. However, both trains passed through the interlocking on the D-2 track without incident. (See table 2.) At 1624:07, the supervisor

7/ The term "tucked under" is used by WMATA Metrorail employees to indicate that the closed switch point is fitting tightly against its mated stock rail.

reported "All switches are blocked and tucked under at this time." The OCC responded by instructing the supervisor to stay at the interlocking and "wave the trains through."

Table 2.—Train movements through the Smithsonian Interlocking before the accident.

Time 8/	Train Number	Track	Direction of Travel
1544	403	D-2	South
1545	910	D-1	North
1547:30	408	D-1	North
1551:30	912	D-1	North
1552:30	413	D-2 to D-1	South
1554:30	907	D-2 to D-1	South
1556	404	D-2 to D-1	South
1558	902	D-2 to D-1	South
1559:30	414	D-2 to D-1	South
1604	903	D-2 to D-1	South
1615:17	403	D-2 to D-1	North
1623:04	904	D-2	South
1625:18*	415	D-2	South
1627:34	410	D-1 to D-2	North

* The supervisor reported that all the switches were blocked at 16:24:07.

When the supervisor was questioned later, he stated that he never did crank any of the switches at the interlocking, but that he did observe all of the switches to be aligned for normal movement. He also stated that he inserted wood blocks in switches 3B, 1B, 3A, and 1A, in that order, and that he tapped them in with the switch crank to make sure they fit snuggly. However, he also stated that when he inspected switch 1A after the accident, he found the wood block for that switch lying undamaged on the tunnel catwalk adjacent to the switch.

The Accident

Blue/Orange Line train No. 410, en route from National Airport to New Carrollton, had been held at the McPherson Square Interlocking until the last of the six National Airport-bound trains had detoured around disabled train No. 403 and had returned to the D-2 track at the McPherson Square Interlocking. At approximately 1618, six-car train No. 410 was under way again on the D-1 track and was told by the OCC to hold up at the Federal Triangle Station when it reached that location. The operator immediately acknowledged the instruction. At 1621:40, train No. 410 arrived at the Metro Center Station for offloading/loading at the platform. Since Metro Center is the junction of the two Metrorail lines and since No. 410 was the first New Carrollton-bound Blue/Orange Line train to arrive at Metro Center in 34 minutes, the station platform was jammed with people. The train was loaded to crush capacity and the operator stated that he had extended difficulty closing the train doors as a result, delaying departure until 1624:28. Shortly afterward, the operator of train No. 410 notified the OCC that his train was approaching the Federal Triangle Station. The OCC responded by telling the operator to

8/ Times shown are those of entry into the interlocking and are based on signal circuit occupancy times recorded in WMATA's computer log, or the times indicated on WMATA's train movement graph which generally agree event-wise with the log times. Radio transmission times shown elsewhere in the report have been adjusted to conform with the log times.

disregard the earlier order to hold at that location. Train No. 410 left the Federal Triangle Station in manual operation at 1626:32. At 1626:43, the OCC instructed trains Nos. 410 and 906, a National Airport-bound train then standing on the D-2 track at the Smithsonian Station, that "Supervisor. . . is in the interlocking there at Smithsonian. He will instruct you." The operator of train No. 410 immediately acknowledged, "Roger, 410 copy." The operator of train No. 906 did not respond and the OCC made no further attempt to contact him.

Train No. 906 left the Smithsonian Station shortly after 1626:43 on the D-2 track. According to the operator, the train was in the automatic mode, and as soon as he closed the doors, he received a speed command and the train moved forward. The operator stated that when the train approached the Smithsonian Interlocking, the train automatically came to a stop at a point which he guessed to be 60 to 75 feet short of signal DO2-08 at the entrance to the interlocking. The operator stated that he never changed to the manual mode, that he did not move the train after it stopped, and that he did not hear the OCC telling him and the operator of train No. 410 to operate on instructions from the supervisor at the interlocking. The operator of train No. 906 did state, however, that before train No. 410 entered the interlocking, he heard what he assumed was the OCC giving someone, "permission to run the red signal...if you have the right alignment." He also stated that he did not know what that meant, that no signal number was given, and that he was not sure what train was being addressed.

The supervisor stated that he was standing at the end of the barrier wall (see figure 3) separating the two main tracks at the Federal Triangle end of the Smithsonian Interlocking when he heard the OCC tell the operators of trains Nos. 410 and 906 to operate on the basis of his instructions. Both the supervisor and the operator of train No. 410 stated that train No. 410 made the required stop short of signal D02-02, displaying a "stop" aspect, at the entrance to the interlocking. At 1627:20, the supervisor used his hand radio to tell the operator of train No. 410 to proceed. He also gave the vertical, up-and-down hand signal for proceed with his flashlight, but gave no instruction regarding the route to be taken or speed. The operator immediately acknowledged, "Roger, 410 proceeding through red." At 1627:34, the train's front end passed the signal and headed into the crossover track at switch 1A. Ten seconds later, the supervisor reacted by repeatedly telling the train operator to "hold up." By this time, the front end of the train had passed beyond the crossing frog and was at least 50 feet beyond the point where it fouled the D-2 track. The operator responded by applying the train's brakes in full service and at 1627:47 transmitted that he was holding. When the train stopped about 3 seconds later, the lead pair of wheels of the lead truck (car No. 1029) had trailed through switch 1B, separating the closed switch point from its stock rail, and had come to a stop beyond the first insulated joint past the switch. The trailing pair of wheels of the lead truck was in the switch and the front end of the car was not less than 13 1/2 feet beyond the switch. (See figure 4.)

The operator of train No. 906, which was on the D-2 track short of signal D02-08, stated that when he first saw train No. 410 entering the crossover it was going so fast that he thought there was going to be a collision. However, he heard a voice on the radio shout, "Hold it," and train No. 410 stopped on the track ahead at the switch. The train appeared to the operator to be normal, "not tilted," and he thought that, "...it looked O.K. to go back."

The operator of train No. 410 stated that after his train entered the crossover, he could see the reflection of another train's headlights on the rails of the D-2 track and on the barrier wall adjacent to the track ahead. However, he said he never actually saw the headlights. Due to tunnel curvature, forward visibility along the D-2 track north of the interlocking was about 250 feet.

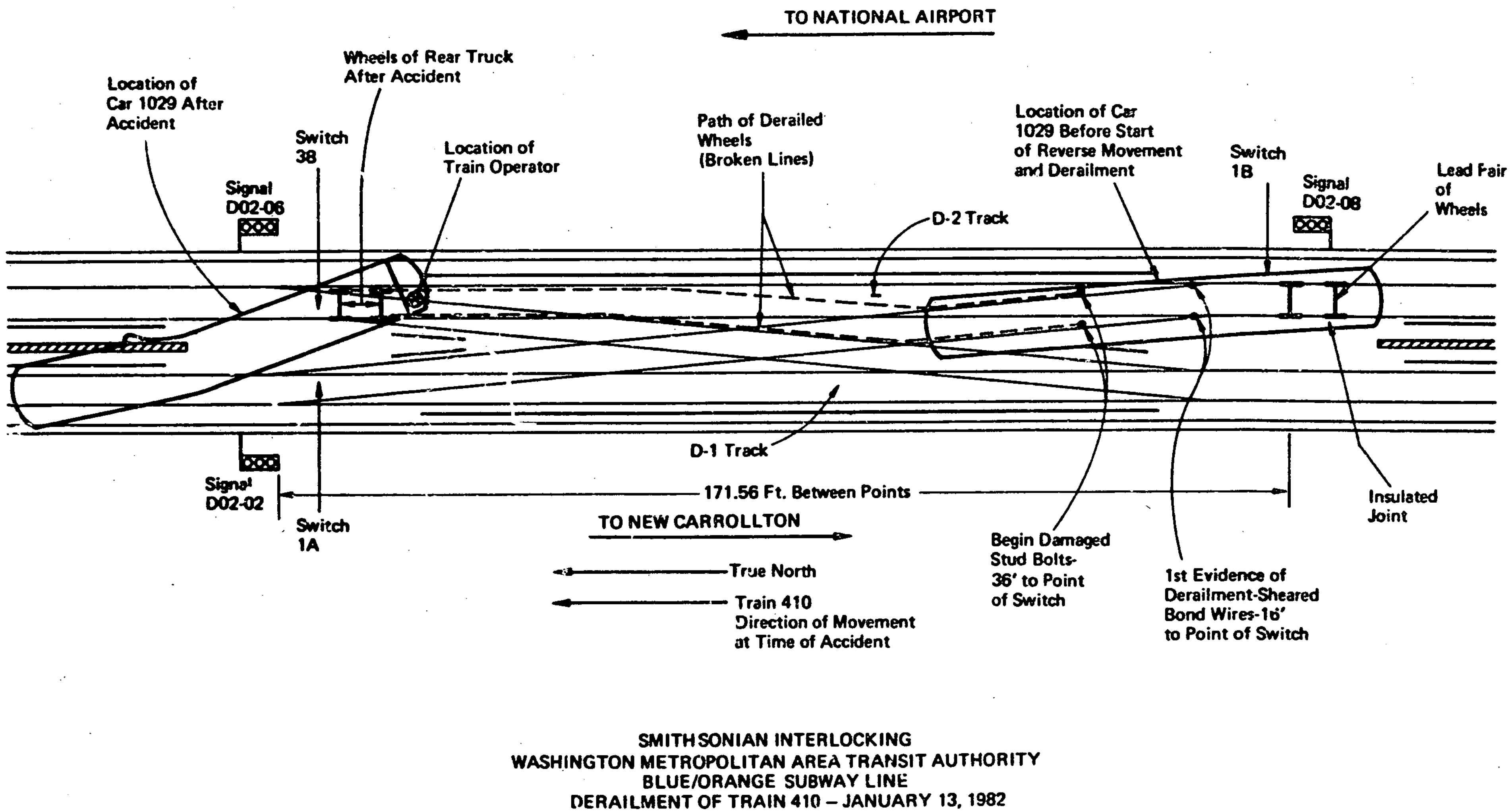


Figure 4.--Locations of car No. 1029 before the reverse movement of train No. 410 and following its derailment and collision with the barrier wall. Dotted lines indicate the paths taken by the wheels cf the car's derailed truck.

At 1628:03, the supervisor informed the OCC that "This, ah, switch doesn't look right. I am going to pull this train back and try again." The OCC attempted twice to learn whether or not the D-2 track was affected, but received only evasive and garbled responses. At 1629:03, the OCC again asked, "How about track two? Can we let the trains operate in there or is it not right there either?" The supervisor responded, "No. Negative. Let me pull this train back first." The OCC radio controller followed at 1629:12 with, "Alright. Train at D02-02 hold your position." The OCC radio controller later stated that the assistant superintendent at the OCC had acquiesced in permitting the supervisor to pull train No. 410 back. The assistant superintendent, however, stated that he was preoccupied with a work-related telephone call at the time and was unaware of what was being said over the radio.

When train No. 410 stopped, the supervisor was still at the Federal Triangle end of the interlocking, about 175 feet from switch 1B. He did not go toward the switch to determine the location and condition of the front end of the train, and he did not contact the operator before going to the rear of the train which he boarded through the end door of the rear car. After entering the operator's compartment, the supervisor called the operator over the intercom and told him to remove his key from the operating console so that he could pull the train back from his end. The supervisor stated that he also told the operator to notify him when the train had cleared the crossover track. By changing the operating end of the train, the supervisor had taken over all the controls. The operator could still, however, initiate emergency braking by pushing the "mushroom" emergency button, and he could use the radio and the intercom. The operator stated that during his training he had been instructed to use the "mushroom" button only in an actual emergency.

About 1630, the supervisor applied power to train No. 410 and began to move it south on the D-1 track toward the Federal Triangle Station. Shortly afterward, the trailing truck of what was now the rear car (No. 1029) derailed in switch 1B. The truck at first followed the crossover track with the west wheels on the gauge side of the west rail and the east wheels on the field side of the east rail. However, when the lead west wheel reached the crossing frog, the truck was slewed to the right, followed in line with the No. 3 crossover track and the D-2 track, and came to a stop in switch 3B. This diversion from the proper route caused the car to swing diagonally as the lead truck of the car continued to follow the rest of the train through switch 1A and into the D-1 track. As a result, the car body overrode the short covered traction power third rails between the crossover tracks and struck the end of the barrier wall separating the main tracks at the Federal Triangle end of the interlocking. The point of impact was behind the right forward door, in the direction of movement. The penetration of the carside extended rearward to the left center door. (See figures 5, 6, and 7.)

The train had moved a total distance of about 150 feet before it came to a stop. According to the supervisor, the train first went into braking and then started "jerking." After the jerking, the supervisor noticed first the loss of brake pressure and then propulsion power which indicated the overspeed control had functioned. The supervisor further stated that he did not reduce power to control speed and he did not initiate braking. The operator stated that after he realized that the train had derailed he called, "Hold it. Hold it. Hold it." to the supervisor over the intercom. The operator also stated that he did not try to initiate emergency braking before the car struck the wall because he did not recognize that he had derailed and that an emergency existed.

At 1631:13 another road transportation supervisor, No. 35, who had arrived at the Federal Triangle Station on the train following train No. 410, reported to the OCC that the third rail traction power was apparently out at that location. Because of that report, the OCC at 1631:48 queried Supervisor No. 31 as to whether or not the right-of-way was

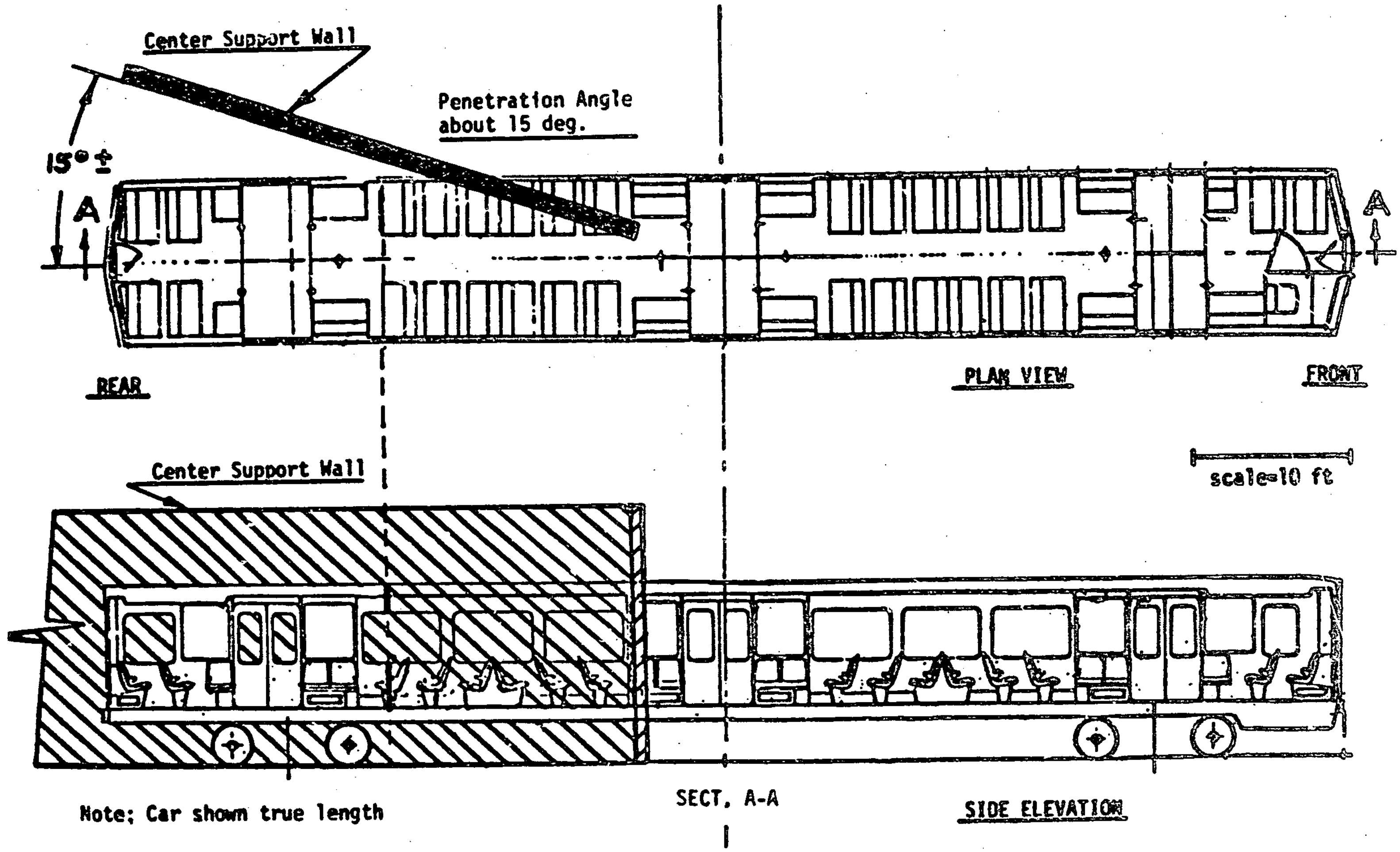


Figure 5.—Plan view and side elevation showing point of impact between car No. 1029 and barrier wall, and degree of penetration by the wall.

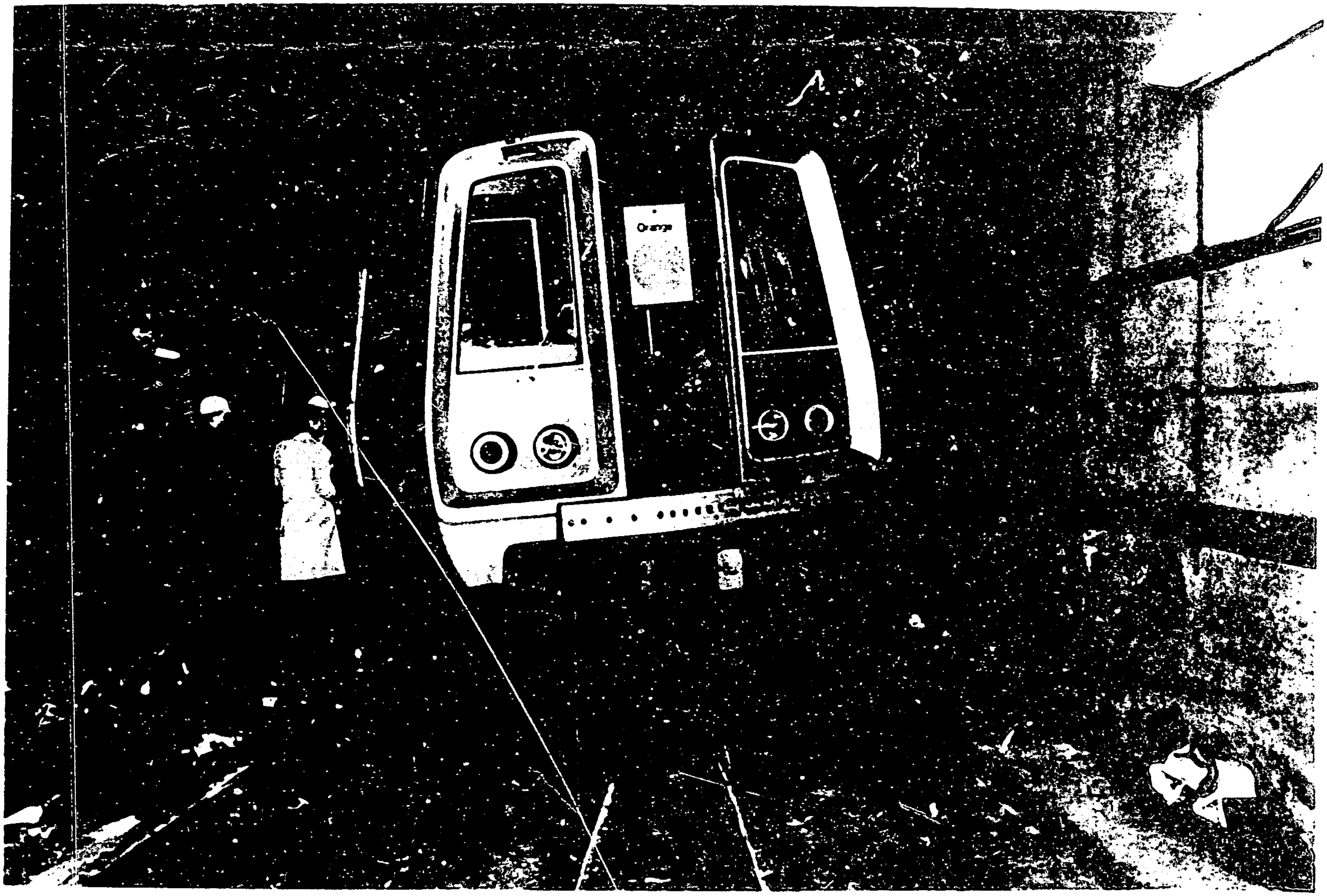


Figure 6.—Car No. 1029 from track level viewed facing south in the direction train No. 410 was moving at the time of the accident.

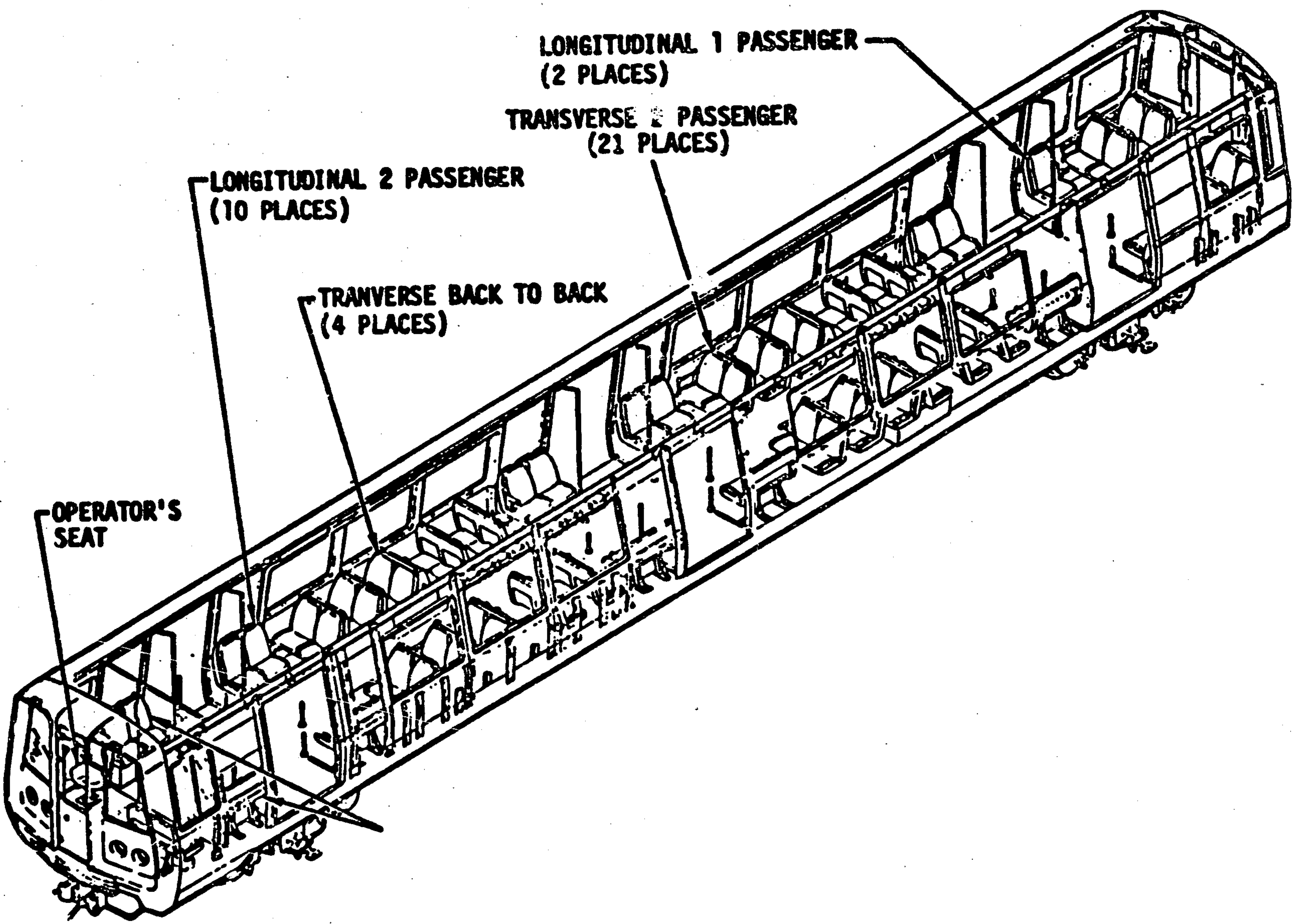


Figure 7.—Door, window, and seating arrangement of typical WMATA rapid transit car.

clear. This supervisor, still on the lead car and apparently unaware of the derailment and the impact with the barrier wall, replied, "Roger. Right-of-way is clear." The OCC immediately followed with, "Which track are you on? Where are you?" The supervisor responded at 1631:55, "I am on track one. I am going to try to pull it back into the station and clear that switch." The supervisor then informed the OCC that the traction power was dead and that the operator was on the other end of the train. At 1632:16, the OCC instructed the supervisor to contact the operator to determine where the rear-end of the train was.

Because the batteries on the derailed car were destroyed in the accident, the operator had no intercom or radio communicating capability to contact the OCC or the supervisor. The supervisor was also unable to contact the operator. After the supervisor walked back to the interlocking and realized an accident had occurred, he informed the OCC of the derailment about 1633:52. After several radio transmission exchanges with the supervisor, the OCC understood and acknowledged by radio at 1634:54 that the derailment involved and blocked both main tracks and that there were passenger casualties.

Evacuation and Emergency Response

A WMATA policeman in plain clothes was on car No. 1029 near the operator's compartment when the accident occurred. The policeman was assigned to WMATA's bus division and was riding the Metrorail to get to a police station. He had a portable radio that could transmit to the WMATA police dispatcher but not on the OCC channels. The policeman identified himself to the operator of train No. 410 and learned that the train had derailed. He could not see to the other end of the car where the damage had occurred because there was no lighting in the car, and he was unaware that there were passenger casualties when he notified the dispatcher of the accident at 1632. Four minutes later, the policeman was told to stand by and that the assistant superintendent of the OCC would advise him concerning evacuation of the passengers. Because the OCC could not directly talk to the policeman, the information had to be relayed through the police dispatcher. The policeman then alighted from the end door of the car and as he did noted that sparks were coming from below the car. The arcing resulted from the car being in contact with a live traction power bridge rail. At 1638, he asked the police dispatcher if the power was down, and was told that he would be advised. At 1639, the policeman reported that there were people hurt at the other end of the car and then followed with, "There are people hurt. One woman trapped between the train and the wall." The dispatcher responded, "Power is down on track two. Fire and rescue will be coming in track two from Federal Triangle."

Five minutes after the accident occurred, the supervisor informed the OCC that he was going to have to try to unload the train. The OCC controller responded, "O.K." At 1635:34 and again at 1637:24, the supervisor asked that the OCC make certain that the third rail power was shut down. Following the second request, the controller replied, "Roger." Supervisor No. 35, who in the meantime had been told to assist Supervisor No. 31 at the accident site, asked the OCC at 1639:36 for authority to offload the passengers. The OCC did not respond.

Most of the passengers on the train were unaware that an accident had occurred, and they waited patiently for someone to do something or to tell them that something was going to be done. 9/ The WMATA policeman on the derailed car calmed the passengers

9/ Many passengers on the forward part of the train did not know the train had derailed until after they got home. A number of passengers on the derailed car were unaware that anyone had been injured.

there by identifying himself and stating that help was on the way. However, as the air in the car became hot and close, the passengers became so uncomfortable and irritated that some knocked out windows with dislodged stanchions. Some even jumped from the window openings and made their way to the Smithsonian Station. Some passengers on the front cars exited through the unlocked end doors between cars, jumped to the catwalk, and went home. The WMATA cars do not have instructions posted on how to manually open the doors from the inside, and the manual door controls are completely concealed.

Although they knew that they were not allowed to evacuate a train between stations without explicit authority, Supervisors Nos. 31 and 35 decided to do so. Using the manual door controls, they opened the side doors of the four forward cars of the train. Unable to use one of the small ladders carried on the cars, 10/ the supervisors helped the passengers negotiate the 3-foot drop to the subway catwalk. They were assisted by the operator of the train behind train No. 410, by the Federal Triangle Station kiosk supervisor, and by four volunteers. Although the passengers had to walk single file on the narrow catwalks, the north end of the train was only about 150 feet from the Federal Triangle Station platform and the evacuation of the five forward cars of the train was completed 40 to 45 minutes after it was started.

Meanwhile, at 1644 the WMATA policeman on the derailed car again reported sparks coming from below the car and at 1646 requested permission to evacuate the car so that he could get to the injured. A minute later, the policeman was given permission to evacuate the train and was told that power was down on both tracks.

By this time, the OCC had become preoccupied with terminating and offloading trains elsewhere on the Blue/Orange Line and setting up bus service to bypass the blocked section of the subway. The assistant superintendent was shuttling back and forth between the OCC and the other WMATA command centers located in other parts of the building to arrange for the alternative service, to keep posted on what the policeman was reporting, and to have maintenance employees sent to substations to open and deactivate the circuit breakers for the third rail power in the accident area. No one in the OCC had assumed the responsibility for directing the evacuation procedures and coordinating them with the District of Columbia's Fire Department rescue operations.

The WMATA policeman, the operator of train No. 410, and another WMATA policeman opened one leaf of the right rear door of the derailed car and began evacuating the remaining passengers directly to the catwalk against the tunnel wall on the D-2 track side at about 1657. Since they were unable to locate a ladder in car No. 1029, they had to help the passengers step down to the catwalk. By the time the first Fire Department company arrived at the accident site about 1702, approximately two-thirds of the passengers had been evacuated. The remainder, who were forward of the damaged section, were helped to the evacuation door by firemen. All of the ambulatory passengers were off the car by 1750. As with the passengers on the forward cars, the passengers on the derailed car left the subway through the Federal Triangle Station.

At 1634:15, the OCC superintendent used a direct push-button telephone to contact the Fire Department's Communications Center. The call was answered 3 seconds later and the superintendent reported, "We need an ambulance down here between Smithsonian

10/ Each WMATA car has a 2-piece wood ladder with round rings which is stowed under a seat at the front of the car. When assembled, the ladder is about 4 feet long. It is designed to be used to evacuate passengers from the end of the car to track level. There is no device to secure the ladder to the car. In this case, it proved too long and unstable to be used between a side door and the tunnel catwalk.

and Federal Triangle Stations. There is an interlocking with approximately 1,000 feet between each station. We have a train that is derailed there." The Communications Center responded at 1634:33, "Oh, come on, you are kidding." The superintendent stated at 1634:35, "No, I am not kidding. We got some people injured. We don't know how many at this time." At 1634:42, the Communications Center asked the superintendent, "Where's it going to meet me now?" following which the superintendent gave the location as being between the Smithsonian and Federal Triangle Stations and stated, "You will have to enter through that part." The Communications Center asked at 1634:48, "Triangle Station, right?" and then asked for a milepost location. The superintendent responded at 1634:55, "Central. At chain marker. Let me see. I will have to look that up for you at this time." The Communications Center then asked in succession who the caller was, if the train was derailed, and whether there were people injured. At 1635:12, the superintendent told the Communications Center to hold on so he could give him the chain marker location. One minute 15 seconds later, the superintendent gave the Communications Center the chain marker location and this was acknowledged. The superintendent was next told, at 1636:33, "We will get on it right now," and the call was terminated. At 1637:07, the Communications Center called the superintendent back and an extended discussion ensued concerning the precise location of the accident. This ended at 1638:12.

The response of the District of Columbia's Fire Department through its Communications Center, firefighting companies, rescue squads, and Emergency Ambulance Division was materially affected by the adverse weather conditions, extraordinary traffic congestion, and the fact that 30 minutes before the Metrorail accident, an Air Florida B-737 jetliner taking off from National Airport had crashed into the 14th Street Bridge over the Potomac River. The location was about 1.2 miles, via the streets, from the subway accident site. The two accidents occurred in the same Fire Department response zone and 7 of the 10 fire units assigned to this zone as well as three of the Fire Department's four rescue squads and all but two of its ambulances had responded to the Air Florida disaster.

The Fire Department put out a radio alarm at 1641 which was ultimately responded to by four engine and two ladder companies scattered around the perimeter of the downtown area at distances of .42 to 1.55 miles from the Federal Triangle Station. All of these companies encountered serious difficulties in getting to the destination. It was often necessary to push parked or stalled automobiles onto the sidewalks and for firemen to walk ahead of the engines and to order motorists to clear the way. The first to arrive at the Federal Triangle Station was Engine Company 3 which had been returning to its station at the time it was dispatched at 1649 from a point estimated to be about one-half mile from the Federal Triangle Station. Although delayed on Independence Avenue by heavy traffic, Engine Company 3 arrived at the station entrance at 1653:34. En route, Engine Company 3 had crossed the Mall above the subway and had passed both entrances to the Smithsonian Station. Despite difficulty encountered getting past passengers being evacuated from the Federal Triangle Station, the five-man crew was at the accident site shortly after 1700 with oxygen resuscitation equipment. A second engine company arrived at the Federal Triangle Station entrance about 2 minutes behind Engine Company 3.

The only available Fire Department rescue squad was en route to its station when contacted by radio and diverted to Federal Triangle at 1648. The rescue squad required 17 minutes to travel about 1 1/2 miles to the station. The two available ambulances were not dispatched until 1658, and the first of these covered the 2 miles from its base in 15 minutes. En route, the ambulance followed the same course as Engine Company 3, past the Smithsonian Station entrances and across the Mall. Ultimately, the Fire Department committed 15 fire units and 11 ambulances and paramedic units, including 7 diverted from the air crash site--a total of 84 men and 32 vehicles. (See appendix E.) Several fire companies and ambulances from Maryland suburbs also responded to the accident.

Firemen had to use Hurst power tools to pull back and block the peeled sidewall and to cut a section of flooring of car No. 1029 in order to remove the dead and seriously injured. The operation required more than an hour. The last of the injured were removed at 1826 and brought to the triage 11/ area at the Federal Triangle platform at 1828. Transportation of the injured from the triage site was delayed by traffic-congested streets. The ambulances transported 3 dead and 19 injured passengers to four District hospitals. Several passengers were later admitted to hospitals where they had gone on their own. The first of the injured passengers arrived at a hospital at 1821; the last of those transported by ambulance arrived at 1936. The most seriously injured passenger arrived at George Washington University Hospital at 1850.

The Fire Department's radios proved to be virtually ineffective as a means of communicating to and from the accident site. This was because WMATA's radio repeater system in the subway had not been modified to accommodate the Fire Department's radio frequencies. As a result, the Fire Department forces had to rely on the use of WMATA's telephone conference line from station kiosks and wayside telephones in the subway. Adequacy of the telephone communications for Fire Department use was at times restricted by noise, WMATA's need to use lines, and other limitations. At such times, the Fire Department had to employ messengers to carry communications between the accident site and the command posts which had been established above ground at the station entrances.

Following the accident, WMATA furnished the Fire Department with portable "land line" telephones for use in an emergency until the radio repeater system in the subway can be modified to accommodate Fire Department radios. According to WMATA, since the accident, it has contracted to have the modifications completed on the entire Metrorail system by 1983.

Injuries to Persons

Injuries	Passengers	Employees
Fatal	3	0
Hospitalized	25	0
Minor/None	1,293 *	3
Total	1,320 *	3

* Estimated

Damage

WMATA personnel decided that car No. 1029, the car that struck the barrier wall, was beyond repair and it was dismantled at the accident site. Since all WMATA cars are in "married" pairs, and therefore since the mate to car No. 1029 could not be used independently, WMATA considered it to have only salvage value. WMATA estimated the total value of parts that could be salvaged from the cars to be about $400,000. A replacement pair of cars would cost $1,700,000, according to WMATA, if the pair could be bought as part of a current order for new cars.

11/ A location used in disaster situations to sort out patients and allocate treatment to them on a priority basis.

Switch 1A and about 200 feet of track were damaged. About 80 feet of the third rail cover and several support insulators had to be replaced. Two 4-foot Automatic Train Control circuit loops were destroyed and other signal circuitry was damaged.

Damage was estimated as follows:

Train equipment	$1,300,000
Signal circuitry	17,650
Track and structures	7,350
TOTAL	$1,325,000

Personnel Information

The operator of train No. 410 was qualified under WMATA rules without restriction, and he was working his regular 1149 to 1911 shift. The operator had reported for duty at the National Airport Station and had operated train No. 408 out of that location at 1202, arriving at New Carrollton at 1250. On the return trip, he had departed with train No. 401 at 1303, arriving back at the National Airport Station at 1353. After a lunch break, the operator departed for New Carrollton at 1526 with train No. 410. At the time of the accident, the operator had been on duty 4 hours 41 minutes, of which he had actually been en route on board trains for 2 hours and 42 minutes.

According to the operator, he had been off duty for more than 16 hours before reporting on January 13. He stated that during this time he had 9 1/2 hours bed rest. The operator had last eaten during his lunch break, about 2 hours before the accident. He stated he had not used alcohol or drugs before the accident. The operator was not subjected to a physical examination following the accident.

The supervisor who was operating train No. 410 at the time of the accident, worked the 1100 to 1900 shift. He stated that he worked as a road supervisor "trouble-shooting" train problems on the Metrorail lines 2 days a week and as a terminal supervisor primarily engaged in dispatching trains the other 3 days. On the day of the accident, he had reported for work at National Airport at 1130 and had been on duty 5 hours when the accident occurred. The supervisor stated that he had not encountered any unusual situations on the day of the accident before going to the assistance of disabled train No. 403 at the Federal Triangle Station.

The supervisor had been off duty for 16 hours and 30 minutes before reporting for work on January 13. He stated that he had dined about 2100 the night before and had slept from 2300 to 0900. The supervisor stated that, except for a cup of coffee when he got up, he had not eaten anything for 19 hours before the accident. According to the supervisor, he was under treatment for hypertension and daily took 500 mg of Diuril and 150 mg of Hydrochlorothiazide. 12/ The supervisor also stated that about 10 years before the accident, a physical examination had indicated that he had a low blood sugar count. However, he said that he had not been treated for this and that as far as he knew there had been no recurrence of the condition.

The supervisor stated that he had taken the anti-hypertension medicine at about 0930 on the day of the accident but that he did not use alcohol or any other drugs. The supervisor gave his height as 5 feet 9 inches and stated he had recently reduced his weight

12/ These are closely related diuretic and anti-hypertensive drugs which may be prescribed concurrently in the management of hypertension. The dosages indicated are within the normal adult range.

from 240 to 220 pounds. According to the supervisor, he did not wear or need to wear eyeglasses. He was not subjected to a physical examination after the accident.

The controller assigned to the radio console in the OCC was working his regular 1000 to 1800 assignment. He had been off duty for about 16 hours before reporting for work on January 13. The controller described himself as being in normal physical condition. Although he reported for work at 1000, the controller's duties required him to prepare reports at the offices of the director of rail operations and general superintendent until 1400. At that time, he assumed the role of radio controller 13/ for the balance of his shift. At the time of the accident, he had been handling the radio for 2 1/2 hours.

The assistant superintendent in the OCC was working his regular 1430 to 2230 assignment and had been on duty 2 hours when the accident occurred. He stated that he was in normal physical condition on the day of the accident. The superintendent in charge of the OCC normally worked from 0630 to 1500. On January 13, he reported at the regular time but stayed beyond his normal tour of duty to help out. When the accident occurred, he had been on duty for 10 hours. (See appendix B.)

The Metrorail System

At the time of the accident, the Metrorail system carried about 290,000 passengers on a normal weekday. Service was provided between 0600 and midnight. The morning peak period lasted from 0600 to 0900 and the evening peak period from 1500 to 1830. On January 13, 1982, according to WMATA the peak traffic period of the day occurred between 1430 and 1600. During the peak periods, Metrorail schedules called for operation of 256 cars in 43 trains. The New Carrollton-National Airport schedule required 16 six-car trains and the Ballston-Addison Road operation required 8 six-car and 6 four-car trains. Operating headway was nominally 3 minutes during the peak periods and 6 minutes during the 0900-1500 offpeak period when a total of 16 trains were used on the Blue/Orange Lines. Scheduled running time was 45 minutes between New Carrollton and National Airport.

WMATA's Metrorail system is one of four highly automated "state-of-the-art" rapid transit systems combining subway and surface operation presently in operation in the United States. The first such system, the Port Authority Transit Corporation of Pennsylvania and New Jersey (PATCO) began operations in its present form in 1969. The Bay Area Rapid Transit District (BART), operating lines in the San Francisco-Oakland Bay area of California, started up in 1972. Most recently, the Metropolitan Atlanta Rapid Transit Authority (MARTA) began operation of its first section of line in Atlanta, Georgia, in 1979.

Method of Operation

WMATA's Metrorail lines are operated under the General Railway Signal Company's (GRS) Automatic Train Control (ATC) System consisting of three primary elements, or subsystems, each of which functions largely independently of the other two. According to GRS, the WMATA ATC system "...provides not only assurance that trains operate in

13/ The radio controller monitored the two operations radio channels, one for the Red Line and one for the Blue/Orange Line and communicated as necessary with the train operators, supervisors, and others involved in train operations. When working as radio controller at the OCC, his duties also included the writing of reports of delays, accidents, etc., as they occurred.

conformance with signal indications, but also provides fully automated train operations...." 14/ Operation of the ATC subsystems is coordinated through a computer installation to achieve an integrated control system. The subsystems and their functions are:

Automatic Train Protection (ATP) is the most fundamental and critical of the systems from a safety standpoint. Utilizing high-frequency circuits governing relatively short track segments to establish block occupancy and conditions, the ATP directs and separates the trains, controls the switches and wayside signals of the interlockings, guards against the switches not being safely secured in position, imposes the limiting or command speeds on the trains, and protects against overspeed operation. Cab signals in the form of digital speed indications are displayed on the train operator's control console. Each track circuit has its own dedicated wires and its condition, whether occupied or unoccupied, is recorded in the central computer log at 1-second intervals. Speed commands transmitted by the control logic are based on safe braking distances and other parameters, including safe curve speed. Train speed is enforced by means of a frequency generator designed to detect axle rotation which, in turn, controls a speed relay.

Automatic Train Operation (ATO) performs the traditional functions of the train operator. By controlling motoring and braking, ATO starts the train, accelerates it to the desired speed, regulates speed, and brakes the train to a stop at the proper station platform locations.

Automatic Train Supervision (ATS) is designed to carry out supervisory responsibilities traditionally identified with dispatchers and train starters. It was intended for the ATS subsystem to dispatch the trains and keep them on schedule by controlling their arrivals and departures at stations through speed regulation and the extension of times spent at stations as necessary. However, much of the ATS performance level adjustment function has not yet been made fully functional and has been assumed by the controllers in the Operations Control Center. (See table 3.) Additionally, the ATS was designed to provide computersupplied train identification and destination data to be stored in each train's data memory and to be retrieved by the computer as the train progressed across the railroad. The computer was also to track each train's progress, correlate and report block occupancy with train identification, and to automatically route trains through interlockings. However, according to Operations Control Center personnel, the train identification and routing functions were not fully reliable.

Operations Control Center

According to the GRS description of WMATA, the "...nerve center of the ATC system" was the Operations Control Center (OCC). The OCC was built around the control computer which was designed to monitor total system performance, perform the various ATC functions, and to select and exercise control strategies necessary to regulate the operations of the trains. Provision was also included for monitoring the traction power system and for keeping event logs. Status of the ATC and traction power systems was displayed on a bank of eight CRT 21-inch video display screens mounted vertically in two rows in front of four control consoles. Supervisory controllers were responsible for monitoring the CRT's, responding to alarms, and for initiating action whenever an emergency or other traffic control problem occurred which the ATC system could not handle.

14/ See Elements of Railway Signaling, General Railway Signal Pamphlet 1979, pp. 1201-1209, for a detailed description of the WMATA ATC system.

Table 3.--Normal complement of personnel at Operations Control Center.

Individual	Function
Superintendent (0630 to (1430) or Assistant Superintendent (1430 to 2230)	Nominally in charge of facility.
Radio Console - Supervisory Controller	Monitors operations radio channels: Responds to and instructs train operators by radio.
Train Control Console - Supervisory Controller	Monitors Automatic Train Control System and ATC alarm display. Calls up CRT displays for interlockings. Controls train routing and control through switches and signals.
Emergency & Support Console - Supervisory Controller	Monitors traction power system, can open or close power circuit breakers, operates tunnel fans and pumps.
Emergency Telephones Console - Supervisory Controller	Has connection with all system emergency telephones. Makes announcements over public address system at stations.

At the time of the accident, the OCC was located in a 25- by 30-foot basement-floor room of WMATA's general office building adjacent to the bus command center, transit police dispatcher's officer, and system maintenance command center. GRS had originally contemplated that the OCC could be managed by one person per shift, but at the time of the accident, it was staffed by the normal complement of four controllers and an OCC supervisor per shift. Most of the space in the room was taken up by computers, printers, the CRT display bank, and the consoles. The regular personnel took up most of what room was left and there was very little room to move about. The radio controller was assigned to the radio console handling all radio communications on the Metrorail system over two channels. The other controllers were each in charge of the ATC console, traction power console, and an emergency telephone console. The controllers had to monitor the CRT display screens as they applied to their individual function. Only one of the CRT screens could be used to monitor the downtown subway of the Blue/Orange Line. This screen was primarily a tool used by the ATC console controller. When necessary, he could call up a detailed schematic display of an interlocking to determine its status and he could manipulate buttons on his console to change the position of the track switches of the interlockings.

The superintendent was the senior supervisor of the OCC and he normally worked the shift from 0630 to 1430 when he was relieved by the assistant superintendent. According to the superintendent, he normally stayed in the OCC until about 1500 after which the assistant superintendent was in charge of the facility. In the absence of either of these men, the senior controller was in charge. According to WMATA's standard operating procedures (see appendix D), whoever of these persons was in charge was responsible for all OCC functions during his tour of duty, for properly establishing and overseeing the prescribed absolute block procedures in the event of failure of the ATC system, for initiating and directing train evacuations, and when authorized by the general superintendent of rail operations, for initiating the prescribed storm alert procedure.

The superintendent reported to the general superintendent of rail operations who, in turn, worked for the director of rail services. These were the top operating officers of Metrorail and had offices elsewhere in the building. The general superintendent had held that position for only a few weeks, and the director of rail services had been on that job for less than a year. On the afternoon of the accident, they had gone to the OCC at about 1530 following the first of the Blue/Orange Line train breakdowns. From that time to the time of the accident and for some time afterward, they had stood in the confined area behind the controllers. The assistant superintendent was located next to the radio controller and the superintendent, who had stayed on to help out, was located on the opposite side of the room near the emergency telephone console. A kiosk supervisor who was being trained as an OCC controller and the superintendent's daughter were also in the room.

Before and after the accident, there was confusion as to who was in charge of the OCC. The superintendent stated that he thought that since the assistant supervisor had relieved him the assistant superintendent was in charge, but he repeatedly gave instructions to the controllers. The assistant superintendent and the radio controller stated that they thought that as long as the superintendent was there, he was in charge. According to the assistant superintendent, the general superintendent and director of rail services did not directly take command of the situation, but he remembered that there was much "shouting of orders" and he felt that the presence of the two top Metrorail operating officers made the situation even more difficult.

A standard operating procedure in force at the time of the accident stipulated that the OCC supervisor was responsible for coordinating all activities during an emergency and that his primary concern "shall be the safety of passengers and employees and the protection of property and equipment." (See appendix D.) The investigation, however, developed that the assistant superintendent focused his attention on providing alternative service for what he stated were 35,000 to 40,000 other people in the subway. The superintendent informed the fire department of the accident, but aside from this, no one in the OCC room assumed the responsibility for the direction and coordination of the response to the emergency and the evacuation of train No. 410.

During the morning peak period on the day of the accident, train problems had caused cancellation of 21 scheduled trains on the Blue/Orange Line. On the Red Line, inbound trains from Silver Spring were repeatedly experiencing brake problems which resulted in six trains being cancelled. Both lines encountered extensive delays in moving the inbound commuter rush. During the off-peak period when the headway was increased from 3 to 6 minutes, operations were virtually normal. However, after the evening peak operation began at 1500, Metrorail again began to experience serious problems. At 1527, a National Airport train on the downtown subway stalled at the Foggy Bottom Station, resulting in extended delays and a long and difficult detour operation. Before this problem was cleared up, a train out of New Carrollton began to experience repeated brake problems at 1546. A minute later, train No. 403 had stalled at the Federal Triangle Station. During the 90 minutes between resumption of full schedule service and the accident at the Smithsonian Interlocking, 3 trains were taken out of service and 20 were cancelled on the Blue/Orange Line. At 1443, a Red Line train had propulsion problems which caused smoke in the subway. At 1605, another Red Line train experienced the first of repeated brake problems. As a result, this train was taken out of service and 14 others were cancelled.

The assistant superintendent stated that January 13 was the worst day in terms of delays and breakdowns that he had encountered during his 7 years in the OCC. The superintendent said that there were so many train problems at one time that it was impossible to concentrate on any one of them. Voice tape transcripts indicate that the radio controller was regularly prodding train operators to "move out," asking them to give their locations, and otherwise attempting to directly supervise train operations on all the Metrorail lines. The assistant superintendent tried to take over the Red Line radio channel to help out the radio controller, but could not do so because the only spare headset in the OCC was out of order. The emergency telephones were in constant use. Whenever the OCC neeeded to communicate with one of the other WMATA command centers, the assistant superintendent had to leave the room and go to the other offices because the "hot-line" intercoms from the OCC to those offices were out of order. According to one OCC supervisor, "We were losing control."

WMATA Operating Modes

Under WMATA's Automatic Train Control system, there are three methods by which trains can be operated. (See appendix C.) The normal method is the fully-automatic Mode 1 with the Automatic Train Operation and Automatic Train Protection subsystems fully operative. In Mode 1 operation, the train operator's primary duties are to close the doors and to announce stations over the public address system. When the ATO function is lost en route, the train is automatically stopped and cannot be moved until the method of operation is changed to one of the manual modes. WMATA operating rules 61 and 62 prohibit the operator from changing to one of the manual modes without authorization from the OCC.

Mode 2, the manual or manual-cab signal method, is employed when the train's ATO system is inoperative but the ATP remains fully functional. The operator runs the train in accordance with the ATP speed commands. If he fails to comply with the speed commands, the overspeed protection will stop the train. A unique feature of WMATA's Mode 2 is that there is no overspeed enforcement under 15 miles per hour (mph). A train may be moved across the entire line, even through successive zero-mph speed command circuits and past interlocking signals displaying "stop" aspects, without stopping as long as speed does not exceed the nominal 15-mph setting of the overspeed device. At the time of the accident, train No. 410 was being operated in this mode. An analysis of the WMATA radio voice tapes indicated that five other Blue/Orange Line trains were authorized to operate in this manual mode in the 40-minute period preceding the accident. The investigation also revealed that it was common for operators to change to Mode 2 when ATO was lost without receiving authority to do so and that WMATA rules 61 and 62 were not enforced. According to the assistant superintendent at the OCC, trains without functioning ATO were usually taken out of service during the offpeak hours, but were kept in operation during peak periods because of the shortage of available cars.

Mode 3, the fully manual method of operation, is employed when the ATO system is inoperative and the ATP protection has been cut out. WMATA rule 64 prohibits Mode 3 operation unless such operation has been authorized by the OCC and an absolute block has been established. 15/ The established practice was to use interlocking signals as the limits of absolute blocks.

15/ WMATA's Handbook of Operating Rules defines an absolute block as "A section of track between two specific locations into which no train is permitted to enter while it is occupied by another train. This absolute block is established and governed by the Operations Control Center when necessary due to a carborne malfunction (ATP or braking) or ATC failure."

According to WMATA engineers and officials, the Mode 2 feature permits trains to close up through zero-mph circuits when there is a prolonged delay-producing event in progress. They stated that at 15 mph the stopping distance would not greatly exceed 50 feet. Supervisors in the OCC stated that they believed that a collision with a standing train at this speed would not be serious. The other "state-of-the-art" systems use ATC systems, but none have a corresponding unregulated manual feature. PATCO and MARTA have 3-mode operating systems, but there is complete overspeed protection down to zero mph in their middle mode. MARTA will permit occupied trains to operate up to 25 mph in their "road manual" Mode 3, but this line utilizes wayside block signals located on each side of its stations, and a Mode 3 train may only proceed under the direct supervision of the central control facility. BART has only two modes - fully automatic and fully manual. Operation in the latter is restricted to 25 mph, and train orders must be received to proceed in this mode. According to BART, it is currently changing its system to include a Manual Cab Signal (MCS) Mode 2 similar to that used by PATCO and MARTA.

Radio communications between the OCC and the trains were usually prefaced by or included the number of the train involved. Trains were numbered according to the line to which they were assigned, No. 401 through No. 416 for the Blue Line and No. 901 through No. 914 for the Orange Line. A given set of cars is likely to retain the same train number throughout the day, unless it is seriously delayed or laid up from service during the off-peak period. Once a WMATA train is en route, the train's number is automatically fed into the ATS system and appears with its location on the CRT screen. Frequently, however, the OCC alarm screen will indicate that the displayed number is incorrect. Particularly when radio traffic is heavy and the radio controller loses track of trains, it may be necessary for him to try to contact a train by transmitting, for example, "Train at Smithsonian," or "Train at D02-02." According to the OCC supervisors, trains have been reportedly misrouted by the ATS at junctions because of a faulty identification number.

Rules and Procedures

In October 1975, WMATA had issued a "Handbook of Operating Rules" for the use of Metrorail train operators and supervisors. There were also general safety rules and 31 written standard operating procedures which had not been issued to the train operators. The standard operating procedures had been formulated on an ad hoc basis by committees, and many were very lengthy and detailed. According to OCC personnel, copies of the standard operating procedures were kept on hand in the office, but these had been superseded in many cases by verbal instructions issued to the OCC by higher authority. Since the accident, WMATA has issued to all Metrorail operating employees a combined book of rules which includes the general safety rules and the standard procedures. This was funded under a grant from the Urban Mass Transportation Administration (UMTA).

The old handbook of operating rules, as well as the new combined rulebook, contained an identical "lexicon of definitions." This, however, was brief and did not contain many standard railroad and rail transit terms or much of the terminology that is peculiar to Metrorail. There was no definition of "restricted speed" or any other defined speed. According to WMATA's director of safety, restricted speed was considered to be 15 mph enforced by the overspeed feature of the ATP system. He also stated that restricted speed through an interlocking without functional track circuits was 5 mph and that this had been set forth in a notice. However, the Safety Board has been unable to secure a copy of this notice. Supervisors and operators interviewed after the accident variously defined restricted speed as 5, 10, or 15 mph, "less than normal," or simply "restricted."

WMATA's standard operating procedure No. 15 (see appendix D) required the OCC to establish a temporary absolute block whenever there was a failure in the ATC system. This required trains to use Mode 2 in the block and the presence of a supervisor to control the entry of trains into the block. The supervisor was required to orally instruct the train operators of the nature of the operation and speed restrictions imposed and to record the passing of trains by number and time. If the ATC failure affected the automatic operation of a switch, the switch had to be hand-cranked, if necessary, and blocked by a qualified employee. After inspecting the switch, the supervisor was supposed to hand flag trains through the switch. Additionally, the OCC was required to instruct train operators approaching an emergency interlocking where the signal could not be cleared that the switch must be observed to be blocked in normal position before the train was moved through the interlocking. WMATA rule 56 prohibits operators from backing or reversing a train if it has run through a switch. The operator must stop the train, inform the OCC, and operate on its instructions. However, neither this rule nor any other addresses what must be done before a reverse movement is inadvertently made through a turnout to a crossover or diverging track where the condition of the switches involved has not been established. (See appendix C.)

Another WMATA standard operating procedure required the OCC to issue a storm alert when sleet or snow warnings were issued or unexpected storms occurred. Under such an alert, train operators and other employees were to be retained after their normal duty hours to operate extra trains in addition to normal schedules. Also, the OCC was responsible for assigning employees to interlockings to operate switches, and to stations to keep platforms and accessways clear of ice and snow. (See appendix D.)

General Safety Rule 155 states that "Messages affecting train movement should be addressed to only one train at a time." In an emergency, the OCC is allowed to transmit a "blanket" message to all trains in or approaching a given area, but all trains involved are required to individually acknowledge the message. General Safety Rule 154 requires that radio calls be transmitted ". . .in a manner that insures establishment of communications between the intended parties."

At the time of the accident, the maximum authorized operating speed on the Metrorail system was 75 mph. However, the maximum available speed commands in the subway varied from 34 to 59 mph depending on the location. Because the maximum safe speed for the curves between the Federal Triangle Station and the Smithsonian Station was judged by WMATA to be 35 to 37 mph, the maximum speed command that could be received in this area was 34 mph. The maximum speed command for movement through the crossover track of an interlocking was 22 mph .

WMATA Evacuation Procedures

WMATA has long and complicated standard operating procedures for evacuating passengers from trains. (See appendix D.) The preferred method involves transferring the passengers through the end doors to an empty evacuation train. The "last resort" method, of evacuating to the right of way, is not permitted until the OCC has notified all WMATA departments and has made certain that the following requirements have been met:

(a) A transportation supervisor, transit police, and fire department personnel are at the scene.

(b) Third rail power has been removed from the power sections for both tracks through the area that have to be used by the passengers.

(c) Systems Maintenance has taken the circuit breakers out of service at the involved substations and tie breaker station.

According to the OCC assistant superintendent, it would take the OCC 5 seconds to command the breakers open and remove third rail power from the affected section. However, on January 13, 1982, the last required action was requested by the OCC at 1639 and not accomplished until 1840.

WMATA has never undertaken a program to educate passengers on the procedures to follow in case of an emergency.

Train Information

Train No. 410 consisted of three identical "married" pairs of cars which were numbered, from north to south, 1029, 1028, 1199, 1198, 1235, and 1234. Collectively, the train consist was 450 feet long over the coupler faces, had a total seating capacity of 478 persons, and standing room for 582 persons. According to WMATA personnel, the crush capacity of the train was 1,320 persons. The train consist was never altered after being placed in service as train No. 903 at New Carrollton, Maryland, at 0610 on the day of the accident. However, because of a defective track circuit, it was necessary to offload the train at 0618 at Cheverly, the second station south of New Carrollton. Since the train operator was instructed to operate through the circuit in Mode 3, the fully-manual mode, he had to break the seal on the ATP cut-out switch located in the operator's compartment of lead car No. 1234. 16/ This enabled the operator to put the switch in the cut-out position which voids the overspeed protection. After proceeding through the faulty circuit, the train was returned to revenue service and loaded passengers at the remaining stations en route to the Ballston, Virginia, station. The following is the history of the train's movements on January 13, 1982:

Train Number	Lead Car	From	At	To	At	Running Time
903	1234	New Carrollton	0610	Ballston	0655	45'
903	1029	Ballston	0657	Addison Road	0733	36'
903	1234	Addison Road	0738	Ballston	0816	48'
903	1029	Ballston	0819	New Carrollton	0859	40'
402	1234	New Carrollton	1008	National Airport	1053	45'
410	1029	National Airport	1526	Smithsonian Int.	1627	61'

It is not known whether the ATP was cut back in after the train cleared the faulty circuit at Cheverly or whether the cut-out switch was resealed. The resealing would have to be done by a car maintenance employee and may have been done when the car was reportedly inspected at New Carrollton about 1000. The inspector's report indicated that all seals were intact at that time and that no defect was found in the car.

The cars in train No. 410 were part of the original fleet of 300 cars built for WMATA by Rohr Industries, Inc., and delivered during 1976-1977. These cars were all in "married" pairs measuring 150 feet over coupler faces with each car 74 feet 9 inches over the anti-climbers. The cars are 10 feet 1-3/4 inches wide, and they have an overall height of 10 feet 10 inches above the top of the rail. Maximum floor to ceiling height inside the cars is 6 feet 10 inches. There are three door openings on each side of the car for

16/ The ATP cutout switch has a guard and locking pin which is normally kept sealed in the cut-in position.

passenger loading and offloading. The openings are 50 inches wide and 76 inches high. The electrically-operated side doors are of the double-leaf design and are operated by the train operator from his location in the operator's compartment. In the event that traction power and emergency power are both lost, each door can be opened manually using controls concealed behind a hinged panel directly adjacent to the door leaf. The cars have 28-inch-wide hinged doors at both ends which are opened by turning a lever-type door handle. The end doors between cars are ordinarily kept unlocked.

The WMATA cars seat 80 persons in 39 double and 2 single seats. However, the operator's compartment located at the front end of the lead car of the train will have a vestibule door closed and locked, which prevents access to one double seat. The seating arrangement in the main compartments of each car consists of 16 40-inch-wide double seats with armrests, 12 of which are transversely mounted and 4 of which are mounted longitudinally. The latter are located in facing pairs at each end of the compartment. The transverse seats are arranged in six adjacent rows, three facing forward and three rearward. The center pair are back to back in a single floor-mounted unit. The remaining transverse seats are cantilever-mounted to the lower sidewall to permit easy floor cleaning. (See figure 7.) The aisle between the transverse seats of the main compartment is 34 inches wide. Seat cushions are vinyl-covered neoprene, and each transverse double seat has a full width stainless-steel handrail mounted on the top of the seat back.

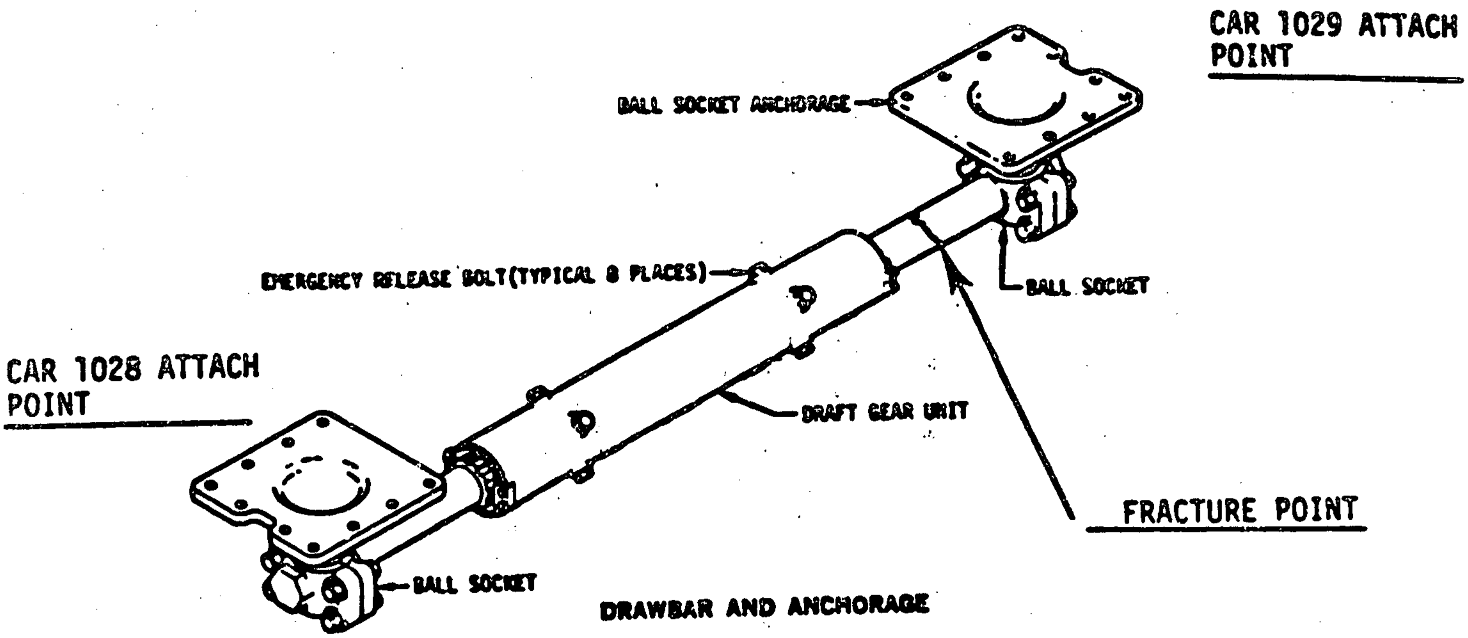
There are six large and two small double-glazed windows on each side of the car. The outer layer of the windows is 1/4-inch clear acrylic and the inner layer is 1/4-inch laminated glass. The large windows, 36 1/2 inches high and 56 inches wide, are located in the main compartments between the doors. The small windows are located in the end compartments. None of the windows was designed for ready removal for emergency evacuation.

Vacuum-formed acrylic polyvinyl chloride (PVC) is used for the interior lining of the carbody. The floor is fabricated of aluminum-faced plymetal panels except for the entryways which are stainless-steel faced. Cushion-backed synthetic wool carpeting is adhesive bonded to the floor which is separated from an aluminum subfloor by fiberglass insulation.

The front end of each car has two conventional sealed dual-beam 200-watt headlights, one on each side of the end door. (See figure 6.) Interior lighting is provided by 40 fluorescent lights of 20 to 40 watts each. Each married pair of cars has a 25-cell, 275 ampere-hour-rated, nickel-cadmium storage battery bank mounted in a steel cabinet under the double-backed seat in the left side of the rear main compartment of the "B" car. 17/ Each battery bank is capable of operating the emergency systems which include the public address system, emergency radio communicating ability, electric door controls, and the emergency interior lighting for 2 hours. The battery is recharged by a motor generator mounted under the floor of the "B" car. The battery banks of all the "B" cars in a train are connected through 37.5-volt battery train lines.

The rear ends of the married cars are coupled by a semi-permanent drawbar (see figure 8) that is fixed at the "A" car to prevent rotational movement. The drawbar between cars 1028 and 1029 fractured through the tail socket. The normal 3-inch opening between the two cars' anti-climbers was stretched to about 4 feet, which caused the battery train line between the cars to part, shorting out the entire emergency power system of the train and rendering all its emergency systems inoperative.

17/ Cars in the married pairs are designated "A" and "B" with the "A" cars bearing even numbers and the "B" cars odd numbers.



Note: Emergency release bolts did not fracture.

Figure 8.—Semi-permanent drawbar and anchorage between WMATA married cars, showing fracture that occurred between cars Nos. 1028 and 1029 on January 13, 1982.

The WMATA carbodies are constructed primarily of aluminum extrusions which are both the structure and exterior skin of the roof, sidewalls, and rear end. The front-end cowl of the carbody is fabricated of molded fiberglass. The main underframe consists of transverse aluminum beams attached to the lower side wall extrusions (also aluminum) which run the full length of the car and serve as side sills. The cars do not have center sills but do have intercostals between some transverse beams. The end underframes are fabricated of low-alloy, high-tensile steel and consist of bolster, draft sill, and angular end sill, fitted with a conventional anti-climber. (See figure 9.)

The vertical carside struts are aluminum extrusions riveted to the roof and lower sidewall extrusions on each side of the side doors and the windows. There are two vertical collision posts on each end of the cars that also serve as the frames for the end doors. The posts are butt-welded to the end sills and have a maximum horizontal buff force resistance of 200,000 pounds. (See figure 10.)

WMATA accepted its cars on the basis of the manufacturer's May 1974 report of carbody compression and vertical load tests which was approved by the equipment consultant. No side impact crashworthiness tests were performed. According to WMATA, the state-of-the-art of rapid transit car design and testing at that time primarily addressed the forces that act on the end of a car.

WMATA's cars are double-truck and have 52-foot truck centers. Each truck has two pairs of 28-inch wrought-steel wheels with anti-friction journal bearings. Each wheel has an outboard mounted 20-inch friction brake disc. The brake pads are attached to truck mounted calipers that are air-actuated and hydraulically operated. There are two axle mounted Westinghouse model 1462B series-wound traction motors per truck. Each has a

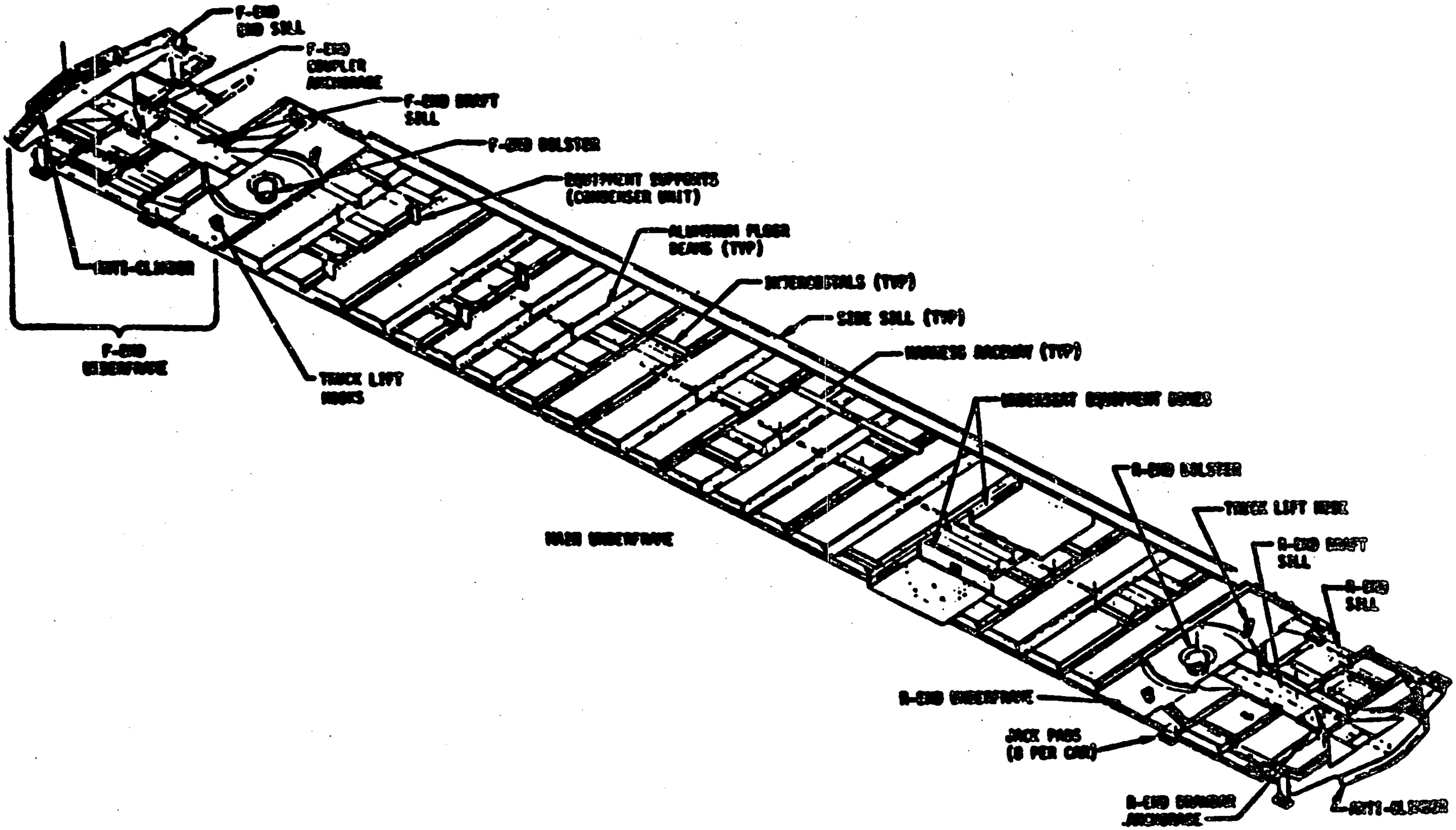


Figure 9.—Underframe structure of typical WMATA rapid transit car.

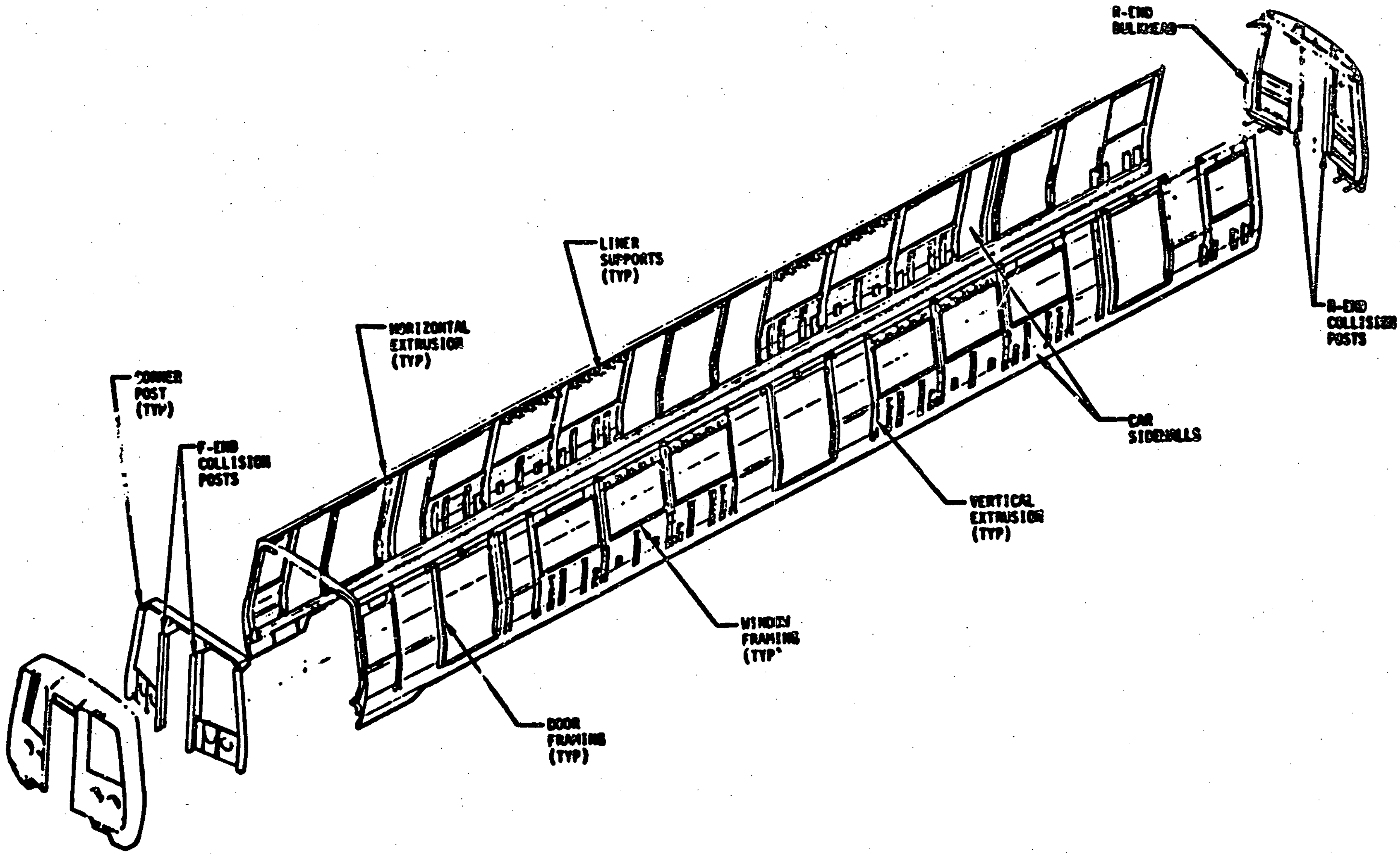


Figure 10.—Carbody structure of typical WMATA rapid transit car.

rating of 175 horsepower with 5.414:1 traction gear ratio that is designed to achieve the maximum 75-mph train speed from standing in 23 seconds with a full seated passenger load. The truck wheelbase is 7 feet 3 inches, and the car overhang on each end is 7 feet 9 inches. The WMATA cars have a light weight of 72,000 pounds, including the 25,000-pound combined weight of the trucks. The weight of the trucks includes the 5,840-pound weight of the motors. The WMATA cars are the most powerful rapid transit cars in North America. 18/ They compare with the cars of the other state-of-the-art lines as follows:

	WMATA	PATCO	BART	MARTA
Light weight (tons)	36	37	29.5	38
Motor horsepower per car	700	560	600	640
Ratio, HP to tons weight	19.4:1	15:1	20.3:1	17:1
Maximum speed (mph)	75	75	80	75
Maximum acceleration rate (mph/sec)	3.25	3.0	3.0	3.0
Maximum braking rate (mph/sec)	3.2	3.0	3.0	3.5
Rated max. horiz. buff force (pounds)	200,000	250,000	150,000	175,000

The front ends of the WMATA cars have an operator's compartment, which, when closed and in use, extends the full width of the cars. On each side of the compartment, there are sliding windows which the operator can open to monitor the loading/unloading of passengers at the platforms. When the operator's compartment is in use, the vestibule door is kept closed and locked. The glass in this door and the adjacent bulkhead is virtually opaque. The operator's seat is located facing the right front window and the operating console.

The operating console consists of two panels. (See figure 11.) In the center of the upper panel, three speed indications are displayed in lighted, digital form. These three speeds are the limiting speed, or speed command established by the ATP system, in red; the regulating speed, or desired speed established by the ATP or the ATS system, in yellow; and the actual train speed, in white. There are also train control information lights that indicate what operating mode is in use. A red "ATP cutout" light is illuminated when the ATP system is cut out and there is no overspeed protection. There is also a red light that illuminates when the ATS regulated speed indication is "invalid" or "missing," as well as an audible overspeed alarm which sounds when actual speed exceeds the regulated ATP speed in manual operation.

The lower portion of the control console contains the energizing key switch, the ATC stop and start buttons, the red "mushroom" emergency braking button, a communications control panel with adjustable microphone, the mode selector switch, and the master controller for control of propulsion and braking. A "deadman" switch is incorporated into the main handle which, if it is released, causes the brakes to apply in emergency.

18/ See Roster of North American Rapid Transit Cars, 1945 to 1980, American Public Transit Association, Second Edition, July 1980.

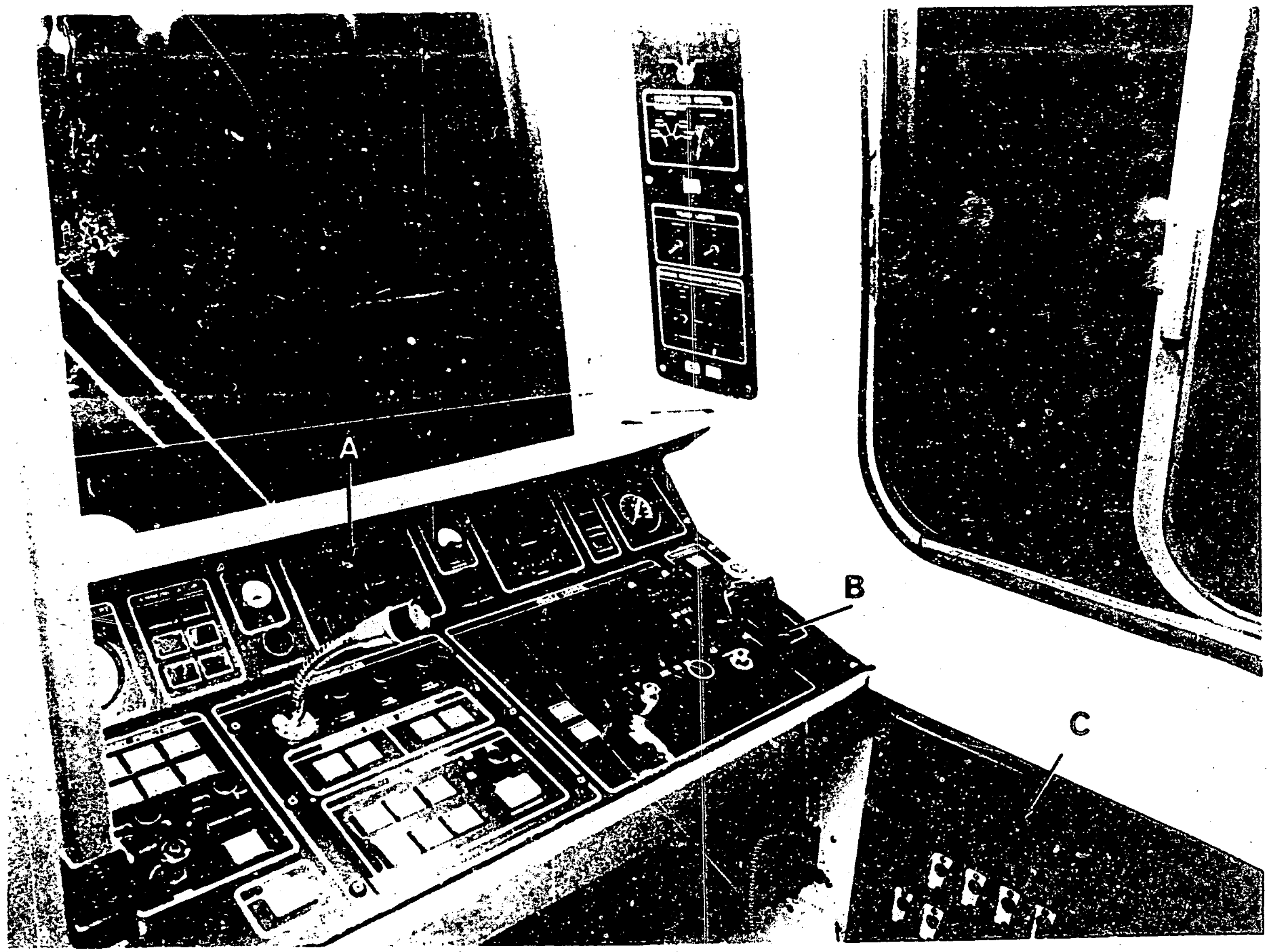


Figure 11.--Operator's compartment of WMATA car No. 1029. Control console and front window at left, circuit breaker panel at lower right, and auxiliary control panel at upper center. (A) is speed panel, (B) is master controller handle, (C) is ATP cut-out switch.

The communications equipment includes the onboard mobile radio, built into the console, the public address system, and the passenger-operator speaker. The radio can transmit two types of calls--normal and urgent. The urgent call transmits an overriding signal to the base station at the OCC, and the control logic is designed to give precedence to the urgent call over other radio traffic. The radio and public address systems can operate from both the auxiliary and emergency power. However, if both these power systems are lost, the operator loses all radio and public address capability. 19/

Each married pair of WMATA cars has a Harris Carborne Monitor (CBM) fault indicator mounted on the "A" car. This device is designed to record on a 30-minute continuous loop tape the transmitted speed commands, the actual speed, the digital time division, and several critical vehicle subsystem parameters. In a 1979 memorandum, WMATA's assistant director of equipment pointed out that the CBM could be used to accurately document the chain of events leading to an incident, including both equipment and operator actions while acknowledging that the WMATA CBM "has never been given an opportunity to work or even to be line tested." He further stated that MARTA's vehicle monitoring system had proven extremely valuable during the short time it had been in use. The current order for 294 additional WMATA cars does not provide for the installation of CBM equipment.

WMATA's cars are not equipped with derailment detectors which utilize a frangible detector bar mounted on the underside of each side of each car truck about 1 1/2 inches above the top of the rail. When a derailment occurs, the bar will impact against the rail and break. This interrupts the main train circuits, terminates traction motor operation, and applies the train brakes. Such devices were installed on the BART cars by the builder and are still in use.

Subway, Track, and Signal Information

At the Federal Triangle Station, the Blue/Orange subway line is under 12th Street, N.W., and would have followed this street under the Mall to the Smithsonian Station except that 12th Street passes under the Mall in a tunnel of its own. As a result, it was necessary to divert the Metrorail route around the 12th Street tunnel and incorporate a pair of long curves into the alignment. The distance between the two 600-foot-long Station platforms is 1,416.25 feet. Except for short distances adjacent to the station platforms, there is a 1.9-percent ascending grade from the Federal Triangle Station to the Smithsonian Station.

The Federal Triangle Station has a single escalator-equipped entrance located just west of 12th Street between Pennsylvania and Constitution Avenues. An automatic elevator for use by the handicapped is also at this location. A kiosk, attended to by a Metrorail employee, is located on the mezzanine level of the station. Smithsonian Station has two entrances, each with escalators and an attended kiosk; one is located at the intersection of 12th Street and Independence Avenue, S.W., the other is on the Mall adjacent to Jefferson Drive west of 12th Street. There is an automatic elevator at the Independence Avenue entrance.

19/ The radio does not have a self-contained power source. Some rail transit systems use the so-called "jerk and run" radio which is mounted in the console but can be removed and carried by the operator should he have to leave the operator's compartment. Others issue ordinary portable radios to their operators.

The tracks in the subway are laid throughout with 115-pound continuous welded rail. There are no crossties since the rails are directly anchored to concrete inverts with fasteners on 30-inch centers. At Smithsonian Interlocking, the main tracks are tangent, the distance between the centerlines of the main tracks is 14 feet, and the box-type tunnel is 30.5 feet wide and has a typical height of 12 feet above the tops of the rails. A 1-foot thick reinforced concrete barrier wall extends from floor to ceiling on the centerline of the tunnel between the stations except for a 200-foot opening at the Smithsonian Interlocking. The barrier wall has closely spaced openings which permit passage from one side to the other. There are 2-foot-wide, 1-foot 9-inch-high, raised catwalks located adjacent to the tunnel wall or barrier wall, whichever is located on the opposite side of the track from the traction power, or third rail. The catwalks do not have handrails, but there are steps between the catwalks and the station platforms. Fluorescent fixtures mounted on the tunnel sidewalls provide lighting throughout the tunnel.

The distance between the Federal Triangle Station platform and switch 1A of the Smithsonian Interlocking along the D-1 track is 534.25 feet. Most of this alignment is laid in a 7-degree 36-minute right-hand curve southbound and its spirals which end 35.16 feet from the point of switch 1A. Most of the 710.44-foot alignment between the Smithsonian platform and switch 1B of the Smithsonian Interlocking is laid in a 7-degree 35-minute right-hand curve northbound and its spirals which end 25.4 feet north of switch 1B.

Smithsonian Interlocking is one of five double-crossover interlockings spaced generally about 1 mile apart in the 6.52-mile section of subway between the Rosslyn Station and the Stadium-Armory Station. It consists of a double No. 8 crossover with railbound manganese steel frogs. The turnouts are of standard design with insulated 16.5-foot straight switches. The covered dual control switch machines are located to the inside of the tracks and are remotely thrown through the ATC system on command from the OCC. The switches can also be thrown manually with a crank that is inserted through a port in the end of the switch machine. The switch points are tapered Samson-type with mated undercut stock rails which are anchored by fasteners.

The crossover tracks are 172 feet 4 inches long between opposing switch points, and a train entering a crossover track fouls the opposing main track 69 feet beyond the point of switch at an angle of about 3 degrees. Headed toward New Carrollton, the facing point switch is identified as 1A and the trailing point switch as 3A. Headed toward National Airport, the facing point switch is 1B, and the trailing point switch is 3B. The nearest insulated joints are located 5 feet 7 1/2 inches beyond the switch points. Interlocking signals are mounted on the tunnel wall to the field side of the track they govern. The signals are identified as D02-02 at switch 1A, D02-04 at switch 3A, D02-06 at switch 3B, and D02-08 at switch 1B. The signals display the double red "stop" aspect and a lunar white "proceed" aspect. No route indication is displayed. 20/ The switch points have electronic sensors which detect any gap between the point and its mated stock rail. If a switch is gapped, the OCC will receive an indication on the CRT alarm screen that the switch and the opposing switch do not correspond in position. However, the screen will not indicate which switch is gapping. When this condition exists, none of the interlocking signals can display a lunar aspect.

There were four separate sections of the 750-volt third rail power supply system between the Federal Triangle and Smithsonian Stations. The third rails are located

20/ PATCO uses similar interlocking signals and has modified them by adding interrupters and relays so that a flashing lunar aspect can be displayed to indicate the route is aligned through the crossover track.

between the main tracks between the Smithsonian Station and the Smithsonian Interlocking, and between the Smithsonian Interlocking and a point 142 feet short of the Federal Triangle Station platform. Between that point and through the stations, the third rails are outside the main tracks. The traction power third rails are supported by insulators and are shielded by coverboards.

Each section of the third rail had independent circuit breakers with a load-sensing automatic reclosure feature. As with all the breakers on the system, these could be commanded open from the electrical and support console in the OCC. The OCC could also determine the condition of all the circuit breakers and power circuits in the Smithsonian-Federal Triangle Section by calling up a schematic diagram of the section on the traction power CRT screen.

Figure 12 shows the four power circuits and the third rails involved. When car No. 1029 crossed the two short acceleration or bridge power rails at the north end of the interlocking, both power sections (A) and (B) were momentarily shorted out. When the car came to rest with the forward end on the third rail along the D-1 track, a fault occurred which caused the breakers of the (A) section to open. The middle of the car was between, but clear of, both third rails of power section (B). The rear end of the car stopped in contact with the long outside bridge power rail that was part of power section (C). Although the breakers for this section did not trip open, witness testimony indicates that there was arcing and smoking at this location after the accident.

After the supervisor asked that power be shut down so that evacuation of train No. 410 could be started, at 1636, the OCC began to command tripping of the breakers on the power circuits that were still energized. Section (B) was deenergized at 1639 and section (D) at 1650. Because the OCC wanted train No. 906 to pull back to the Smithsonian Station to offload its passengers, section (C) was not tripped out until 1655. The OCC never did command tripping of the breakers on section (A).

About 1707, about 20 minutes after its evacuation was started, car No. 1029 shifted because some passengers had been evacuated. As a result, contact with the third rail along the D-1 track was lessened enough to remove the fault and allow the breakers for section (A) to automatically reset. There was sufficient contact remaining to cause explosions, arcing, and smoke, which alarmed the rescue firemen. They stopped evacuating people from the car and radioed for someone to shut down the power. WMATA personnel used the emergency trip station at the Federal Triangle Station to shut down the power at approximately 1711.

According to WMATA's train control engineer, there are three track circuits on the D-2 track between the platform of the Smithsonian Station and signal DO2-08 which are 152, 174, and 370 feet long, respectively, from south to north. All of these circuits would have had zero speed commands at the time train No. 906 left the Smithsonian Station. The computer log analysis provided by WMATA indicated that the lead end of train No. 906 passed through the first circuit and into the second circuit in 7 seconds, and about 2 1/2 minutes later, at 1629:26, the train entered the third circuit. WMATA calculated that train No. 410 had vacated that circuit 6 seconds earlier as it was being pulled back through the crossover.

Meteorological Information

The weather in the Washington area on January 13, 1982, had been characterized during the day by obscured ceilings, snow, and northeast winds. The barometric pressure

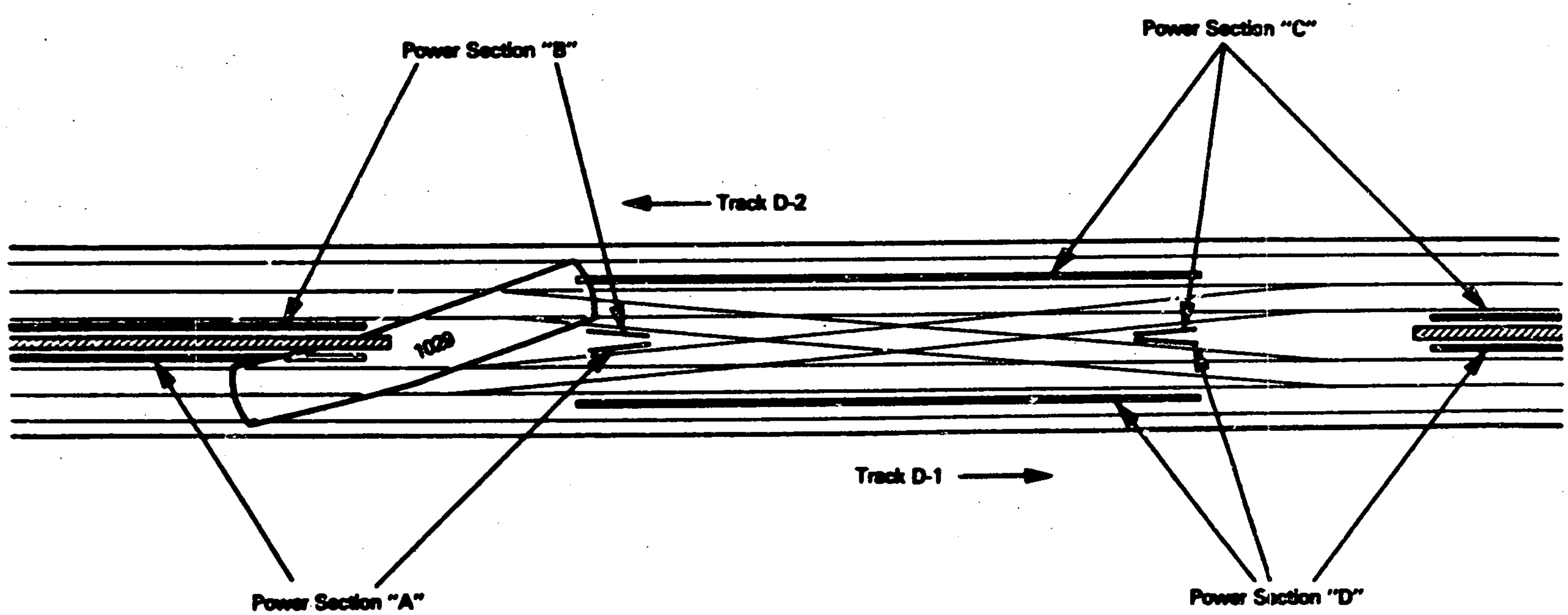


Figure 12.—Position of derailed car No. 1029 in relation to third rail traction power sections at the Smithsonian Interlocking.

had fallen steadily since midnight. There was very little temperature change during the day. From midnight to 1900, the recorded high and low temperatures were 26° F and 20° F, respectively. The temperature at 1614 was 24° F.

The local weather forecast at 0940 included light snow until 1300 and light snow and occasional moderate snow from 1300 to 1700. At that time, there was a .4-inch accumulation of snow. By 1252, the accumulation had increased to 3 inches. A total of 3.8 inches of new snowfall was recorded between 1200 and 1700.

Survival Aspects

Car No. 1029 struck the barrier wall at a point about 20 feet from the forward end of the car on the right-hand side. 21/ The actual impact point was in the right front main compartment, just behind the first large window, about 8 feet behind the forward door and opposite the forward-facing half of the double-backed middle seat. The car impacted the barrier wall with sufficient force (possibly as high as 300,000 pounds) to fracture both the upper and lower side sills. Longitudinal penetration at an angle of about 15 degrees was about 14 feet through the rear half of the compartment to a point between the middle doors. Transverse penetration occurred through fully one-third of the car width. The lower sidewall was severed and peeled outward along the D-2 track side of the barrier wall. (See figures 3 and 13.)

Because the sidewall extrusions were the primary longitudinal compression members and critical elements of the car structure, integrity was compromised and the bending moment applied to the car caused a permanent deformation to the structure. The transverse beams and intercostal supports were buckled, bent and broken causing the floor structure to collapse in the area which struck the wall. Electrical apparatus under the floor was dislodged and destroyed as was the battery bank under the middle seat. The vertical struts, frames, and glazing of the two rear large windows and the sidewall skin were crushed inward. The vertical stanchions in the middle entryway were bent and dislodged. The roof and ceiling panels collapsed inward.

When the car side was penetrated by the barrier wall, the middle back-to-back seat, the batteries under this seat, and the three double seats behind it on the right side of the forward main compartment were torn from their mountings and shoved backwards. These seats and other debris were compressed into a relatively small area as the wall penetrated deeper into the car. (See figure 14.) Two of the fatally injured had been seated side by side in this area. They were crushed between the wall and the overturned back-to-back seat. A passenger who survived with serious chest injuries was also trapped in this confined space. The other fatality was crushed between the wall and a seat located in the same area. Another seriously injured passenger was found pinned by the legs between the peeled car sidewall and the barrier wall.

Seats ahead of the point of impact were disturbed by deformation of the car sidewall but remained attached to the sidewall and upright. The back-to-back middle seat on the left side of the compartment was broken loose, probably by impact, but it also remained upright. According to witnesses, at least two passengers fell through the floor after it collapsed but apparently were helped back up into the car interior.

21/ Given in terms of facing forward in the direction of movement at the time of the accident. The end referred to as forward was actually the designated rear end of the car.

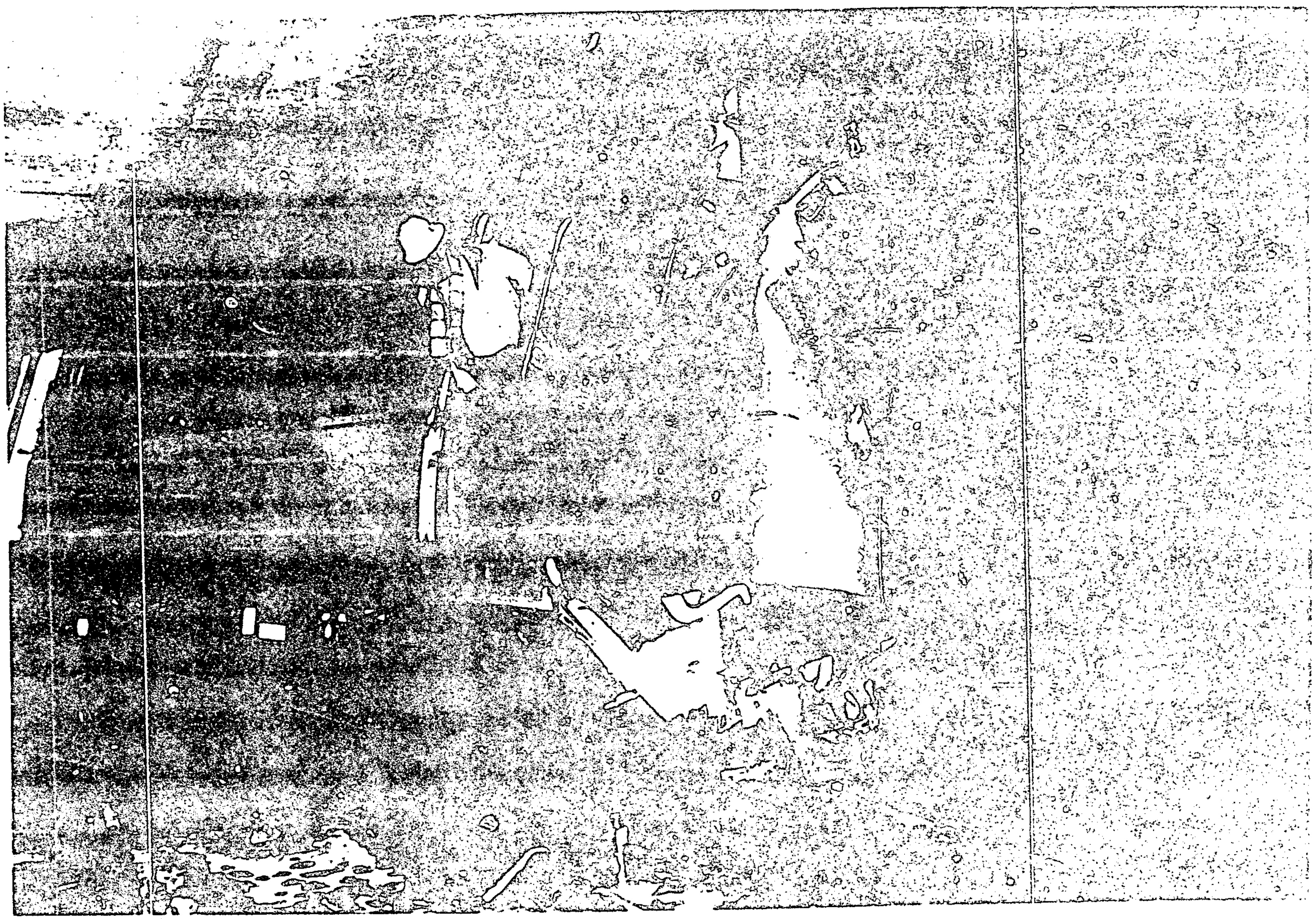


Figure 13.—View facing north showing forward end of WMATA car No. 1029 impinged on the center barrier wall. The D-2 main track is in the foreground.

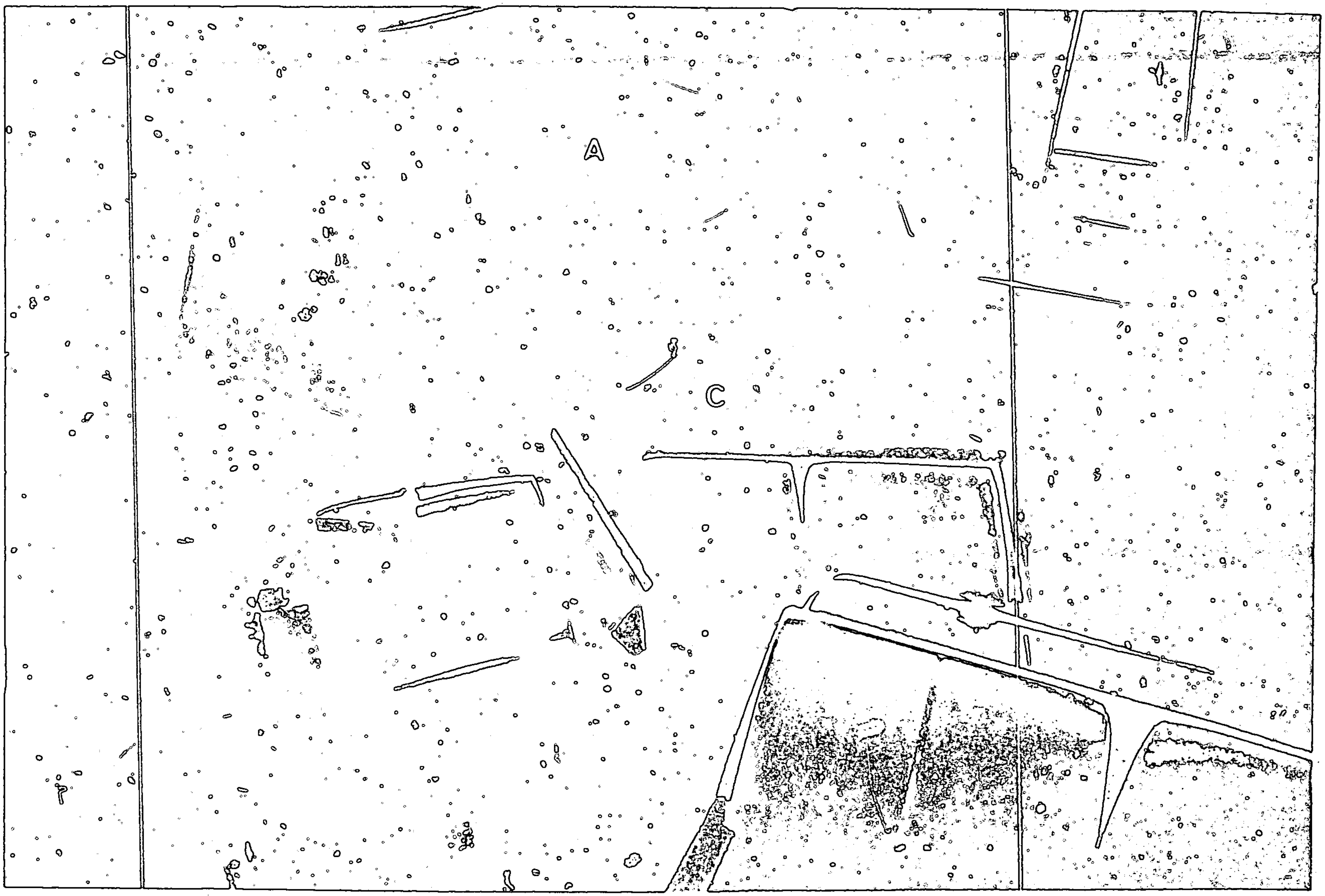


Figure 14.—Interior view of WMATA car No. 1029 facing rearward and showing penetration of the barrier wall. "A" is the wall and location where fatal and most serious injuries occurred. "B" is overturned right side back-to-back seat. "C" are batteries that had been under "B".

Witnesses described "loud" electrical explosions, or arcing coming from under the car after the accident. The arcing was accompanied by bright flashes of light and smoke. Some smoke entered the car through the floor openings; however, there was never any indication of fire. With the side doors closed and doors on both ends of the train locked, all of the passengers were trapped. There was no light or ventilation anywhere in the train. Because of the extreme crowding, most of the passengers were completely immobilized. Passengers in the derailed car experienced the greatest discomfort because of the greatly compressed interior space.

Medical and Pathological Information

According to the first rescue workers to arrive on the scene, no life signs were detectable in the three persons who were fatally injured. They were pronounced dead on arrival at the Washington Hospital Center about 2020. The causes of death for the three fatally injured were given as asphyxia due to chest compression with multiple fractures and internal injuries in one instance, asphyxia due to compression of chest in the second instance, and multiple fracture and injuries in the third instance.

The five most seriously injured were admitted to District hospitals for treatment for, (1) fractured ribs, (2) fractured leg, (3) fractured ankle and foot, (4) fractured ankle, and (5) fractured patella. The 20 other injured passengers suffered minor injuries for which they were treated and released.

Tests and Research

Following the accident, a six-car test train which included the undamaged married pairs of cars from train No. 410 was used to perform certain tests at the accident location. Safety Board investigators and members of the American Public Transit Association Panel of Inquiry were present while the tests were made. Safety Board investigators observed that while the test train was making a full power movement toward the Federal Triangle Station in Mode 2 on the D-1 track, such as was being made by train No. 410 when the accident occurred, the overspeed function performed at about 14 mph after which speed continued to accelerate to 16 mph before braking deceleration commenced. Safety Board investigators also noted that with the train stopped short of signal D02-02 and switch 1A, it was impossible because of sight angle and distance to determine the position of switch 1B from a standing position at any location in the operator's compartment.

The carborne monitor on car No. 1028 had a tape cassette, which was taken by a member of the Safety Board's Bureau of Technology to the Transportation Systems Center at Cambridge, Massachusetts, for readout and analysis. Although the tape yielded various data, the data did not conform with known elements of train No. 410's operational history before the accident. Since the exposed portion of the tape was kinked in several places, it was concluded that it had been stationary inside the recorder for an extended period of time before the accident.

Other Information

Training

Since the inception of the Metrorail system, all persons trained to become train operators were previously employed as drivers in WMATA's bus system. The train operators' training course included 7 weeks of classroom instruction and supervised "hands on" experience, 2 weeks of on-the-job training with experienced operators, and 1 week of training on an interlocking board. A multiple-choice written test with a minimum passing grade of 70 was given to trainees before they were qualified as operators. The instructors who trained and tested the operator-trainees were former busdrivers who had received training in rail transit operation at PATCO prior to the initial startup of Metrorail. According to WMATA, there has never been an in-house program to train or evaluate instructors, nor has the staff included professional training specialists. Train operators have never been offered a refresher course, and there has never been a follow-up program to evaluate the performance of operators after they have been qualified.

In September 1981, the WMATA operators' training course was shortened from 10 to 7 weeks by eliminating 3 weeks of classroom instruction and "hands-on" training. Trainees were still provided the period of on-the-job training except when there was an urgent need for more operators as a result of expansions of the Metrorail system. According to WMATA, no evaluation study of the protential effect of these changes was made before they were implemented.

From the inception of the WMATA Handbook of Operating Rules, Rule 2(e) has required Metrorail employees to pass an annual examination on the book of rules, safety rules, and standard operating procedures. However, the examination has only been given twice since 1976 and was not given in 1981.

Every rail transportation supervisor must have a year's service as a qualified train operator and must demonstrate "strong job-related skills and supervisory capabilities." There has never been any regular, formalized training for these supervisors, although they receive some on-the-job training in the yards and terminals.

Before being assigned to the OCC, supervisory controller candidates receive approximately 3 weeks of training on the hardware and software in the facility from WMATA's train control engineer. Controllers are not required to have prior service on the Metrorail system and they have never been subjected to refresher training, annual testing, or recertification.

According to WMATA, the Metrorail training program has been severely limited by budgetary restrictions over the years. Generally, the Director of Rail Service is responsible for rail training and the Director of Transit Engineering and Evaluation is responsible for rail safety. Aside from the original instructors, WMATA has never sent any rail personnel to PATCO or other rail transit lines for training, retraining, or observation of that system's training program. The OCC assistant superintendent stated that WMATA has never sent its OCC employees to any other transit property to observe rail operating methods.

The Safety Board has examined the training program of PATCO which, of the other high-density, high-performance state-of-the-art transit systems, most closely approximates WMATA in terms of geography and climate. Since 1969, PATCO has had a well defined training program under the direction of staff officers with broad experience in the railroad and rail transit industries. It has compiled a fine safety record while consistently maintaining near perfect operational performance. PATCO train operators have moved up to key operating, safety, and training positions, not only in their own organization, but in the American Public Transit Association (APTA) and in the newest U.S. rail transit systems in San Diego, Buffalo, Baltimore, and Miami.

Initial training for PATCO student train operators begins with 5 days of intensive classroom instruction with progressively more complex written tests given daily to determine if students retain what is taught. As with all PATCO testing, the minimally acceptable grade is 80. Student operators then receive 30 days of closely supervised on-the-job training. During this time, the Supervisor of Operations, who is in charge of the training program, makes periodic followup progress checks. Following the on-the-job training, students are brought back to the classroom, reinstructed, and given a very difficult rules and equipment test. They are also graded on their handling of a train on the line. If performance is satisfactory, they are granted probationary operator status for 30 to 60 days, during which period they receive daily reinstruction and evaluation by supervisors. Full certification then follows the satisfactory completion of a final refresher course and written examination.

Only train operators who demonstrate the ability to handle greater responsibility can be chosen for training as field supervisors. Candidates receive 3 to 4 weeks of specialized training from qualified supervisors on all positions, after which they must pass extensive testing on rules, equipment, and administrative procedures. Before being considered fully qualified, they serve for an extended period as auxiliary supervisors.

To become a qualified dispatcher in PATCO's counterpart of WMATA's OCC, an employee must first be a field supervisor and a qualified train operator, receive 3 weeks of specialized training in equipment and procedures, and pass an 8-hour verbal and written rules examination given by PATCO's superintendent.

All PATCO train operators and field supervisors must attend the annual retraining and reexamination course in order to have their certification renewed. Failure to be recertified results in automatic suspension from service. The annual course also includes special instruction at the car shops on equipment modification and trouble-shooting. Supervisors are also sent annually to other transit systems to observe operating methods.

After qualification, dispatchers are given refresher courses three times a year. Included are the retraining/recertification course, equipment instruction at the shops, and visits to other rail transit systems. To remain qualified, dispatchers must also annually work with a field supervisor during his assignment on the line, and actually operate trains in revenue service.

Although WMATA busdrivers must pass rigorous physical examinations periodically, as required by Federal regulations, there is no written requirement for train operators or rail supervisors to pass a physical examination. WMATA did state, however, that it is the policy to have train operators over 50 years of age examined annually, and those under 50 examined every 2 years. The policy did not extend to the supervisors. However, since the accident, WMATA has changed its policy and now requires all Metrorail employees and supervisors to be physically requalified on the same basis as train operators.

Previous Metrorail Incidents

The accident on January 13, 1982, was the second side-rake collision on the Metrorail lines. The first occurred on September 11, 1977, in the Rhode Island Avenue double-crossover interlocking on the Red Line. One train stopped short of an improperly aligned trailing point switch and was struck in the side of the forward main compartment of the lead car by a second train which had been routed through the crossover. Several WMATA and contractor employees were injured. The moving train penetrated the standing train to a depth of 39 inches. Four seat sets were destroyed.

According to WMATA, before January 13, 1982, there had been 44 incidents of collisions, derailments, and train movements through misaligned switches, as well as the undesired movement of an unmanned train on the main line. About one-fourth of the total incidents occurred at interlockings and other mainline locations; the rest in the yards. None resulted in fatalities. The investigation revealed that there had been a number of "near-miss" incidents at interlockings which had not resulted in derailment or collision. According to the OCC supervisors, it was not uncommon to have trains misrouted at interlockings nor to make reverse movements in such cases.

System Safety Assurance

Less than a year after Congress had authorized the building of the Metrorail system, the Safety Board published a special study of the safety procedures for the system. 22/ This study was addressed to the general manager of WMATA and expressed the Board's concern over what were perceived to be potential safety problems in the proposed system. Included were the apparent disregard of proven system safety principles by the design engineers, proposed high-speed rapid transit operations next to railroads also operating high-speed trains, and poor crashworthiness features of the proposed rapid transit cars. The Board commented, "WMATA's Manual of Design Criteria does not specify the level of safety required in any engineering phase of system design. The responsibility for including safety requirements in all engineering phases has been left to the judgments of the engineers and architects." Elsewhere it was noted that, "A general recognition of the need for the development of a safe system exists; however, it appears that no procedure has been developed by WMATA to insure it."

As for car crashworthiness, the Board stated that, "The preliminary design criteria for the cars does not provide for the protection of the passengers in cases of collision, derailment, or emergencies requiring immediate evacuation of the occupants." Elsewhere it was noted that, ". . .the car is not designed to maintain its structural integrity."

The study concluded that, ". . .the absence of provisions for a disciplined, systematic review of the entire project has resulted in a system with identifiable hazards which could lead to disaster in the future operations." The Safety Board recommended that, "WMATA develop the capability within its organization for system safety engineering and apply system safety principles to all aspects of the proposed Metro System to identify, assess, and correct those deficiencies identified by the analysis."

Shortly after the first 4.6-mile segment of the Metrorail system was opened on March 29, 1976, the Urban Mass Transportation Administration (UMTA), the Transportation Systems Center (TSC), and the Federal Railroad Administration (FRA) made a very comprehensive safety and systems assurance review of WMATA's rapid transit system development program. A report of the findings and recommendations brought out in the review was presented to the general manager of WMATA in September 1976. This report cited and repeated the 1970 Safety Board recommendation to WMATA with the comment that, "The present situation as far as the WMATA organization is concerned, has not changed in 6 years, for all the work in these areas is being done by consultants."

22/ See "Study of Washington Metropolitan Area Transit Authority's Safety Procedures for the Proposed Metro System," September 28, 1970" (NTSB-RSS-70-1).

According to the joint review report, the management of WMATA lacked expertise in scientific areas which impacted definitively on safety and system assurance. The report cited man-system technology as the area of expertise which was most lacking. The report asserted that WMATA never had a staff member with the expertise, responsibility, and authority to insure integration of the subsystems, including personnel, necessary for ". . .any transit property to have the system assurance it must have for safe, effective, and efficient operation to which the public is entitled." The report also stated that WMATA's philosophy seemed to be that all problems could be eliminated by increased automation. "The apparent belief is that through this increased automation the impact of human error could be reduced or even eliminated."

Aside from its criticism of what it characterized as WMATA's "automation for the sake of automation" and the use of "a human operator to monitor and back up their automatic system," the report expressed serious reservations about the manual Mode 2 feature of the ATP system, WMATA's reluctance to undertake a program to educate the riding public in evacuation procedures, and the lack of protection afforded to the operator in the event of a collision. Concern was also expressed regarding the low annual training budget of $25,000 which would "severely limit the scope and depth of training."

The 1976 review endorsed the Safety Board's 1970 recommendation that WMATA have a staff member responsible for a systems approach to safety, and recommended that WMATA ". . .define a very positive, visible and professional internal system safety certification process;" test and verify that the OCC can acknowledge, interpret, and act upon the maximum rate of alarms and that commands will be carried out promptly enough to prevent saturation of the OCC function; require all rail personnel to be conversant with the operating rules and test them periodically on the rules; and "Establish and enforce stringent physical and mental health requirements for the selection and retention of all operating personnel."

Disaster Preparedness

The Safety Board's investigation revealed that there was no area-wide disaster plan which provided for joint reponse by emergency units of the District of Columbia and the adjoining suburban areas of Virginia and Maryland. However, there were mutual-aid agreements in force between the District Fire Department and some of the suburban municipalities. Under these agreements, rescue units from two surburban Maryland counties provided backup assistance to District units responding to the Metrorail emergency.

The District Fire Department and WMATA had jointly conducted three simulated emergency disaster drills in the subways prior to the accident. One of the drills, conducted on May 2, 1981, included the evacuation of 292 passengers from a train in the subway. An October 1981 report of the Metro/Fire Rescue Liaison Officers Subcommittee, based on the drills, identified several potential problem areas, including communication and equipment difficulties. At the time of this accident, WMATA had taken action to alleviate the most serious of these problems. However, the simulations did not include participation by surburban fire and rescue units, District Police, or the metropolitan area hospitals. The October 1981 report stated that the evacuation ladders in the Metrorail cars were not adequate and recommended that they should be modified to improve their stability. However, the issue was not addressed in detail nor was it assigned a priority. According to WMATA, since this accident they have begun replacing the ladders with ones that can be secured to the end sills of the cars to prevent slippage.

ANALYSIS

The Accident

WMATA sought to minimize the impact of human failure on the safety of Metrorail through automation, and its ATC system was designed to eliminate many of the traditional human functions of a rail transit system. If a breakdown occurred within the ATC system, a Class 1 alarm was automatically generated to alert personnel in the OCC. It was the OCC's responsibility to perceive and acknowledge the alarm and to have the ATC maintenance forces correct the problem. If the number of incoming alarms was so great that a Class 1 alarm somehow went undetected, there was backup protection in that the alarm would be repeatedly logged by the computer until it was acknowledged. Monitoring the alarm alert system was a critical function of the OCC, and routine periodic checking of the log should have revealed any breakdown in the ATC system. Nevertheless, the failure of a fuse affecting the ability to remotely throw switch 1A at Smithsonian Interlocking went undetected and unreported by the OCC for 3 days.

Despite the OCC's failure to detect and report the alarm, the fuse failure should not have gone uncorrected for so long a time. The fuse had a popup failure indicator which should have been observed by ATC maintenance personnel during the six occasions they were at the fuse location after the failure occurred.

About 40 minutes before the accident occurred, the OCC had been able to remotely reverse switches 1A and 1B at the Smithsonian interlocking in order to detour six trains around disabled train No. 403 which was stopped at the Federal Triangle Station. When the last of the detouring trains had cleared the Interlocking, the OCC commanded the switches to return to normal position; one switch threw, the other did not. Although the personnel in the OCC knew from looking at the CRT screen that the switches did not correspond in position, the CRT did not indicate which switch was misaligned. This condition seriously affected the safety of trains operating on both main tracks, and it was imperative that the OCC determine which switch was not properly aligned. The malfunctioning switch would have to be hand cranked to normal position and both switches inspected to assure that their switch points fit tightly and would not be split open by a train passing over them. These measures had not been taken when the OCC decided to cross train No. 403 over to the D-1 track and return it to New Carrollton.

The OCC knew that the problem at the interlocking was with either switch 1A or 1B and should have informed the supervisor of this after he boarded disabled train No. 403 at the Federal Triangle Station. On arrival at the interlocking, the supervisor could have readily observed that switch 1B was in normal position from his location on the leading end of the train, and after alighting from the train and taking a few steps, he should have been able to see that switch 1A was still reversed. After reporting this to the OCC, both he and the OCC would have known the nature of the problem and what needed to be done to correct it. However, no one ever established which of the switches was malfunctioning.

There was no compelling need to hold train No. 403 at the interlocking. The train could have been allowed to proceed through the crossover while the supervisor cranked switch 1A to normal position and blocked it. The OCC was able to command switches 3A and 3B to align in both normal and reverse position and would have received CRT displays that the switches corresponded in either case. The OCC could have restored the number 3 switches to normal after train No. 403 had cleared the crossover, and the supervisor could have then blocked these switches and switch 1B in normal position. If he had somehow overlooked blocking one of these switches, no harm would have been done. But in following the instructions he was given, the last thing Supervisor No. 31 was to do was the thing he should have been directed to do first.

After train No. 403 cleared the crossover without incident, the OCC had the supervisor remove the blocks on the No. 3 crossover switches and apparently intended that he hand crank the switches back to normal. The supervisor spent the next 3 minutes unblocking and attempting to hand crank one of the switches. Finally, the OCC remotely commanded the switches back to normal, and the radio controller told the supervisor to block the switches on the D-2 track (3B and 1B) in normal position first because he wanted to start running trains on that track. At this point, the assistant superintendent at the OCC instructed the supervisor to make sure the switch points fit tightly on "switch one." Since the OCC was concentrating on resuming service on the D-2 track, the assistant superintendent was no doubt referring to switch 1B. This caused the supervisor to focus his attention on the D-2 track turnouts and diverted his attention from locating the problem with switch 1A. After the supervisor reported that "switches 1 and 3" were tucked under and blocked, the OCC determined that he was only referring to the turnouts on the D-2 side and told him to, "go to the other side and block it." Following this instruction, the supervisor reported only that all switches were blocked and tucked under. No mention was made of the position of the switches. Had the OCC at this point explicitly questioned the supervisor about the alignment, it is possible that the alignment of switch 1A in reverse would have been detected and corrected.

Although the OCC knew that switches 1A and 1B still did not correspond in position, the OCC radio controller began operating trains manually through the Smithsonian Interlocking. This created the possibility of a side collision since a New Carrollton-bound train, routed through the crossover, would strike an opposing train after moving only 69 feet into the crossover track. Taking into account gradient and the time required for the operator to perceive and react plus the transition from power to braking modes, a New Carrollton-bound train operating at 15 mph in manual Mode 2 without overspeed protection would need 130 feet to stop. The movement of trains through the interlocking at any speed at this point without establishing that the switches were properly aligned was clearly unsafe and unnecessarily jeopardized the safety of passengers. The Safety Board believes that all movement through the interlocking should have been halted until the problem had been clearly defined and corrected.

Following the accident, the supervisor stated that he did not manually align any switch in the interlocking. He also insisted that he had blocked all the switches. However, since the block for switch 1A was found undamaged outside the switch after the accident, it is doubtful that the supervisor had blocked the switch. The supervisor had been told that the OCC wanted both main tracks aligned for normal train movement, but he may not have realized that switch 1A was improperly aligned. The switch machine had no device to visually indicate the switch's position. If the supervisor had looked at the switches only from the side, it is possible that he could have misread the position of the switch points. The Safety Board believes that the supervisor either did not think to check the alignment or he misread the position of the switch points. It is possible that the supervisor's judgment and efficiency were affected by the fact that he had not eaten in 19 hours.

The instructions given to the supervisor were imprecise and confusing largely because the OCC was trying to accomplish too many things at once and was giving only fragmented attention to the situation which in fact bore the highest priority. By the time the supervisor was told what to do at Smithsonian Interlocking, the serious train breakdowns had been cleared up. However, throughout the entire period preceding the accident, the OCC radio controller was regularly prodding train operators to "move out," and otherwise displaying his impatience with the train operators. With station platforms jammed and people trying to force their way on and off the trains, it was very difficult for the operators to get the doors cleared and closed properly. The trains could not move until this was done. These unnecessary communications from the controller only served to unsettle the operators, monopolize the radio channel, and distract the OCC from focusing on its foremost responsibilty which at that time was the critical problem at Smithsonian Interlocking.

The transcript of the radio communications indicates that the operator of train No. 410 always responded promptly and properly to instructions directed to him. However, he probably did not hear the radio transmissions between the OCC and the supervisor regarding the aligning of switches for normal train movement at Smithsonian Interlocking. At the time, the operator of train No. 410 was preoccupied with getting his doors closed at Metro Center and then making the required station announcements approaching the Federal Triangle Station. Furthermore, because of the numerous radio transmissions that were being made at the time, the operator would tend to concentrate on listening for calls specifically addressed to him. The operator was never told by the OCC what route his train was to take or informed as required of any speed restriction; he was told only that he was to follow the instructions of the supervisor at the Smithsonian Interlocking.

After trains Nos. 904 and 415 had passed through Smithsonian Interlocking on the D-2 track, the supervisor instructed the operator of train No. 410 to proceed, both by radio transmission and hand signal, as the train approached the interlocking. However, he did not inform the operator as to the route his train would be taking nor did he give him the required instructions regarding speed. The operator of train No. 410 acknowledged the proceed instruction, and the train's front end passed the signal and headed into the crossover at switch 1A.

When the operator of train No. 410 entered the crossover track, he could not have seen the position of the opposing switch, even if he had been looking intently. The operator had no reason to believe that the switch might be improperly aligned for a crossover movement. WMATA train operators had never been conditioned to be concerned about what route their train was to take at an interlocking because the "lunar" white proceed aspect did not tell the operator whether his train was to proceed on the main track or through the crossover; only that the train was to proceed. As for speed, the operator had not been made aware of any special speed restriction in the situation. WMATA's speeds were regulated by the ATP subsystem, and although the term "restrictive speed" was used liberally, neither this nor any other speed was defined in the book of rules. According to WMATA, restricted speed was considered to be 15 mph, enforced by the ATP, or the maximum speed a train could be operated in manual Mode 2. It was determined that in order for a train to stop short of the point where it fouled the D-2 track, 69 feet beyond the turnout at switch 1A, it could not exceed a speed faster than 8 mph after it entered the turnout.

Analysis of circuit occupancy times indicate that train No. 410 probably did not exceed 10 mph in the crossover. When the supervisor made the transmission to "hold up," the lead wheels of the train were already within 60 feet of the switch points of switch 1B. The operator responded immediately with a full-service application of the brakes and the train came to a stop after traveling about 70 feet with the lead wheels on the D-2 track beyond switch 1B. Had the supervisor reacted sooner, the train probably could have been stopped well short of the switch, although it still would have fouled the D-2 track. By the time the lead end of the train was midway through the crossover, the operator should have observed that the switch was aligned against his train's movement, but he was apparently distracted by the reflection of train 906's headlights on the rails of the D-2 track and on the tunnel barrier wall ahead.

The supervisor at this point informed the OCC that the switch did not look right and that he was going to attempt to pull the train back. The OCC, apparently concerned about keeping the traffic moving, only questioned whether or not the D-2 track had been affected. Although the OCC did not specifically ask the supervisor where the train was, the transmissions between the supervisor and the operator of train No. 410, which included the frantic call to "hold up," and the indications on the CRT screen (see figure 15), should have indicated the location of the train to the OCC.

The Safety Board believes that the assistant superintendent and the OCC radio controller realized they were confronted with the complete blockage of the Blue/Orange Line, and being movement oriented, were motivated to take immediate action. Only 5 seconds elapsed between the time the supervisor began transmitting, "No. Negative. Let me pull this train back first," and the start of the controller's response, "Alright. Train at DO-02, hold your position." The supervisor's transmission had consumed 3 to 4 seconds. Hence, the controller's response was made without hesitation or deliberation. The train at DO2-02 was No. 410, but it appears that the controller was probably trying to tell train No. 906 to hold its position at signal DO2-08.

The appearance of "phantom" 23/ track occupancy indications on the CRT screens, first at the crossing, next at switch 1B, and finally in the main track circuit beyond the switch, although irregular, explicitly informed the controller of the train's locations. The superintendent and the assistant superintendent, both of whom understood the indications of the CRT, should also have identified the phantoms as indicating the train's locations. The Safety Board believes that at this point the OCC should have been aware of a potentially dangerous problem in the interlocking and should not have permitted the supervisor to pull the train back until the switches had been inspected. Had the OCC exercised more caution, 24/ the derailment and the subsequent impact with the barrier wall could have been avoided.

Concerned with clearing the crossover track as quickly as possible, the supervisor did not consider the possibility of the train derailing as it was being pulled back. He did not check the location and condition of the wheels on the front end of the train nor did he instruct the train operator to do so. Since the train had not derailed before coming to a stop, it never occurred to the supervisor or the train operator that it might derail if it was pulled back. The Safety Board believes that under the circumstances it is not reasonable to expect the train operator to have left his post or to have questioned the judgment of his superiors. He had never been consulted or in any way brought into the decision-making process.

The operator of train No. 410 understood that the supervisor had boarded the other end of the train, had changed operating ends, and was going to pull it back so that it cleared the crossover track. Although the supervisor had control of the train, the operator knew that he still had the capability of applying the brakes in emergency. At a

23/ Normal depiction of a train on the CRT display would be a solid arrowhead followed by the train's number. In a "phantom" depiction, the train appears as a arrowhead outline followed by three small zero outlines where the train number would normally appear. (See figure 15.)

24/ The assistant superintendent had every reason to exercise prudence in the matter. He had previously formally reprimanded the supervisor for failing to dispatch a train as instructed. At the time, the supervisor was working as a terminal supervisor.

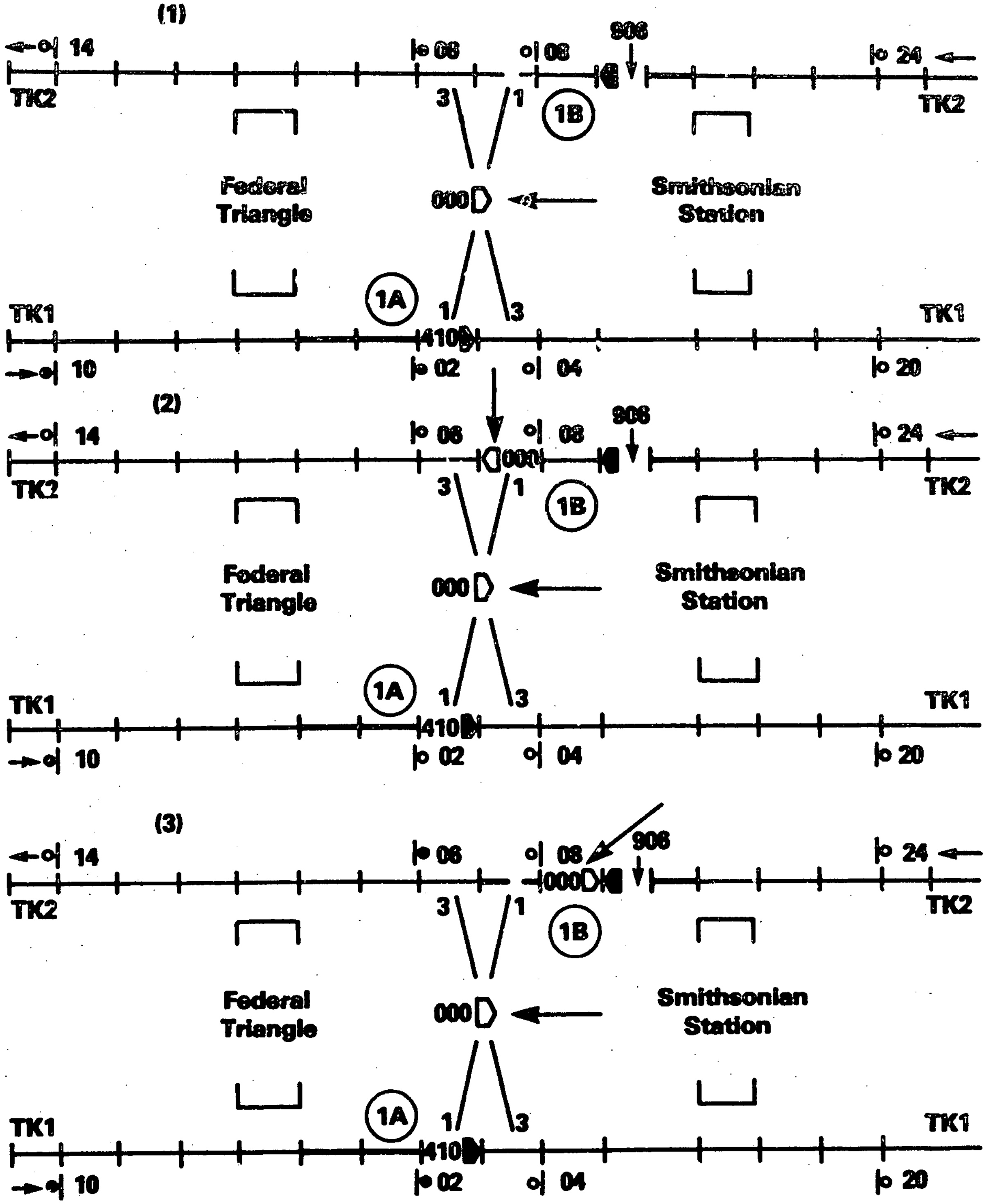


Figure 15.--Cathode Ray Tube (CRT) screen displays that occurred as train No. 410 passed from the D-1 main track to the D-2 main track at Smithsonian Interlocking. From top to bottom, the displays show "phantom" indications (arrows) appearing as the train progressively occupied, (1) the crossing, (2) switch 1B at Signal D02-08, and (3) the first main track circuit beyond the interlocking.

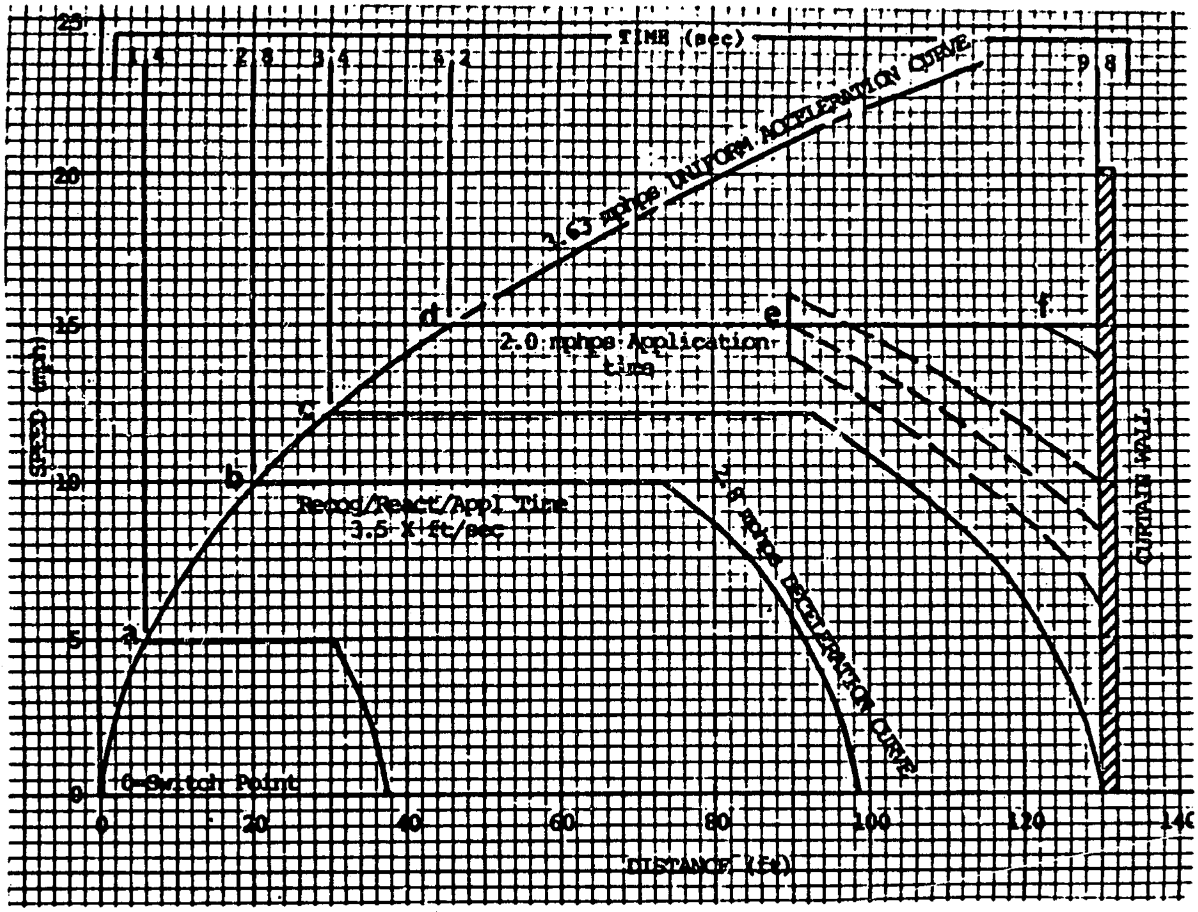
NOTE: Designations of switches 1A and 1B and marker arrows pointing to the phantoms have been superimposed on the displays.

uniform 3.63-mph-per-second rate of acceleration in full power on the 1.9-percent downgrade, the train would have reached a speed of 10 mph in 2.8 seconds and 15 mph in 4.2 seconds. (See figure 16.) At this point, the overspeed feature of the ATP system would have cut out the power and applied the brakes. The supervisor's postaccident statements corroborate these calculations. As shown in postaccident tests, speed would have continued to increase to 16 mph during the transition from power to braking modes, and the impact with the barrier wall would have theoretically occurred at a speed of about 10 mph, 9.8 seconds after power was applied.

From the track damage, it was evident that the lead wheels of the rear-most truck of car No. 1029 derailed shortly after the reverse movement was started. There was evidence that indicated the outboard-mounted brake discs, which were only 4 inches shorter in radius than the wheels, rode on the stock rails for some distance. The first damage to track fasteners occurred about 30 feet from the point where the reverse movement started. It was calculated that the train could have been accelerated to 12 mph in that distance. The derailed truck followed the proper crossover track for another 30 feet by which time the overspeed feature had already activated. It is doubtful that the derailed wheels had any effect on the rate of acceleration up to this point. Thereafter, however, the slewing of the truck and its then following the wrong track created significant resistance to forward momentum. This caused the "jerking" which the supervisor noticed after the brakes applied, and it probably resulted in an increase in the rate of deceleration and reduced the impact speed to somewhat less than 10 mph.

The operator was located behind the derailed truck and should have noticed the jolt caused by the lead wheel rims dropping off the rails. There should have been a second, even more noticeable, jolt when the rear wheels came off the rails. It is questionable as to whether or not the operator would have recognized these events as constituting an emergency. However, when the lead wheels began riding on the rail fasteners, there should have been no doubt that the car was derailed. At the time, the speed of the train would have not exceeded 12 mph. Had the operator immediately reacted and pushed the emergency "mushroom" button, the train would have stopped before car No. 1029 struck the barrier wall. (See figure 15.) However, the only thing the operator had been taught that related to the situation was that he should never use the "mushroom" except in what he perceived to be a real emergency.

The operator of train No. 906 stated that he left the Smithsonian Station in the automatic mode and never changed to the manual mode. However, he also stated that the train was stopped automatically at a point where he could see signal DO2-08 and that he actually witnessed the misrouting and subsequent derailment of train No. 410. Had train No. 906 left the Smithsonian Station in automatic mode, it would have been subject to loss of power and transition to penalty braking before it attained any degree of speed and probably would have been stopped within the first 152-foot track circuit beyond the Smithsonian Station. However, the head-end of the train maintained an average speed of 15 mph across this circuit. This could have been achieved only if the train was being operated manually. Because the operator had never heard the OCC's message to both train No. 410 and himself to approach Smithsonian Interlocking, operation in the manual mode was being done without proper authority. Had the operator interpreted the "permission to run red signal" transmission he said he heard as applying to his train and proceeded without stopping, it is possible that the two trains could have collided in the interlocking.



Corrected for 1.9 percent negative curve.

(a) Stopping distance from 5 miles per hour.
(b) Stopping distance from 10 miles per hour.
(c) Approximate location where first discernible effect of derailment occurred and last point where an emergency brake application would have stopped train short of the wall.
(d) Approximate location where overspeed device would have cut off propulsion power.
(e) Braking curves for 14, 15, and 16 miles per hour.
(f) Operator-initiated stop from 15 miles per hour.

Figure 16.--Calculated acceleration/deceleration curves for train No 410. Reverse movement in crossover track, Smithsonian Interlocking, based on 1.5 seconds perception and reaction time plus nominal 2 seconds for transition from power to braking modes.

Operations Control Center

In their efforts to automate the Metrorail operation, the planners and designers foresaw little need for direct human intervention in the operation of the railroad. The OCC was regarded as a necessary element in the system because people had to watch over the ATC and traction power systems, and to respond to failures and emergencies. However, it was not contemplated that the OCC should actively manage the routine operation of the trains; that was to have been a function of a computer. A modelboard monitoring system useful for human supervision of the system was not provided nor was the OCC staffed with persons who had the necessary training and expertise to adequately perform this function.

As the operational rail system expanded and WMATA increasingly coordinated its bus operations with it, the demand for dependable rail operation intensified. However, it is evident that the ATC system never became fully functional or fully reliable. Much of WMATA's technology proved to be impractical in meeting the scheduling loads being imposed on the system. As breakdowns of the sophisticated system and delays became more and more commonplace, there was mounting pressure to improve performance. Since the OCC was the logical place to try to achieve this, active train management increasingly became a function of OCC personnel.

The events of January 13, 1982, illuminated many of the inadequacies of the OCC, but none so vividly as the manner in which the radio controller performed his duties. Aside from prodding the train operators, he was also prone to ask them their locations. The controller was trying to ramrod 43 trains without any adequate means of following their movements. He repeatedly told train operators to pass red interlocking signals at restricted speed, an instruction that easily could have been and probably was interpreted to mean without stopping. Critical instructions sometimes went unacknowledged by operators, but the radio controller did not follow up or take protective action to make sure the instructions were received as required by WMATA safety rules 154 and 155. Although he told trains Nos. 410 and 906 to approach Smithsonian Interlocking and operate through it on the instructions of the supervisor located there, the radio controller never received acknowledgement from train No. 906. Since an absolute block was supposed to be in effect, two trains could not be allowed into the interlocking at the same time. It was imperative that the radio controller establish that the operator of train No. 906 understood the instructions. Until that was done, train No. 410 should have been held outside the interlocking. However, he made no additional attempt to contact train No. 906, nor did he or the supervisor instruct train No. 410 to hold.

Radio discipline insofar as the train operators was concerned was generally good. In referring to a signal, they almost always called it by its complete and proper number. The radio controller, however, invariably referred to signals by their last two numbers only, even when authorizing trains to pass them when they displayed "stop" aspects. He did this on four occasions during the 30 minutes preceding the accident. In one instance, the controller authorized a train to pass "02 red" when the train was actually approaching signal D02-08. Later, he again referred to this signal as "02" when restricting the movement of another train. This was a particularly serious shortcoming on the part of the controller because the various interlockings on this part of the railroad all had signals numbered 02, 04, 06, and 08. To differentiate between them, WMATA had prescribed the interlocking identification—CO2, DO2, KO2, etc.-- to be a part of the signal number. On another occasion, the controller told an operator to pass a red signal at McPherson Interlocking without referring to any part of its number. Considering the difficulties often encountered with train identification, the frequency with which runaround operations were conducted, and the virtually unregulated operation of trains in Mode 2, lax train management of this sort increased the potential for serious accidents.

Compounding the problems that the OCC encountered on the afternoon the accident occurred was the fact that the superintendent and the two top officers of the rail operation, who were not exercising effective supervisory backup, were present in the room. The radio controller should not have had to make so many critical decisions on his own. The Safety Board's investigation revealed that no one took command of the situation, and no one in the room had a clear understanding of who was in charge. There was, however, much shouting of orders, according to the assistant superintendent who apparently retreated from his usual supervisory role and simply tried to assist the controllers as much as he could. The assistant superintendent stated that the presence of the top operating officers was intimidating, since these men were relatively new on the job, and they were probably evaluating how the regulars did their jobs. Following the accident, WMATA issued orders requiring the establishment of who is in charge of the OCC at all times and prohibiting persons not directly connected with the functions there from entering the room.

The failure to properly maintain the intercom lines between the OCC and the other command centers (including the WMATA police dispatcher) prevented the prompt exchange of important information between the OCC and the transit policeman on train No. 410. Moreover, the assistant superintendent was forced to waste time shuttling back and forth between the offices to make postaccident arrangements that could have been made more expeditiously from within the OCC. The inability of the assistant superintendent to take over the Red Line radio load because the extra radio headset was out of order may have had an impact on the way the radio controller did his job.

Emergency Response and Evacuation Procedures

The confusion that existed in the OCC as to who was in charge hampered the ability of the OCC to respond quickly and efficiently to the emergency. While the need to keep trains moving to handle the overcrowded stations existed, priority attention should have been directed to the coordination of the rescue response. Response to emergencies had always been a primary function of the OCC. Additionally, one of the controllers in the OCC was responsible for monitoring the third rail traction power system and shutting down power when necessary. However, on the day of the accident, there were serious deficiencies in exercising both these responsibilities that could have impacted severely on the lives of hundreds of people. While the assistant superintendent's statement that there were 35,000 to 40,000 people in the system who had to get home was valid, the safety of 1,300 people trapped on board train No. 410 warranted the full attention and direction of someone in the OCC. Since the assistant superintendent began immediately to set up arrangements to transport people in the stations and on trains, the superintendent should have assumed responsibility for responding to the emergency at the Smithsonian Interlocking and should not have allowed anything to distract him from that responsibility.

Both the WMATA policeman on the derailed car and the supervisor on the lead car requested permission to evacuate passengers. The supervisor, in addition, requested that the OCC make certain that the third rail power was shut down. WMATA's preferred procedure of evacuating passengers directly to an empty train could not be used, since power was lost on the D-1 track. The "last resort" method of evacuating to the right of way had to be employed. Not only did the procedure require that the appropriate personnel be at the scene, it required that all third rail power be shut down in the affected areas. No one in the OCC issued instructions regarding the passenger evacuation, and because the OCC wanted to move train No. 906, the third rail along the D-2 track remained energized 11 minutes after the WMATA policeman had reported arcing under car No. 1029. In spite of the lack of guidance, the supervisors, employees, and volunteers did a highly creditable job in evacuating the passengers. However, because the traction power controller and his superiors did not make certain that the circuit breakers could not automatically reclose along the D-1 track, the third rail was energized as the passengers were being evacuated and were walking along side the third rail. All OCC traction power controllers and their supervisors should understand that all automatic reclosing circuit breakers for the traction power sections in the affected emergency area must be commanded open in a timely manner before passenger evacuation begins.

WMATA has not educated the riding public as to what to do in an emergency, and there are no placarded emergency instructions inside the cars. Even the emergency manual door controls and instructions for operating them were concealed from view. Because there were no removable emergency exit windows, passengers had to knock out windows when the conditions in the derailed car became unbearable. The Safety Board believes that entrapping hundreds of uninformed passengers in the cars in an emergency unnecessarily leaves them virtually helpless in the face of a life-threatening situation. WMATA needs to rectify this situation immediately.

The investigation revealed that the supervisors had difficulty with the ladders provided for evacuating passengers to the right-of-way and that the ladders need a device to secure them to door tracks or end sills to prevent slippage. WMATA needs to correct these deficiencies immediately and to place placards in their cars to indicate where the ladders are stowed and how they should be used in an emergency.

Any substantial separation between the cars, such as occurred in this accident, will result in a parting of the trainline and immediate shorting out of the entire battery power system rendering all emergency systems inoperative. Lighting is lost as well as the intercom and radio systems for communication. Had a WMATA policeman with a portable radio not been on the derailed car and had other supervisors who also had radios not been nearby, there would have been a substantial delay in reporting the derailment and injuries. WMATA needs to equip its cars with self-contained battery-powered emergency lights that can be used in the event battery power is lost. Train operators need some form of self-contained radio equipment. WMATA should also consider the possibility of modifying the operator's control console to accommodate a portable-type radio.

The OCC superintendent promptly contacted the District Fire Department's Communications Center on the direct "hot line" telephone, but too much valuable time was lost unnecessarily in pinpointing the exact location of the derailment. It was sufficient that the Fire Department knew that the emergency site was between Federal Triangle and Smithsonian Stations. Once in the stations, firemen could be headed in the right direction by kiosk attendants. The superintendent failed to impress the Fire Department's Communications Center with the urgent need for ambulances, and the Fire Department did not dispatch them until 23 minutes after the superintendent had called. The Safety Board believes that WMATA and the Fire Department should establish better defined procedures to assure prompt ambulance response to emergencies in the Metrorail system.

After the Fire Department's Communications Center had been informed of the exact location of the accident site, additional delay in responding to the emergency resulted from the need to determine which emergency units were still available. According to the Fire Department, the Communications Center had to follow a manual search procedure to do this because of limited computer storage space. The first District fire company headed for the accident site 6 minutes after the accident, but the only available rescue squad did not start out for 13 minutes, and the first ambulances were dispatched 23 minutes after the Fire Department's Communications Center was notified of the accident. The OCC had instructed the Fire Department to use the Federal Triangle Station as the entry point for rescue operations. However, the rescue forces were hampered in reaching the Federal Triangle Station, located between busy Pennsylvania and Constitution Avenues, because of the congested traffic in the streets. When the rescue forces did arrive, they had to enter against the flow of passengers being evacuated from train No. 410 through the station's only access route. The Safety Board believes that the superintendent should have directed rescue forces to the Mall entrance of the Smithsonian Station as their entry point to the subway. Rescue vehicles then could have reached this location quicker by simply driving down the Mall to that entrance. As it was, the first fire and ambulance units to reach the Federal Triangle Station had driven by the Mall entrance of the Smithsonian Station en route. Since this station had two entrances, kiosk attendants could have been told to keep the Mall entrance clear and directed rescue forces to the accident location.

Once the rescue forces arrived at the accident site, extrication work proceeded effectively; however, it required 2 hours 20 minutes to get the most seriously injured passenger to a hospital. In addition, no emergency routes were opened to the hospitals, and two of the hospitals were not advised that injured persons would be arriving. The Safety Board urges the Fire Department to require that advance information regarding delivery of injured persons in a Metrorail accident is relayed to hospitals and to establish procedures for clearing emergency routes.

The District's four rescue trucks are manned by the personnel of four fire engine companies. The rescue trucks have special tools required in extrication work, and the fire companies assigned these trucks have been trained in their use. If a company has responded to a fire alarm, no one is available to man its rescue truck. On January 13, three of the District's four combination fire/rescue companies were at the Air Florida crash site. Had the one remaining company been out on a fire call, there would have been no reserve rescue squad available to respond to the Metrorail accident. In the Safety Board's view, the city of Washington, D.C. should have a disaster plan which provides for sufficient overall capability to respond to multiple disasters.

Because WMATA's radio repeater system in the subway would not accommodate the Fire Department's radio frequencies, the Fire Department's forces had to rely on the Metrorail telephone line to communicate to and from the accident site. To keep abreast of the situation and to carry messages underground, the command post commanders above ground had to frequently send aides on foot to the accident site. Although WMATA states that modification of its radio repeater system to accommodate Fire Department radios has high priority and will be completed by 1983, some interim means of improving underground communications should be adopted immediately. WMATA radios using the WMATA police frequency which is presently compatible with the underground repeater system could be kept at station kiosks and issued by the kiosk attendents to Fire Department personnel responding to an emergency.

Although the District of Columbia Fire Department had an adequate number of emergency fire, rescue, and ambulance units available to respond to the Metrorail accident, it was necessary to call upon units from outside the District to provide backup assistance. However, had the number of casualties been substantially higher and required a much larger scale of timely response, it is doubtful that a commensurate level of response could have been managed, because there was no area-wide disaster plan in effect.

Several joint WMATA and District of Columbia Fire Department disaster simulations prior to this accident had resulted in the recognition of potential problems and action to eliminate them. These drills would have been even more valuable had they involved suburban rescue units, District police, and the metropolitan area hospitals. The Safety Board believes that future drills should be conducted frequently and should include participation by all organizations who may be potentially involved in responding to any future disaster.

WMATA's Mode 2 Operation

WMATA's manual Mode 2 operation is unique among the state-of-the-art rapid transit systems in that it permits unregulated operation up to 15 mph through red interlocking signals and successive zero speed track circuits without a backup collision avoidance system. This was a factor in this accident. During both movements of train No. 410 through the crossover track, the train was operated in Mode 2 at speeds up to or near the 15-mph minimum setting of the overspeed device, more than twice what WMATA says it permits in a manually-operated interlocking. In a similar situation on the other automated systems, the operator would have to get authority to go to manual Mode 3: receive a clearance form (in the case of PATCO), a train order (in the case of BART), or absolute dispatcher control (in the case of MARTA). In each case, the operator would have to comply with a specific limiting speed. Furthermore, the investigation developed that operation of trains in Mode 2 was commonplace, particularly during the peak operation periods. There are a number of sharp curves on the Blue/Orange Line which are located at the approaches to stations. Forward visibility is often limited at these locations. Beyond this, the investigation revealed serious recurrent discrepancies in dispatching methods when trains are being restricted or allowed to pass restricting signals. Faulty train identification problems have reportedly resulted in misrouted trains at junctions. As long as Mode 2 permits unregulated operation up to 15 mph, there will be a very real possibility that a serious head-on, rear-end, or side collision may occur. WMATA should modify its Mode 2 operating system so that overspeed protection is provided down to zero mph; it should also modify its procedure to provide for greater use of Mode 3 operation with an absolute block or other form of positive protection when there are operating problems.

The investigation also revealed that on the morning of January 13, the train involved in this accident was operated for the greater part of one revenue trip and all of another without the locking pin in the overspeed cut-out device being sealed. Several following trains were operated similarly. This permitted totally unregulated operation with the overspeed device cut-out as long as the switch remained unsealed. The investigation developed that the practice was not uncommon. WMATA Standard Operating Procedure 15 required that an absolute block be established in this situation. Resort to operating in Mode 3 when a failure in the ATC system occurred was a deliberate effort to circumvent the standard operating procedure so as to minimize train delays.

Weather and Train Problems

Even during normal winter weather conditions, the Metrorail lines had been plagued with train problems when operations were started up in the morning and when peak service was resumed in the afternoon. The CCC assistant superintendent stated that, ". . . a train will not settle down and operate properly until it has worked one round trip and the operator has worked the kinks out of it." The normal problems are aggravated by snow, with trains developing brake, door, or other problems as they are brought out of the open yards and put back into service. Train performance on January 13 was particularly bad with the inbound service during the morning rush hours having been extensively delayed and many scheduled runs cancelled. The offpeak operation, however, was fairly smooth; almost half of the trains during this period were taken out of service and placed in the yards, but those left running were thoroughly broken in.

Although WMATA's storm alert procedure provided for holding operators over and running more than the usual complement of offpeak trains, it was never put into effect on the day of the accident. Not even when snow began to accumulate in the forenoon and the forecast was for snow throughout the afternoon, did WMATA begin to make preparations to cope with the unusual circumstances. Predictably, many downtown offices began sending their workers home after lunch, and at 1330 the Federal Office of Personnel Management (OPM) decided to do the same thing. Although notified by OPM, WMATA even then did not activate the storm alert procedure. Belated and futile efforts were made to call in operators, but driving conditions had deteriorated badly, and even the regularly scheduled operators had trouble making it to work.

The afternoon rush started about 30 minutes earlier than usual, but the trains that had been running all day were handling the load. Operations began to deteriorate, however, once WMATA began adding the laid up trains to the operation after 1500. A constant flow of train problem reports began to come into the OCC culminating in the complete breakdown of three trains at critical locations in the Blue/Orange Line subway in one 20-minute period. Stations which were to have a train arrival every 3 minutes were now experiencing intervals as long as 30 to 35 minutes between trains, and the stations soon became jammed with people. Tens of thousands of persons were in the subway stations, and the pressures on the OCC to somehow keep things moving became enormous. The situation was not so much the result of the predictable events, such as the weather, the early release of workers, and the train breakdowns, as it was the failure of WMATA to invoke its procedures to prepare for them.

Rules and Procedures

WMATA's operating and safety rules need careful and thorough evaluation to eliminate ambiguous and complex provisions. Some rules, such as Rule 56 are too narrow. This rule needs to be rewritten so that there is no doubt that it applies to movements within interlockings and that protective provisions apply whether or not it has been established that a switch has been run through. The lexicon of definitions needs to be enlarged and put into the front of the rulebook where it can easily be found.

The full range of the existing standard operating procedures is so vast and so detailed that it is inconceivable that the typical WMATA supervisor and train operator could be expected to remember everything that has to be done in a given situation. Standard Operating Procedure 4 (see appendix D), for example, has so many time-consuming requisite conditions that it is totally impractical. Had it been followed in complete detail on January 13, the passengers of train No. 410 would have had to wait more than 2 hours before they could have been allowed to get off the train. The net effect of such procedures is to force employees to ignore them in order to get the job done. Other procedures, such as the clearly worded storm alert procedure, are equally worthless if they are never invoked when needed. The rules and procedures need to be objectively reviewed in depth, perhaps through a peer review board of the American Public Transit Association (APTA) which has already made many recommendations for procedural and technical changes through the report of its Board of Inquiry which investigated this accident.

<u>Training and Examination Requirements</u>

Under WMATA's Standard Operating Procedure 15, manually-controlled absolute block operations were to be directed and controlled by rail transportation supervisors or other qualified employees in the field. This responsibility included properly instructing train operators, recording the passage of trains, controlling entry into absolute blocks, and inspecting, hand cranking, and blocking of interlocking switches. All of these critical functions directly affected the safety of trains and passengers. Nevertheless, the supervisor stated that he had performed the duties of cranking and blocking switches at an interlocking only 3 or 4 times in the 3 years he had been a supervisor (see appendix B). He also stated that he had never received formal training on the standard procedures and no training on the rules since being qualified as a train operator. Aside from sporadic, informal on-the-job training, WMATA has never had a program for training its rail supervisors. If the present corps of 65 rail supervisors were given added skills through a comprehensive training program, they could be given the responsibility to deal with the full range of operating situations and would constitute a tremendous asset to the efficiency of Metrorail operations. In the process, they could also relieve many of the pressures on the OCC.

Whether it was intended to happen or not, the OCC has taken over much of the actual management of train operations, and without some fundamental restructuring of operating rules and practices, there is not likely to be much change in the situation inasmuch as the same performance pressures will continue to exist. As the WMATA system grows in size, the pressures will increase to unmanageable proportions. The controllers need thorough education in basic rail operating principles. Neither the controller nor the assistant superintendent had a close working familarity with the physical characteristics of the subway, nor were they required to periodically refresh their knowledge of the system. Of all the WMATA personnel in the OCC at the time of the accident, only the controller working the traction power console had ever worked as a train operator. All the others, including the superintendent and the assistant superintendent, had gone into the OCC directly from the bus system without experience in or extended exposure to the Metrorail operations. The investigation further developed that the radio controller, his supervisor, and the assistant superintendent did not have a good working knowledge of the rules and standard operating procedures and they had never received any retraining in this area. According to the assistant superintendent, the OCC had apparently functioned largely on the basis of verbal instructions which often were contrary to standard operating procedures. The Safety Board believes that it is imperative that WMATA set up its own in-house training program for the rail system under the aegis of a management level, man-system specialist. Until this happens, all OCC personnel should be given immediate training to improve their knowledge and skills. This should include first-hand knowledge of the railroad itself, periodic exposure to the command centers of state-of-the-art transit systems, and hands-on train operating experience. It would not seem inappropriate that they be made to qualify as train operators before being assigned to OCC.

The supervisor had not eaten for 19 hours prior to the accident, a circumstance that could have resulted in a hypoglycemic condition with symptoms including, "... irritability, blurring of vision, irrational behavior, hypotension, and syncope. . ." even in a person with a normal blood glucose level." In its 1976 investigation of an aircraft accident in Alaska, the Safety Board concluded, ". . .that 13 hours without food could lower the blood sugar level in a healthy person to the degree that his efficiency would be adversely affected." Inasmuch as the supervisor was not subjected to a postaccident physical examination, and he had not been examined by a WMATA doctor for many years, very little can be concluded about his physical condition including any effects of the anti-hypertensive drugs he was taking, and it would not be appropriate to conclude that the supervisor experienced an abnormal hypoglycemic condition. However, given his history of low blood sugar and the prolonged period since he had last eaten, it is not beyond the realm of possibility that the supervisor's capability may have been diminished before he pulled train No. 410 back through the crossover. Although WMATA did not require periodic physical qualification for supervisors before the accident, it states that it has since required Metrorail supervisors to meet the same physical standards and periodic examination requirements that are imposed on the train operators. In addition, all employees involved in a Metrorail incident must now submit to a physical examination following the incident.

In its 1970 study of the then-proposed Metrorail system, the Safety Board expressed concern with what were perceived to be potential safety problems and strongly recommended that WMATA create staff responsibility for a systems approach to safety. However, 6 years later a comprehensive Department of Transportation (DOT) study found that the Board's recommendation had not been followed and that WMATA management had chosen, instead, to continue to rely on outside consultants in the areas of safety and training. In addition, the DOT study concluded that those who made WMATA policy still believed that the impact of human error could be virtually eliminated through automation and that, as a result, only minimal training and retraining were being provided to Metrorail employees.

The Safety Board believes that since 1976 WMATA management has consistently failed to comprehend and provide for the training needs of the Metrorail system. If anything, the amount of training offered was diminished, even to the point of eliminating on-the-job training for new operators, whenever it was expedient to do so, and to overlook the requirement that operators be retrained and tested each year. These reductions in fundamental training were made without considering the potential impact on operator proficiency and system safety. WMATA management should have been aware, as well, that expansion of the system, equipment breakdowns, and problems with automation were placing unanticipated burdens on the OCC. Yet, management never provided OCC personnel the equipment and training they needed to cope with their expanding responsibilities. The Safety Board is convinced that many of the deficiencies revealed in its investigation of this accident would not have existed had WMATA responded to the need for professional man/system expertise within its management structure.

WMATA's Cars

According to WMATA, the design of its cars did not take into account the effect of high lateral forces such as are presented in a side or side-rake collision, and no prototypical tests of this aspect of crashworthiness were ever made. The use of lightweight aluminum material in the construction of the cars represented a radical departure from what was and still is the state-of-the-art in rail transit car design. Of all the other U.S. rapid transit systems, including those presently under construction, only BART, whose cars were built by the same manufacturer that built the WMATA cars, has ever bought cars built of aluminum. The Safety Board's investigation indicates that WMATA chose a lightweight carbody because it permitted larger and heavier motors, air conditioning, and other apparatus while keeping total car weight relatively low. The WMATA cars are second only to the smaller BART cars in terms of horsepower-to-weight ratio. According to WMATA, the high horsepower motors were chosen so that trains could meet the operating schedules even when problem cars within the trains had to be isolated.

Typically, modern rail transit cars are built of stainless steel and have box-frame construction with conventional sills. Although the greatest design strength of rail cars is available to resist longitudinal buff forces, the typical rapid transit car's framing will resist side forces effectively, particularly when they are delivered at a relatively narrow angle. A vehicle that will carry 220 passengers should offer at least minimal side protection at the main passenger compartments where they are most vulnerable to side impacts.

When the Metrorail system is completed, 30 percent of its 101-route miles will be directly adjacent to operating railroad tracks on common rights-of-way. On the existing system, the Red Line tracks are laid between and at the same level as the main tracks of a railroad for 5 miles. It is conceivable that a high-speed Metrorail train may simultaneously pass an opposing Metrorail train on the one side and an opposing high-speed railroad train on the other with hardly more than standard main track clearances separating them. In its 1970 special study, the Safety Board expressed grave concern over the design and structural integrity of the WMATA cars as well as the fact that they would be operated on the same right-of-way as high-speed railroad trains. The 1977 side collision at Rhode Island Avenue demonstrated how easily and deeply the side of a WMATA car could be penetrated, even at a very narrow angle of attack, with resultant destruction of the seats in the passenger compartment. Nevertheless, WMATA has on order 294 additional cars essentially of the same design as the first group without added strength in the carside and underframe construction.

In this accident, at an impact speed of less than 10 mph, the aluminum sidewall extrusion was easily severed and there was little remaining structural integrity to resist penetration by the barrier wall. As in the Rhode Island Avenue accident, the cantilever-mounted seats broke loose and were driven out of position. The serious and fatal casualties were all seated in the immediate area of penetration and were crushed between the dismounted seats and the wall. There was insufficient data and evidence available to Safety Board investigators after the accident to analyze the effect of a 15-mile-per-hour collision/impact on car No. 1029 and the passengers inside it. However, the Safety Board was able to determine that the forces of such an impact would have been three times greater than what had resulted from the actual collision.

Since the accident, WMATA has recognized the vulnerability of the carsides and has ordered a study to determine how the cars can be strengthened. In the least, WMATA's study should reflect the opinions of competent mechanical engineers of the other U.S. rapid transit systems, perhaps through a review board convened by APTA. Similarily, the design specifications of the 294 additional cars now on order should be reviewed for structural improvement. In the meantime, WMATA should take all possible measures to reduce the probability of a side collision. For example, it is very likely that had car No. 1029 been equipped with derailment detector bars, train No. 410 would have been stopped before the car struck the wall.

Much valuable data that would have been useful in the investigation was lost because the WMATA carborne monitor had not been maintained and used. The Safety Board has been advised that this is recognized by WMATA, and it is contemplating the acquisition of the necessary readout equipment as well as placing the monitors on the cars presently on order.

CONCLUSIONS

Findings

1. A fuse affecting the ability to remotely align Smithsonian Interlocking switch 1A to normal position failed 3 days before the accident. Operations Control Center (OCC) personnel did not note the failure when it was reported on the alarm screen or thereafter when it was repeatedly recorded in the computer log.

2. Despite the failure of OCC personnel to note and report the alarm generated by the fuse failure to WMATA Maintenance Control, the failure should have been discovered and corrected in repeated onsite inspections reportedly made by maintenance personnel before the accident.

3. Since the control malfunction had never been noted and corrected, the OCC was unable to remotely command switch 1A to throw to normal position when it was necessary to do so on January 13.

4. After the OCC attempted to restore switch 1A from reverse to normal position on January 13, the CRT video display in the OCC could only indicate that switches 1A and 1B were out of correspondence. The display could not indicate the actual position of either switch, and the interlocking signals could not be cleared until the fuse failure was corrected.

5. Shortly before the accident on January 13, the OCC notified Maintenance Control that there appeared to be an Automatic Train Control system problem at Smithsonian Interlocking. The supervisor who was at the location was assigned to manually control the operation of trains through the interlocking until maintenance forces could respond and correct the problem.

6. OCC's instructions to the supervisor regarding the switches at Smithsonian Interlocking were fragmented, imprecise, and incomplete. The supervisor was never told the nature of the switch alignment problem.

7. After placing the interlocking under the manual control of the supervisor, the OCC failed to follow Standard Operating Procedure No. 15 and ordered two trains to proceed through the interlocking on track D-2. Trains should not have been operated through the interlocking until it was determined that the routes were properly aligned.

8. The OCC did not comply with WMATA Standard Operating Procedure No. 15 requiring that an absolute block be established where a failure of the ATC system occurs, that special speed restrictions be imposed, that supervisors and train operators be notified of the speed restrictions, and that the passing times of the trains into the block be recorded.

9. A train could enter the crossover at switch 1A only at a limited speed and still be stopped in time to avoid colliding with a train moving on the adjacent main track. The investigation developed that the maximum speed from which a stop could be made short of the fouling point was 8 miles per hour.

10. The OCC controller directed the operator of train No. 410 to operate through the interlocking on the instructions of the supervisor, but neither the controller nor the supervisor told the operator what route his train was to take.

11. When train No. 410 entered the crossover, the operator could not see the position of switch 1B, and he had no reason to believe that it might not be aligned for the crossover movement. When ordered to stop by the supervisor, the operator used a full service brake application to do so, but the train had gone too far to be stopped short of switch 1B.

12. The OCC controller had heard the supervisor repeatedly tell the train operator to stop, was told by the supervisor that OCC could not run trains until train No. 410 was pulled back, and should have taken note of the "phantom" track circuit occupancies that appeared on the CRT screen as train No. 410 moved through the crossover. Despite this evidence that train No. 410 had run through switch 1B, the OCC shortly thereafter allowed the supervisor to make a reverse movement of the train.

13. After train No. 410 stopped, the supervisor did not check the condition of the switch and the train, nor did he instruct the operator to do so. Rather, he assumed it was safe to pull the train back, and he asked the OCC for permission to do so. A properly trained supervisor would not have made this assumption.

14. Train No. 410 derailed shortly after the reverse movement was started, but the supervisor, who was operating the train, was not aware of this. He did not take action to reduce speed or initiate braking. Although braking was initiated by the overspeed control before the rear car struck the barrier wall, it did not occur in time to prevent collision with the barrier wall.

15. Had the train operator recognized that an emergency existed and applied the train's brakes in emergency before the train had attained a speed of about 12 miles per hour, the derailed car probably would have stopped short of the barrier wall.

16. Had the derailed car been equipped with a derailment detection bar system, the train's brakes would have been automatically applied in time to stop the train before the rear car struck the barrier wall.

17. Collision of the car with the barrier wall probably occurred at a speed of less than 10 miles per hour, but the lightweight aluminum sidewall extrusion and underframing were inadequate to prevent the wall from deeply penetrating the car.

18. The operation of train No. 410 was not affected by any known onboard equipment malfunction that contributed to the cause or severity of the accident.

19. WMATA stores its out-of-service trains in open, above-ground yards where they are exposed to the weather. Trains frequently develop mechanical problems when they are taken from storage yards and placed in service during adverse winter weather conditions.

20. During the 90 minutes preceding the accident, widespread equipment breakdowns caused long delays, created the need for several single track runaround operations, and severely disrupted operations over the entire system. This, in combination with adverse weather conditions and the early release of downtown office workers, led to the overcrowding of stations and trains and placed enormous stresses on the OCC.

21. The weather conditions and the somewhat early evening rush hour peak on January 13 were predictable. Had WMATA prepared for them by invoking its storm alert standard operating procedure, many of the mechanical breakdowns and the overcrowding of trains and stations that occurred in the Metrorail operation would have been averted.

22. Although the WMATA system had not been designed for the OCC to manage routine train operations, OCC personnel routinely had assumed this role, since difficulties with the Automatic Train Control system and frequent train breakdowns regularly disrupted normal operations. The OCC personnel did not have the training and expertise necessary to manage train operations when control difficulties arose.

23. Before the accident and during the emergency, the stresses within the OCC were aggravated by confusion as to who was actually in charge of the OCC.

24. A single OCC radio controller had to handle all traffic on both the Red Line and Blue/Orange Line operations radio channels, and he was expected to simultaneously prepare reports of the train delays as they occurred. The assistant superintendent attempted to take over one of the radio channels but could not do so because the spare radio headset was inoperative.

25. All of the intercom "hotlines" connecting the OCC with the other WMATA command centers were out of order, and as a result, the assistant superintendent had to frequently leave his post in the OCC to communicate with the other offices.

26. Potentially dangerous situations were created by the undisciplined manner in which the radio controller referred to signals, restricted trains, and otherwise used the radio when communicating with train operators. This was particularly critical in light of the similarity in the numbers used to identify the various WMATA interlockings and signals.

27. The personnel in the OCC lack a working knowledge of the rules and procedures, the physical characteristics of the rail system, and the fundamentals of rail transit operation. This is due to WMATA's failure to provide them adequate training.

28. Many verbal instructions issued to the OCC personnel by higher authority were in conflict with WMATA's printed rules and standard operating procedures.

29. The operation of trains in the manual Mode 2 without speed regulation below 15 miles per hour was commonplace, particularly during peak traffic periods when trains have heavy passenger loads and operating headway is reduced to 3 minutes. Such operation is potentially dangerous since there are numerous curves in the subways, many in the approaches to stations, where forward visibility is limited.

30. WMATA is the only automated rapid-transit system which permits unregulated operation of revenue trains without overspeed protection or some form of limiting collision-avoidance protection such as train orders, clearance forms, or wayside automatic block signals. Unless WMATA subjects such trains to strict absolute block procedures or some other form of block protection, the potential for train collisions will continue to exist.

31. This accident as well as an earlier accident in September 1977 demonstrated the inability of WMATA's cars to withstand relatively low-speed side impacts.

32. There was no power for lighting or communications equipment aboard train No. 410 after the accident because the emergency power system trainline was severed by substantial separation of the cars. WMATA trains and operators are not furnished with self-contained lighting and radio equipment.

33. There are no emergency exit windows on the WMATA cars, and the emergency manual door controls are concealed. There are no posted instructions enabling passengers to find and operate the door controls. WMATA has not had a program to educate passengers on the procedures to be followed in the event of an emergency.

34. Extended and unnecessary delays in starting evacuation of the train resulted from the OCC's failure to properly authorize, direct, and coordinate an evacuation through Metrorail supervisors and employees on the scene.

35. The existing WMATA standard operating procedure for emergency train evacuation is impractical and has too many time-consuming prerequisite conditions. Had it been followed in detail on January 13, the evacuation of train No. 410 could not have been started until more than 2 hours after the accident occurred.

36. The OCC delayed shutting down two traction power sections and failed to command open the circuit breakers to prevent automatic reclosure on another section. This unnecessarily endangered the passengers, emergency personnel, and WMATA employees at the accident site and prolonged the risk of fire.

37. District of Columbia Fire Department radio frequencies are not compatible with WMATA's radio repeater system in the subway. This delayed communications between rescue forces in the subway and aboveground command posts.

38. Response by the Fire Department to the emergency was delayed by the OCC unnecessarily taking time to first determine the precise location of the derailment, by the OCC's directing the Fire Department to the least accessible and most congested entrance to the subway, and by the Fire Department's having to resort to a manual procedure to establish which of its units were available.

39. There were serious delays in the injured receiving hospital treatment because of the lack of preagreed criteria by WMATA and the Fire Department for the dispatching of ambulances to the accident site, and because of the failure to clear routes from the site to the hospitals. The OCC did not select the optimal location for the Fire Department to get access to the accident site.

40. Because the WMATA Automatic Train Control is not reliable, the OCC will continue to have to provide extensive human management of train operations; such management will increase proportionately as the system grows larger. WMATA must either improve the reliability of its ATC system or provide for conventional train management by the OCC that provides safety in operations. A combination of part-time automation and untrained human intervention will pose continuing safety hazards.

41. Because WMATA relied entirely on employees of its bus system for train operators and rail supervisors, it should have provided indepth training in rail operations to the OCC personnel and the rail transportation supervisors. Additionally, WMATA has never evaluated the quality of the train operators' training course and has not provided periodic retraining and recertification of train operators. There has never been a staff position responsible for implementing and directing a systems approach to employee training. At the time of the accident, there were no minimal physical standards nor provisions for periodic medical examination of supervisors.

42. WMATA management did not follow recommendations of the Safety Board and other Federal agencies that it adopt a systems approach to safety. As a result, the Metrorail training program has been inadequate, and there has been no impetus to improve it.

43. WMATA's operating rules and procedures need to be thoroughly examined and analyzed for improvement.

44. Valuable data concerning this accident and the events that preceded it were not recorded because WMATA does not maintain and use the carborne monitors on its cars.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the Metrorail Operations Control Center (OCC) to stop movement of trains through the Smithsonian Interlocking until it ascertained the nature of and corrected the switch misalignment; the failure of the OCC over a 3-day period to note discrepancy reports concerning a wayside control failure in the Smithsonian Interlocking and to order repairs; the failure of the onscene rail transportation supervisor to check conditions at the original lead end of train No. 410 before initiating the reverse movement of the train; and the failure of the train operator to timely recognize the train had derailed and to apply the brakes in emergency. Contributing to the accident was WMATA management's failure to put into place an adequate program of initial and recurrent training for OCC and Metrorail operating personnel and its failure to adopt adequate rules and procedures for safe operation of trains in the manual mode.

RECOMMENDATIONS

During its investigation of this accident, the National Transportation Safety Board on March 19, 1982, made the following recommendations to the Washington Metropolitan Area Transit Authority:

> Modify its operating rules and standard operating procedures to require the establishment of an absolute block whenever it is necessary to operate a train in other than the fully automatic mode. (Class I, Urgent Action) (R-82-8)

Include in its operating rules a requirement that whenever it is necessary to operate a train manually, the Operations Control Center will not permit the train to proceed into the block to the next station as long as that block is occupied by another train. If there is an interlocking between the stations, require that the absolute block between the stations will apply to both main tracks unless the Operations Control Center has an oscilloscope indication that all crossover switches are aligned for main track movement. (Class I, Urgent Action) (R-82-9)

Include in its operating rules a requirement that train operators report to the Operations Control Center whenever they are unable to operate in the fully automatic mode, and enforce the operating rules requiring authorization by the Operations Control Center to change operating modes. (Class I, Urgent Action) (R-82-10)

Include in its operating rules a requirement that before a manually operated train is permitted to enter a block containing an interlocking, the Operations Control Center must instruct the train's operator as to the intended route for the train and receive proper acknowledgement from the operator. (Class I, Urgent Action) (R-82-11)

Modify its operating rules to prohibit the reverse movement of a train within interlocking limits until it has been established that no derailment has occurred, that switches are properly aligned, and that there are no conflicting train movements. (Class I, Urgent Action) (R-82-12)

Improve the maintenance and redundancy of the communications equipment in the Operations Control Center and of "hot line" intercoms between the Operations Control Center and the other Washington Metropolitan Area Transit Authority command centers to provide continuous communications between all centers. (Class I, Urgent Action) (R-82-13)

Provide radio communicating capability for the Operations Control Center that is commensurate with peak radio traffic demands of the expanding Washington Metropolitan Area Transit Authority rail system. (Class II, Priority Action) (R-82-14)

Upgrade the training given to rail transportation supervisors and assign them the necessary authority to effectively supervise train operations and correctly deal with the full range of operating situations. (Class I, Urgent Action) (R-82-15)

Implement a program of mandatory periodic instruction and examination on the combined book of operating rules and standard operating procedures, including emergency train evacuation procedures, for all rail supervisors and train operators. (Class I, Urgent Action) (R-82-16)

Amend its standard operating procedures to require the Operations Control Center (1) to require that, whenever a train emergency which requires evacuation is known to exist at a location between stations, all third-rail power circuits between the emergency location and the stations on each side of that location be deenergized as soon as all other trains have cleared the area, and (2) to direct the nearest qualified rail employee to begin the timely evacuation of passengers from the train. (Class I, Urgent Action) (R-82-17)

Implement a continuing program to educate passengers on the procedures to be followed when it is necessary to evacuate a disabled train. (Class I, Urgent Action) (R-82-18)

The Safety Board has not yet received a response to these recommendations.

As a result of its completed investigation of this accident, the National Transportation Safety Board made the following additional recommendations:

--to the Washington Metropolitan Area Transit Authority:

Immediately implement an indepth continuing training program for controllers and their superiors in the Metrorail Operations Control Center which includes instruction in the rules, procedures, and fundamentals of rail transit operations; familiarization with all Metrorail operations; radio protocol; and periodic testing and certification by a professional training specialist who is knowledgeable in rail transit operations. (Class I, Urgent Action) (R-82-55)

Establish a Training Department for Metrorail that is accountable to top WMATA management and is staffed by professional specialists in this field. (Class II, Priority Action) (R-82-56)

Evaluate the quality of the curriculum, instruction, training aids, and periodic certification process of the present Metrorail train operators' training course, and implement necessary improvements. (Class II, Priority Action) (R-82-57)

Modify the overspeed control on the Metrorail cars to enforce speed commands of the Automatic Train Protection subsystem to and including zero miles per hour. (Class II, Priority Action) (R-82-58)

Change the identification numbers of its interlockings and interlocking signals to eliminate possible misunderstandings which could result in a train improperly passing a restricting signal. (Class II, Priority Action) (R-82-59)

Require the Metrorail Operations Control Center personnel, rail transportation supervisors, and train operators to refer to all signals by their complete and proper designation. (Class II, Priorty Action) (R-82-60)

Require that the Metrorail Operations Control Center personnel and transportation supervisors understand and implement provisions of Standard Operating Procedure No. 15 for the establishment of an absolute block when there is a failure in the Automatic Train Control system. (Class I, Urgent Action) (R-82-61)

Include in Metrorail operating rules a definition of restricted speed. Establish and require that all employees involved in the operation of trains understand and abide by the maximum allowable speed for trains being operated through an interlocking with inoperative track circuits. (Class II, Priority Action) (R-82-62)

Eliminate the practice of issuing verbal instructions to the Metrorail Operations Control Center personnel which modify or amend operating rules and standard operating procedures. (Class I, Urgent Action) (R-82-63)

Modify the automated alert system to segregate the "serious" physical plant-related Type 1 visual alarms from the less serious train-oriented Type 2 alarms, and to provide an audible indication of a Type 1 alarm which must be manually acknowledged. (Class II, Priority Action) (R-82-64)

Require that Type 1 automated alert alarms be immediately reported by the Operations Control Center to Maintenance Control for corrective action. (Class II, Priority Action) (R-82-65)

Require that maintenance forces inspect switch machine fusetrons while making their regular preventive maintenance inspections of the control system apparatus. (Class II, Priority Action) (R-82-66)

Provide train operators with some type of self-contained radios which will function in the event that auxiliary and emergency car power sources are lost. (Class II, Priority Action) (R-82-67)

Arrange for a comprehensive review of its Metrorail safety program and of its rules and procedures by a peer review board of the American Public Transit Association. (Class II, Priority Action) (R-82-68)

Provide all Metrorail Operations Control Center controllers and their supervisors with clear instructions that all automatic reclosing circuit breakers for the traction power sections in the affected area must be commanded open prior to the commencement of an evacuation of a train. (Class II, Priority Action) (R-82-69)

Require the installation of an adequate number of marked emergency escape windows on all new Metrorail cars and implement a program to similarly retrofit existing cars. (Class II, Priority Action) (R-82-70)

Equip each Metrorail car with an adequate number of self-contained, battery-powered emergency lights which will automatically illuminate the car interior in the event the car's auxiliary and emergency power is lost. (Class II, Priority Action) (R-82-71)

Post emergency information inside Metrorail cars at locations near the doors regarding the location and method of operation of the manual emergency door handle. (Class II, Priority Action) (R-82-72)

Retrofit existing Metrorail cars with derailment detector devices which will apply the brakes in emergency when a car wheel leaves the rail. Require that all new cars be so equipped. (Class II, Priority Action) (R-82-73)

Maintain the carborne monitors on existing Metrorail cars and require their installation on cars presently on order. Acquire the necessary equipment to read the monitor tapes. (Class II, Priority Action) (R-82-74)

Provide a portable radio, compatible with the Metrorail communication system, at each station kiosk for dedicated use by fire/rescue personnel. (Class II, Priority Action) (R-82-75)

Expedite the completion of its underground communication system. (Class II, Priority Action) (R-82-76)

In conjunction with the District of Columbia Fire Department, expand the scope and frequency of the Disaster Crash Simulations and include hospitals and fire/rescue units from surrounding jurisdictions. (Class II, Priority Action) (R-82-77)

--to the Mayor of the District of Columbia:

Require the District of Columbia Fire Department to review its planning for maintaining its rescue squad capability at all times. (Class II, Priority Action) (R-82-78)

Improve the emergency procedures to be activated in the event of a Metrorail emergency which establishes effective and ongoing liaison between the District of Columbia Fire Department's onsite command post and its Communications Center, the Washington Metropolitan Area Transit Authority, the Metropolitan Police, and the hospitals, to (1) communicate the number of seriously injured persons together with the general nature and severity of their injuries; (2) ascertain each hospital's capacity to receive casualties; (3) direct ambulances to the appropriate hospitals; and (4) clear the most direct evacuation routes from the accident site to the hospitals. (Class II, Priority Action) (R-82-79)

Require that the District of Columbia Fire Department expand its computer storage capability to include all the information needed by the Fire Dispatcher for automatic assignment and response of units to multiple incidents. (Class II, Priority Action) (R-82-80)

Require the District of Columbia Fire Department in conjunction with the Washington Metropolitan Area Transit Authority to expand the scope and frequency of the Disaster Crash Simulations and include hospitals and fire/rescue units from surrounding jurisdictions. (Class II, Priority Action) (R-82-81)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ G.H. PATRICK BURSLEY
Member

/s/ DONALD D. ENGEN
Member

October 14, 1982

APPENDIXES

APPENDIX A

INVESTIGATION

The National Transportation Safety Board learned of the accident about 1650, January 13, 1982. The chief of the Railroad Accident Division immediately went on foot to the accident site and was joined there shortly afterward by Board Member Patricia A. Goldman. The Board's investigative team included Operations, Vehicle Factors, and Human Factors groups.

APPENDIX B

PERSONNEL INFORMATION

Train Operator Michael Jerome Greene

Operator Greene, 40, was employed as a student busdriver on September 26, 1966, and qualified as a busdriver for D.C. Transit, Inc., a predecessor of WMATA, on October 21, 1966. He transferred to the Metrorail operation as a train operator on March 4, 1979. Mr. Greene had completed the WMATA train operator's course at the time he transferred to Metrorail. His service record does not show that he had received any additional training or examination since that time. Mr. Greene received a thorough WMATA physical examination on June 30, 1980. The examining physician found him to be in good health with vision within standards without glasses and with good color perception.

As a busdriver, Mr. Greene was frequently cautioned and reprimanded for various violations and he was suspended from May 21, 1968, to July 27, 1968, for insubordination. He was involved in 24 accidents as a busdriver. There is nothing in his service record to indicate he was disciplined for any violations during his service as a train operator.

Rail Transportation Supervisor James Sterling Davis

Supervisor Davis, 49, was employed as a streetcar motorman by Pittsburgh Railways from September 30, 1957, to January 13, 1962, when he was furloughed on account of a reduction in force. He actually worked a total of 28 months and was considered to have been a satisfactory employee. He was employed by D.C. Transit, Inc. as a busdriver on March 26, 1962, and worked in that capacity until July 22, 1970. Mr. Davis was dismissed by D.C. Transit on August 27, 1970, on account of "extended absence." On March 29, 1974, Mr. Davis was rehired by WMATA as a bus operator and on February 17, 1976, he was transferred to the position of Metrorail station attendant. On March 28, 1977, Mr. Davis was transferred to the position of train operator and in August 13, 1979, he was promoted to rail transportation supervisor. According to Mr. Davis, he attended the WMATA basic train operator course when he was transferred to the position of train operator. There is no entry in his service record to confirm this.

The last recorded company physical examination to which Mr. Davis submitted was on March 29, 1974, when he was found to be physically qualified with vision within standards. Following the accident, he stated his vision was good and that he did not need to wear glasses. His service record indicates that Mr. Davis was reprimanded for failure to follow instructions by assistant superintendent P.T. Hobgood on August 13, 1979.

Supervisory Controller Kenneth George Banks

Controller Banks, 40, was employed by WMATA as a bus operator on March 26, 1971, was appointed utility clerk on March 14, 1973, and was promoted to depot clerk on February 16, 1975. On May 10, 1975, Mr. Banks was promoted to bus radio dispatcher and he was transferred to the Metrorail Operations Control Center as a dispatcher on June 6, 1977. According to Mr. Banks, he had worked as radio controller in the OCC for about 2 years. According to his service record, Mr. Banks last passed a WMATA physical examination on December 13, 1974. During his 2 years as a busdriver, he had been involved in 11 accidents.

Mr. Banks stated that he had about 2 weeks of training when he was transferred to the OCC. This was conducted by WMATA's train control engineer and included a written examination. He subsequently received some on-the-job training. According to Mr. Banks, he had never received any formal training on radio procedures and he had never been provided with, or had seen, a manual on how to work the radio assignment.

Assistant Superintendent Paul Taylor Hobgood, Jr.

Assistant Superintendent Hobgood, 34, was qualified as a busdriver for D.C. Transit on October 22, 1969. He was appointed utility clerk on September 9, 1971, qualified as a sightseeing lecturer on April 13, 1972, and was promoted to street supervisor on September 13, 1975. On November 17, 1975, Mr. Hobgood was transferred to the Metrorail OCC as supervisory controller and on September 9, 1978, he was promoted to assistant superintendent of the OCC. According to his service record, Mr. Hobgood was last examined and found physically qualified on October 9, 1975. Mr. Hobgood stated he had about 2 or 3 weeks of training when he was made a supervisory controller in the OCC.

Mr. Hobgood was involved in 18 accidents as a busdriver and he was formally reprimanded in 1979 by an OCC superintendent for "Poor Judgment."

Superintendent Joseph Earl Taylor

Superintendent Taylor, 47, was employed by D.C. Transit as a bus operator on August 11, 1958. He was qualified as a sightseeing lecturer on December 2, 1959, and worked from July 1963 to December 1964, as a utility clerk before returning to the position of busdriver. On November 9, 1974, Mr. Taylor transferred to the Metrorail OCC as train operations supervisor. He was promoted to assistant superintendent on April 10, 1976, and to superintendent of the OCC on August 12, 1978. Mr. Taylor last submitted to a company physical examination on October 17, 1972.

As a bus operator, Mr. Taylor was involved in 29 accidents and he was suspended 1 day in 1968 for using obscene and abusive language.

APPENDIX C

EXCERPTS FROM METRORAIL HANDBOOK OF OPERATING RULES AND GENERAL SAFETY RULES

2. Knowledge of Rules, Instructions and Procedures

(e) Employees shall be required to pass an annual examination on "Book of Rules," and Standard - Operating Procedures and General Safety Rules that apply to their assignments.

58. Employees shall not attempt to back or reverse a train if it runs through a track switch, but shall stop and call the Operations Control Center or Yard Supervisor for instructions.

II. Operating Modes

A. Mode I

61. Mode I is the normal operating mode for trains in revenue service. Train Operators must not change from Mode I without authorization from the Operations Control Center.

62. When a malfunction occurs to any part of the Automatic Train Operation system preventing Mode I operation; or if deemed necessary by the Operations Control Center, the Train Operator shall change operating mode, "only after authorization by the Operations Control Center".

B. Mode 2

63. Trains must be stopped before changing from Mode 1 to Mode 2.

C. Mode 3

64. Train Operators must stop their trains before changing to Mode 3 and shall be governed by operating instructions from the Operations Control Center, and Train Operator shall not move the train unless an Absolute Block is established.

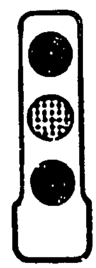
65. Train Operators must exercise extreme caution and be prepared to stop their trains short of any obstruction. They must not exceed fifteen miles per hour unless instructed to do so by the Operations Control Center, after an Absolute Block has been established with a prescribed regulating speed.

III. Signals

A. Interlocking Signals

68. Interlocking signal indications (Fig. 7) are given by the following lighted aspects:

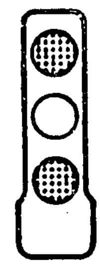
(a) Red indicates stop.



NAME: ROUTE NOT ALIGNED, NOT LOCKED, BLOCK OCCUPIED

ASPECT: RED OVER RED

INDICATION: STOP

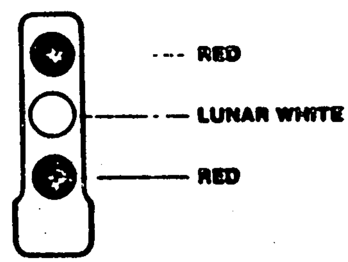


NAME: INTERLOCKING CLEAR

ASPECT: LUNAR WHITE

INDICATION: OPERATE ACCORDING TO CAB SIGNAL INDICATION

NOTE: IF EITHER OF THE LAMPS ARE DARK, THE INDICATION IS STOP



INTERLOCKING SIGNAL **FIGURE 7**

154. Radio calls must be initiated and acknowledged in a manner that insures establishment of communications between the intended parties.

155. Messages affecting train movement should be addressed to only one train at a time. However, in an emergency a blanket message may be sent to all trains in or approaching a particular area. Following a blanket transmission, all trains involved will individually acknowledge receipt of the message.

APPENDIX D

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
STANDARD OPERATING PROCEDURE

METRORAIL STANDARD OPERATING PROCEDURE #1

OUTLINE OF OPERATIONS CONTROL CENTER (OCC) SUPERVISORS' FUNCTIONS

A. GENERAL OPERATIONS

1.1 OCC Supervisors shall be in charge of and responsible for all Operations Control Center functions during their tours of duty.

1.2 OCC Supervisors shall have a working knowledge of all Operations Control Center facilities and systems.

1.3 OCC Supervisors shall have a comprehensive knowledge of the Operations Control Center computer functions and be familiar with computer language that will be displayed on the alarm CRT's.

1.4 OCC Supervisors shall be capable of operating the manually operated function panel group buttons which are used to:

a. initiate and establish train routes at the intermediate interlocking locations and terminals; establish other interlocking functions at interlocking locations from the Operations Control Center;

b. control all circuit breakers in the system for traction power and monitor the electrical support systems;

c. alter train movement, increase or decrease train headways to offset train congestion and minimize train delay;

d. select daily, Saturday and Sunday schedules and modify them when the need arises;

e. cause listed train information to be displayed on the train information CRT s;

f. monitor and operate support systems.

1.5 OCC Supervisors shall be familiar with and capable of operating the various functions of the Communication Console located in the Operations Control Center.

1.6 OCC Supervisors shall be responsible for directing the correct performance of duties by all Transportation Department employees.

a. They shall make certain that instructions in general orders, notices, and bulletins are complied with by employees.

b. They shall report violations of rules, and meritorious actions by employees to the Division Superintendent of Operations, Rail Transportation.

1.7 OCC Supervisors shall be responsible for:

a. the safe operation of revenue trains in accordance with approved timetables or modifications of them when necessary,

b. the safe operation of trains not scheduled by the timetable,

c. the safe operation of revenue trains when they are not under the protection of the ATC System or on the computer schedule. They shall be familiar with Standard Operating Procedures governing these operations,

d. the safe movement of any trains in a single track operation, a train being operated other than from the lead car, and train movements against the established direction of traffic.

1.8 OCC Supervisors shall initiate supplemental train schedules to cover planned single track operations, special functions, anticipated cold, snow and sleet, and holiday train service.

1.9 OCC Supervisors shall make certain that prior to peak hour operations all terminals have sufficient cars to meet train schedule car requirements. If necessary, they shall order a transfer of surplus cars from one line to supplement a deficient line's requirements. When there is a car shortage and peak hour car requirements cannot be met, the OCC Supervisors shall make a report to the General Superintendent of Rail Transportation indicating the number of cars not available and the reason for the car shortage.

1.10 OCC Supervisors shall be familiar with the characteristics of the Metrorail right-of-way.

1.11 OCC Supervisors shall be familiar with all yard operations and storage areas.

1.12 OCC Supervisors shall have a knowledge of track switches and interlocking operating procedures and other support interlocking features.

B. EMERGENCIES - UNUSUAL OCCURRENCES

1.13 OCC Supervisors shall make certain that reports of incidents occurring during their tours of duty are submitted to the General Superintendent of Rail Transportation. Incident reports shall be submitted for the following reasons:

a. train delays,

b. accidents involving passengers and employees,

c. accidents involving equipment, also equipment failures,

d. employee negligence or failure of duties,

e. commendatory action by employees.

1.14 "Emergency" will be defined as: any condition which can or has resulted in harm to passengers or employees; damage to equipment or property; a service disruption; or any combination of these circumstances.

1.15 When notified of an emergency condition, the OCC Supervisor shall be responsible for coordinating all activities to alleviate the condition. The OCC Supervisor's primary concern shall be the safety of passengers and employees and the protection of property and equipment.

1.16 The OCC Supervisor shall notify the following Authority departments when an emergency condition exists:

a. Car Maintenance Control Office

b. Communications or Train Control and Power Control Office

c. Track or Plant Control Office

d. Transit Police Control Office

e. Safety Control Office

f. General Superintendent of Rail Transportation

g. Community Services Office

1.17 The OCC Supervisor shall notify concerned departments when the following conditions exist:

a. Anticipated, severe delay to train service.

b. Passenger evacuation from trains.

c. Death or injury to passengers or employees.

1.18 The OCC Supervisor shall notify the Fire/Rescue Communications Center immediately if the following conditions exist:

a. Smoke or fire.

b. Flood condition requiring special pumping apparatus.

c. Passengers or employees requiring medical assistance.

1.19 The OCC Supervisor shall maintain, in chronological order, a detailed record of all activities occurring during an emergency.

1.20 The OCC Supervisor shall request the following information from employees who make notification of an emergency condition:

a. Caller's name, title and department.

b. Reason for notification.

c. Location (track number, line identification, and an approximation of their distance from the nearest station.)

d. Gravity of the condition.

1.21. The OCC Supervisor shall dispatch a Transportation Supervisor to the scene to do the following:

a. Evaluate the condition.

b. Be responsible for coordinating all activities.

c. Provide protection for train movements.

d. Cooperate with outside agencies.

e. Establish a communications center at the site to keep the Operations Control Center informed of activities and developments.

1.22 Based on information reported to the Operations Control Center the OCC Supervisor shall evaluate the situation and order one or a combination of the following protective actions:

a. Stop all train movement in approach to or within the emergency area.

b. Remove third rail power by supervisory.

c. Operate the fan and ventilation systems based on conditions at the scene.

d. Evacuate passengers.

e. Provide flagging protection.

f. Order speed restrictions.

g. Institute a manual absolute block.

1.23 The OCC Supervisor shall keep Station Attendants, Train Operators, and Transit Police informed of all operating procedures when there is a service disruption.

1.24 The OCC Supervisor shall specify the content of public address announcements made by Train Operators and Station Attendants.

C. MAINTAINING SERVICE DURING EMERGENCIES

1.25 After passenger and employee safety has been ensured, the OCC Supervisor shall initiate operating procedures to minimize the impact of the disruption to train service by providing alternate means of travel for passengers and by preventing a back up or cessation of train movement. The operating procedures may include one or a combination of the following methods:

a. single track operation,

b. train shuttle service,

c. turning trains,

d. rerouting trains,

e. Metrobus shuttle service,

f. making terminal schedule adjustments.

1.26 Under emergency conditions, movement of trains shall have specified speed restrictions imposed by the OCC Supervisor depending upon the circumstances and condition of the equipment. The minimum speed shall not exceed 45 mph.

1.27 When a train is operated from other than the front car, the OCC Supervisor shall be certain that;

a. before authorizing a move, communications are established between the Transportation Supervisor flagging at the front end of the train and the Train Operator;

b. If communications are lost between the Transportation Supervisor and the Train Operator, the Train Operator shall immediately stop the train until communications are re-established.

1.28 Before initiating a train movement against the established direction of traffic, the OCC Supervisor shall follow prescribed procedures in SOP #4 paragraphs 6-9.

D. RESUMPTION OF NORMAL SERVICES

1.29 When the Transportation Supervisor notifies the Operations Control Center that the emergency condition is corrected and all personnel and equipment are in the clear, the OCC Supervisor shall:

a. request a restoration of third rail power if it has been removed, and the breakers have been racked out and tagged;

b. order a Train Operator to discharge passengers and operate the train through the area in Mode 2 as a test train, if considered necessary;

c. order the resumption of normal train service;

d. instruct Station Attendants and Train Operators to discontinue public address announcements prescribed during the emergency;

e. discontinue the Metrobus shuttle service;

f. notify all departments that the emergency condition has been corrected and normal service resumed.

METRORAIL STANDARD OPERATING PROCEDURE #4

PASSENGER EVACUATION FROM TRAINS

A. NOTIFICATION

4.1 When an evacuation of passengers from a train is requested and ordered by the OCC Supervisor, all concerned departments shall be notified by the OCC Supervisor.

B. PASSENGER EVACUATION FROM A DISABLED TRAIN THROUGH THE USE OF CAR UNITS WITHIN THE TRAIN

4.2 This method is used to evacuate passengers from a disabled train consisting of four or more cars.

4.3 When a disabled train is expected to be delayed 30 minutes or more, and two or more cars in the consist are capable of being operated safely, the OCC Supervisor shall instruct the Train Operator to start passenger evacuation.

4.4 When the disabled car units are at the rear of the train, the OCC Supervisor shall instruct the Train Operator to do the following:

a. Secure the train. Key out the console and check for brake cylinder pressure reading of 700 psi in the first two or three cars.

b. Request passengers to move from the disabled car units to the front car units.

c. Secure the disabled car units with hand brakes after all passengers are out.

d. Close and lock the end doors of the disabled and rescue car units.

e. Uncouple the rescue car units from the disabled car units and operate the train in Mode 2 to the station.

4.5 When the disabled car units are at the front of the train, the OCC Supervisor shall instruct the Train Operator to do the following:

a. Secure the train.

b. Request passengers to move from the disabled car units to rear car units.

c. Secure the disabled car units with hand brakes after all passengers are out.

d. Close and lock the end doors of the disabled and rescue car units.

e. After the permissive block has been established, uncouple the rescue car units from the disabled car units and operate the train in Mode 2 against the established direction of traffic.

C. ESTABLISHING A PERMISSIVE BLOCK

4.6 Before initiating a train movement against the established direction of traffic, the OCC Supervisor shall direct the Transportation Supervisor at the scene to establish a permissive block for the distance the train will travel against the direction of traffic.

4.7 The Transportation Supervisor shall do the following:

a. Determine that no trains are within the designated limits of the permissive block.

b. If an opposing interlocking signal is located at the distant end of the permissive block, be certain it is placed in the stop position.

c. If the distant end of the permissive block is not an interlocking signal location,be certain that the Train Operator of an approaching train is instructed to stop and stay outside the distant limit of the permissive block and has reported that the train has stopped and the position reported to the Operations Control Center.

d. After the first three actions have been implemented, the Train Operator of the train making the reverse move shall be instructed to:

1. Change to Mode 2.

2. Proceed at restricted speed or be flagged to the distant end of the permissive block and stop.

3. Sound the warning horn as the train proceeds.

4.8 If the train is to be routed to the adjacent track,the route shall be established after the train has been stopped at the interlocking signal and the adjacent track is clear. The Train Operator shall return to Mode 1 operation after the next station stop,unless otherwise instructed by the OCC Supervisor.

4.9 When it is necessary for the train making the reverse move to pass through a track switch section where the interlocking signal cannot be cleared because traffic direction cannot be established, the following precautions must be implemented after the switches are placed in the desired position:

a. The switch points over which the train will move must be blocked.

b. The blocking must be rechecked for safe train movement.

c. The Train Operator, operating the train in Mode 2 shall be hand flagged through the switch section and instructed to proceed at restricted speed to the distant end of the permissive block.

D. RESCUE TRAIN EVACUATION

4.10 This method is used to evacuate passengers by having an empty train dispatched to a disabled train stopped between stations.

4.11 The OCC Supervisor shall establish a permissive block to permit the rescue train to operate in both directions.

4.12 The Train Operator of the rescue train shall operate the train in Mode 2 at restricted speed sounding the train horn at frequent intervals.

4.13 The Train Operator of the rescue train shall stop the train as near to the disabled train as possible without coupling.

4.14 The Train Operator of the rescue train shall secure the train, unlock and open the end doors of both trains and assist passengers from the disabled train into the rescue train.

4.15 When all passengers have been transferred to the rescue train, the end door of the rescue train shall be closed and locked. The Train Operator of the rescue train shall change operating ends and upon instructions from the OCC Supervisor or Transportation Supervisor in charge, operate the train to a designated passenger station.

E. CLOSE-IN EVACUATION FROM TRAINS STOPPED BEHIND A DISABLED TRAIN

4.16 This method is used to evacuate passengers to a station platform through another train stopped in a station.

4.17 When train service is interrupted for any reason preventing trains from proceeding through an area, the Train Operator nearest a station shall operate the train in Mode 2 into the station. Passengers shall be discharged and the doors of the train shall be left open.

4.18 The Train Operator behind the train in the station shall operate the train in Mode 2 at a restricted speed to close-in to the train in the station as near as possible without coupling.

4.19 Before beginning passenger evacuation, the Train Operator of the train closing-in must inform the Train Operator of the train in the station to secure the train.

4.20 The Train Operator of the train closing-in shall secure the train, unlock and open the end doors of both trains and assist passengers through the train in the station.

4.21 After all passengers have been evacuated, Train Operators shall report to the OCC Supervisor and be governed by instructions.

4.22 Succeeding Train Operators in the area shall be instructed to follow the same procedure.

F. EVACUATION TO THE RIGHT-OF-WAY

4.23 The following procedure shall be used as a last resort to evacuate passengers from a disabled train.

4.24 Before evacuating passengers from a train to the right-of-way, the OCC Supervisor shall be certain that all Authority departments have been notified and the following directives have been issued and implemented:

a. A Transportation Supervisor is at the scene to coordinate all activities and to cooperate with other public assistance agencies.

b. Transit Police are at the scene.

c. Power Department personnel are available at the involved substation and tie-breaker station to rack out and tag the circuit breakers that are tripped when third rail traction power is removed by supervisory.

d. Local fire department personnel are at the scene.

e. Sufficient personnel are available at the evacuation location to assist and guide the passengers.

f. Third rail traction power has been removed from the required power sections of both tracks for the area through which the passengers will walk in accordance with SOP #2, "Extended Emergency".

4.25 An emergency ladder stored in the end car, shall be securely positioned between the end door of the car and the roadbed.

4.26 The passengers shall be assisted down the ladder and guided to the nearest station or emergency exit.

4.27 After all passengers are evacuated from the disabled train, the Train Operator shall apply all handbrakes on the train.

4.28 The OCC Supervisor shall activate the ventilation system based on conditions at the scene.

G. RESCUE TRAIN ON THE ADJACENT TRACK

4.29 Evacuation of the passengers from a disabled train to a rescue train on the adjacent track may be attempted, provided there are no obstructions to hinder the passengers walking from one track to the other. If this method of evacuation is feasible, preparations for the evacuation as prescribed in paragraphs 4.23 through 4.27 shall be implemented.

H. THIRD RAIL TRACTION POWER RESTORATION

4.30 Third rail traction power shall be restored on advice from the Transportation Supervisor at the scene after:

a. all passengers have been evacuated and are off the right-of-way,

b. the senior fire official has cleared the scene of fire department personnel and authorized the Transportation Supervisor to place the system back in operation.

c. all other public assistance agency personnel have left the right-of-way.

d. all remaining personnel are aware of the restoration.

The OCC Supervisor shall restore third rail power in accordance with SOP #2.

I. DISPOSITION OF PASSENGERS AND CAR UNITS AFTER EVACUATION

4.31 The OCC Supervisor shall issue instructions to Station Attendants, Train Operators and all concerned departments for appropriate actions to be taken on disposition of passengers and trains after an evacuation.

METRORAIL STANDARD OPERATING PROCEDURE #15

ABSOLUTE BLOCK

A. DEFINITION

15.1 An absolute block is a section of track between two specific locations into which no train is permitted to enter while it is occupied by another train.

B. REASONS FOR ESTABLISHING A TEMPORARY BLOCK

15.2 The OCC Supervisor shall establish a temporary absolute block of defined and controllable limits when it becomes necessary to ensure the safe movement of trains because:

a. it is necessary to move a train on mainline track to the nearest unused siding or yard after being removed from service if:

1. it has developed a malfunction that required the carborne Automatic Train Protection (ATP) subsystem to be cut out, or

2. it has developed less than 75% braking capability.

b. there is a failure of the Automatic Train Control (ATC) system.

15.3 Depending on the length of the track section affected by the failure of the Wayside Automatic Train Control (ATC) system, and the existing or desired headway of revenue train service on the line involved, a series of temporary absolute blocks could be established within the affected track section to expedite train movement.

C. TEMPORARY ABSOLUTE BLOCK FOR THE MOVEMENT OF A MALFUNCTIONING TRAIN

15.4 To ensure the safety of the revenue train preceding a malfunctioning train being moved to the nearest unused siding or yard, the OCC Supervisor shall establish the necessary temporary absolute block using the interlocking signals of adjacent intermediate interlocking locations, in the direction of travel, as its limits.

15.5 The temporary absolute block shall be moved progressively forward as the preceding revenue train clears the limits of each intermediate interlocking location. This shall continue until the malfunctioning train is stored on an unused siding or arrived within the limits of the nearest yard.

15.6 To establish this type of temporary absolute block the OCC Supervisor shall:

a. cause the interlocking signal at the entrance to the first temporary absolute block to be established to display "stop"

b. cause the interlocking signal at the exiting end of this first temporary absolute block to display "stop" after the preceding revenue train has cleared the interlocking signal.

c. advise the Train Operator of the malfunctioning train of the limits of the temporary absolute block, mode of operation and any operational and speed restrictions

d. when the section of track between the two interlocking signals is clear of the preceding train permit the malfunctioning train to enter the temporary absolute block after the Train Operator has confirmed the length of the block, mode of operation and any operational and speed restrictions.

15.7 The procedure outlined in paragraph 15.6 shall be repeated for each successive temporary absolute block being established until the malfunctioning train is off the mainline tracks.

D. ESTABLISHING A TEMPORARY ABSOLUTE BLOCK OR SERIES OF TEMPORARY ABSOLUTE BLOCKS BECAUSE OF THE FAILURE OF THE WAYSIDE AUTOMATIC TRAIN CONTROL (ATC) SYSTEM

15.8 To control train movement through a section of mainline track affected by the loss of the Wayside Automatic Train Control (ATC) System, a manually controlled temporary absolute block or a series of manually controlled temporary absolute blocks shall be established to conform to the existing revenue train headway.

15.9 When the train headway is either two or four minutes the manually controlled temporary absolute block shall not contain more than three successive stations.

15.10 When the revenue train headway is six to ten minutes at the time of the loss of the Wayside Automatic Train Control (ATC) System, the limits of the manually controlled temporary blocks can be extended to stations between which the train headway can be maintained and allow occupancy by only one train at a time.

15.11 When only one station is affected, the manually controlled temporary absolute block shall be established with the station preceding and the station following as its limits.

15.12 When more than one or a series of stations is affected by the failure during a period of minimum train headway, a series of successive manually controlled temporary absolute blocks shall be established with manual control points as follows:

a. at the unaffected station immediately preceding the section of track with the loss of the wayside ATC system,

b. at each alternate station following the first manual train control point in the direction of train movement; (with this arrangement the exiting manual control point for the first absolute block will become the manually controlled point for entrance to the second absolute block and so on),

c. at the unaffected station immediately following the last affected station whether or not the last affected station is a manual train control point,

d. at active track switch locations within a temporary absolute block where diverging and converging revenue train service has to be maintained.

15.13 A Transportation Supervisor or a qualified transportation employee shall be assigned to each designated manual train control point.

E. METHOD OF TRAIN CONTROL

15.14 Communication channels shall be established between each adjacent manual train control location and the Operations Control Center. The communication channels, when established, shall be used solely for train movement control.

15.15 Train identification for trains entering and using the manual controlled temporary absolute blocks shall be established by the OCC Supervisor. Either the number of the lead car of each train or the train identification number can be used.

15.16 All trains in revenue service operating within the temporary absolute blocks shall be operated in Mode 2.

15.17 The Transportation Supervisor or qualified transportation employee assigned to manual train control points shall control, by oral instructions and directions, the entry of trains into the temporary absolute block and the use of that block until the train arrives at the next manual train control point.

15.18 The Transportation Supervisor or qualified transportation employee assigned to each manual train control point shall keep a record of the train identity of each train and the time it arrived and left their control point.

15.19 Before permitting a train to proceed from their manual control point the Transportation Supervisor or qualified transportation employee shall:

a. await notification from the next manual control point, in the direction of travel, that that control point has no train in the station

b. verify, by train identification, that the train last dispatched from that control point was the last train to leave your control point,

c. when the next train arrives or you are holding one at your control point, notify the next manual control point and request permission to dispatch the train.

d. notify the Train Operator of the operation, the location of the next manual control point and any speed restrictions imposed because of the absolute block operation.

e. When permission is received from the next manual control point, furnish the train identification, the time it will depart and dispatch the train.

f. notify the manual control point preceding your location that your station is clear and furnish the train identification of the last train dispatched.

15.20 The Transportation Supervisor or qualified Transportation employee assigned to the last manual control point at the exiting end of the last temporary absolute block (outside the affected area) shall instruct Train Operators of train departing that location to return to normal train operation.

F. MAINTAINING TRAIN SERVICE AT ACTIVE TRACK SWITCH LOCATIONS

15.21 When the failure of the wayside ATC System affects the automatic operation of track switches at junctions and/ or terminals, the OCC Supervisor shall assign a qualified employee(s) the task of hand cranking the switch points if necessary, and blocking the switch points in the desired position. Hand cranking and blocking will be in accordance with Section I, Paragraphs 15.41 and 15.42.

15.22 The Transportation Supervisor, qualified transportation employee or other designated employee shall hand flag the trains through the track switch section after it has been inspected and judged safe for train movement.

G. OPERATIONS CONTROL CENTER ACTION WHEN THE WAYSIDE AUTOMATIC TRAIN CONTROL (ATC) SYSTEM FAILS

15.23 When the Operations Control Center (OCC) receives an alarm indicating a failure of the Wayside Automatic Train Control (ATC) System the OCC Supervisor shall ascertain the limits of the affected area.

15.24 The OCC Supervisor shall immediately order the Train Operators of trains operating in the manual mode in the affected area to stop their trains, report their position and await further instructions.

15.25 The OCC Supervisor shall direct the Train Operators of other trains stopped in the affected area to report their position and await further instructions.

15.26 The OCC Supervisor shall instruct Train Operators of trains on unaffected track in immediate approach to the affected area to hold their trains in stations, keep the door open and await instructions.

15.27 The OCC Supervisor shall notify Systems Maintenance Control advising them of the problem, the line, area and tracks affected.

15.28 The OCC Supervisor shall notify all other concerned Authority department, Station Attendants and Terminal Supervisors on the affected line.

15.29 The OCC Supervisor shall arrange for appropriate public address announcements to be made to passengers on trains and in stations.

15.30 The OCC Supervisor shall dispatch Transportation Supervisors and/or qualified transportation personnel to the manual train control points that will be established in the affected area in accordance with Section D, Paragraphs 15.8 through 15.13 of this procedure.

15.31 Train control shall be in accordance with Sections E and F, Paragraphs 15.14 through 15.22 of this procedure.

H. MOVEMENT OF TRAINS IN THE AFFECTED AREA BEFORE MANUAL TRAIN CONTROL POINTS ARE ESTABLISHED

15.32 The OCC Supervisor, after receiving the identification and position of the trains stopped in the affected area, shall alert the Train Operators to the situation, instruct them to disregard scheduled operation, change to Mode 2, proceed at restricted speed with caution and continue to make station stops.

15.33 The OCC Supervisor shall instruct Train Operators approaching an emergency crossover, in which a signal cannot be cleared, that the switch points must be blocked in the normal position, prior to proceeding through an interlocking.

15.34 The OCC Supervisor shall instruct each Train Operator to notify the OCC when they make a station stop, what station, and furnish their train identification. The Train Operators shall continue these reports from each station until their train clears the affected area. In accordance with reports received, the OCC Supervisor shall maintain a station to station separation between the trains in the affected area.

15.35 The OCC Supervisor shall keep a written log of the operation recording the train identification and the time the trains are dispatched from each station.

15.36 The OCC Supervisor shall also instruct the Train Operators of trains held in approach to the affected area to follow the same procedure outlined in Paragraphs 15.32 and 15.34 when they enter the affected area. When train congestion occurs outside the affected area because of slow movement of trains through the affected area, the OCC Supervisor shall turn trains at intermediate interlocking location on both sides of the affected area, and instruct the Terminal Supervisor to institute terminal schedule adjustments.

15.37 The OCC Supervisor shall instruct Train Operators of trains approaching junction points, where the automatic route selection is affected by the failure of the wayside ATC System, to use the manual route selection push button located in approach to the turnouts. Should the signal fail to clear, the switch points shall be blocked in accordance with Paragraph 15.40, or hand cranked and blocked in accordance with Paragraph 15.41 prior to proceeding through an interlocking.

15.38 The OCC Supervisor shall request the assistance of the Transit Police for crowd control at any station reporting passenger overcrowding.

15.39 When all designated train control points in the affected area, stations and junction track switch locations if necessary, are covered by qualified transportation personnel, the manual controlled absolute block operation shall be initiated.

HAND CRANKING AND BLOCKING OF SWITCHES

15.40 Upon the request of the OCC Supervisor to block the switches the following steps will be taken:

a. Insure that proper alignment has been established.

b. Visually check that the switch points are tucked under the running rail and that the rail is aligned for the required route.

c. Insert the block between the open switch point and the running rail and strike the end until it is securely wedged.

d. Proceed to all switches in the interlocking and repeat steps a through c.

e. Notify Central Control Supervisor that the switches have been blocked.

f. At no time should a switch be blocked for a crossover move without a Transportation Supervisor or an ATC Maintenance Crew on the scene.

g. Transportation Supervisor or ATC Maintenance Crew may remove and replace blocks for the purposes of maintaining revenue traffic.

h. NO ONE except an ATC Maintenance Crew will be allowed to remove blocks in order to place the interlocking back in service on the revenue railroad.

15.41 Upon the request of the OCC Supervisor to hand crank switches, the following steps will be taken:

a. Insert crank into switch crank hole until it engages the crank shaft. Do not use excessive force on crank handle.

b. Turn the crank in the direction the switch points have to travel.

c. Continue to turn the crank until the switch points are tucked under the rail and the switch clutch begins slipping.

d. Insert the block between the open switch points and running rail prior to removing the crank. (See Paragraph 15.40 above).

15.41 cont..

e. Remove the crank and proceed to crank the other switches within the required route, using steps a through d.

f. Proceed to the next track and repeat steps a through e if necessary.

g. Notify Central Control Supervisor that the switch has been cranked and blocked.

h. Transportation Supervisor or ATC Maintenance Crew may crank and block switches for the purpose of maintaining revenue traffic.

i. NO ONE except an ATC Maintenance crew will be allowed to remove blocks in order to place the interlocking back in service on the revenue railroad.

21. STORM AND SNOW OPERATIONS

A. NOTIFICATION

21.1 When sleet or snow warnings are issued by the Weather Bureau, or when unexpected storms occur, the Command Center will issue a "storm alert" upon authorization of the General Superintendent of Rail Operations.

21.2 The "storm alert" will be issued to the following:

a. Supervisors of stations, main line, terminals and yards.

b. All concerned Metrorail departments.

B. RETENTION OF EMPLOYEES

21.3 At the conclusion of their tours of duty, employees shall be governed by the following:

a. Train Operators shall report to their supervisors at terminals and yards for work assignments.

b. Interlocking Attendants shall report to Yard Supervisors for work assignments.

c. Porters shall report to their immediate supervisors for work assignments.

C. OPERATIONS

21.4 Depending upon the nature and intensity of the storm and the time of day, supplemental storm schedules will be placed into effect by the Command Center.

21.5 Supplemental storm schedules will provide for any one or combination of the following conditions:

a. When headways are ten minutes or revenue service is not being operated, the Command Center will:

1. Order the insertion of trains (without passengers) to operate over the exposed portions of the system to keep tracks and the third rail clear of ice and snow accumulations,

2. order storage of revenue trains undercover by utilizing car maintenance shop tracks and designated portions of the subway.

b. When trains are stored in the subway portion of the system, Train Operator work program adjustments will be included in the supplemental storm schedule for dispatching the stored trains to terminals, in order to meet the scheduled start of operations.

21.6 Interlocking Attendants shall be assigned to satellite interlockings located at the controlling end of main line tracks exposed to the elements in order to:

a. Frequently operate track switches.

b. Turn back extra trains.

21.7 Yard Supervisors shall do the following:

a. Instruct Interlocking Attendants to operate track switches at frequent intervals.

b. Order trains operated over main yard leads from storage tracks in order to keep yard tracks and third rail clear of snow and ice accumulations.

21.8 Porters shall be responsible for keeping stations exposed to the elements free of snow and ice accumulations on platforms, stairwells, elevators and escalators.

21.9 Maintenance-of-Way shall be responsible for keeping yard leads and track switches in yards and terminals clear of snow and ice accumulations. They shall also control electric switch heaters.

21.10 Car Maintenance shall assign personnel to yards and terminals.

21.11 The Supervisor in charge of power shall be responsible for maintaining a power output capable of meeting increased service and heating requirements.

21.12 The Command Center will initiate, maintain, and conclude storm and snow operations.

APPENDIX E

SUMMARY OF DISTRICT OF COLUMBIA FIRE DEPARTMENT RESPONSE TO THE EMERGENCY

UNITS	VEHICLES	DISPATCH TIME	ARRIVAL TIME	TRAVEL TIME/DISTANCE	AGENCY CAPACITY	AVAILABLE AT TIME OF DISPATCH	PERSONNEL
ENGINE COMPANIES					32	21	
First Alarm (BOX)							
Engine Co. No. 23	2	16:40:56		/.638mi			6
Engine Co. No. 3	2	16:48:44	16:53:36	4min50sec/.466mi			5
Engine Co. No. 1	2	16:40:56		/.857mi			6
Engine Co. No. 18	2	16:40:56	16:55:21	14min25sec/.990mi			5
Task Force Alarm							
Engine Co. No. 8	1	17:14:52	17:26:21	11min29sec/1.419mi			4
Engine Co. No. 9	2	17:14:52	17:23:08	8min16sec/.990mi			5
Special Alarm; Water Supply to Standpipe							
Engine Co. No. 26	1	18:20:00		/1.386mi			
LADDER COMPANIES					17	15	
First Alarm (Box)							
Truck Co. No. 1	1	16:40:56		/.419mi			6
Truck Co. No. 2	1	16:48:44	17:00:21	11min37sec/1.552mi			6
Task Force Alarm							
Truck Co. No. 4	1	17:14:52		/.848mi			5
RESCUE SQUAD COMPANIES (Heavy)	1st alarm only				4*	1	
Rescue Squad No. 4	2	16:48:44	17:04:51	16min7sec/1.581mi			7
BATTALION FIRE CHIEFS					8	6	
First Alarm (Box)							
Battalion Fire Chief 2	1	16:40:56	17:04:58	24min2sec/.857mi			1
Battalion Fire Chief 7	1	16:40:56	16:53:57	13min1sec/.990mi			1
Task Force Alarm							
Deputy Fire Chief - Reserve	1	17:14:52	17:31:00	16min29sec/.857mi			2
SPECIAL PURPOSE UNITS							
First Alarm (Box)							
Salvage and Compressed Air Truck	1	16:40:56		/1.552mi			2
AMBULANCE UNITS					16**	2	
Ambulance No. 8	1	16:57:57	17:17	13min/.981mi			2
Ambulance No. 16	1	16:57:57	17:14	15min/1.286mi			2
Medic No. 9	1	17:42:00	17:58	16min/.933mi			2
Ambulance No. 6	1	17:48:00	18:05	17min/.933mi			2
Ambulance No. 7	1	17:49:00		/.933mi			2
Medic No. 1	1	17:59:00	18:05	6min/.933mi			2
Medic No. 27	1	18:02:00	18:15	13min/.933mi			2
Ambulance No. 5	1	17:49:00	17:57	8min/.933mi			2
Medic No. 11	1	18:01:00	18:06	5min/.933mi			2
Medic No. 18	1	not avail	19:00	/.133mi			2
Ambulance No. 4	1	not avail		/.895mi			4

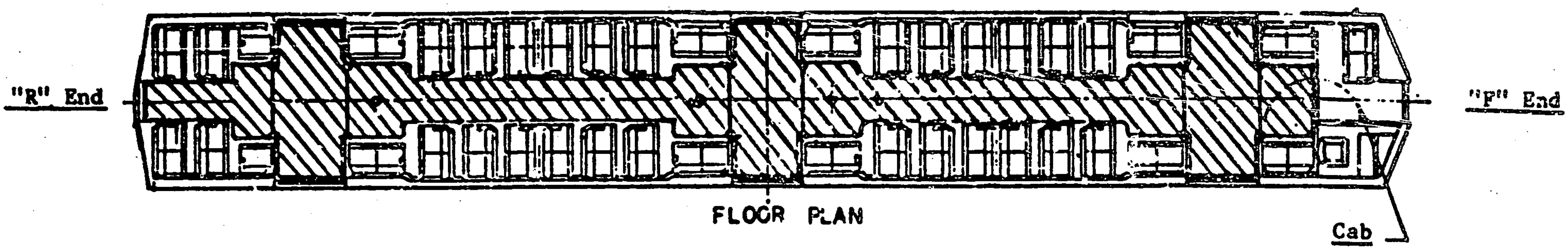
	UNITS	PERSONNEL	VEHICLES
Fire Fighting	15	60	21
Ambulance	11	24	11
TOTAL	26	84	32

* Combination Engine Co. and Rescue Squad

** 16 units between 0800 & 2400 hours
10 units between 0001 & 0759 hours

APPENDIX F

FLOOR PLAN AND DISTRIBUTION OF INTERIOR SPACE OF WMATA CAR NO. 1029



FLOOR PLAN

Car outside dimensions:			
Length:	75'-0"		
Width:	10'-1 3/4"		
Outside plan area:		757.3 sq.ft.	757.3 sq.ft.
Published inside floor area, sq. ft. (incl. cab)		630.0 sq. ft.	630.0 sq. ft. (*)
Less seat area, including foot space.			
fore/aft facing seats:	236 sq. ft.		
side seats:	78 sq. ft.		
Total (approx.)	314 sq. ft.	314.0 sq. ft.	
Less cab area: (approx.)		35.0	
Net floor area available for standees: (approx.)			281.0 sq. ft.
Crush passenger load:	220 passengers		
Seating capacity: (cab car)	78 passengers		
Total standees, crush load:	142 passengers		
Floor area available for each standee			2.0 sq. ft. (288 sq.in.) 17 in. x 17 in.

(*) Roster of North American Rapid Transit Cars, 1945 - 1980 (UMTA - DC-06-0121-80-1) July 1980, Page 171

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