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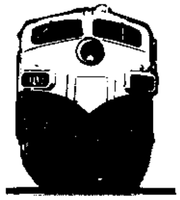

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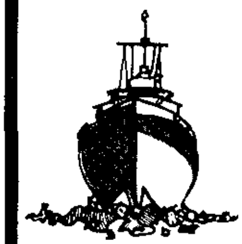
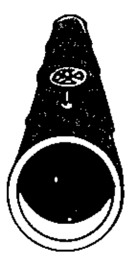


RAILROAD ACCIDENT REPORT



REAR END COLLISION OF METRO-DADE TRANSPORTATION ADMINISTRATION TRAINS NOS. 172-171 AND 141-142 MIAMI, FLORIDA JUNE 26, 1985

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UNITED STATES GOVERNMENT

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16 Abstract

About 11:35 p.m. on June 26, 1985, Metro-Dade Transportation Administration (MDTA) nonrevenue test train No. 172-171 struck the rear of MDTA revenue train, No. 141-142, which was stopped on track 2 about 1,927 feet south of the Northside Station interlocking in Miami, Florida. Neither train was derailed. Test train No. 172-171 was returning northbound after completing a southbound test run. Twelve passengers and four MDTA employees were taken to nearby hospitals where they were treated and released. The MDTA estimated the damage to be $1.6 million.

The National Transportation Safety Board determines that the probable cause of this accident was the failure of the rail attendant of train No. 172-171 to follow Metro-Dade procedures by operating the train with the ATP system bypassed and his failure because of inattention, distraction, or the effects of drugs, to monitor the track ahead of the train, perceive the standing train, and react in time to stop his train safely. Contributing to the cause of the accident were flawed transit system procedures which resulted in the testing of trains with known equipment defects on the same track with revenue passenger trains.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

Adopted: August 5, 1986

REAR END COLLISION OF METRO-DADE TRANSPORTATION ADMINISTRATION TRAINS NOS. 172-171 AND 141-142, MIAMI, FLORIDA, JUNE 26, 1985

SYNOPSIS

About 11:35 p.m. on June 26, 1985, Metro-Dade Transportation Administration (MDTA) nonrevenue test train No. 172-171 struck the rear of MDTA revenue train, No. 141-142, which was stopped on track No. 2 about 1,927 feet south of the Northside Station interlocking in Miami, Florida. Neither train was derailed. Test train No. 172-171 was returning northbound after completing a southbound test run. Twelve passengers and four MDTA employees were taken to nearby hospitals where they were treated and released. The MDTA estimated the damage to be $1.6 million.

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INVESTIGATION

Events Preceding the Accident

Between June 3, 1985, and June 26, 1985, rail attendants 1/ of Metro-Dade Transportation Administration (MDTA) two-car set No. 171-172 reported eight times that the car set had brake problems. The trouble reports indicated that an undesired emergency application of the brakes on the car set would occur and cause the car set to stop. Technicians in the MDTA shop facilities at Palmetto Yard, Miami, Florida, tried to locate and correct the trouble, but they could not determine whether the trouble was in the automatic train protection system (ATP), 2/ in the F-2 brake control unit 3/ or other on-board equipment. Instrumented static tests did not provide the technicians with all the information they required, and test facilities were not available at Palmetto Yard for the cars to be operated at a speed high enough for the technicians to make the desired tests. For the car set, or any car set or equipment not in scheduled revenue service to be tested on the main track, it would have to be operated as an unscheduled train. Operating Rule 4055 states that unscheduled trains must receive train orders before being operated on the main track. (See appendix B.)

1/ In the Metro-Dade system, the train operator is called a rail attendant.
2/ ATP is a signal/speed control system that forces the rail attendant to observe speed command signals transmitted by the wayside signal equipment.
3/ The F-2 unit is a solid-state electronic control that monitors the various train braking functions.

An MDTA Work Order, which provided for unscheduled operating moves, was issued for Wednesday, June 26, 1985 to cover testing operations known at that time. The work order provided for the testing of two 2-car sets of equipment belonging to Transit America (neither of these car sets were test train No. 171 -172) that had not been accepted by the MDTA, and it stated:

> Transit America (Budd Company), upon receipt of train orders will perform testing with two 2-car trains and two operators from south of crossover south of Okeechobee Station to Northside Station on track II (2) 7:00 p.m. Wednesday (6/26/85) to 4:00 a.m. (6/27/85). Single tracking is required on track 1.

Arrangements had not been made to test car set No. 171-172 at the time this work order was issued, and therefore, the tests for car set No. 171-172 were not mentioned. At 7:13 p.m., the controller issued a train order to the rail attendant on Budd Company test train No. 189-190 so the testing could proceed as provided by the work order. Testing of one set of the Budd cars began at 8:44 p.m. on track 2 between Okeechobee Station and Northside Station.

About 6 p.m. on June 26, maintenance supervisors at Palmetto Yard asked the rail traffic controller (controller) on duty at MDTA central control for permission to test car set No. 171-172 on the main track. The maintenance supervisors identified the problem with car set No. 171-172 to the controller only as excessive "dumping." They did not mention any suspected faults with the ATP on the car set. The controller authorized the test to be performed on the main track, which was in accordance with MDTA policy.

About 9:45 p.m., train No. 171-172 departed Palmetto Yard to Okeechobee Station where it would enter onto track No. 1. On the test train were a rail attendant, who was operating the train from the control compartment of car No. 171, a rail vehicle electrician (train control electrician), who was skilled in the ATP equipment, and two friends of the train control electrician 4/ who were not authorized by MDTA rules to be on the car set. The yard dispatcher instructed the rail attendant to pick up a rail vehicle technician who was skilled in the train's electronic braking control system at Okeechobee Station.

The rail attendant said 5/ that when he began operating train No. 171-172 from Palmetto Yard, the master control handle did not seem to be operating properly and the brakes did not appear to be stopping the train effectively. He did not complain about the stopping performance of the train at stations where the train was stopped during the test run southbound or later when the train stopped at Dadeland South Station.

When train No. 171-172 arrived at Okeechobee Station about 10 p.m., the brake technician boarded the train. The rail attendant said that he requested train orders from the controller via radio channel 1. The request for train orders is not in the transcript of conversations recorded on channel 1 on June 26 and there is no record of the request.

4/ The train control electrician expected to be off duty about 9 p.m. after which she and the two friends were going to dinner. When the train control electrician was assigned to test car set 171-172 she invited the friends, who had arrived at Palmetto Yard, to go with her.

5/ Testimony hereinafter referred to (as given by the rail attendants, the rail traffic controller, the train brake technician, and the train control technician), was obtained during a fact-finding deposition proceeding.

However, the controller confirmed in testimony that he had told the rail attendant sometime before train No. 171-172 departed Okeechobee Station that written train orders were not required.

The controller said he believed that, since train No. 171-172 belonged to the MDTA, it could be operated on the main track along with revenue trains without written train orders because it was equipped with ATP. When the rail traffic controller was able to release train No. 171-172 to go south he issued instructions to the rail attendant. The transcript of conversations made on radio channel 1 revealed that at 10:22 p.m. 6/ the controller told the rail attendant to "proceed on signal sir. You will proceed all the way to Dadeland South while you make your station stops or whatever shop personnel wants you to do." According to MDTA's operating officers, this verbal instruction satisfied the requirement of operating rule 4055, which requires unscheduled trains to be given a train order. (See appendix B.) The rail attendant responded "QSL" to the controller, meaning an affirmative answer, that I am receiving you okay and that I understand you. The controller said that he also instructed the rail attendant to "follow speed commands." This instruction is not in the radio transcript. The rail attendant said that he understood from the controller that he would take his verbal train orders from the on-board technicians.

At 10:20 p.m., test train No. 171-172, being operated in the manual mode with the ATP operative, departed Okeechobee Station southbound on track No. 1 en route to Dadeland South Station. Between Okeechobee Station and Earlington Heights Station (see figure 1) the train was stopped several times by undesired emergency brake applications. The rail attendant, the train control electrician, and the brake technician observed that the speed commands displayed on the operator's console were erratic.

They said that the displayed speed commands would change erratically, oscillating from a higher speed command to a zero speed command. At times the changes were so fleeting that the rail attendant could not respond to the change quickly enough, and the emergency brake would apply. Some emergency brake applications occurred even after the rail attendant responded to the overspeed alarm. When changes occurred in the speed commands, the overspeed alarm did not sound in all instances. When the brakes automatically applied following the inability of the train attendant to respond to the rapidly changing speed conditions, they could not be released until the train stopped. After the train stopped, an 8-second delay had to be observed before the rail attendant could recharge the brakes to an operative condition. No one on train No. 171-172 advised central control that the train was being stopped by undesired brake applications. The rail attendant said that he thought that since train No. 171-172 was a test train, he was not required to report the emergency stops as an unusual operating occurrence. However, operating rules T-2015 and T-4037 7/ required the rail attendant to report any unusual occurrence to central control.

6/ Times shown on the tape monitor were not synchronized to an MDTA system time base.

7/ Operating rule T-2015 requires that the rail attendant contact Central Control for unusual circumstances. MDTA operating rules are designated by: prefix "T," prefix "M," or no prefix. Rules with no prefix are general rules and all employees are responsible for knowing and obeying general rules. Rules with the prefix "T" are primarily for transportation department employees, and rules with the prefix "M" are primarily for mechanical department employees.

NO SCALE

Figure 1.--Metrorail route and station locations.

When the train control electrician and the brake technician onboard train No. 171-172 attempted to diagnose the cause of the emergency brake applications, they could not determine the source of the trouble. The train control electrician maintained that there was no trouble with the ATP system, and the brake technician maintained that there was no fault with the F-2 brake control unit. The brake technician said that he did, however, detect an irregularity in the slip-slide equipment 8/ between Okeechobee Station and Earlington Heights Station. At some point after the train departed Okeechobee Station, (with the ATP operational), but before it reached Northside Station, the train control electrician (according to her statement), replaced the entire card file for the ATP electronic control assembly with another card file that she said was functioning properly. However, she said that she did not remember at what location she replaced the card file, whether it was before or after the ATP had been bypassed. In any case, she said that this change made no difference in the erratic speed commands or the braking pattern of the train.

The rail attendant said that while train No. 171-172 was stopped at Northside Station, he, the train control electrician, and the brake technician agreed that, for the train to proceed to Dadeland South Station without the intermittent stopping caused by the undesired emergency brake applications, they would have to change the mode of operation from the manual mode to the yard mode, bypassing the ATP. The brake technician cut and removed the lead wire seal from the ATP bypass switch locking pin, removed the pin, and operated the two-position toggle switch from the "ATP-In-Service" position to the "OFF" position which bypassed the ATP.

When the ATP system is bypassed, the maximum speed limit for the displayed speed commands that the ATP normally enforces is removed, and no protection is provided against possible adverse signal block 9/ conditions ahead.

Neither the rail attendant, the train control electrician, nor the brake technician asked the controller, as required by rules 3026 and T-4029, for authority to bypass the ATP, nor did they advise the controller that train No. 171-172 was being operated in the yard mode with the ATP bypassed between Northside Station and Dadeland South Station.

By the time train No. 171-172 reached Earlington Heights Station, the train control electrician and the brake technician agreed that there was no need for further testing on the main track and that the additional testing they would like to do would have to be done in the Palmetto Yard, their point of origin. The train control electrician wanted to check the car's cabling network, the speed sensors, and the ATP antennas (the ATP signal pickup coils) at the front of the train. At 10:37 p.m., the brake technician radioed the controller and asked, "Is it necessary for us [train No. 171-172] to go all the way down to Dadeland South?" The controller replied "QSL, sir, there ain't no way you can get turned around before then." 10/ Therefore, train No. 171-172 continued toward Dadeland South Station.

8/ Slip-slide equipment is a combination of on-board sensors and equipment to detect and overcome, through corrective brake responses, traction loss due to wheels slipping or sliding on the rails.

9/ A length of track over which trains are operated, governed by a wayside or a cab signal aspect. An adverse condition would be any condition affecting a signal block such as a broken rail, misaligned switch, or occupancy by another train, which would cause a reduced speed command to be displayed.

10/ On June 26, the interlocking signals and crossovers located at stations throughout the system could be operated only from a local control panel (LCP) at the station. Rail attendants trained to operate the LCPs were sent to a station when a need arose to cross a train over at that location. There were no rail attendants on duty at any of the LCPs between Northside Station and Dadeland South Station that evening.

At 11 p.m., revenue train No. 141-142 departed Dadeland South Station on the No. 2 northward track en route to Okeechobee Station. At the same time, train No. 171-172 arrived at Dadeland South Station. The controller 11/ met train 171-172 at the platform. The controller said that he did not remember seeing any external indicator lights (mounted on the outside of the car at the upper left side of the operating compartment) illuminated to indicate that the train was being operated with the ATP bypassed. The brake technician said that he did not remember if he reset the ATP bypass indicator light relay after the train arrived at Dadeland South Station. The controller said that he told the rail attendant of train No. 172-171 12/ that the train could proceed northbound on signal indications and speed commands. He said he told the rail attendant to watch out for revenue train No. 141-142, which probably would be standing south of the Northside Station interlocking when train No. 172-171 arrived, and to be careful in that area. The rail attendant of train No. 172-171 denied having had this or any direct conversation with the controller at Dadeland South Station. However, both the train control electrician and the brake technician testified to seeing or hearing the rail attendant conversing with the controller, although neither heard the content of the conversation.

The brake technician said that just before train No. 172-171 departed Dadeland South Station, he asked the controller when train No. 172- 171 could leave northbound. He said the controller told him that they could leave anytime they were ready. The brake technician said that he commented to the controller that it had only been about 6 minutes since train No. 141-142 had left Dadeland South Station northbound and asked if that was not "kind of close on his time for us to leave, since we won't be making station stops?" The technician said that the controller told him that would be no problem under ATP operation and that the train could depart. At 11:08 p.m., train No. 172-171 departed Dadeland South Station northward on the No. 2 track en route to Palmetto Yard. The rail attendant and the on-board technicians said that the train was being operated in the manual mode with the ATP operative.

The Accident

Testimony from the rail attendant, the train control electrician, and the brake technician is conflicting concerning the trip northbound. The train control electrician said that an undesired emergency brake application occurred once, but that when she inquired about the trouble, the rail attendant and the brake technician told her, "Don't worry about it, it's not your problem." The rail attendant also said in his written statement that an undesired emergency application occurred once during the northbound trip; however, in sworn testimony he recanted that statement and stated that no undesired emergency application occurred. The brake technician said that they did not receive any Sonalert 13/ signals to indicate an overspeed but that undesired emergency brake applications occurred two times. The rail attendant said that when the train arrived at either Vizcaya Station or Brickell Station (see figure 1), the brake technician told him to stop, and that the technician, just as he had done earlier in car No. 171, removed the lead wire seal from the ATP bypass switch locking pin, removed the pin, and operated the switch that bypassed the ATP. No one testified as to who moved the mode selector

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11/ The central control facility was located in a temporary office on the Dadeland South Station platform.

12/ Trains are identified by the lead car number. Southbound, the lead car in the car set was No. 171, hence train No. 171-172. Northbound, the lead car would be No. 172, from which the rail attendant would be operating the train, hence train No. 172-171.

13/ An audible alarm that sounds when the train's speed exceeds that allowed by the speed command.

switch to the yard mode. Then, according to the rail attendant, he continued operating the train northward. The rail attendant said that when train No. 172-171 reached Dr. Martin Luther King, Jr. Plaza Station, the brake technician told him to call out any speed commands that appeared on the operator's console. The brake technician told investigators that he did not place train No. 172-171 in the yard mode with the ATP bypassed on the northbound trip and that he did not ask the rail attendant to call speed commands to him after the train passed Dr. Martin Luther King Jr., Plaza Station. The train control electrician reluctantly testified under oath that following the accident the brake technician told her that he had placed the train in the yard mode and operated the ATP bypass switch on the northbound trip. The train control electrician also said that the brake technician told her that he had resealed the ATP bypass switch after the accident.

As the train moved north from the location at which the ATP was bypassed, the brake technician was in the passenger compartment working on the F-2 brake control unit and making tests on the logic panel to determine what he believed to be a fault in the slip-slide control. The train control electrician was gathering her tools and equipment.

The rail attendant said that, after the train left Dr. Martin Luther King, Jr. Plaza Station, the speed commands shown on the operator's console changed from "58 to 25" to zero mph. 14/ The speed commands were still presented on the operator's console with the ATP bypassed, but they did not affect the speed of the train. The rail attendant testified that he called the speed commands to the brake technician, who acknowledged them. The two unauthorized passengers who were seated in the passenger compartment within 10 feet of the rail attendant said that they did not hear this exchange of information. The rail attendant said that, as the train continued moving northward from Dr. Martin Luther King, Jr. Plaza Station, at a speed he reported to be about 40 mph, he observed the speed commands on the operator's console go from 58 to 25 to zero and called back to the brake attendant. Then he looked up and saw a "big tree on the left side going around a bend." (See figure 2.) He said, "All I saw there was the tree." He then said, "As I got into the turn, I hollered out to him [the brake technician], 'There's a train in front of us. . .' " The rail attendant testified that he believed the train's speed at this time was about 35 to 38 mph. He said that as he was calling an alarm about the train to those onboard, he moved the master control handle to the position for a full service brake application. He said that the train did not appear to be slowing so, in an almost continuous movement, he moved the master control handle into the emergency brake position.

According to the brake technician, he was testing the equipment in the passenger compartment when he heard the rail attendant call out about the train ahead. He immediately ran forward and stood by the rail attendant. He said that although the rail attendant said that the emergency brakes were applied, they both apparently believed that the train was not slowing so together they pushed the emergency brake valve, referred to as the "mushroom."

About this time, the train control electrician arrived at the operating compartment. She said that she noticed the master control lever was positioned for either a full service or an emergency brake application, and that she saw the rail attendant and the brake technician push the emergency brake valve. The train control electrician said that when she saw how close the standing train was, she called to the rail attendant and the brake

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14/ Speed commands are indicated on the operator's console as one of the following: 0, 15, 28, 38, 46, 58, or 70 mph. There is no 25 mph speed command.

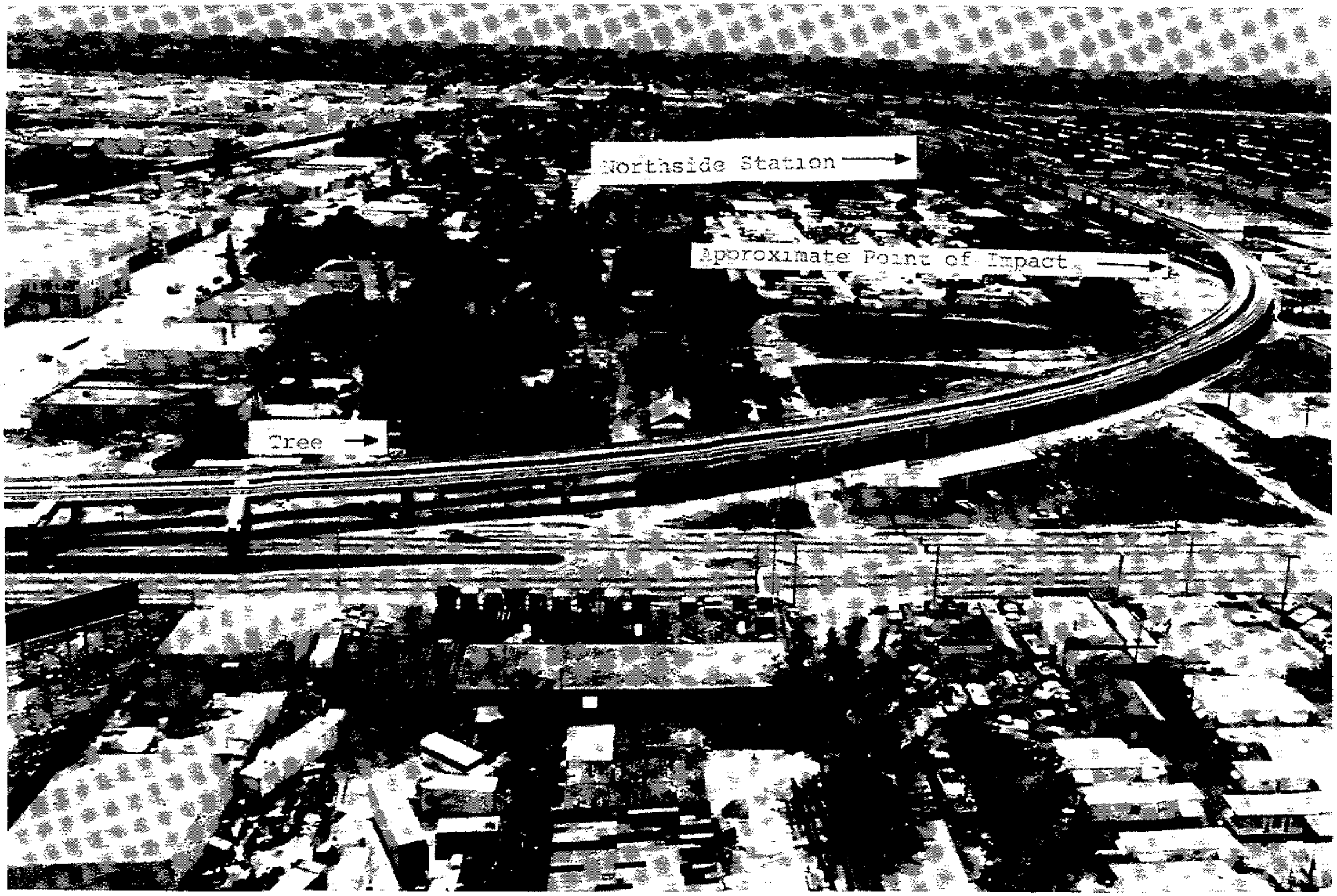


Figure 2.--Accident site.

technician to get out of the operating compartment and she began running toward the rear of the train. Neither the rail attendant nor the brake technician left the operating compartment.

About 11:35 p.m., train No. 172-171 struck the rear of standing train No. 141-142, about 1,927 feet south of the Northside Station interlocking. Train No. 141-142 was moved forward about 68 feet, and train No. 172-171 moved about 52 feet beyond the point of impact. Slide marks found on the rails indicated that the front and rear truck wheels of car No. 171 were locked and sliding for 44 feet and 64 feet, respectively, before the impact. After initially contacting train No. 141-142, train No. 172-171 separated from car No. 142 and stopped about 20 feet from the rear of that car. (See figure 3.)

The impact forces crushed the operating compartment of car No. 172. The rail attendant and brake technician were trapped temporarily in the operating compartment because of the deformation of the compartment, but, although injured, they were able to extricate themselves without assistance. The train control electrician and the two unauthorized passengers were also injured.

The emergency lights for train No. 141-142 failed to remain illuminated after the impact because of damage to the wiring system.

Injuries to Persons

Injuries	Crewmembers of train No. 141-142	Employees onboard train No. 172-171	Passengers	Total
Fatal	0	0	0	0
Nonfatal	1	3	12	16
None	0	0	1	1
Total	1	3	13	17

Damage

Car No. 141 received moderate damage. The truck safety hanger welds broke on both the front and rear trucks of car No. 141. The draft gear tension bolts on the rear coupler broke, and the floor at the rear (R-end) 16/ was buckled slightly. The threshold at the R-end was destroyed, but the exterior shell was not damaged.

Car No. 142 was damaged severely. (See figures 4 and 5.) The front and rear car truck safety hanger welds broke, and the radius rods on the F-end (the impacted end) were bent on both sides. The coupler and draft gear on the F-end broke, and the draft gear tension bolts were sheared. The floor covering at each floor board joint buckled and an end window (windshield) was broken. Rescuers broke a right-rear side window through which passengers were evacuated. The side doors on both sides were buckled and the exterior shell had ripples throughout its length on both sides. The body bolster on the F-end was bent and twisted. Both sides of the side sill were buckled, and the buffer box and anti-climber was crushed 13 3/4 inches.

Damage similar to that of cars Nos. 142 and 141 was noted on cars Nos. 172 and 171, respectively. Car No. 172 was severely damaged (see figures 6 and 7) and car No. 171 was moderately damaged.

16/ The F-end of the car is identified by the operating compartment irrespective of the direction of travel. The R-end is the end that is semi-permanently coupled to another car.

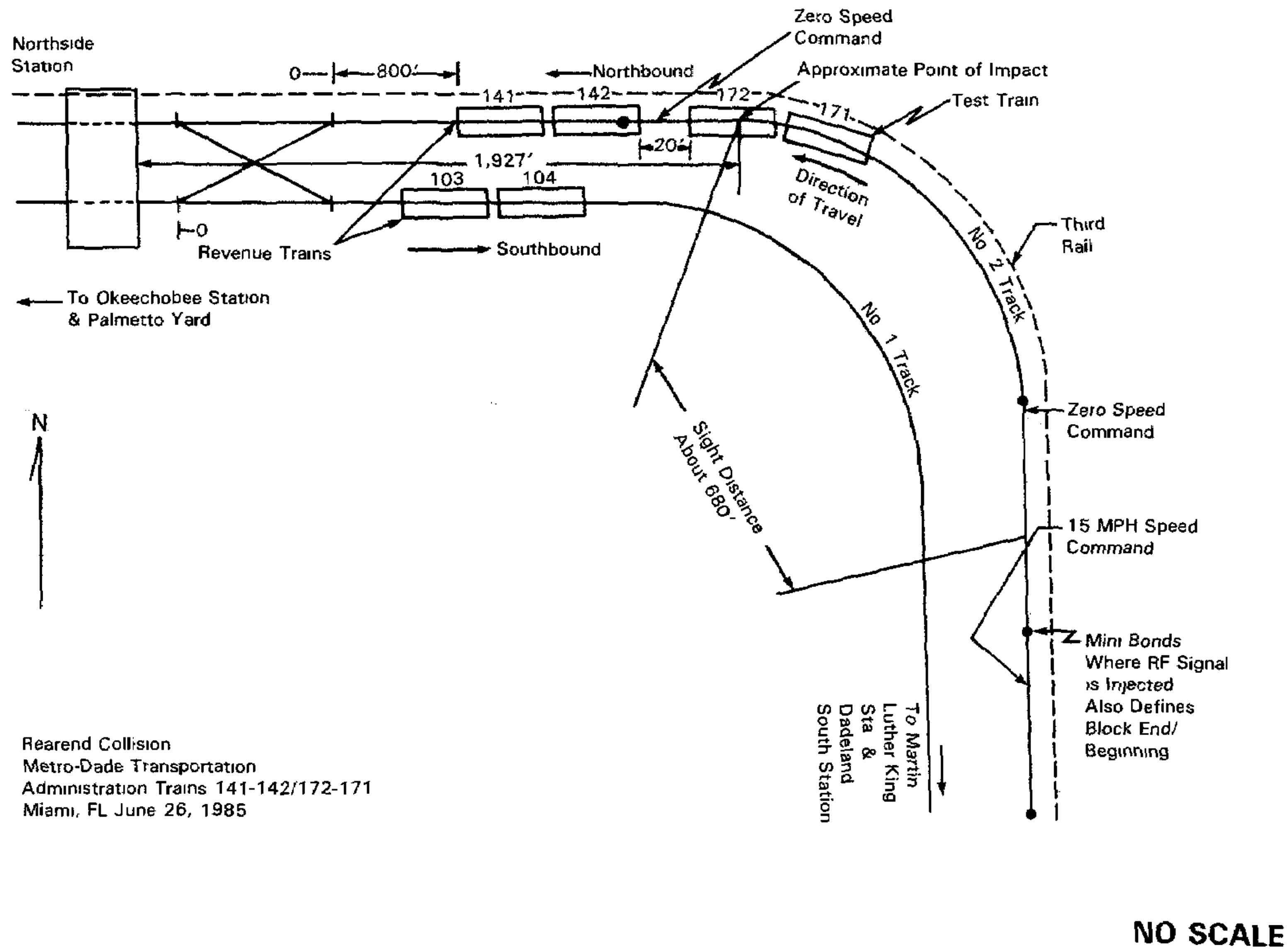


Figure 3.--Plan view of accident site.

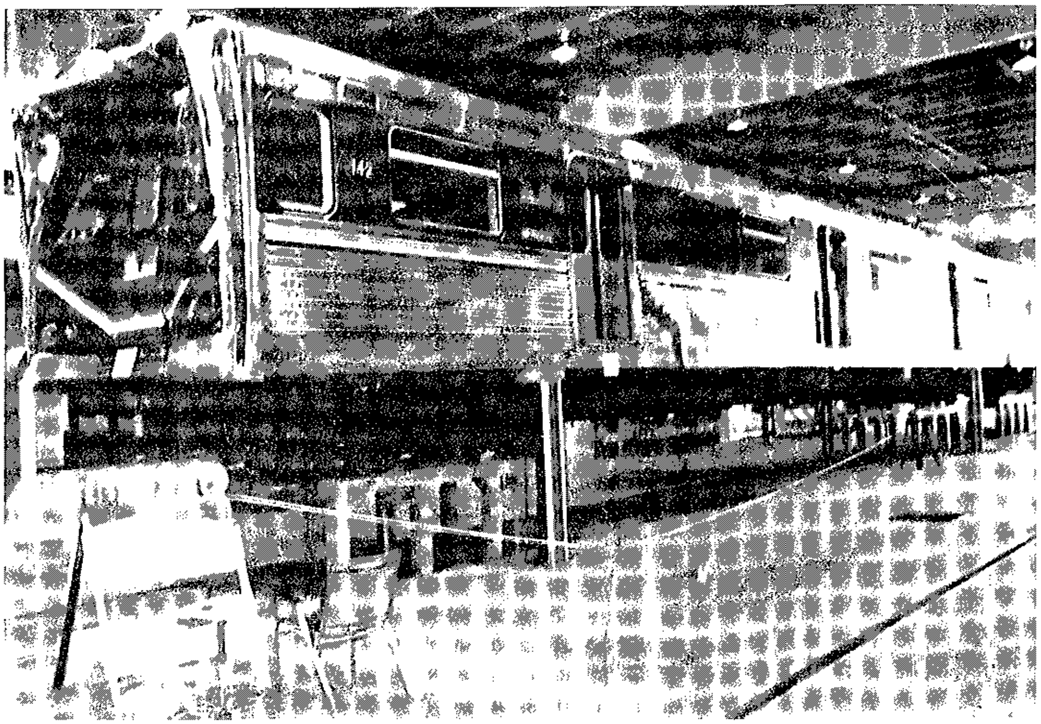


Figure 4.--F end of car No. 142.

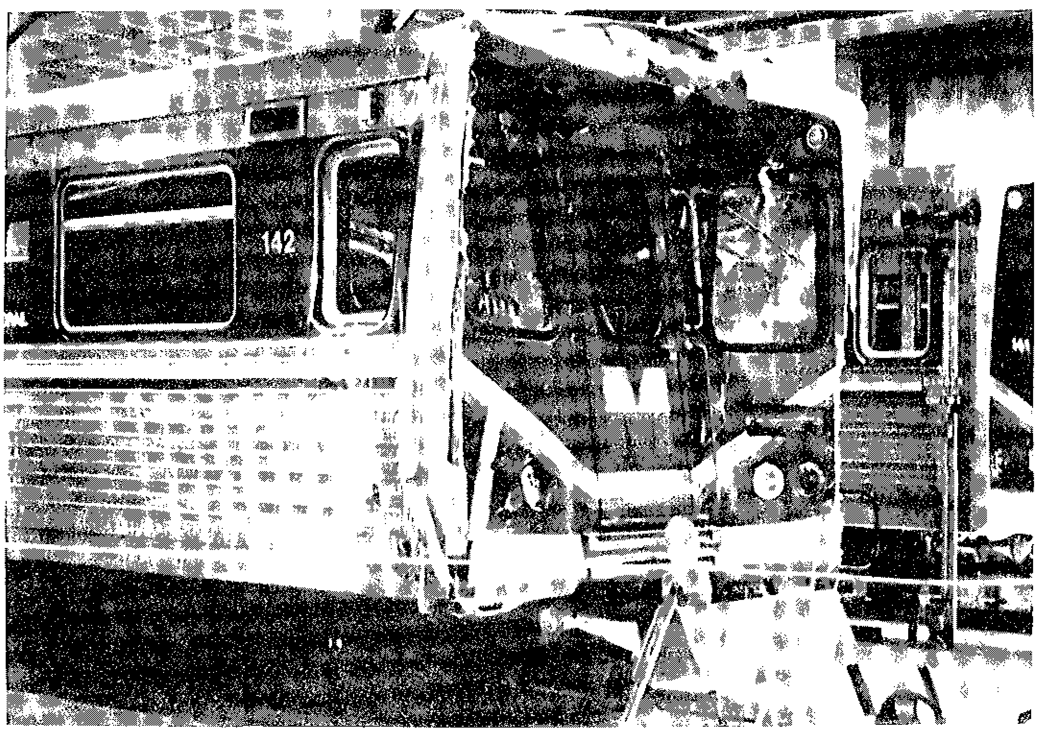


Figure 5.--F-end of car No. 142.

Figure 6.--F-end of car No. 172.

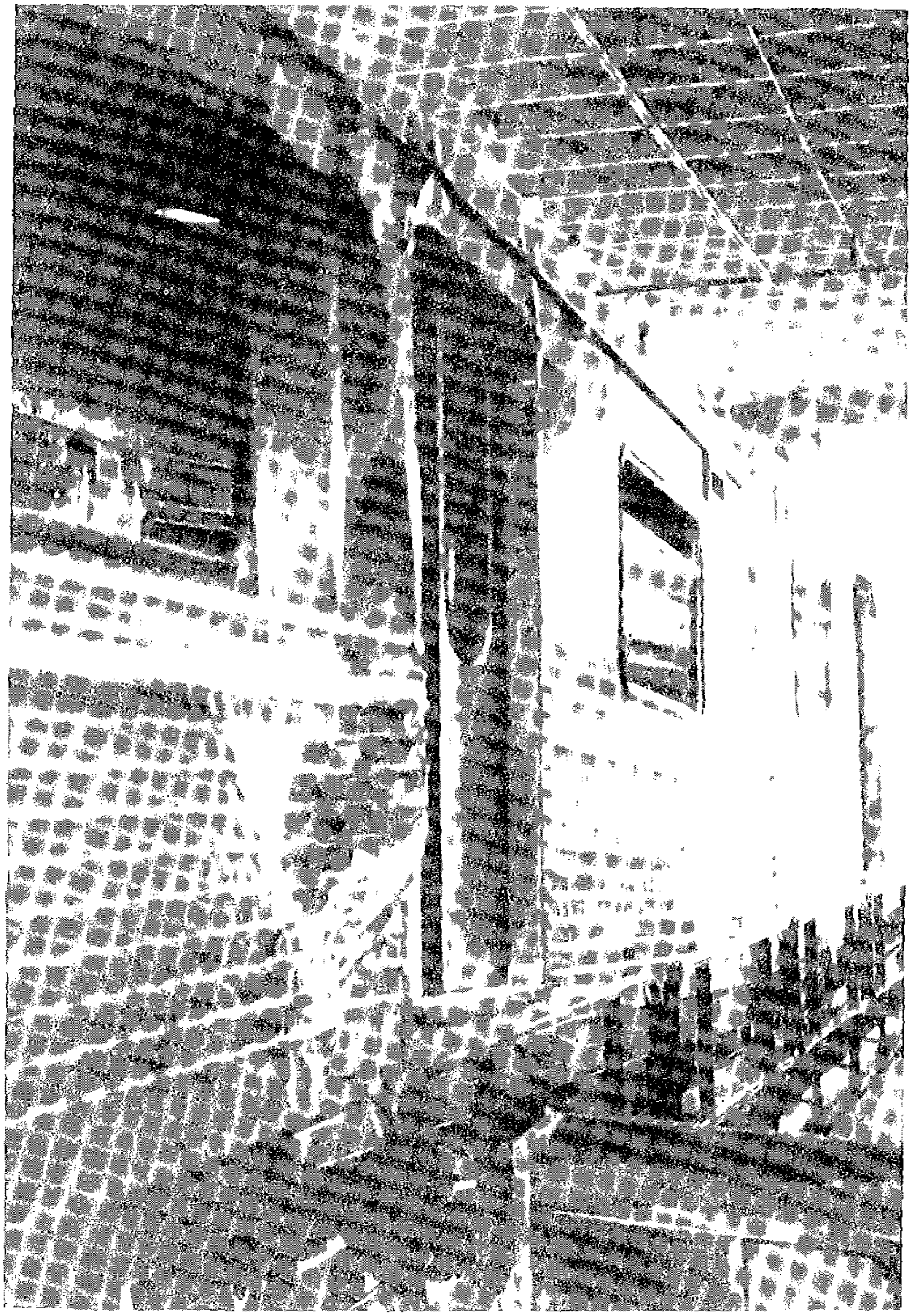


Figure 7.--R-end of car No. 172.

The MDTA estimated the damage to be as follows:

Car No.		Damage
141		$ 86,500
142		692,450
172		709,825
171		86,500
	Total	$1,575,275

Personnel Information

The employees involved in the accident had met the MDTA training and operating requirements for their respective positions. When the MDTA first opened for revenue service, some employees were required to work more than 8-hour tours of duty because of a shortage of qualified persons on certain jobs. The long tours of duty have been reduced for MDTA personnel because ample qualified persons are now available for the various assignments.

MDTA rail traffic controllers normally work an assigned 8-hour shift. However, the rail traffic controller who was on duty at central control at the time of the accident had worked a 12-hour shift, from 3 p.m. on June 25 to 3 a.m. on June 26, 1985. After 12 hours off duty, he reported for work at 3 p.m. on June 26 for an assigned 12-hour shift. He was working the 4 extra hours because some rail traffic controllers were attending training classes. The controller had worked 5 years as a rail traffic controller and 11 years as a train operator for the Port Authority Transit Company (PATCO) in New Jersey. He began work for the MDTA on December 17, 1984, as a rail traffic controller.

Because the rail traffic controller had previous controller experience with PATCO, which had an operation similar to the one at MDTA, he attended an abbreviated version of a rail attendant's training course. The major emphasis in the training was on-the-job training as a rail traffic controller for the MDTA system under a qualified MDTA controller. His personnel records indicate that he passed the course satisfactorily on June 14, 1985. However, he had been working as a controller before he completed his training. There was no numerical grade shown for his test, but he missed two questions out of 30. The two he missed were correct in meaning, but the answers were not worded exactly as the instructor wished. On June 17, 1985, he also completed the basic fire prevention course.

The rail attendant of train No. 172-171 was promoted from bus operator to rail attendant on January 19, 1985. He had completed the required company training courses satisfactorily. His personnel file contains the results of a physical examination required before his being promoted to the position of rail attendant, and there were no restrictions imposed on his service as a rail attendant, and he was not required to wear corrective lenses. During his training to become a rail attendant, he was given 12 quizzes and examinations along with fellow class members and his average grade was 90 percent, an average grade for his class. The rail attendant said that the training he had received was good and adequate. He had been working nonrevenue assignments primarily in Palmetto Yard rather than revenue assignments since he became qualified as a rail attendant.

Before June 20, the rail attendant of train No. 172-171 was assigned a work shift beginning at 5 a.m. or 6 a.m. until 1 p.m. or 2 p.m., but he frequently worked until 4 p.m. On June 23, after 2 days of rest he began working a new work shift assignment, working the hours of either 1 p.m. to 9 p.m. or 3 p.m. to 11 p.m. On June 24, he had worked from 2:50 p.m. until 12:50 a.m., 10 hours. On June 25 he had worked from 1:59 p.m. until 11:58 p.m., 9 hours 59 minutes. On June 26, the rail attendant reported for duty at 1:59 p.m.

The train control electrician onboard train No. 172-171 was hired by the MDTA on December 12, 1983. She had been trained in train control vehicle maintenance, basic fire prevention, basic emergency safety/electrical hazards, explosives and incendiary devices, and cardiopulmonary resuscitation and first aid. She was not required to pass an operating rules examination.

The brake electrician onboard train No. 172-171 was hired by the MDTA on January 14, 1985. He had been trained in basic fire prevention and had been tested in 14 different areas related to his job function for which he received passing grades. His supervisor had given him an above-satisfactory rating in his last performance evaluation. On June 25 he had worked from 10 p.m. to 6 a.m. He reported for duty on June 26 at 10 p.m. and was relieved shortly after the accident. He was not required to pass an operating rules examination.

Selection Criteria

The MDTA management selects potential rail attendants from bus operators in accordance with an agreement with the Transport Workers Union of America (TWU), which represents the operating employees. Preference is given to employees with the most service, and selection is based on the TWU agreement and guidelines provided by the MDTA's Office of Equal Employment Opportunity (EEO). However, on the MDTA, the guidelines provided by MDTA's Office of EEO are subordinated by the contractual agreement with the TWU.

The selection criteria for rail attendant trainees are as follows:

- seniority - (agency date in TWU)
- physical examination - (individuals who fail are temporarily bypassed until their medical problem is under control)
- reading comprehension test 17/ (individual must pass test with a score of at least 37 out of 50 to participate in the training)
- affirmative action goals to be established by EEO (the fiscal year 1984 goal was 14 percent women).

Rail Attendant Training

The MDTA's training program for rail attendants lasts about 25 days. Eight days are spent introducing and familiarizing students with the rail equipment and operating procedures. Instruction is given in the classroom and onboard the equipment. A rail instructor spends 7 days with the students in rail operations either in the yard or on the main track in nonrevenue service. Following the initial part of their training, the students ride in revenue service with qualified rail attendants for another 8 days and then spend 2 to 4 days with a rail instructor in rail operations.

The MDTA training course covers vehicle operations, safety rules and regulations, and job skills. The student's proficiency in the study material is tested by six tests and/or quizzes on vehicle operations, an operations safety test consisting of 100 questions, and a job skills tests series, divided into sections A through J and consisting of 200 questions.

17/ The MDTA first administered this test to the tenth (10) class, which began December 10, 1984, and to all classes thereafter. An NTSB staff member, who has a background in Human Performance, reviewed the validation process used by the MDTA and believes the test has reasonable validity as a selection instrument to measure minimum reading comprehension of applicants for the Rail Attendant training program.

The tests in all categories consist of a mixture of true or false, multiple choice, or fill in the blanks. Job/task analytic methods were not used in the development of the MDTA's training program. The rail attendant training curriculum was developed in-house by MDTA's senior-level management staff based on their combined knowledge and experience.

The series of tests are designed to refine the selection procedures so that those students who are not well suited to become rail attendants are failed and dropped from the training program. Eleven training classes have been conducted by the MDTA since it began operation. One hundred three students have enrolled in the training course and 21 have failed to pass the course. The rail attendant of train No. 172-171 enrolled in class No. 10 with 15 students in the class. Seven failed to graduate. Class No. 10 was the first class to take a reading comprehension test, the failure of which disqualifies the individual as a trainee. A grade of 85 percent and 75 percent for safety and job skills respectively, is required to pass the course. Upon approval by the rail instructor and after successfully passing all tests and quizzes, students are considered qualified as rail attendants. Students who fail to complete the rail attendant's training satisfactorily are allowed to return to bus operations.

In addition to the training described above, students are given about 30 hours of classroom instruction in basic fire prevention, basic emergency procedures, explosives and incendiary devices, and cardiopulmonary resuscitation and first aid.

Train and Equipment Information

General.--The MDTA cars are configured as a semipermanently coupled two-car combination referred to as a married pair. Two-car combinations can be combined to form four-car, six-car, or eight-car trains. Each car is provided with operating controls and most necessary operating accessories. However, single cars cannot be operated alone because some common components are shared. Even-numbered cars contain the ATP equipment while odd-numbered cars have the air compressors.

The car shells, the body skin, and the body structural frame members are constructed of stainless steel. The front of the car has a fiberglass end cap. The front of each single car is equipped with an energy-absorbing, automatic electric coupler. The draft gear on the F-end is designed to withstand compressive forces of 175,000 pounds. When this force is exceeded, the draft gear bolts are designed to shear and the draft gear compresses. When the draft gear compresses, the anti-climbers engage to prevent an override. Vertical collision posts adjacent to the end openings have a combined longitudinal shear load of 200,000 pounds and a transverse shear load of 50,000 pounds.

The car has three sets of double doors on each side. The center doors are equipped with emergency opening devices operable from either the inside or the outside, but the other side doors can only be opened from the inside. One half of each door is released by the operation of a manually operated emergency device. There are no emergency exit push-out type windows because the doors are intended as emergency exits. The car's end doors also can be used as emergency exits. Instructions in English only are posted to describe the operation of the side doors. Ladders are carried in the ceiling of each car for passengers to use to descend to the Guideway 18/ during an emergency evacuation, but their location is unmarked. However, a rail car key or a flat-blade screwdriver is necessary to release the ladder access cover, and it is intended to be accessed only by the rail attendant during an emergency. Each car has two fire extinguishers, one in the operating compartment and one in the passenger compartment.

18/ The elevated track structure.

The equipment used on the MDTA was manufactured by the Budd Company, built to specifications provided by Dade County. Car set No. 141-142 was delivered to the MDTA in October 1984, and car set No. 171-172 was delivered in March 1985. Each car is 75 feet long and has an average empty weight (no passengers but fully equipped) of 75,600 pounds.

Safety Systems.--The speed and brakes are manually controlled by a master control handle mounted on the operator's console. The master control handle is provided with a rotatable lever on the tip, which controls a deadman safety system. At all times when the train is in motion, the lever must be held in a position rotated 90 degrees toward the direction of travel. Immediately after the lever is released while the train is moving, a retrievable service brake application will be initiated. To retrieve brake control, the attendant must rotate the lever 90 degrees toward the direction of travel, and momentarily place the master control handle in the full service brake detent. 19/ If done immediately, this action will forestall the penalty service brake application.

The MDTA cars are provided with an overspeed audible alarm (sonalert) which activates when the train's speed exceeds the displayed speed command. Under certain conditions, the Sonalert will not sound: if the train is being operated in the yard mode with the ATP bypassed; if the rail attendant anticipates that a speed command is going to change to a lower speed and the car is in a braking mode when the change occurs; if the rail attendant is braking when a speed condition changes; if the train is being operated in the automatic train operation (ATO) mode; or, if the master control handle is in a coast 20/ position.

Three indicator lights are mounted on the outside of each car at the top left of the operating compartment which, when illuminated, indicate:

> Red----The car is or has been operated with the ATP bypassed. The red light can be extinguished only by a technician who must reset a control relay in an equipment cabinet located in the passenger compartment behind the rail attendant's operating position.
> Yellow--The train brakes are applied.
> Blue----The intercom push-to-talk button has been pushed by someone to use the intercom.

Brake Systems.--The MDTA equipment is provided with an electrical (resistive/dynamic) braking system and an on-wheel friction air-operated system activated by the master control handle. The car equipment has an electronically controlled brake monitoring system for which the main electronic control is identified as the F-2 brake control unit. The brake systems are blended, a function of the F-2 brake control unit, until the speed of the train decreases to about 4 mph, at which speed only the air brakes are effective. Through a tachometer, the F-2 brake control unit monitors the car wheels to detect a slip (spin) when the train is in power, or a slide when the train's brakes are applied. If either condition exists, the F-2 unit causes corrective brake responses to eliminate the condition. If the F-2 unit detects a slip/slide, it normally will reduce the brake cylinder pressure in corrective action for about 1 second. Corrective action will be applied only for a maximum of 3 seconds.

19/ A mechanical slot or indentation on a surface that will mark a position in the travel of a control lever to provide specified operating parameters.
20/ The master control handle in the coast position causes a minimum service brake application at a 1.5-miles per hour per second (mphps) deceleration rate.

The F-2 unit functions in a number of ways: to control the application and release of the brakes; to control the blending of the electric (dynamic) and air brake; to adjust the friction braking in service brake applications; to adjust braking responses based on passenger loading; and to monitor the deceleration rate during braking. The F-2 unit will impose a penalty emergency brake application if the deceleration 21/ rate is inadequate.

The service brake provides a controlled deceleration rate up to 3.0 miles per hour per second (mphps). The emergency brake is applied by pulling the master control handle rearward until it moves over a detent in its operating slot into the emergency position. Emergency braking initiated by the master control handle provides a deceleration rate of 3.2 mphps, and slip-slide protection is provided. An additional emergency brake valve, referred to as the "mushroom," is provided on the operator's console. When the "mushroom" emergency brake valve is used, the slip-slide protection is not provided.

The train brakes are designed to initiate in a service brake application if any of the following conditions exist when the train is being operated in the manual mode with the ATP operative:

(a) The rail attendant operates the train faster than the authorized speed command and does not acknowledge an overspeed alarm by reducing the train's speed within 3 seconds.
(b) The rail attendant is too slow acknowledging a reduced speed command.
(c) The rail attendant attempts to operate the train with a zero speed command.
(d) A door is opened en route, or a door opens and the train is not properly platformed for the loading or discharging of passengers.

The train brakes are designed to initiate an emergency application if any of the following conditions exist when the train is being operated in the manual mode with the ATP operative:

(a) The ATP/F-2 systems detect that the deceleration rate is not great enough to comply with a reduced speed command. Excessive slip/slide could create this condition.
(b) The rail attendant attempts to change operating modes while the train is moving.
(c) The speed command signal is lost.
(d) The ATP bypass switch position is changed while the train is in motion.

Modes of Operation-Equipment.--The MDTA equipment can be turned off or operated in three selectable modes. A selector switch enables the train operator to select either yard mode, manual mode, or automatic train operation mode (ATO). At the time of the accident, the ATO was not operational and trains were being operated in the manual mode. When the equipment is being operated in the manual mode with the ATP operative, the rail attendant controls the train's speed and braking by use of the master control handle. The train's maximum allowable speed is based on the speed commands displayed to the rail attendant on the operator's console. (See figure 8.)

When the ATP is operative, and the train is in the yard mode of operation, and a zero speed command is being displayed to the rail attendant on the operator's console, the train can only be operated at a maximum speed of 15 mph. If the ATP

21/ The minimum deceleration rate is 1.5 mphps.

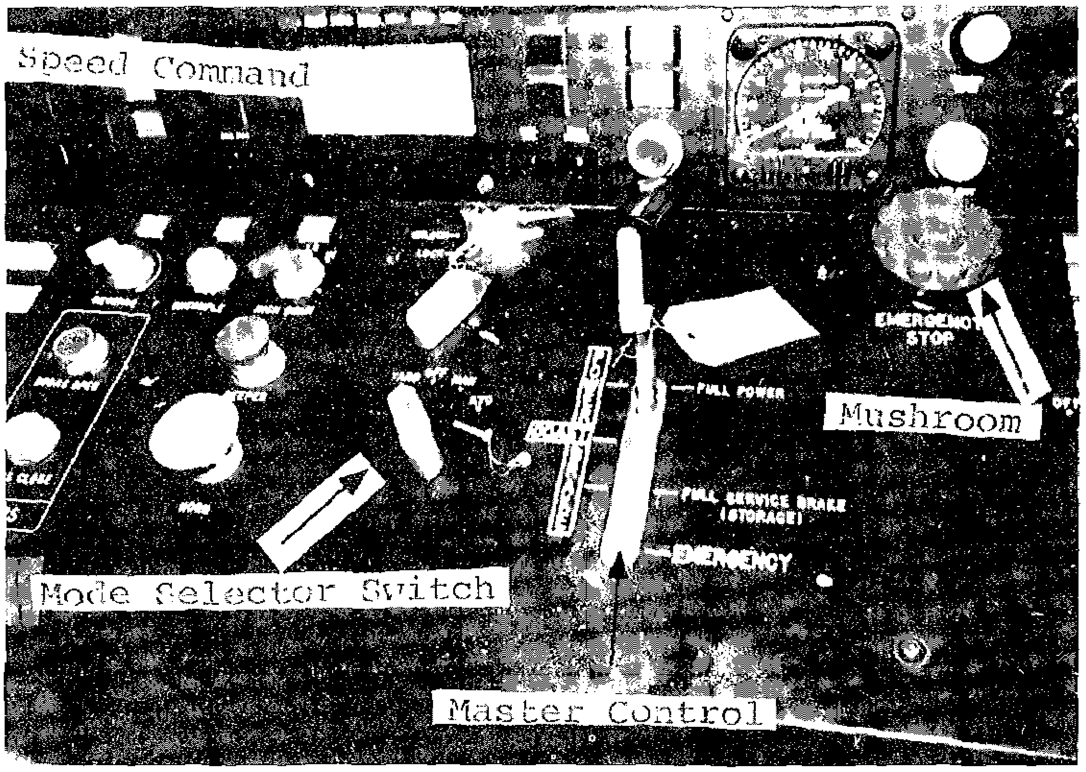


Figure 8.--Operator's console.

is bypassed while the train is in the yard mode of operation, the speed is unlimited (except for equipment limitations). The equipment cannot be operated with the ATP bypassed unless it is in the yard mode of operation.

In order to place the train in the yard mode and bypass the ATP, the train must be stopped and the mode selector switch moved to select the yard mode. Then the lead wire seal protecting the ATP bypass switch must be cut or broken and removed from the blocking pin. The blocking pin can then be removed and the two position toggle switch operated to the bypass position. (See figure 9.)

To change operating modes, the train must be brought to a stop and the master control handle must be in the full service brake detent. This action releases an interlock switch on the mode selector switch. Changing the mode selector switch to another mode while the train is underway will result in an emergency brake application.

After the accident, the operating controls of train No. 172-171 were found as follows:

(a) Master Control handle--full power, deadman control released
(b) ATP bypass switch--normal and lead wire seal applied
(c) Mode selector switch--yard mode
(d) ATP bypass indicator--red light-illuminated
(e) Radio channel selector switch--channel 1
(f) Emergency brake valve--- depressed.

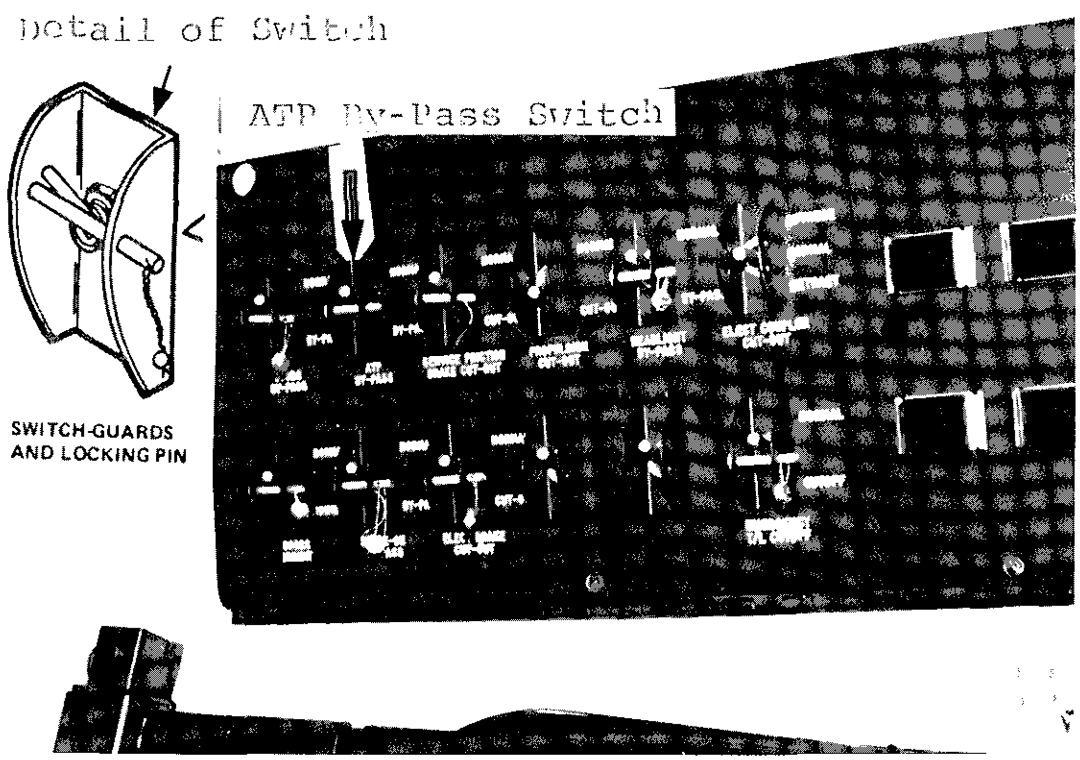


Figure 9.--ATP bypass switch.

Although the ATP bypass switch was in the normal position (ON) and apparently sealed, the ATP bypass indicator light was illuminated, indicating that train No. 172-171 had been operated in the bypass mode. The seal, however, was not properly applied and by pulling the wire at the base of the lead seal, the seal was opened. A properly applied seal would not open because the crimping tool applicator would have compressed the lead on the wire so tightly that the wire could not have been pulled out.

Signal Equipment.--Speed commands are generated by the trackside signal equipment. Speed command signals are injected into the rails at a separate and discrete audio frequency for each allowable speed. Programmed speeds are 70, 58, 46, 38, 28, 15, and 0 mph. Two antenna pickup coils are mounted on the front of the control car positioned directly over each rail. The antennas couple the audio frequency speed command signals from the rails into the on-board ATP equipment. The allowable speed for a given signal block is based on the signal block conditions ahead, and it is displayed to the rail attendant as a speed command on the operator's console.

Communications Equipment.--The operating compartment of each car is equipped with a two-way radio and an intercom system for intra-train communications. The radio is provided with three channels. Channel 1 can be used to contact the rail traffic controller or another train, channel 3 is a yard channel, and channel 5 is a maintenance channel. All trains in service on the main track are supposed to have Channel 1 selected and all communications transmitted on Channel 1 can be heard by everyone else on Channel 1. Radio communications on all three channels are recorded on a tape monitor.

The MDTA operating rules and procedures for the most part provide only general information on the use of the radio communication system, including some rules set forth by the Federal Communications Commission (FCC). However, specific rules state that:

> Communications pertaining to emergencies take priority over all others. . . : "Employees using radio communications must be certain they are in communication with the proper person. Radio calls must be initiated and acknowledged in a manner that ensures establishment of communication between the intended parties:" "Employees shall not take action until they are positive all transmissions or receptions are heard, fully understood and acknowledged." and "A radio communication in progress must not be interrupted except in case of emergency."

Track Information

The MDTA system is built almost entirely upon an elevated concrete structure. The system is comprised of the No. 1 track, normally designated for southbound trains, and the No. 2 track, normally designated for northbound trains. Interspersed along the route are interlocking signals and crossovers, which at the time of the accident were controlled from a local control panel. These facilities eventually will be controlled from the central control complex located at the MDTA headquarters, which is scheduled to become fully operational in 1986.

At the accident site the track is configured in a 4-degree, 40-minute left curve northbound with 4 inches of superelevation. The track is supported on precast concrete piers about 30 feet above street level. The continuously welded 115-pound, RE section rail, manufactured by the Colorado Fuel and Iron Company, rests on steel plates that are bolted directly to plinth pads. 22/ The rail is secured by Pandrol clips and is electrically isolated from the plinth pad and Guideway. (See figure 10.) The MDTA system is constructed to a standard gage, 56 1/2 inches between rails, used by major railroads in the United States.

Power System

Power for the MDTA train operation is provided from a 700-volt d.c. third rail. The third rail is positioned beside the operating rails and is covered by a protective fiberglass shield. The power system at the time of the accident was divided into six sections. (See figure 11.) Power is supplied simultaneously to each section from the north and south ends. When a circuit breaker is "tripped" by a fault at one end, the feed breaker at the opposite end also "trips," and the section is electrically dead. The power system has bridgeable gaps. However, the train control system is designed to prevent a train from entering a deenergized power section by presenting a zero speed command to the train before the train enters the deenergized power section. Thus, the train would be stopped before it bridged the power section gap, and the train would not become a conductor to allow electricity from the energized third rail to flow to the deenergized third rail. At stations with side loading platforms, a red emergency trip station (ETS) power removal button is located at the north and south ends of each platform. At stations where center loading platforms are provided, an ETS button is located at the north and south ends of the platforms. The locations of the ETS buttons are marked by blue lights.

22/ A small square or continuous elevated concrete base upon which the pad and tie plates are set to support the rail.

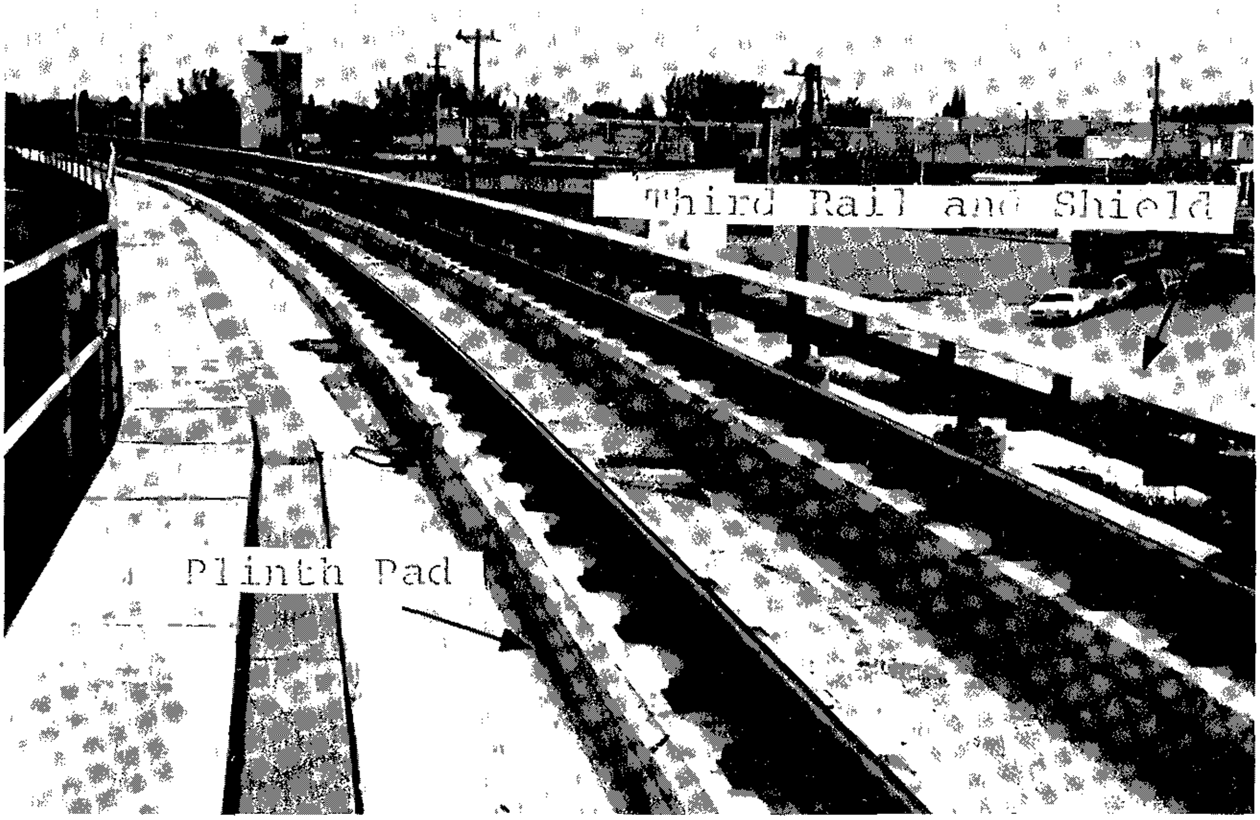
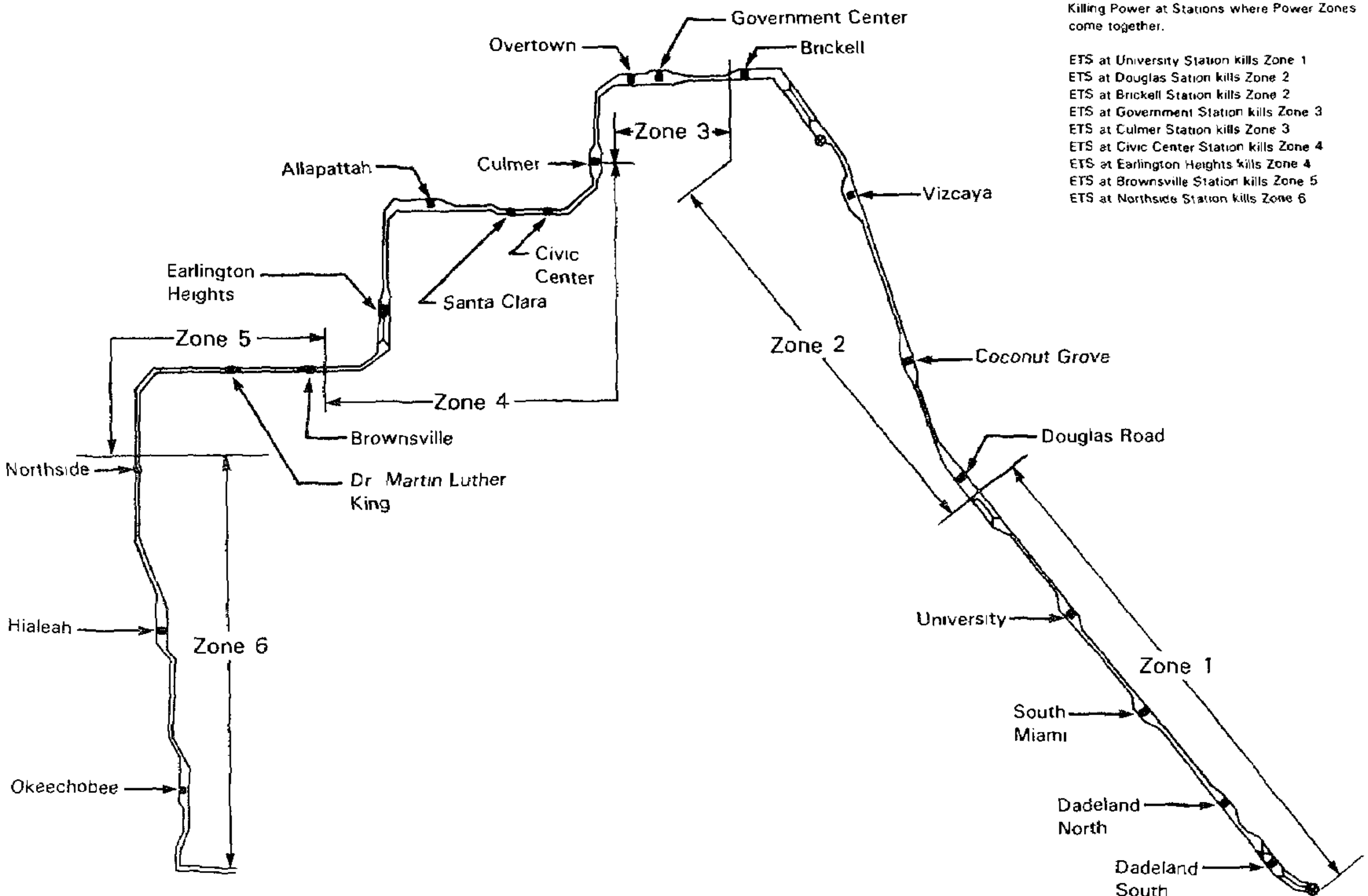


Figure 10.--Plinth pad on track.

When employees or emergency response personnel desire to remove power from a third-rail section while they are on the Guideway, one of the ETS buttons must be pushed. When the ETS button is pushed, a power feed relay is deenergized in the substation, and the power is removed from that power section. The ETS button is provided with a lockout feature to prevent power restoration. If the lock were released after the button has been pushed and released, an interlock would prevent power from being restored until the ETS button has been reset. However, to reenergize the third rail, power feed would have to be reestablished at a substation by the resetting of the feed breakers. There is no information provided to the operator of the ETS button that power has been removed from the section for which the button is operated, and there is no diagram at the ETS location to indicate the power section limits. Diagrams of the power section limits are provided to certain MDTA supervisory personnel and to fire/rescue personnel.

In addition to MDTA employees, emergency response personnel are trained also by MDTA instructors to know the location of the ETS buttons and how to operate them to remove third-rail power. Established and accepted procedures require the battalion chief of a responding emergency unit to send a member of his battalion to the nearest MDTA station to operate the ETS button or to check to see that it has been operated and locked out. The beginning and end of each power section are marked and identified by decals affixed to the sides of the third rail protective covering. Also, at points where the metrorail system crosses a city street, the power section is identified and the distance and direction to the nearest ETS button is shown.



Killing Power at Stations where Power Zones come together.

ETS at University Station kills Zone 1
ETS at Douglas Sation kills Zone 2
ETS at Brickell Station kills Zone 2
ETS at Government Station kills Zone 3
ETS at Culmer Station kills Zone 3
ETS at Civic Center Station kills Zone 4
ETS at Earlington Heights kills Zone 4
ETS at Brownsville Station kills Zone 5
ETS at Northside Station kills Zone 6

Zone 1 Tailtrack to Gap Just South of Douglas Road Station
Zone 2 Gap Just South of Douglas Road Station to Gap Just North of Brickell Station
Zone 3 Gap Just North of Brickell Station to Gap Just North of Culmer Station
Zone 4 Gap Just North of Culmer Station to Gap Just South of Brownsville Station
Zone 5 Gap Just South of Brownsville Station to Gap South of Northside Station
Zone 6 Gap Just South of Northside Station to Gap Just Before You Enter the Yard at N W 74th Street and 72nd Avenue

NO SCALE

Figure 11.--Third-rail power zones.

The rail traffic controller is the only person who is authorized to restore power. Before power can be restored to a deenergized power section, the controller must be assured, verbally, by the individual who requested the power's removal or his supervisor that power can be restored safely. When the controller is satisfied that it is safe for power to be restored, he can authorize a power service employee to restore the power. The power service employee can restore the power at a substation by resetting the power feed relays for the appropriate power section.

When this accident occurred, the rail attendant of train No. 141-142 and the rail attendant assigned to operate the Northside Station interlocking local control panel each operated separate ETS buttons at Northside Station to remove power from the third rail through the accident site. They believed this action removed the power at the location where the collision occurred, but they were not certain. Rescue forces, however, were told by MDTA personnel that power was off at the accident site when they arrived there about 11:48 p.m. Train No. 132-131 northbound arrived at Dr. Martin Luther King, Jr. Plaza Station on track No. 2 about 11:58 p.m. using propulsion power obtained from power section No. 5. Track maintenance personnel did not remove power from section No. 5 until shortly after 11:58 p.m.

Since the ETS buttons at Northside Station remove power from power section No. 6, which ends about 800 feet south of Northside Station, and the collision occurred 1,927 feet south of the Northside Station platform, which would be in the area served by power section No. 5, power was not removed from the accident area when the buttons at Northside Station were pushed. Fortunately, as a safety precaution, MDTA personnel used care and cautioned the passengers to keep away from the third rail during the evacuation.

To ensure that the third rail is deenergized certain MDTA supervisory personnel carry test meters and are trained to measure third-rail voltage. In addition, flexible wire straps used to ground the deenergized third rail are kept at each station, and some MDTA maintenance personnel and supervisors keep them in their automobiles. Only track maintenance personnel are authorized to apply ground straps. The battalion chief and the MDTA representative in the command post at an accident scene decide jointly whether or not to apply a ground strap. In this instance, ground straps were applied to the third rail after the power was cut off following the collision.

Method of Operation

The MDTA began rail service between Dadeland South Station and Overtown Station (see figure 1) on May 20, 1984. Trains are operated on the MDTA system by the ATP and ATO systems, and by cab signal indications, and when necessary, by oral or written train orders.

Trains can be operated on either track No. 1 or No. 2 in either direction. Direct communication between the rail attendant and the rail traffic controller is conducted by radio. The rail traffic controller, located in central control, is the final authority for train movement under all operating situations.

Trains are operated at 6-minute intervals during the morning or evening rush hours. At other times trains are operated at 12-minute or 15-minute intervals, and from 7 p.m. until service is discontinued, at 30-minute intervals. At the time of the accident, 30-minute intervals were being observed. Trains were scheduled to leave Dadeland South Station on the hour and half-hour, and from Okeechobee Station at 2 minutes and

32 minutes past the hour. A scheduled trip from Dadeland South Station to Okeechobee Station takes about 38 minutes. The controller keeps a record of train movements and unusual occurrences.

Before May 19, 1985, train orders, either oral or written, were issued to rail attendants at the beginning of their assigned runs because the ATP had not been certified for use and was not operational. Therefore, trains were being operated manually by train order authority and manual block rules. 23/

ATP System.--On May 19, 1985, the ATP was placed in service and thereafter, trains were operated in the manual mode by signal indications. The operation of trains with train orders and manual block operating rules was discontinued, and train orders were issued only when required. In the ATP mode of operation, the rail attendant controls the speed of the train in accordance with speed commands generated by trackside signal equipment based on track occupancy or conditions of advance signal blocks. The commands are displayed on the operator's console in a color-coded light display or in accordance with speed signs posted along the Guideway. The most restrictive speed of the two governs. Trains were being operated in the manual mode with the ATP operative on June 26.

When the ATO was certified and placed in service on December 9, 1985, the rail attendant's responsibility changed from that of an operator to that of a monitor for the train's operation; hence the title, rail attendant.

Several MDTA operating rules require a specific action by the rail attendant before the ATP system can be bypassed. Rule 2017 states, "Employees are not to alter or render inoperative any safety devices." Rule 4057 states in part, " . . . the operators of train shall change operating mode only after authorization from Central Control." (Other applicable rules are included in appendix B.) On June 27, 1985, the Deputy Director for rail operations issued Special Order No. 18, which outlined specific procedures to be followed when the ATP must be or is bypassed.

The operating rules do not specifically charge the technicians, such as those on test train No. 171-172, with the responsibility either of asking permission of the controller to bypass the ATP or of informing him if it is done. The technicians are not trained in operations or on the operating rules. However, rule 1055 states that all employees are expected to know and comply with all the rules in the operating rules manual.

Rail Attendant.--The length of signal blocks are adjusted to provide safe operation of the trains by providing adequate stopping distance from the maximum authorized speed for the most or a more restrictive signal aspect. The ATP also provides the rail attendant information about the track occupancy conditions ahead through the display of speed commands. When a train is approaching another train ahead, the speed commands gradually decrease block-by-block until a zero speed command is displayed. The rail attendant must stop the train when a zero speed command is displayed or the ATP will automatically stop the train. One or two zero speed commands, depending upon the

23/ Under manual block rules, the rail attendant was authorized to proceed to a designated location by the controller, who had determined that no other trains were occupying that section of track.

stopping distance available, are given in approach to an interlocking home signal 24/ displaying a stop aspect or behind an occupied signal block. An occupied signal block always presents a zero speed command to a following train.

The rail attendant can operate at a speed equivalent to or less than the speed command displayed on his console. If the displayed speed is exceeded, an audible alarm (the Sonalert) will sound, and within 3 seconds the rail attendant must make a service brake application to reduce the train's speed to conform with the speed command displayed, or the train will be stopped by the ATP system.

Rail Traffic Controller.--The MDTA system is designed so that, when the system is fully operational, the rail traffic controller will have a system model board displayed before him, by which he will be able to follow the movement of all trains by illuminated track occupancy lights. In addition, the board will indicate a train that is being operated with the ATP bypassed, and the rail traffic controller will be able to relate a train's location, as shown by the occupancy lights, to the power section being used by the train.

MDTA operating rule 4055 requires that the rail traffic controller issue a train order for unscheduled trains to be operated on the main track. The rule also requires that train orders be issued for unusual occurrences. Operating rule T-2015 requires that the rail attendant contact central control when unusual circumstances arise. (See appendix B.)

Meteorological Information

At 11:50 p.m., on June 26, 1985, the National Weather Service at the Miami International Airport reported that the temperature was 78 degrees F., the dew point was 73 degrees F., and the wind velocity was 6 knots from the south. The skies were clear and the visibility was 7 miles. There was no precipitation.

Medical and Pathological Information

At 3 p.m. on June 27, about 15 1/2 hours after the accident, the rail attendant of train No. 172-171 at the request of the MDTA voluntarily submitted blood and urine samples for toxicological analysis. Because of the interval between the accident and the time that the samples were taken, the rail attendant was requested to provide information about any food, medications, alcohol, or illegal substances, if any, he had consumed from the time of the accident until the samples were drawn. On June 27, he voluntarily signed a statement saying that he had not ingested any drugs or medications between the time of the accident and the time the samples were drawn. In fact, he said that he had not taken any medication on the day preceding the accident or the day of the accident.

The results of the toxicological analysis obtained by the Toxicology Testing Services, Inc. for the Worker's Compensation Medical Center, Miami, indicated that the blood sample contained 61 ng/ml (nanograms per milliliters) of diazepam and 40 ng/ml of nordiazepam, a metabolite of diazepam which is distributed under the trade name Valium. The urine analysis indicated the presence of 17 ng/ml of cocaine, 1,900 ng/ml of benzoylegconine, a metabolite of cocaine, and 240 ng/ml of delta-9 tetrahydrocannabinol (THC), the active ingredient of marijuana. The Toxicological Testing Services, Inc. concluded that the rail attendant had used cocaine and marijuana within 24 hours before

24/ A roadway signal at the entrance to a route or block to govern trains in entering and using that route or block.

the urine sample was taken, and that Valium had been taken within 48 hours before the blood sample was taken. The test for alcohol was negative. Portions of the blood and urine samples were sent to the Center for Human Toxicology in Salt Lake City, Utah, for comparative analysis. The results of the analysis from Salt Lake City confirmed the results of the Toxicology Testing Services, Inc. (See appendix C.)

The rail attendant denied taking any of these substances for a week before the accident. None of his coworkers detected any abnormal behavior in the rail attendant the evening before the accident. During a medical examination in November 1984, the rail attendant stated that he had been undergoing dental work and at that time occasionally he had taken Tylenol 3 (codeine and acetaminophen) for pain relief. Safety Board investigators contacted four dentists with the last name of the dentist identified by the rail attendant but none of them had a record of the rail attendant as a patient. Therefore, Safety Board investigators were unable to confirm his dental work.

MDTA operating rule 1037 prohibits an employee from possessing or being under the influence of alcohol or narcotics while on duty. Rule No. 1038 requires employees of the MDTA to report to their supervisors when they are taking medication that might affect their performance on the job. Supervisors are expected to be alert for employees who are taking medication, or who might otherwise be impaired in the performance of their duties. (See appendix B.) The MDTA requires employees to have physical examinations annually.

Crew and Passenger Injuries

The rail attendant of train No. 141-142 received a neck injury. The rail attendant of train No. 172-171 received a knee injury, bruises, and lacerations on his body. The brake technician received a broken arm and nose and neck injuries. The train control electrician received bruises and lacerations and a slight neck injury. The two unauthorized passengers on train No. 172-171 received cuts, bruises, and lacerations. The passengers on train No. 141-142 received cuts, bruises and facial and body lacerations. Individuals with injuries were taken to hospitals, where they were treated and released.

Survival Aspects

The F-end of car No. 172 was crushed severely. The operating compartment was survivable, but the deformation made it difficult for the rail attendant and the brake technician to extricate themselves from the compartment. The end door could not be opened. The train control electrician was able to open the first side door behind the operating compartment by using the manual emergency release. The occupants of car No. 172 evacuated the train by that route. Not all of the side doors were readily operable because of the body deformation. Because of the height of the track and cars above street level, rescue efforts were difficult. About three passengers were removed to the street by use of the emergency forces ladders, but the other passengers, led by either MDTA or emergency force personnel, walked along the Guideway to Northside Station where they were taken to nearby hospitals by emergency vehicles. By about 12:15 a.m. on June 27, all passengers had been removed from the trains and had left Northside Station.

The forward car in train No. 141-142, car No. 141, was not crushed or deformed so passenger's detraining was not a problem. Car No. 142 was crushed severely on the F-end where it was struck by train No. 172-171. The R-end of car No. 142 (the semipermanently coupled end) was distorted so that the end door (for passage between cars) could not be opened. Several of the side doors could not be opened readily because the car body was distorted. Rescue personnel broke a right-rear side window to get passengers out of the car. Eventually some of the side doors were forced open. Some passengers in car No. 141 left through the end door between car Nos. 141 and 142 and were able to reach the Guideway by that route.

After the accident, while the rail attendant of train No. 141-142 was attempting to open the end door at the R-end of car No. 142 to check the condition of the passengers, two male passengers came up to the door from inside the car seeking a way out. Through the closed door, the rail attendant warned them that they should not touch anything because they might be electrocuted. The two passengers later stated that after receiving this information they panicked and opened a small ventilator window over the top of a side car window and dropped to the Guideway.

When the accident occurred, the brake technician on test train No. 172-171 used a portable radio to contact the rail traffic controller and report the collision. The controller immediately notified emergency response forces via the 911 emergency number. Shortly after the brake technician had reported the accident, the rail attendant on the Budd test train (No. 189-190) on track No. 2, who had overheard some of the radio conversations relative to the accident at Northside Station, called the controller and reported that her train had not been involved in an accident and that the call was obviously a hoax. Based on this report, the controller was preparing to cancel the emergency call, but a rail supervisor, who was operating southbound train No. 104-103 on track No. 1, arrived at the accident site opposite the wrecked trains moments after the accident occurred and confirmed to the controller that there had been an accident. As a result, the 911 call was completed and emergency forces began arriving at the accident site by 11:48 p.m. (Appendix D is an evaluation of the emergency forces response as submitted by a Dade County Fire Department Official.)

Tests and Research

Car Equipment.--Following the accident, all critical safety components of train No. 172-171 were tested that were suspected or alleged to have been faulty and possibly to have contributed to the cause of the accident.

The ATP electronic unit was tested in a test rack following prescribed testing procedures. Next, the unit was installed in car No. 162, a car similar to car No. 172, for an operational test. The ATP antennas or pickup coils were tested for d.c. resistance and continuity. The resistance was within the specified values provided by the manufacturer, and there were no discontinuities in the coil windings. The ATP system was operating as designed and intended.

During the initial shop inspection of the cars' undersides, an intracar cable used to transfer ATP information between car Nos. 171 and 172 was found to be disconnected from its mating socket on car No. 171 and hanging loose. The end connected to car No. 172 was not locked securely in position, but was in its socket.

When a two-car unit is being operated from the controls of the odd-numbered car, all ATP signals picked up by the antennas on the odd-numbered car must pass through the intracar cable to reach the ATP unit contained on the even-numbered car for interpretation. When a two-car unit is being operated from the controls of the even-numbered car, the ATP signals are passed directly into the ATP unit, where the signals are analysed and the correct control function is executed. The intracar cable is not required in this instance.

The F-2 brake control unit installed in car No. 172 was removed and placed in car No. 161 for an operational test. It functioned as intended. Because of impact damage, not all of the cars' brake components could be tested, but air was supplied to the brake system and the critical components worked properly. The master control handle operated as it was designed to do.

On June 27 the wayside signal equipment was tested between Northside Station and Dr. Martin Luther King, Jr. Plaza Station. The wayside equipment was tested for the proper speed commands and occupancy responses under the following conditions:

(a) Signal 2, the northward home signal on track No. 2 at Northside Station interlocking, displaying a clear (proceed) aspect — no track circuits occupied.
(b) Signal 2 at Northside Station interlocking displaying a stop aspect.
(c) Signal 2 at Northside Station interlocking displaying a stop aspect — simulated train No. 141-142 standing on track No. 2 at the location of train No. 141-142 of June 26.
(d) Signal 2 at Northside Station interlocking displaying a stop aspect — simulated train No. 141-142 stopped as in (c) above. Simulated train No. 172-171 approaching train No. 141-142 from Dr. Martin Luther King Jr. Plaza Station.

On June 30, the same tests were repeated using rail equipment similar to that of trains No. 141-142 and No. 172-171. During all tests, the signal system transmitted the correct speed commands for the track conditions and track occupancy, and the system worked according to the design intent. When test train No. 172-171 approached test train No. 141-142, the speed commands decreased from 46 mph to 28 mph to 15 mph to 0 mph. When the 0 mph speed command was received, test train No. 172-171 was stopped within 60 feet after receiving the command.

Sight Distance and Stopping Tests.--Sight distance and stopping tests were conducted on June 30 and again on July 2, 1985. The environmental conditions were similar to those that prevailed on June 26 except that the rail was damp on July 2 because of a rain shower. Equipment of the same design and operating parameters was used for the tests.

Lighted markers were placed at the point where the rear of train No. 141-142 had been located before the collision. As test train No. 172-171 approached the markers simulating train No. 141-142, the markers were visible from a distance of 680 feet measured along the track. Seven test runs were made at different speeds. These tests were conducted based on the facts available at the time, to simulate what might have occurred during the accident. In five of the tests, the operator of the test train delayed between 5 and 8 seconds before applying the brakes; these simulated delayed response times were timed by a stop watch from the first sighting of the markers. (See appendix E.) These test runs were performed at speeds (40 to 46 mph) which were somewhat higher than speeds (35 to 38 mph) which had actually been attained during the accident sequence, according to subsequent testimony by the train attendant.

Impact Speed Calculations.—The MDTA estimated an impact speed of 30 mph. The Safety Board has estimated the impact speed to be about 26.4 mph using two mathematical methods based on the conservation of energy principle, obtained from the Department of Transportation's Technical Service Center, Cambridge, Massachusetts. (See appendix F.)

Method No. 1 was based upon the car manufacturer's design specifications. This method assumes that the damage (final) energy was distributed as work and friction over a finite distance. The kinetic energy relationship used, estimated the impact velocity to be 28 mph.

Method No. 2 was based on the average energy estimated to have been expended in the equipment's draft gears and the deformation damage inside and outside the cars of both trains. The total damage for both trains was estimated and the kinetic energy relationship yielded an impact speed of 24.8 mph. Averaging the impact speeds determined by methods No. 1 and No. 2 provided an estimated impact speed of 26.4 mph.

The brake technician on train No. 172-171 said that when he heard the rail attendant remark that a train was standing ahead of them, he ran from his position at the F-2 panel into the operating compartment. It took a person about 3.5 seconds to run from the F-2 panel into the operating compartment in a timed exercise.

ANALYSIS

The Accident

The design of the MDTA System allows for the safe operation of a number of trains on close headway on the same track through the automatic train protection (ATP) system. This system is designed to force the rail attendant to comply with the displayed maximum allowable speed since the train will stop automatically if the rail attendant ignores either an overspeed or a zero speed command. In this way, the ATP system provides protection for trains operating in close proximity to each other on the same track, whether the trains are following each other or opposing each other. It also provides protection for trains being operated against the accepted direction of traffic. A functioning ATP system would have provided protection for the trains being diverted from the No. 2 track to the No. 1 track between Northside Station and Okeechobee Station. However, the ATP system can provide protection only if it is used properly. MDTA's operating rules prohibit bypassing the ATP system without the permission of the controller, but the rules did not prevent test train No. 171-172 from being operated with its ATP system bypassed. Further, MDTA's failure to restrict the testing of trains during hours of revenue service was a dangerous operating practice and the Safety Board is pleased that corrective action was taken so quickly after the accident to ban testing of trains during revenue service.

Signal facilities on the track also protected the train against any trains or obstructions ahead, provided the ATP system was operative. The stop (red) signal aspect displayed by the home signal at the Northside Station interlocking provided a zero speed command to train No. 141-142 as it approached the interlocking home signal. The rail attendant of train No. 141-142 responded to the zero speed commands and correctly stopped the train. Likewise, the signal block occupied by train No. 141-142 and the signal block behind that occupied by train No. 141-142 presented zero speed commands to train No. 172-171, which ordinarily would have caused the ATP to initiate an emergency brake application. At the time of the accident, however, the ATP system had been bypassed on train No. 172-171.

When the ATP system is inoperative, the controller's role becomes critical because he must implement manual block operation and ensure that the necessary distance between trains for them to operate trains safely is maintained; on these occasions, the controller must issue train orders. The controller would have had to follow this procedure if the rail attendant had reported to him that the ATP has been bypassed. However, the rail traffic controller was not informed of the ATP system bypass. The rail attendant explained that he did not report that trains No. 171-172 /172-171 were being operated in the yard mode with the ATP bypassed, as required by rule T-1007, because he thought the controller had told him to take his instructions from the on-board technicians. While the two technicians knew that the controller was required to authorize operation of the train in the yard mode with the ATP bypassed, it was not their responsibility either to request permission from the controller to execute the bypass or to report the fact to him afterward. According to the MDTA operating rules, the rail attendant is responsible for the operation of the train.

The controller had been told by maintenance supervisors at Palmetto Yard that car set No. 171-172 had "dumping problems" when they asked him for permission to test the car on the main track. However, the controller had no information indicating that train No. 171-172 had been operated with the ATP bypassed or that it was, in fact, dumping. Although the rules required the rail attendant to report unusual occurrences, which would have included the undesired emergency stops, it seems hardly reasonable to expect that each stop would be reported, given the frequency at which they were occurring. Also, the train had been dispatched to test for this specific problem. However, the rail attendant should have given the rail traffic controller a summary report indicating that the train was being stopped repeatedly. Such a report may have generated a conversation about the desirability of cutting out and bypassing the ATP, in which case the controller could have established the correct operating procedure. He was not informed of these facts by anyone on train No. 171-172, and he did not recall seeing the red ATP bypass indicator light illuminated when train No. 171-172 arrived at Dadeland South Station. Although it is possible that the light relay had been reset, the brake technician, who was the only one who could have reset the bypass light relay, did not remember doing so.

Under the assumption that the ATP system on train No. 172-171 was operative, the controller was directing the movement of trains within the designed safety parameters of the system when he dispatched train No. 172-171 eight minutes behind train No. 141-142. Insofar as timing and headway were concerned, the 8-minute separation was well within the MDTA system's tolerance for safety.

The rail attendant gave no reason for the brake technician's putting train No. 172-171 in the yard mode of operation and bypassing the ATP system northbound. However, the ATP bypass light was found lighted after the collision, indicating that the train had been operating with the ATP bypassed. Additionally, with the mode selector switch positioned in the yard mode, the speed of the train could never have exceeded 15 mph with the ATP operational and the reported speed of up to about 40 mph would not have been reached. The train had to have been operated at a speed greater than 15 mph or it could not have reached Northside Station in 27 minutes. The attempt to reseal the ATP bypass switch was obviously an attempt to cover up the ATP bypass operation.

Since the rail attendant claimed he was taking his train orders from the technicians, he apparently did not question the technician's change of the operating mode. Inasmuch as the brake technician made the change in the operating mode, he may have assumed that it would be beneficial in facilitating the train's return to Palmetto Yard. The testimony concerning undesired emergency brake applications early in the northbound trip is conflicting, but there is no evidence that car set 172-171 experienced "dumping" problems, as such. Therefore, it is not clear why the ATP system was bypassed.

If the brake technician asked the rail attendant to call speed commands to him, he probably wanted to use the rate of the speed commands to facilitate his testing of the F-2 panel. However, whether or not the brake technician asked the rail attendant to call speed commands after the train passed Dr. Martin Luther King, Jr. Plaza Station probably is irrelevant. The rail attendant should have operated the train at the lesser of the two speed indications displayed either on his operator's console or by the speed signs posted on the Guideway as required by the operating rules. He testified that he saw a zero speed command displayed on the operator's console before the train entered the curve and before he saw either the tree or the standing train. Had he complied with the zero speed command displayed on the console before he observed the tree along the right-of-way and before he saw the rear of train No. 141-142, even with the speed enforcement feature of the ATP nullified, he would have been able to stop before striking the train. Postaccident tests proved that the ATP would have stopped the train well before impact if it had been operational.

Rail Attendant's Performance

The rail attendant's failure to respond to the zero speed command may have been affected by the periodic "dumping" on the southbound run. Each time the train "dumped," the speed command went to zero mph before the "dump," and this was observed by the rail attendant. Further, with the ATP bypassed, the speed commands would have continued to display a zero mph speed command when it would have "dumped" (by ATP action), but since the ATP was bypassed, the speed commands could be and were ignored without negative consequences. Therefore, the rail attendant may have been conditioned such that he no longer would respond to a zero mph speed command as he normally would. Further, he may simply have become desensitized to the speed commands by the erratic action he observed on the trip southbound. It is also possible that the rail attendant's actions or inactions may have been the result of the effects of drugs.

Although the rail attendant denied having taken any medication or drugs before or after the accident, the results of the laboratory tests indicated the presence of a metabolite of Valium in his blood and traces of benzoylecgonine (cocaine) and THC (marijuana) in his urine. The findings were verified by two separate and independent laboratories. Based on these independent findings, the Safety Board concludes that the rail attendant had used cocaine and marijuana within the 24 hours before the urine sample was taken, and that he had taken Valium within the 48 hours before the blood sample was taken. Since the samples were taken about 15 1/2 hours after the accident, the rail attendant could have consumed cocaine and/or marijuana anytime from 8 1/2 hours before to 15 1/2 hours after the accident. Any such use of drugs before the accident would have been in violation of rule 1037.

The time between the accident and the taking of the blood and urine samples in this accident complicates the interpretation of the results. The Safety Board believes that those employees subject to testing after an accident should be under surveillance until they are tested and that testing should be done immediately. Total urine THC metabolite concentrations greater than 100 ng/ml measured by the EMIT technique represent marijuana consumption within the previous 24 to 36 hours. (See appendix C.) The toxicological results from gas chromatography-mass spectrometry showed a 240 ng/ml concentration of THC metabolites in the rail attendant's urine (equivalent to a reading of 350 to 750 ng/ml by the EMIT technique), indicating a heavy use of marijuana. (See appendix C.) Experimentally, it has been shown that the urine of a subject who smokes one marijuana cigarette does not reach a THC concentration of 100 ng/ml as measured by the EMIT technique.

Although the rail attendant's actions at the time of the accident suggest that he may have been affected by these drugs, the Safety Board cannot positively attribute his actions to the use of these drugs. How frequently or extensively the rail attendant used drugs, either licit or illicit, is not known; the laboratory test results only confirmed that he had taken or used a variety of drugs sometime before or after the accident. The Safety Board is unable to determine the extent to which the use of drugs may have played any role in this accident because of the extensive period of time that elapsed between the accident and the testing.

The rail attendant of train No. 172-171 estimated that the speed of his train was between 35 and 38 mph when he saw the standing train ahead. The Safety Board has estimated that the impact speed was 26.4 mph. Assuming the train was traveling at 35 mph when the brakes were applied, at a deceleration rate of 3.2 mph/sec the train would have traveled 122 feet after the brakes were applied to decelerate to the 26.4 mph impact speed. Thus, had the attendant been alert and monitoring the track ahead, as he should have been, he would have had 558 feet while traveling at 35 mph, or 10.87 seconds, in which to have observed that train No. 141-142 was standing on the track and apply the brakes. At 38 mph, the train would have required 170 feet to decelerate to 26.4 mph and the attendant would have had 510 feet, or 9.15 seconds, in which to have perceived the stopped train and applied the brakes. Thus, had the attendant been alert and properly monitoring the track ahead, he would have had between 9 and 11 seconds within which to see the standing train, and perceive that it was stopped, prior to applying the brakes. A vigilant and otherwise unburdened operator of this type of vehicle should have been able to observe and recognize the standing object and react to it by manipulating the proper vehicle control within a few seconds at the most. Thus, from the time the rail attendant first had the opportunity to take action until the brakes were actually applied, between 9 and 11 seconds had passed, when only a few seconds, at the most, were needed to see the train, perceive it was stopped, and apply the brakes. Further, the stopping distance tests indicate that the train could well have been stopped in the time that would have been available had the rail attendant been alert and had he reacted within normal reaction time. Even at a speed of 46 mph, the greatest speed at which the stopping distance tests were performed, the train could have been stopped safely by the train attendant had he been alert and attentive to his primary duty of monitoring the track ahead.

It is difficult to identify the specific reason the attendant failed to stop the train when he clearly had the opportunity to do so, had he been alert, vigilant, and not physically or mentally slow to react. The controller at the Dadeland South Station may have alerted him to standing train No. 142-141 at Northside Station, but this fact is under dispute. If the controller did alert the attendant, this would have been 25 minutes before the accident, and the attendant could have forgotten the warning. Nevertheless, the attendant's primary duty while the train was between stations was to monitor the train speed and the track ahead. Little else required his attention. Even the calling out of speed commands should not have deterred the attendant from routinely monitoring the track ahead.

Therefore, the rail attendant either did not see the train, saw it but did not perceive it was stopped, or perceived it was stopped but was not able to apply the brakes in time to stop the train prior to the collision. The Safety Board cannot be certain which of these possible scenarios actually took place. If the train attendant did see the train in time to stop it safely but failed to perceive that it was stopped, or failed to react after realizing that it was stopped, it is possible that he failed to stop because of distraction; it is just as likely that the attendant's perception and/or reactions had been degraded, perhaps by drugs.

What is clear is that the attendant did not properly perform his duties of vigilantly monitoring the track ahead of the train or, if he was monitoring the track, he was unable to react in time.

Drug Use in Rail Operations

Although the Board sees the use of illicit drugs, such as marijuana and cocaine, to be a major safety problem, it also has investigated accidents in which the operator's performance may have been affected by prescription drugs apparently being taken in compliance with physicians' orders.

On December 3, 1984, in Atlanta, Georgia, Metropolitan Atlanta Rapid Transit Authority (MARTA) train No. 103, consisting of four multiple-car units, ran off the end of the track, approximately 1,000 feet west of MARTA'S Hightower Station. The lead car traveled at approximately 25 mph through a sandpile placed at the end of the track to stop runaway trains. As a result of this accident, two cars derailed. Fortunately, all of the passengers on the train had disembarked at Hightower Station. Property damage was estimated at $420,000. The operator of MARTA train No. 103 had evidence of dimetane, a prescription drug that should not be taken when operating machinery or vehicles.

On August 17, 1984, in Chicago, Illinois, southbound Chicago Transit Authority's (CTA) eight-car "A" train No. 135 struck CTA train No. 143. The motorman had stopped train No. 135 on a 3.1-percent grade and stepped out of the cab into a car. While the motorman was out of the cab, the train began to roll backward down the grade. The motorman reentered the cab and attempted to stop the train, but his efforts failed, and train No. 135, moving at about 20 mph, struck train No. 143. One passenger was killed, and 46 passengers and 3 crewmembers were injured. For a period of time prior to the accident, the operator of CTA train No. 135 had been given a combination of chemotherapy agents under the care of a physician, including vincristine, prednisone, cytoxan, and tagamet. The Safety Board concluded that "the medications the motorman of train 135 was taking for his illness had side effects that could have adversely affected his ability to perform his duties." The Safety Board further concluded that evidence does not indicate that this occurred.

The Safety Board believes that the findings of both licit and illicit drug involvement in these and other accidents indicate the need for prompt action by the rail rapid transit industry, labor unions, and government to evaluate licit drug use and to curb substance abuse by rail rapid transit operating employees.

The investigators of human performance aspects for rail rapid transit accidents are hampered because toxicological tests for drug use (licit or illicit) are not made immediately after serious rail rapid transit accidents in which the operator is not fatally injured. For example, the operator of MDTA train No. 172-171 was not tested for drugs until nearly 15 1/2 hours after the accident. The Safety Board believes that rail rapid transit safety would be improved if employees knew that toxicological tests would be administered immediately after an accident that involved (1) a fatality, (2) an injury, or (3) any property damage. Results of such toxicological tests could be reported to the Urban Mass Transportation Administration (UMTA), and disciplinary action could then be taken by the involved transit property.

On August 2, 1985, the Federal Railroad Administration (FRA) issued rules prohibiting substance abuse by railroad employees. Six areas, as listed below, are addressed in the FRA rules 25/ and may be useful as a guide for developing

25/ Title 49 Code of Federal Regulations Part 219--Control of Alcohol and Drug Use, August 2, 1985.

regulations appropriate to the rail rapid transit industry. These areas provide a useful starting point for the rail rapid transit industry in their development of regulations; however, the regulations developed for rail rapid transit should eliminate the loopholes found in the FRA's rules that exclude from testing employees involved in accidents because of arbitrary monetary damage reporting thresholds.

- Prohibit employees from reporting to work when they are impaired by alcohol or drugs and prohibit on-the-job alcohol or drug use.
- Mandate post-accident toxicological testing for the more significant accidents.
- Authorize the railroads to test employees for alcohol or drug impairment where there is reasonable suspicion.
- Require improved accident reporting.
- Mandate pre-employment drug screening.
- Require policies to promote early identification of problem drinkers or drug users.

Currently, there are no Federal or uniform State requirements for toxicological tests in the event of a rail rapid transit accident. UMTA has not taken any action to develop such requirements for the transit industry. The sister agencies of UMTA, which include the FRA, the Federal Aviation Administration, and the Federal Highway Administration's Bureau of Motor Carrier Safety, have developed regulations and programs addressing substance abuse in their respective industries. Additionally, the United States Coast Guard has recently issued an advance notice of proposed rulemaking (recreational boating operations) and a notice of proposed rulemaking (commercial marine operations) to address substance abuse in the marine transportation mode. 26/

The use of pre-employment drug screening may be useful for applicants for rail rapid transit safety-sensitive 27/ positions. This precaution would prevent the employment of some people with illicit drug problems, or others using licit drugs which may affect their ability to perform their duties safely. The Safety Board is aware through informal discussion that pre-employment screening has been used by one large transit system and results have indicated that 6 of 10 applicants for the first half of 1986, have tested positive for substance abuse. Pre-employment screening can also work with alcohol abuse problems. Although simple medical tests are not available, driver records can be checked for evidence of alcohol abuse. The Safety Board believes that rail rapid transit systems should check with their State Department of Motor Vehicles to obtain driver record information as a pre-employment screen for alcohol abuse. Further, the National Driver Register (NDR), maintained by the National Highway Traffic Safety Administration, can provide additional driver records; however, information from this system can be made available to transit systems only through the individual applicant's request to the NDR for such information. The applicant would then provide the transit system with the NDR report.

As a result of the August 17, 1984, accident in Chicago, the Safety Board issued Safety Recommendation R-85-90 to the CTA:

> Require the medical department to evaluate the types and dosages of prescribed medications taken by its operating personnel.

26/ U.S Coast Guard Dockets CG-D-099A and 099 entitled "Operation of a Vessel While Intoxicated," issued in 51 FR 18900 to 18913 on May 23, 1985.
27/ Positions charging the incumbent with the safety of traveling public based on his/her response to job functions and the discharge of duty thereto.

The Safety Board is persuaded that this recommendation should be applied to all rail rapid transit systems. Employees in safety-sensitive positions should be removed from critical safety tasks while under medication that adversely affect their performance.

The Safety Board also believes that UMTA should take the lead in developing and implementing regulations to address the growing concerns about drug use (licit and illicit) by rail rapid transit operating employees. The Safety Board supports a substantially increased effort by UMTA to improve its oversight of rail rapid transit systems. The American Public Transit Association (APTA) appears to be vitally concerned about the problem of substance abuse and should be willing to work closely with UMTA in developing uniform safety regulations that can be incorporated nationwide for all transit systems. Compliance with the safety regulations could then be the responsibility of individual transit systems, with UMTA monitoring implementation. The framework for the control of alcohol and drug use has already been developed in the FRA's regulations and, with certain appropriate modifications, may be made applicable to rail rapid transit systems. Further, UMTA should assist APTA and rail rapid transit properties in developing procedures and requirements to inform rail rapid transit employees of the potential deleterious effects of licit over-the-counter and prescription drugs on work performance. Such procedures and requirements should include, but not be limited to, the development of adequate medical records and systems for the dissemination of information on such effects to rail rapid transit operating employees. Finally, the Safety Board believes that every rail rapid transit property should have an effective employee assistance program (EAP). In a special survey for the APTA Personnel Committee, entitled "Employee Assistance Programs," completed on May 15, 1985, it was documented that seven of the heavy rail rapid transit systems had such programs; four had no program; and one did not report. The Safety Board believes that UMTA and APTA should encourage the implementation of such programs for all rail rapid transit systems, with appropriate training of supervisors to detect substance abuse.

Communications between Controller and Rail Attendant

Throughout the events that preceded the collision, there is evidence of a lack of communications between the rail attendant and the controller, and that they failed to understand one another adequately. The lack of communications was shown most clearly by the controller's not being informed, as required by the operating rules, that the ATP had been bypassed on both the southbound and northbound trips. The initial radio communication between the controller and the rail attendant, in which the controller gave instructions to the rail attendant, appears to have led to this misunderstanding. In view of the inexperienced operators in supervision and in train service, management should have provided more explicit guidance to operating personnel to ensure that everyone understood the requirements of their positions.

The rail attendant claims he requested train orders at Okeechobee Station, which would have been in accordance with rule 4055. There is no record of his request for orders but the controller issued orders to the rail attendant at 10:22 p.m. Sometime before that, the controller told him that written train orders were not necessary. The rail attendant said that he interpreted the controller's additional instructions to mean that he was to take verbal operating instructions from the technicians aboard the car set. However, technicians are not authorized to issue operating instructions and the rail attendant may have been misled by the vague instructions given to him by the controller.

During this exchange, the rail traffic controller should have been explicit in his instructions since the entire MDTA rail operation is relatively new, and new and inexperienced rail attendants are being introduced into the system continually. Moreover, since the ATP had been in service just a little more than a month when this accident occurred, the controller should have realized that he might be working with a newly promoted rail attendant, or with one who might not be used to operating trains with the ATP operational. If the controller had explained to the rail attendant that he believed that train orders were no longer required because the ATP had been put into service, the rail attendant may have understood why he was being directed to operate without train orders. It then would have been the rail attendant's responsibility to request clarification on the matter if he did not understand.

The controller also failed to demonstrate that he knew and fully understood the operating rules. Before the rail attendant departed Dadeland South Station operating train No. 172-171 northbound, the rail traffic controller should have issued another train order because train No. 172-171 was an unscheduled train, and rule 4055 requires all unscheduled trains to operate on train orders. It is also possible that this mistake occurred because he was fatigued after working a 12-hour shift on June 25 and being on duty 8 hours at the time of this accident. This could have caused him to overlook the requirement of rule 4055.

When train No. 171-172 stopped at Dadeland South Station for the return trip, the controller again issued verbal instructions to the rail attendant while he was standing on the platform instead of over radio channel 1. As a result, there is no record of the conversation. The rail attendant denied that this conversation ever took place, but the brake technician and the train control electrician said that they saw the two men talking together. No reason could be determined for the rail attendant to deny his conversation with the controller on the platform at the Dadeland South Station. Possibly, he forgot because of the trauma associated with the accident. Nevertheless, the content of the conversation between the two men is not known. Since the rail attendant did leave Dadeland South Station on signal indication, however, it seems reasonable that he must have gotten some operating instructions from the controller; this tends to support the testimony of the controller, the train control electrician, and the brake technician that a conversation took place between the two men at Dadeland South Station.

Both the rail attendant and the controller failed to apply the operating rules properly. When the rail attendant requested train orders at Okeechobee Station, for example, he was complying with operating rule 4055. However, his action seemed to be based on his knowledge of the method of operation before the ATP system became operational (on May 19). Had he understood that, although it is unnecessary to issue train orders to ensure the safe movement of the train with the ATP system operative, and that the safety of this type of operation is totally dependent on an operative ATP system, he should have understood that the ATP system should not be taken out of service without the controller's knowledge. Apparently, operations officers did not emphasize the fact that, even though the use of train orders in conjunction with manual block operation was discontinued for the normal operation of trains, train orders were still required for nonscheduled trains and unusual occurrences.

The rail attendant and rail traffic controller further displayed their inability to interpret the operating instructions properly by not requesting or issuing train orders at Dadeland South, which would have been consistent with their earlier actions at the Okeechobee Station. Apparently, the rail attendant did not realize that train No. 171-172 had completed its run when it arrived at Dadeland South Station and that the instructions he had received relative to the operation of train No. 171-172 were not valid for the trip north as train No. 172-171. He and the rail traffic controller should have known train

No. 172-171 would have needed new orders and instructions for the return trip, although his verbal instructions to the rail attendant, if given, would have satisfied this requirement in the controller's mind.

Training

All of the personnel interviewed during the investigation of this accident believed that their training was adequate. However, the responses to some of the questions asked of the rail attendants during the investigation, as well as the way the rail attendant of train No. 172-171 interpreted the controller's instructions, cause the Safety Board concern. Part of this concern is that MDTA's rail attendants and controllers are unable to discuss the rules fluently or correctly interpret their meaning. These concerns raise major doubts about MDTA's training and evaluation programs for rail attendants and rail traffic controllers.

After many railroad accident investigations, the Safety Board has become increasingly aware that a number of railroad employees seemingly know the company's operating rules in that they can quote them, but they do not know how to use those rules when an occasion arises. 28/ The Safety Board believes that more emphasis should be placed on practical applications of rules, whether in classroom exercises or on-the-job simulations. This concept is needed in the rail rapid transit industry as well. As a result of investigations in the railroad industry, the Safety Board has made safety recommendations to the railroad companies and to the Association of American Railroads (AAR) to encourage the named railroads (involved in the investigations) and the industry as a whole to correct this situation. Individual railroad properties have made some effort to improve such training, but much remains to be done.

One of the most recent recommendations issued by the Safety Board on training stemmed from the Board's investigation of the head-on collision of Amtrak trains at Astoria, Queens, New York, on July 23, 1984. As a result of that investigation, the Board issued the following Safety Recommendation, R-85-84, to the AAR:

> Review member railroads' current methods of conducting operating rules classes and administering tests for deficiencies and develop model instruction and testing procedures that will require employees to demonstrate that they not only know the wording of the operating rules but that they understand how the rules are to be applied both in normal and emergency operating conditions. Disseminate the model program to member railroads and encourage them to adopt the program.

The AAR's October 2, 1985, response indicated that it believed that the different typical characteristics of each property and the various types of operations precluded the development of model instruction and testing procedures. The Safety Board pointed out, in its letter of January 24, 1986, that the recommendation addresses a systematic approach or methodology of rules instruction which would apply throughout the industry regardless of the physical characteristics of the individual properties. The Safety Board

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28/ Railroad Accident Reports—"Head-on Collision of Amtrak Trains Extra 769 East and No. 195, Bristol, Pennsylvania, March 29, 1982" (NTSB/RAR-82/05); "Rear-end Collision between Conrail Trains OIPI-6 and ENPI-6X, near Saltsburg, Pennsylvania, February 26, 1982" (NTSB/RAR-85/02); "Head-on Collision of Burlington Northern Railroad Freight Trains Extra 6760 West and Extra 7907 East, Near Motley, Minnesota, June 14, 1984" (NTSB/RAR-85/06).

urged the AAR to reconsider the full intent of Safety Recommendation R-85-84, which has been placed in an "Open--Unacceptable Action" status. The June 26, 1985, accident in Miami again highlights the need for the railroad industry to conduct systematic job/task analyses for the development of training requirements, operating procedures, and performance standards to measure employee job performance.

The same characteristic exhibited by railroad employees relative to the operating rules is evident with rail rapid transit employees. The Safety Board is aware that the current procedures for instructing and testing railroad and rail rapid transit employees are not criterion-referenced to job performance standards and consequently do not predict how an employee will respond when an occasion requires him or her to apply a rule. The Safety Board believes that greater emphasis should be placed on monitoring employee performance on the job as a means to identify deficiencies in current training programs. One way to improve current training programs would be to add practice drills in simulated emergencies which would measure an employee's understanding and application of operating rules.

The interpretation and the knowledge of the application of the operating rules displayed by the rail attendant of train No. 172-171 in the June 26, 1985, accident in Miami is not adequate. His poor showing here may be due to inadequate training (i.e., by the fact that he did not know the operating rules and/or he did not know how to apply the rules), because he was under the influence of the drugs that he had ingested, or a combination of both factors. According to the results of training tests and quiz records, the rail attendant satisfactorily passed all phases of his training, which included the operating rules. The average 90 percent grade he received on tests during his training is average for his class. However, based on this rail attendant's performance and other rail accidents noted earlier, the Board is concerned that a test of knowledge of the operating rules during training is not sufficient to predict an employee's ability to interpret and apply the operating rules during a given task, especially if it is an emergency.

The Safety Board believes that the industry, UMTA, and APTA should collaborate to support a systematic approach to the development of effective training and evaluation programs so that employees entrusted with the lives of the traveling and commuting public are fully capable of understanding and safely carrying out all safety-critical elements. The Safety Board is aware of the trend in the rail rapid transit industry for an improvement in an individual's knowledge and application of transit company operating rules, just as is being done in the railroad industry, and supports this effort.

Testing of Trains in Passenger Service

Since the ATP system must be operative to safeguard train operations, especially when more than one train is on the same track, and the ATP system was, along with the F-2 brakes system, the object of the testing for car set 171-172, the Safety Board believes it was not a good operating decision to allow the testing of a train suspected of having these problems during revenue service. (On July 2, 1985, Special Order No. 19 was issued by MDTA operating officers, which prohibited testing of trains during times of revenue service.) When the yard supervisors were making arrangements with the controller to test car set 171-172 on the main track, they should have informed the controller that the trouble might be in the ATP or F-2 brake equipment. This might have caused the controller to delay the testing until after revenue service was discontinued for June 26.

Source of Braking Problems

The postaccident tests of the equipment on train No. 172-171 revealed no faults in the components of the ATP system, including the F-2 brake control unit. Other equipment also appeared to be operating correctly. The master control handle was found to be operating freely, and the responses to signal commands from the master control were correct and timely.

Although the technician suspected that the F-2 brake control unit was malfunctioning, the unit operated in accordance with its design in postaccident tests. The technician was rated by his supervisors as a competent technician and it seems unlikely that he would mistake a symptom of slip-slide trouble in the F-2 unit. In addition, since the MDTA was a relatively new operating system, the technician and other test and maintenance personnel were still becoming familiar with all aspects of the equipment and system, and they may not have been able to correctly analyze the problem.

That the brakes functioned at the time of the accident is further confirmed by the skid marks on the rails. In addition, the calculated speed of the train had slowed to about 26.4 mph at impact from the 35 to 38 mph the rail attendant estimated his speed to be when he entered the curve. If the brakes had been applied in sufficient time, i.e., when the first zero speed command was displayed on the operator's console (which the rail attendant saw), the train could have been stopped well before the impact. During the 3 to 5 seconds it took the brake technician to run from the F-2 panel into the operating compartment, the rail attendant had applied first the service and then the emergency brake. Stopping distance obtained for test No. 6 indicates that, even without the 1.5-second additional delay before braking action was initiated, there was still insufficient braking time and distance for the train to have stopped before colliding with train No. 141-142.

The original ATP card file may not have had any discrepancies because the braking problems continued during the train's southbound run when the electrician substituted another ATP card file for the original and the braking problems continued. However, since the ATP was bypassed at Northside Station, and the train control electrician was not certain where she had made the ATP card file substitution, this may not have been a valid test.

After the accident, the cable used to transfer ATP information between the two cars was found to be loose. Although loose, the cable between car Nos. 171 and 172 must have been mechanically, if not electrically, connected while the car set was being operated in the manual mode with the ATP operative during the initial portion of the southbound test run. Had the cable not been connected and making electrical contact most of the time, the train could not have moved at all.

When the intracar cable is connected into its mating socket on either car, the installer must twist a locking ring on the plug connector until it slips over a locking detent. If the locking ring is not rotated past the locking detent, the cable could be "seated" and make electrical contact, without necessarily being properly locked. Under these circumstances, the cable could vibrate loose. It would probably take a period of time for the cable to vibrate loose, but a loose cable could be expected to cause braking problems like those reported on car set 171-172 and could account for the reports of trouble on cars No. 171-172 for the period June 3 until June 26.

A zero speed command generally indicates a track condition which means that no speed signal is being carried in the rails. In other words, the speed signal is absent. If the speed signal from the track is not received in a valid form or not received at all by the ATP equipment, then the ATP equipment interprets that circumstance as no signal and transmits a zero speed command to the car controls. Therefore, in this accident when an ATP signal in the rails was picked up by car No. 171, if the signal was interrupted by a discontinuity in the cable as a result of the connectors being loose, no signal would have been received by the ATP equipment. Consequently, since the speed sensors detected positive speed but a zero speed command was being received by the ATP equipment, the ATP/F-2 equipment would initiate a braking command and stop the train. Because of the intermittent continuity of the ATP signal path through the cable connector, the changes in the speed commands would have occurred so quickly that the rail attendant could not acknowledge the changes fast enough to preclude the brake application. The malfunction could have manifested itself as the undesired brake applications which prompted the testing of train No. 171-172 on June 26. The Safety Board concludes that the equipment was performing according to design.

Car set 171-172 shared common electronic equipment irrespective of the direction of movement. The only difference in the operation of train Nos. 171-172 and 172-171 was that train No. 172-171 was being operated from car No. 172. As a result, the ATP signal received from the rails did not have to pass through the intracar cable, but it was fed directly into the ATP processing equipment contained on car No. 172 for interpretation. Since the ATP signal did not pass through the improperly connected cable, the signal was not intermittent. Therefore, there were no erratic changes in the speed commands to the car's controls and the train operated normally. Inasmuch as the "dumping" was not evident on the northbound trip, the loose cable was apparently responsible for the trouble reported on the car set 171-172, but not for the collision.

The technician's failure to find the trouble with the car set No. 171-172 is understandable because an intermittent problem is difficult to isolate. A casual inspection of the cable would probably not disclose the improperly locked locking rings. The MDTA should emphasize how to thoroughly inspect this cable and should check these connectors on a scheduled basis. Since the accident, the MDTA has instituted an inspection routine for these intracar cables.

Radio Applications

The MDTA's radio rules and procedures do not address specific uses of radio communications. The guidelines provided are general and the occurrences or situations that should be reported by radio are left to the discretion of the employees based on their interpretation of a general rule. Employees are expected to exercise their judgment as to what constitutes an emergency and requires a radio report to central control. The Safety Board believes that the MDTA should issue and enforce radio rules and procedures that provide specific guidance as to when and how the radio should be used. For example, since radio is the principal means of communication between a train and central control, all communications should be made by radio so a record can be maintained, and not by a face-to-face communication such as occurred at Dadeland South Station between the controller and the rail attendant. UMTA should require that rail rapid transit companies equip with operable radios all trains operating in revenue service.

The rail attendant of the Budd test train (No. 189-190) mistakenly believed that the accident report she heard on the radio referred to her train, and, therefore, she reported that her train was not involved in an accident. This caused confusion and could have caused an unacceptable delay in the controller's calling for the assistance of emergency forces. The MDTA should instruct its employees in proper radio discipline. UMTA should develop and promulgate a Uniform Code of Radio Operating Rules and Procedures for use by the rail rapid transit industry.

Power System

During emergencies, the electric distribution systems for electrically powered rail vehicles are a cause of safety concern, whether in the rapid transit or rail industries. The MDTA has worked with the Miami/Dade Fire and Police Departments to develop procedures to follow when an emergency requires emergency personnel to work near the electrified system. There is an ongoing program designed to educate the Miami/Dade emergency forces personnel on the use and control of the MDTA third rail power system. On June 26 however, the emergency personnel who responded to the emergency call accepted the word of various MDTA personnel that the power was off. Those persons who operated the ETS buttons were not certain how far south of the Northside Station the third rail was deenergized by the ETS buttons. There is no indication that any of the operating personnel referred to the power section limits diagram provided to them by their operating officers. As a result, the third rail was not deenergized until about midnight, and in the meantime, passengers, employees, and rescue personnel were present in and around the area of the collision with the third rail still energized.

On May 15, 1984, following its investigation of an accident on the MDTA System on April 29, 1984, 29/ in Miami, Florida, the Safety Board issued Safety Recommendation R-84-30 to the Metro-Dade Transportation Administration:

> Establish a positive method for informing all emergency personnel that third rail power is off and that it is safe to move to the track level.

On March 14, 1985, the MDTA responded that it had developed an interagency plan with the fire department for dealing with emergencies on the metrorail system. This plan included procedures for ensuring that third rail power had been shut down. While the Board classified R-84-30 in an "Open--Acceptable Action" status based on Metro-Dade's efforts to develop a plan, the Board expressed concern that the adopted procedures were not sufficiently encompassing and that they lacked detail and could result in confusion. In response to Metro-Dade's letter of November 20, 1985, the Board noted that the preliminary findings of the June 26, 1985, accident indicated that shortcomings remain in the manner in which the third rail is deenergized and how this information is relayed to appropriate personnel. Consequently, R-84-30 was reclassified in an "Open--Unacceptable Action" status. However, since a new recommendation addressing this subject is being issued as a result of the accident on June 26, recommendation R-84-30 will be superseded and classified as "Closed-Unacceptable action/superseded."

Fortunately, no one was injured as a result of the confusion about the third rail power system. However, the MTDA should provide some means of indicating to a person in the field who may be operating an ETS button, the area for which an ETS button deenergizes the third rail.

29/ Special investigation of a Rear-End Collision of Two Metro- Dade Transportation Administration test trains near Vizcaya Station, Miami, Florida, on April 29, 1984.(Before the system was officially opened for revenue service)

The Safety Board believes rail attendants should be trained in how to inform passengers properly that there is a danger in leaving an electrified car and especially if it is derailed. Comments were received from passengers that they were afraid of fire and of being electrocuted. The rail attendant of train No. 141-142 should have been instructed not to suggest that passengers might be electrocuted because of the derailment without giving valid reasons. Passengers should be encouraged to remain in the car until the propulsion power is removed from the third rail. The manner in which the rail attendant of train No. 141-142 made the announcement concerning the electrical danger caused the two panic stricken passengers, who used the ventilation window, to risk escaping by that route.

Survivability and Crashworthiness Factors

The fact that the rail attendant and brake technician survived in the operating compartment of car No. 172 after an approximate 26-mph impact demonstrates that the equipment crashworthiness was adequate in this accident. It is not surprising that the deformation occurred to the operating compartment, but even so, the two occupants escaped without assistance and without life-threatening injuries. The escape route from the rail attendant's compartment is either through the car end door or through the passenger compartment and out through a side door. The passengers were thrown around within the cars, but the seats and interior furnishings remained intact and no one complained of any specific component or furnishing causing an injury. Overall, the design of the cars seems to have included well proportioned structural members that provided strength against extensive crushing and deformation, and the design provided protection for the passengers.

The jamming of some of the side doors and damage to the end doors does cause the Safety Board concern, however. The Safety Board realizes that engineers cannot design for high speed impact crashes to eliminate all "give" in the car body since the collapsing of the car body is a means of dissipating the kinetic energy of the impacting vehicle. Too much resistance to impact forces could well cause additional injuries to car occupants. However, it is essential that provisions are made for the passengers to get out of the cars. Both end doors of car No. 142 were inoperable. It seems that passengers considered these doors to be their avenue of escape, and they paid little attention to the six side doors. On March 19, 1982, following its investigation of a derailment on the Washington Metropolitan Area Transit Authority (WMATA) on January 13, 1982, 30/ the Board issued Safety Recommendation R-82-18 to the WMATA:

> Implement a continuing program to educate passengers on the procedures to be followed when it is necessary to evacuate a disabled train.

Also, following the same accident, on October 15, 1982, the Board issued Safety Recommendation R-82-72 to WMATA:

> Post emergency information inside Metrorail cars at locations near the doors regarding the location and method of operation of the manual emergency door handle.

30/ Railroad Accident Report—"Derailment of Washington Metropolitan Transit Authority Train No. 410 at Smithsonian Interlocking on January 13, 1982" (NTSB/RAR-82/4).

To eliminate any possible confusion in escape routes, the MDTA should mark the emergency doors more clearly, publicize the manner in which the doors operate, and include instructions for use of the emergency ladders available for descending to the ground or Guideway levels. Also, a warning should be included about leaving the car by a side door because someone in excitement may step off on the field side of the aerial structure where there is no walkway and fall to the ground. Finally, the MDTA should ensure that emergency lighting is provided in passenger compartments when the main lights are lost.

CONCLUSIONS

Findings

1. The wayside signal equipment and the on-board automatic train protection equipment of cars No. 171-172 was tested and found to be functioning as intended.

2. Tests on the F-2 unit of cars No. 171-172 did not indicate any malfunctions that would have caused the brakes to operate improperly, and there was no indication of a failure with the F-2 unit that would have caused a slip-slide problem.

3. The loose cable connections between cars No. 171 and 172 probably caused the "dumping" problem for which the car set was being tested.

4. The crashworthiness design of the rail cars was adequate to prevent life-threatening injury to passengers and crewmembers as the designers intended.

5. The rail attendant of train No. 172-171 had ingested Valium, cocaine, and marijuana either before he reported for duty on June 26, while he was on duty, or after the accident.

6. The concentration of the marijuana metabolites in the rail attendant's urine sample is indicative of a heavy use of marijuana.

7. It could not be positively determined to what degree, if any, the rail attendant may have been under the influence of the drugs or marijuana while he was operating train Nos. 171-172/172-171.

8. The MDTA did not have an alcohol/drug screening or testing program on June 26, 1985.

9. Although the rail attendant satisfactorily passed his tests during his training, his responses to some questions asked during the investigation demonstrated that he did not fully comprehend the operating rules and their application.

10. The rail traffic controller either overlooked the rule requiring that rail attendants of unscheduled trains be given a train order, was not fully knowledgable of its application, or he was not aware of the rule.

11. The rail attendant failed to comply with the rules when he did not ask for the permission of the rail traffic controller to put his train in the yard mode and bypass the automatic train protection system.

12. The train control electrician and the brake technician were not required to obtain authority from the rail traffic controller to change operating modes and bypass the automatic train protection system on the test train in either direction, nor were they required to report the change to the rail traffic controller.

13. The rail traffic controller was not aware that he had complied with the requirements of rule 4055 which required him to issue train orders for train No. 172-171, an unscheduled train.

14. Operating test train Nos. 171-172/172-171 with the automatic train protection system bypassed without manual block rules/train orders, was a violation of operating and safety rules.

15. Tests trains should not be operated on the main track during hours of revenue service if they are suspected of having automatic train protection system or other safety appliance problems.

16. The maintenance supervisors should have specifically advised the rail traffic controller of the suspected problem with the automatic train protection system in addition to the more general "dumping" problem.

17. The rail attendant could have stopped the train before the collision if he had applied the brakes when he first saw the zero speed command on the operator's console unit as he approached the point of impact.

18 The rail attendant had between 9 and 11 seconds to detect the presence of the train, perceive that it was stopped, and initiate braking, and could have stopped his train if he had sighted the stopped train at the first opprotunity to see it.

19. The ATP bypass indicator light found lighted after the collision indicates that train No. 172-171 had been operated with the ATP bypassed.

20. The mode selector switch found positioned in the yard mode following the collision indicates that train No. 172-171 was operated with the ATP bypassed because the trains' speed exceeded 15 mph as evidenced by testimony and running time from Dadeland South Station to the point of the collision.

21. Train No. 172-171 would have been stopped before the collision if the automatic train protection system had not been bypassed.

22. The brakes on train No. 172-171 applied as was evidenced by the skid marks made by the sliding wheels on the rails.

23. MDTA personnel involved in or at the site of the collision did not know the limits of the area of the third rail power controlled by the emergency trip station buttons at Northside Station.

24. Because the deenergization of the third rail was not accomplished in a timely and orderly manner, rescue personnel, MDTA personnel, and passengers were at risk in the accident area.

25. Rescue personnel and MDTA personnel who may have to operate the emergency trip station buttons need to know the limits of the third rail power sections.

26. The rail attendant's uninformed warning about the danger of electrocution caused panic among the passengers of train No. 141-142.

27. Rail attendants should be knowledgable about the electrical hazards presented by accidents, especially in derailments, and how to instruct passengers in such situations.

28. Rescue personnel responded to the scene of the accident in a timely manner, and the rescue of passengers progressed effectively.

29 MDTA's training programs, operating procedures, and performance criterion standards were not developed on the basis of a systematic job/task analysis.

30. A pre-employment screening program should be developed to detect alcohol or drug abuse problems in potential employees.

31. A screening program should be developed to detect drug or alcohol problems in current inservice employees who are being considered for advancement to rail attendant or other safety-sensitive positions.

32. Rail attendants and other MDTA personnel using radio communications are not well trained in radio use and discipline, nor are the procedures for using the radio well developed.

33. The Urban Mass Transportation Administration has not developed radio operating rules and procedures for use by the Rail Rapid Transit Industry.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the failure of the rail attendant of train No. 172-171 to follow Metro-Dade procedures by operating the train with the ATP system bypassed and his failure because of inattention, distraction, or the effects of drugs, to monitor the track ahead of the train, perceive the standing train, and react in time to stop his train safely. Contributing to the cause of the accident were flawed transit system procedures which resulted in the testing of trains with known equipment defects on the same track with revenue passenger trains.

RECOMMENDATIONS

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

--to the Metro-Dade Transportation Administration:

Designate, when an incident requires that the third rail be deenergized, one individual on the scene as the power director through whom all information concerning the status of the third rail is disseminated to on site personnel and to Central Control. (Class II, Priority Action) (R-86-16)

Instruct all rail attendants and supervisory personnel on electrical hazards in and around derailed or damaged electrically propelled equipment, including the proper manner of informing passengers of the hazard and how to protect them. (Class II, Priority Action) (R-86-17)

Provide a diagram at each Emergency Trip Station button location so that persons who operate the button will know the boundaries of the third rail deenergization controlled by that button. (Class II, Priority Action) (R-86 -18)

Instruct rail attendants in the significance of observing the speed commands displayed on the operator's console, especially when the automatic train protection system is bypassed. (Class II, Priority Action) (R-86-19)

Develop radio rules and procedures that provide specific guidance on the timely and appropriate use of radio communications and instruct rail attendants and other employees in radio discipline. (Class II, Priority Action) (R-86-20)

Expedite the development and implementation of a plan to screen potential employees for drug and alcohol abuse. (Class II, Priority Action) (R-86-21)

Require toxicological tests for employees involved in an accident or suspected of being impaired in the performance of their duties because of drug or alcohol use. (Class II, Priority Action) (R-86-22)

Conduct a systematic job/task analysis of the job functions for the positions of rail traffic controller and rail attendant to identify the respective duties, responsibilities and qualifications for these positions. (Class II, Priority Action) (R-86-23)

Develop and implement, based upon the results of the job/task analysis, a program to train personnel selected for rail traffic controller, rail attendant, or other safety-critical positions to interpret and apply correctly operating rules and instructions. (Class II, Priority Action) (R-86-24)

Develop and implement, based upon the results of the job/task analysis, criterion referenced standards for evaluating and monitoring employees' understanding and application of operating rules and procedures as demonstrated by their performance on the job. (Class II, Priority Action) (R-86-25)

Identify clearly, the emergency features, and mark clearly and provide concise operating instructions for emergency equipment, i.e., fire extinguishers, ladders, exits. (Class II, Priority Action) (R-86-26)

Sponsor a public awareness program to inform the public of the safety features of the rail rapid transit cars and of the procedures to be followed for various types of emergencies. (Class II, Priority Action) (R-86-27)

Provide a reliable emergency lighting source that is independent of the car wiring for its power source. (Class II, Priority Action) (R-86-28)

—to the American Public Transit Association:

Assist the Urban Mass Transportation Administration in developing regulations to require that all employees involved in a rail rapid transit accident with a fatality, injury, or property damage be tested in a timely manner for alcohol and drugs. (Class II, Priority Action) (R-86-29)

Assist the Urban Mass Transportation Administration in developing regulations to require that rail rapid transit systems screen for drug and alcohol abuse all prospective and transferred employees prior to employment in safety-sensitive positions on rail rapid transit systems. (Class II, Priority Action) (R-86-30)

Assist the Urban Mass Transportation Administration and rail rapid transit systems in developing procedures and information systems to inform rail rapid transit employees of the deleterious effects on work performance of some over-the-counter and prescription drugs. (Class II, Priority Action) (R-86-31)

Assist the Urban Mass Transportation Administration and rail rapid transit systems in developing requirements that employees will be removed from safety-sensitive positions if the medical department determines their use of legal prescription drugs will affect their work performance. (Class II, Priority Action) (R-86-32)

Encourage the creation of effective employee assistance programs to detect and treat substance abuse among rail rapid transit employees in safety-sensitive positions. (Class II, Priority Action) (R-86-33)

--to the Urban Mass Transportation Administration:

Require that all employees involved in a rail rapid transit accident with a fatality, injury, or property damage be tested in a timely manner for alcohol and drugs. (Class II, Priority Action) (R-86-34)

Require rail rapid transit systems to screen for drug and alcohol abuse all prospective and transferred employees prior to employment in safety-sensitive positions. (Class II, Priority Action) (R-86-35)

Require rail rapid transit systems to institute procedures and information systems to inform employees of the deleterious effects on work performance of some over-the-counter and prescription drugs on work performance. (Class II, Priority Action) (R-86-36)

Require the removal of employees from safety-sensitive positions if the rail rapid transit medical department determines that the employees' use of a prescription drug will affect their work performance. (Class II, Priority Action) (R-86-37)

Encourage the creation of effective employee assistance programs to detect and treat substance abuse among rail rapid transit employees in safety-sensitive positions. (Class II, Priority Action) (R-86-38)

Require that rail rapid transit companies equip with operable radios all trains operating in revenue service. (Class II, Priority Action) (R-86-39)

Develop and promulgate a Uniform Code of Radio Operating Rules and Procedures for use by the rail rapid transit industry. (Class II, Priority Action) (R-86-40)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ JOHN K. LAUBER
Member

/s/ JOSEPH T. NALL
Member

August 5, 1986

APPENDIXES

APPENDIX A

INVESTIGATION AND DEPOSITIONS

Investigation

About 8:30 a.m. on June 27, 1985, the Safety Board's Miami, Florida, Field Office reported a rear-end collision on the Metro-Dade Transportation Administration property about 11:35 p.m. on June 26, 1985. The Railroad Accident Division of the Safety Board's Washington, D. C., headquarters immediately dispatched an Investigator-in-Charge and a team of four investigators from the Safety Board's Bureau of Technology to investigate the accident. The Investigator-in-Charge arrived in Miami about 11:45 a.m. on June 27 and the balance of the team arrived later that evening. Participants in the investigation were the Metro-Dade Transportation Administration and the Florida State Department of Transportation. The American Public Transit Association conducted a separate "Blue Ribbon" investigation.

Depositions

Sworn statements were taken from 12 witnesses on June 28, 1985 in a deposition proceeding for the development of factual information. On Friday, October 4, 1985, depositions were taken from four additional witnesses.

APPENDIX B

RULES

GENERAL RULES FOR METRORAIL

1002 Additional instructions are issued when required, either verbally by members of the supervisory force, or written in the form of a notice which is posted on the bulletin board. Employees must review the bulletin board daily.

1005 Employees shall be required to pass an annual examination on the Operations Rules and Procedures.

1111 Failure to comply with rules, instructions or notices or failure to operate in accordance with operating Procedures is considered sufficient cause for discipline.

1037 Employees must not possess or be under the influence of intoxicants or narcotics of any kind while on duty.

1038 If narcotics have been taken upon prescription by a physician, employees must advise their supervisors of same before reporting to duty.

1055 Rules designated in Part 2 of this manual with a "T" or and "M" for Transportation or Maintenance pertain more specifically to the employees of those departments. However, all employees are expected to be knowledgable of and comply with all the rules in this manual.

SAFETY RULES FOR METRO RAIL

2017 Employees are not to alter or render inoperative any safety devices

4055 Train Orders

Train orders must be issued in written form in order to protect and govern the movements of any unschedule vehicle entering upon the mainline. During emergency situations verbal orders may be issued, however the operator of the vehicle will write the order given by the dispatcher and read it back verbatim, then follow "F" and "G" below

Train Orders.

A Must be issued in the proper format.

B. Must be numbered.

C. Must show the time of completion, (i.e., the time when the order is repeated verbatim to the dispatcher).

D Must be made in duplicate and signed by the operator of the vehicle and the dispatcher.

E. One copy must be presented to the vehicle operator, one copy must be retained for Central Control Files.

F. The operator of a vehicle must ready and understand the train order issued and remain within the specific portion of track governed by the order. If an operator of a vehicle does not fully understand the order, he/she must contact the dispatcher for clarification.

G. Once a train order is in effect, it will continue until fullfilled, superseded, or annulled

GENERAL REGULATIONS

T-1004 Rail Attendants assigned to move defective trains shall request information concerning the condition of brakes, the operating speed, the route and the destination of the cars.

T-1007 Seals on control switches must not be broken without authorization from Yard Dispatcher or Central Control.

DEFINITIONS

3026 MODE (ATP BYPASS) - A submode of the yard mode to be used exclusively as a failure recovery means in the event that an ATP failure occurs such that the trains are rendered non operative. All ATP functions shall be ineffectual while in ATP Bypass. An Absolute Block must be established to allow train movement. Train speed is not automatically limited. ATP Bypass will only be allowed in emergency and only after authorization of Central Control.

OPERATIONS

D. ABSOLUTE BLOCK

4027 The Central Control Dispatcher shall establish an absolute block of defined and controllable limits to ensure the safe movement of train when:

T-2015 The Rail Attendant of a train stopped by fixed signal, cab signal, loss of power or unusual circumstance must contact Central Control immediately.

T-4029 Operator of the train shall request instructions from Central Control when it becomes necessary to cut out any carborne system

T-4035 Operator of the trains operating with the ATP Bypassed must excercise extreme caution and be prepared to stop their trains short of any obstruction. They must not exceed 12 miles per hour unless instructed to do so by Central Control, after an Absolute Block has been established with a prescribed regulating speed.

T-4037 When a train's brake system applies in emergency and it is not initiated by any action on the Train Attendant part, the Train Attendant shall.

A Attempt to recharge the train's brake system

B Notify Central Control and provide the following information

1. The train's identity, location and track number.

2 Whether the brake system recharged

C. Notify the passengers of the delay via the train public address system if the brake system fails to recharge, notify the Central Control Dispatcher you are going to investigate, secure the operating cab, apply parking brakes on the train and proceed to investigate, report back the results of the investigation to the Central Control Dispatcher.

D. Central Control Dispatchers shall inform trains approaching area of the condition, notify Car Maintenance Deparment and dispatch the nearest Transportation Supervisor to the scene

APPENDIX C

TOXICOLOGY REPORT

Toxicology Testing Service, Inc.

RAPID DRUG IDENTIFICATION USING MASS SPECTROMETRY

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July 5, 1985

REPORT PREPARED FOR:
WORKERS' COMPENSATION MEDICAL CENTER
6300 N.W. 77th COURT
MIAMI, FLORIDA 33166

TTS# 1392 and
TTS# 7056

REPORT ON TOXICOLOGY ANALYSIS OF JOSEPH MCRAE

As the attached report forms (Lab nos. 1392 and 7056) show, Toxicology Testing Service, Inc. analyzed blood, serum and urine samples from Joseph McRae. In the urine we found diazepam (Valium); cocaine and its metabolite, benzoylecgonine; and the metabolite of THC, the principal active ingredient in marijuana. Metabolites are products of chemical transformations which take place in the body of a person who takes a drug. These findings prove that Mr. McRae used marijuana, cocaine and valium at some time before providing the urine sample.

We performed additional analyses on blood and serum samples as described below in an effort to assess the significance of these drugs to the causation of the Metrorail crash in which Mr. McRae was a driver. This report will address each drug separately and then comment on the combination which we found.

Marijuana (cannabis) is classified in Controlled Drug Schedule I, so there is no legitimate way for a person to obtain and consume it. When smoked or injested, it produces euphoria, sedation and relaxation, and in high doses it may cause hallucinations, confusion, and anxiety. It distorts the perception of time and distance and impairs short term memory and mental performance. Physical symptoms of marijuana intoxication include tachycardia (increased heart rate) and reddening of the eyes.

When marijuana is smoked the THC is rapidly absorbed into the bloodstream and produces a state of intoxication beginning while the drug is being smoked and lasting for two to four hours. The concentration of THC metabolite, 1-nor-delta-9-tetrahydrocannabinol-9-carboxylic acid, in urine increases for approximately five hours after smoking, and declines over a period of days. The length of time over which marijuana use is detectable varies with the amount of marijuana consumed, the frequency of marijuana use and the sensitivity of the assay. With our assay this limit varies between one and greater than four weeks. However, the concentration of THC metabolite in the urine declines rapidly at first and more slowly after several days. Mano and Mano (1983) concluded that total urine THC metabolite concentrations greater than 100 measured by the EMIT technique represent marijuana consumption within the previous 24 to 36 hours. Our analysis by gas chromatography-mass spectrometry gave a result of 240 ng/ml for the THC metabolite in Mr. McRae's urine. This is equivalent to a reading on the order of 350 to 750 ng/ml by the EMIT technique. Therefore Mr. McRae had consumed marijuana within 24 hours prior to the urine collection within reasonable scientific probability. Furthermore he must have consumed a large amount of marijuana because studies have shown that experimental male subjects smoking one marijuana cigarette never reached concentrations of 100 ng/ml as measured by EMIT.

Cocaine is classified in Controlled Drug Schedule II because it has limited medical use and high abuse potential. It is never used as an out-patient medication, so when it is encountered in the urine of a person who is not hospitalized, i.e. for nasal surgery, it is evidence of "recreational" cocaine use. When used recreationally cocaine is consumed by sniffing the powder, by smoking (free basing), by injection and occasionally by oral ingestion. It produces mental stimulation and euphoria manifested by restlessness, talkativeness and anxiety and paranoia. Physical symptoms of cocaine intoxication include increased heart rate, hypertension, hyperthermia, increased respiration rate, and tremors.

The effects of cocaine appear within 10 to 15 minutes after it is snorted, and immediately when it is injected or smoked. Oral injestion is a relatively ineffective method of consumption because much of the drug is decomposed in the stomach. The duration of the cocaine high varies from approximately an hour to several hours depending upon the amount consumed.

Cocaine is rapidly eliminated from the body by conversion to inactive metabolites, principally benzoylecgonine which is excreted in the urine. The half life of cocaine (the time required for the concentration in blood to decrease by one-half) varies from 0.7 to 1.5 hours so the maximum concentration remaining in the blood would be approximately 1/1000 of the concentration 15 to 16 hours earlier. Therefore it is not surprising that we were unable to detect cocaine in Mr. McRae's blood. The fact that we detected unmetabolized cocaine in the urine is significant in estimating the time of last use of the drug. Baselt reports that a single dose yielded no detectable cocaine in the urine 12 hours later. We estimate an absolute limit of approximately 24 hours for the detection of unmetabolized cocaine in urine. Therefore since we found 17 ng/ml of cocaine in Mr. McRae's urine, I conclude that he used the drug within the 24 hours prior to collection of the urine sample.

Diazepam (proprietary name, Valium) is a sedative-hypnotic drug commonly prescribed to relieve anxiety. It is classified in Controlled Drug Schedule IV. It causes central nervous system depression, suppression of anxiety, diminished reflexes, drowsiness and fatigue. It is usually taken orally in doses of 2, 5 or 10 milligrams, and it is a common active ingredient in "bootleg" Quaaludes. When taken orally it produces effects generally within one hour, and the effects last three to four hours. Larger doses produce longer lasting effects. In studies, a single oral 10 mg dose produced an average peak blood concentration of 148 ng/ml at one hour. The diazepam concentration declined to 37 ng/ml by 24 hours while the nordiazepam concentration rose to 29 ng/ml. We found 61 ng/ml of diazepam and 40 ng/ml of nordiazepam in Mr. McRae's blood. I estimate from these findings that he took 10 to 20 mg of diazepam within the 48 hours before the sample was collected.

Although I cannot be certain that Mr. McRae was intoxicated at the time of the Metrorail accident approximately 16 hours prior to the collection of the samples, the fact that he had traces of three intoxicating drugs in his body indicates that he was heavily involved with drug use during the 24 hours preceeding the testing. Therefore the implications of these tests, while not diagnostic, must be considered as part of the totality of events surrounding the Metrorail accident.

Respectfully submitted,
TOXICOLOGY TESTING SERVICE, INC.

William Lee Hearn

Wm Lee Hearn, Ph.D.

CENTER FOR HUMAN TOXICOLOGY
UNIVERSITY OF UTAH • SALT LAKE CITY, UTAH 84112 (801) 581-5117

CONSULTANT CASE CC-1096-85

August 19, 1985

I. REFERENCE INFORMATION — Joseph McRae

TYPE OF EVIDENCE EXAMINED: Blood, Blood Clot, Plasma and Urine

REQUESTING AGENCY: National Transportation Safety Board
Washington, D.C.

II. EVIDENCE AND SOURCE — The samples were submitted by Dr. William Lee Hearns on July 11, 1985.

III. PURPOSE OF EXAMINATION — It was requested that the samples submitted be analyzed for the presence of drugs.

IV. RESULTS AND CONCLUSIONS — The blood was found to contain 3.6 ng/ml of delta^9-tetrahydrocannabinol, 43 ng/ml of carboxylic acid metabolite of delta^9-tetrahydrocannabinol, .04 mcg/ml of diazepam, .04 mcg/ml of desmethyldiazepam, and benzoylecgonine was found to be present at a concentration less than .05 mcg/ml. The urine was found to contain the carboxylic acid metabolite of delta^9-tetrahydrocannabinol at a concentration of 190 ng/ml and benzoylecgonine at a concentration of 1.9 mcg/ml.

V. DISPOSITION OF EVIDENCE — The samples are retained at the Center for Human Toxicology awaiting further instructions.

Dennis J. Crouch, B.S.
Associate Toxicologist

DJC/job

APPENDIX D

MEMORANDUM

MEMORANDUM

DADE COUNTY FORM 107.07 17A

TO R. J. Bennett, Chief
Training & Safety Division

DATE July 2, 1985

SUBJECT Metrorail Incident
of 6-26-85
Alarm #542354

FROM J. Bigler, Chief
OP-2"C"

As commander of this incident I found that the procedures used by both Metrorail personnel and Fire Department personnel to have been effective in this instance. Metrorail personnel made certain that the track was made safe, assisted in entering the affected cars and assisted in evacuation of passengers.

The cooperation of Metrorail personnel with the Fire Department was very good during this incident. Two Metrorail employees were found to be especially helpful to Fire Department units working up on the track area. These employees were Diane Duran and Linda Reed.

The original dispatch on this incident was a single company rescue (R-2) on a head injury at Northside Metrorail Station. Before arrival the incident was upgraded to a rail accident and the appropriate assignment dispatched.

On arrival at the accident scene R-2 and SQ-2 observed the cars involved and noted obvious damage. Metrorail personnel on scene confirmed that 3rd rail power was off and that track area was safe for our personnel to work. SQ-2 raised the boom ladder to the track and R-2 and SQ-2 crews entered the passenger cars to evaluate passenger injuries. SQ-2 crew also removed one window to allow evacuation of passengers since doors appeared to be jammed by damage from the collision. All passengers and crew members aboard were found to be ambulatory at this time. Four persons were evacuated via the ladder on SQ-2. On my arrival and assumption of incident command I discontinued evacuation by ladder. The remainder of the passengers were evacuated by way of the track walkway to the Northside Station.

After all passengers and crew had been evacuated to the Northside Station, Fire Department operations and command were relocated to the Northside Station for further treatment and transportation of injured passengers. R-2, R-7, SQ-2 and E-7 under command of Battalion 5 and OP-2 completed triage, treatment and transportation of 10 patients at Northside Station. Passengers were transported to Hialeah, Jackson Memorial Hospital and Cedars Hospital by medicar. Following transportation of all injured, the incident was terminated by incident commander.

JB/bs

APPENDIX E

BRAKING TESTS

Time for a train to travel 680 feet at a constant speed.

Train Speed	Time to Travel 680 Ft.	Comment
46 mph	10.1 sec.	Maximum Permitted Speed
40	11.6	High Range of Speed est. by McRae
35	13.2	Low Range of Speed est. by McRae.

Normal stopping distance for speed shown using either a full service brake or the emergency brake applied by use of the Master Control.

Train	Distance to Stop Full Service Brakes	Emergency Brakes
46 mph	520 ft.	485 ft.
40	390	365
35	300	280

Description of Braking Tests

Run No	Approach Speed	Delay Time After Passing Sighting Point	Braking Rate*
1	40 mph	0 sec.	FSB
2	46	0	FSB
3	40	5	FSB
4	46	5	EB
5	46	5	FSB
6	46	5	EB
7	46	7	EB

* FSB = Full Service Braking
EB = Emergency Braking

Run No.	Initial Velocity	Delay Time	Delay Dist.	Brake	Total Dist.	Total Brk Dist.	Over, shot Dist*	Impact Speed	Notes
1	39mph	0		FSB	377 ft.	377 ft.	(303)	None	
2	44	0		FSB	489	489	(191)	None	
3	41	5.6sec	337ft	FSB	754	417	74	17mph	
4	46	4.7	311	EB	796	485	116	26	speed @ brk 44 mph, slides during brk'g.
5	45	4.6	308	FSB	866	558	186	27	speed @ brk 46 mph
6	44	5.5	356	EB	811	455	131	28	slides during brk'g.
7	44	7.2	460	EB	871	411	191	32	speed @ brk 43 mph

Note: Figures in () are undershot, i.e., no impact

APPENDIX F

CALCULATION OF DISTANCE FROM PERCEPTION OF TRAIN AHEAD TO IMPACT

Impact Speed Determination (Conservation of Energy)

Method No. 1

Force Estimate from Damage

Car No.	Damage		Force (lbs)
142	Radius rods bent, F-end		140,000
	Floor Buckled F-end 3" down		50,000
	Coupler pin broken		50,000
	F-end crushed in 13.75"		100,000
	R-end draft bolts broken		100,000
	Safety hangers sheared		40,000
		Total	480,000
141	Floor warp, buckle		50,000
	R-end threshhold destroyed		100,000
	R-end draft bolts broken		100,000
	Safety hangers sheared		40,000
		Total	290,000
172	F-end radius rods bent-broken		220,000
	F-end crushed in 14.5"		100,000
	F-end coupler broken		100,000
	Safety hangers sheared		40,000
	R-end draft bolts broken		100,000
		Total	560,000
171	F-end floor buckled 6" down		100,000
	R-end draft bolts broken		100,000
	R-end radius rods bent		140,000
		Total	340,000

Crush Energy Dissipated = Ec

Ec = F x D = (Energy = Force x Distance)

142	480,000 lbs. x 13.75 in.	= 6,600,000	in-lbs
141	290,000 lbs. x 2.00 in.	= 580,000	in-lbs
172	560,000 lbs. x 14.50 in.	= 8,120,000	in-lbs
171	340,000 lbs. x 4.00 in.	= 1,360,000	in-lbs

Ec= Crush Energy Dissipated = 16,660,000 in-lbs

Movement Energy Dissipated E_T

$E_T = u \times W \times D$ (μ = coefficient of friction)

141-142 $E_T = .14 \times 154{,}600$ lbs $\times$ 70 ft. $\times$ 12 in/ft
$E_T = 18{,}180{,}960$ in-lbs

172-171 $E_T = .14 \times 152{,}600$ lbs $\times$ 55 ft. $\times$ 12 in/ft
$E_T = 14{,}100{,}240$ in-lbs

$E_T = 18{,}180{,}960$ in-lbs + 14,100,240 in-lbs

$E_T = 32{,}281{,}200$ in-lbs

Total Energy Dissipated E_o

$E_o = E_c + E_t$

$E_o = 16{,}660{,}000$ in-lb + 32,281,200 in-lbs

$E_o = 48{,}941{,}200$ in-lb

Vo= impact velocity of train 172-171

$$V_o = \sqrt{\frac{Eo \times 2\,g}{W}} \qquad g = 386 \text{ in/sec}^2$$

$$V_o = \sqrt{\frac{48{,}941{,}200 \text{ in-lb} \times 2(386 \text{ in/sec}^2)}{152{,}600 \text{ lb.}}}$$

$$V_o = \sqrt{247{,}592.43 \text{ in}^2/\text{sec}^2}$$

$V_o =$ 497.59 in/sec

$V_o =$ 28.27 mph 1 mph = 17.6 in/sec.

Impact Speed Determination
(Conservation of Energy)

Method 2
Emperical Estimate

Crush Damage E_{ave} = Average of structure damage for 172-171

$E_{ave} = 1/3\ (E_1 + E_2 + E_3)$

Where E_1 = draft gear damage

E_2 = outside structure damage

E_3 = interior damage

Energy as function of velocity

$$E = \frac{V^2 W}{2g} \qquad g = 386\ \text{in/sec}^2 \quad w = \text{weight}$$

Draft gear (max design 5 mph = V_1)

$$E1 = \frac{V_1^2\ W}{2g} = \frac{7744\ \text{in}^2/\text{sec}^2 \times 152{,}600\ \text{lbs}}{772\ \text{in/ sec}^2}$$

$$E_1 = 1{,}530{,}744\ \text{in-lbs}$$

Outside and Interior (assume $E_2 = E_3$, also impact damage limited to forward 2 feet of vehicle from anti-climber at 10 mph)

$$E_2 = E_3 = \frac{V_{2\text{-}3}^2\ (W)}{2g}$$

$$E_2 = E_3 = \frac{30{,}976\ \text{in}^2/\text{sec}^2}{772\ \text{in/sec}^2} \times 152{,}600\ \text{lbs}$$

$$= 6{,}122{,}976\ \text{in-lbs}$$

$$E_{ave} = 1/3\ (E_1 + E_2 + E_3)$$

$$E_{ave} = (1.530{,}744 + 2(6{,}122{,}976))$$

$$E_{ave} = 4{,}592{,}232 \text{ in-lbs}$$

Crash Damage for 141-142 $E_c = 1/2\ F \times S$

$= 1/2 \times 100{,}000 \text{ lbs} \times 13.75 \text{ in}$

$= 687{,}500 \text{ in-lbs}$

Movement Energy, E_T, from Method 1

$$E_T\ (141\text{-}142) = 18{,}180{,}960 \text{ in-lbs}$$

$$E_T\ (172\text{-}171) = 14{,}100{,}240 \text{ in-lbs}$$

$$E_T = 32{,}281{,}200 \text{ in-lbs}$$

Total Energy Dissipated, E_o

$$E_o = E_{ave} + E_c + E_T$$

$$E_o = 4{,}592{,}232. + 687{,}500 + 32{,}281{,}200$$

$$E_o = 37{,}560{,}932$$

V_o = impact velocity of train 172-171

$$V_o = \sqrt{\frac{E_o \times 2g}{W}}$$

$$V_o = \sqrt{\frac{37{,}560{,}932 \times 2(386 \text{ in/sec}^2)}{152{,}600 \text{ lb.}}}$$

$$V_o \sqrt{190{,}020 \text{ in}^2/\text{sec}^2}$$

$$V_o = 435.9 \text{ in/sec}$$

$$V_o = 24.8 \text{ mph}$$

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