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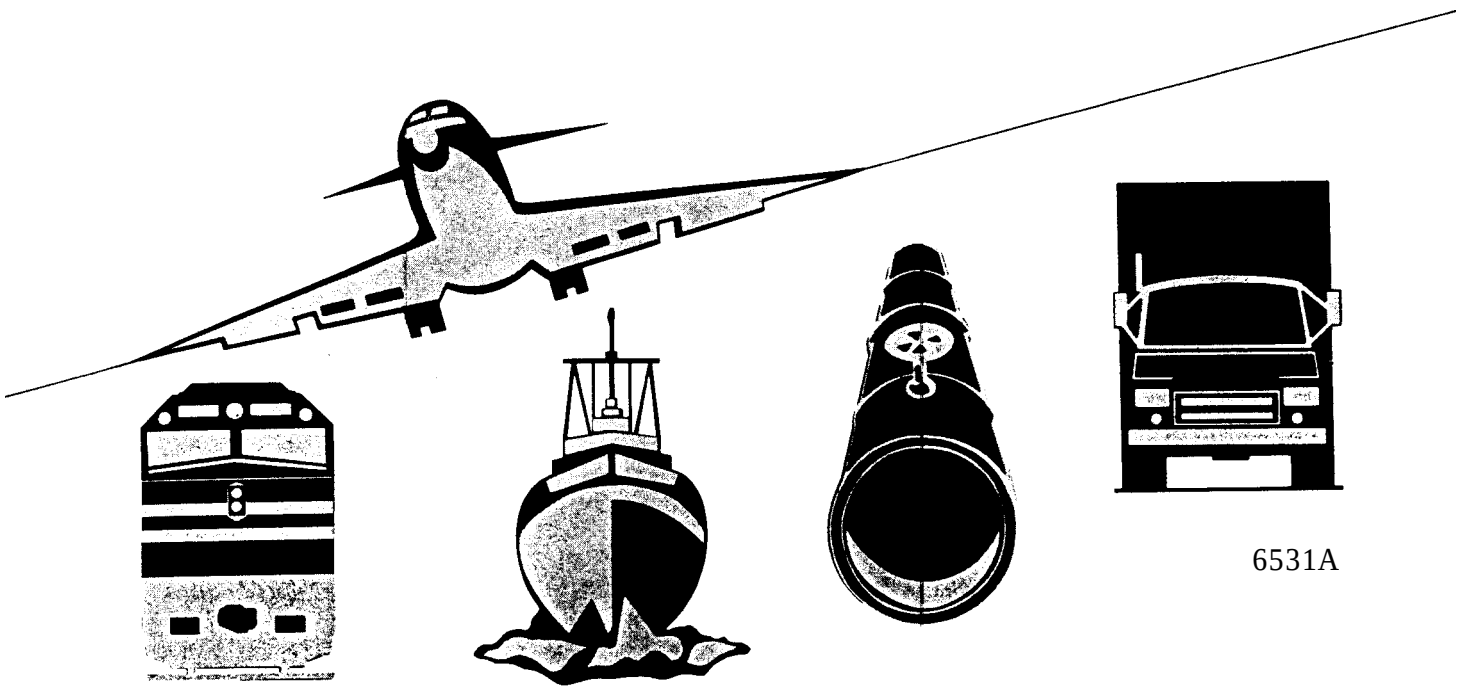
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, DC 20594

RAILROAD ACCIDENT REPORT

**COLLISION AND DERAILMENT OF TWO SUBWAY TRAINS
METROPOLITAN TRANSPORTATION AUTHORITY
NEW YORK CITY TRANSIT
IN BROOKLYN, NEW YORK, ON FEBRUARY 9, 1995**



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Abstract: On February 9, 1995, a Metropolitan Transportation Authority/New York City Transit subway train collided with a stopped subway train. The rear-end collision, in which 11 passengers and 4 transit employees sustained minor injuries, occurred on elevated track south of the Ninth Avenue station in Brooklyn, New York.

The major safety issues discussed in this report are the effectiveness of automatic stop arms to ensure compliance with stop signals and the adequacy of transit system oversight to ensure compliance with operating rules. The report also includes safety issues relating to speedometers, radios, positive train separation, crashworthiness and occupant survivability, and emergency response.

As a result of its investigation, the National Transportation Safety Board issued safety recommendations to the Metropolitan Transportation Authority/New York City Transit.

COLLISION AND DERAILMENT
OF TWO SUBWAY TRAINS
METROPOLITAN TRANSPORTATION AUTHORITY
NEW YORK CITY TRANSIT
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RAILROAD ACCIDENT REPORT

Adopted: March 19,1996
Notation 6531A

NATIONAL
TRANSPORTATION
SAFETY BOARD

Washington, DC 20594

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APPENDIXES

EXECUTIVE SUMMARY

At 2:39 p.m. on February 9, 1995, a Metropolitan Transportation Authority/New York City Transit (NYCT) northbound M line subway train collided with the rear car of a stopped NYCT B line subway train. The collision occurred on elevated track about 1,011 feet south of the Ninth Avenue station in Brooklyn, New York. Four NYCT employees and 11 passengers sustained minor injuries.

The National Transportation Safety Board determines that the probable cause of the rear-end collision between the two subway trains was the inadequate oversight and compliance program of the NYCT to ensure that train operators comply with the published operating rules. Contributing to the collision was the design modification to the automatic key-by feature of the automatic stop arm that enabled the operator of the M train to pass a stop signal contrary to the published operating rules that require stopping at a red signal unless permission to pass is granted by Rapid Transit Operations.

The major safety issues discussed in this report are the effectiveness of automatic stop arms to ensure compliance with stop signals and the adequacy of NYCT oversight to ensure compliance with operating rules. The report will also discuss safety issues relating to speedometers, radios, positive train separation, crashworthiness and occupant survivability, and emergency response.

As a result of its investigation of this accident, the Safety Board makes recommendations to the NYCT.

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INVESTIGATION

Accident

On February 9, 1995, at 2:39 p.m., a Metropolitan Transportation Authority/New York City Transit (NYCT)[1] northbound M line route subway (M) train collided with the rear car of a stopped NYCT B line route subway (B) train in Brooklyn, New York. The 10-car B train in passenger service had departed the Stillwell Avenue station in Brooklyn about 2:20 p.m. en route to 168th Street station in Manhattan, New York. (See figure 1.) The crew consisted of a train operator and conductor. The conductor stated that the last station stop before the collision was the Fort Hamilton Parkway (Fort Hamilton) station in Brooklyn. The operator stopped the train after departing that station at signal D2-518, which displayed a stop signal because a preceding northbound M train was stopped in the Ninth Avenue station in Brooklyn. The train operator stated that after waiting about 3 minutes, he felt a tremendous impact that threw him toward the window. The conductor stated he had no warning of the impending collision, which occurred on the elevated track about 1,011 feet south of the Ninth Avenue station. (See figure 2.) He assisted the passengers during the train evacuation after the collision along the elevated walkway to the Ninth Avenue station. The crew, an off-duty employee, and 11 of the 150 passengers on the B train as well as the M train operator sustained minor injuries.

Earlier the eight-car M train had arrived about 2:20 p.m. at the Ninth Avenue station, and all passengers were discharged. It was then designated an M light[2] train and was boarded by its relay operator at 2:21 p.m. He was assigned to move the train south on track D3/4 from the station to the 62nd Street interlocking, then to cross the train over, and to return it on track D2 to the Ninth Avenue station, where it would become a northbound passenger train to depart at 2:46 p.m. The relay operator had already made five similar trips on February 9 and was scheduled for an additional four trips.

The operator told National Transportation Safety Board investigators that once in the control compartment of the south car, he did a standing air brake test. After departing the Ninth Avenue station about 2:25 p.m., he performed a rolling and then a running air brake test. He said that the air brakes worked properly during the three tests. The operator passed what he thought was a northbound M train at the Fort Hamilton station and another northbound train between the 50th and 55th Street stations. The operator continued that his train then proceeded through the 62nd Street interlocking and reached the 8 to 10 marker[3] on track D3/4 where he stopped it. He then went to and entered the north car that he set as the control car. He stated he performed a

[1]Known as the New York City Transit Authority before April 4, 1994.

[2]Passenger train operating without passengers.

[3]Indicator to operator that end of 8- to 10-car train has cleared interlocking.

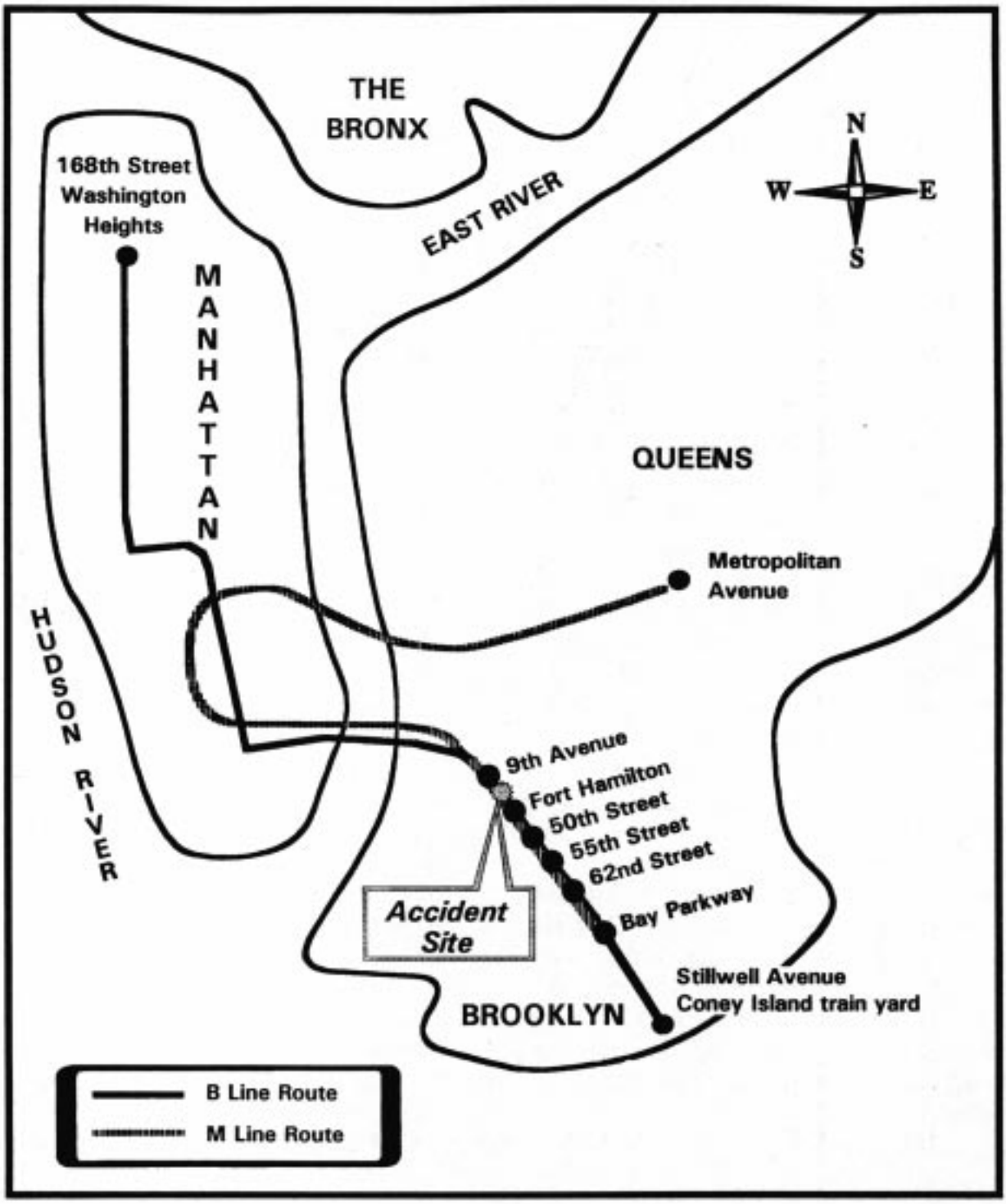

Figure 1--Route of B and M trains.
(Source: National Transportation Safety Board. Not to scale.)

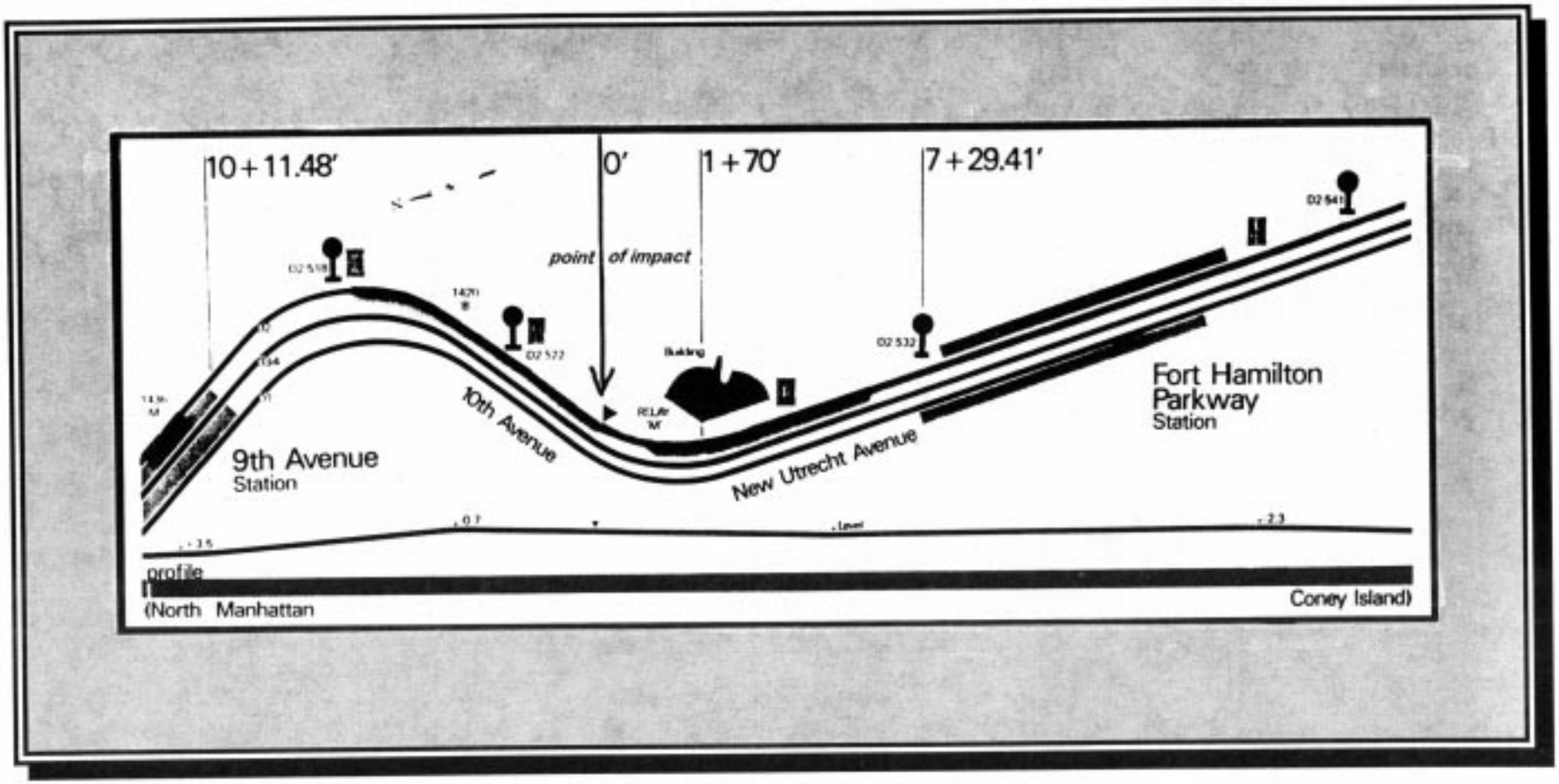

Figure 2--Profile of collision site.

To calculate distances, multiple first number by 100 and add to second number: 1 + 70 = 170 feet.

(Profile: courtesy of Metropolitan Transportation Authority/New York City Transit.)

standing air brake test and added that he took no exception to the brakes or the performance of the train while operating it.

After about 3 minutes, the train operator received a proceed signal to move north through the interlocking onto track D2 and then proceeded through the 62nd Street, 55th Street, and 50th Street stations without incident. He told Safety Board investigators that he received a yellow approach signal (D2-541) as he approached the south end of the Fort Hamilton station and that he could see the next signal (D2-532), showing a red light with a white light illuminated at the bottom, as he entered the station. The signal indicated, according to him, that "if I approach it at the allowable speed, it will clear for me." He added, "The only reason I entered the station is because I thought the lunar white was illuminated. To me, it was lit. If it wasn't lit to me, I wouldn't enter the station because I'm not allowed to stop in the station empty." The operator continued that as he approached, he observed the automatic stop arm, located outside the left rail opposite the D2-532 signal, and his train was moving less than 10 miles per hour (mph) when he saw the stop arm go down. He stated that he could remember neither the aspect of the signal when he passed it nor the signal changing from the red aspect. The operator said that he did not stop at signal D2-532 but proceeded because the stop arm went down and added, "That's usually the last thing I look at when I operate -- the trip arm. When it clears, I make sure it goes down and I go." He reported that he accelerated to approximately 15 mph and that he saw the B train ahead of him as he rounded the right-hand curve. He stated that he immediately released the power and instinctively made a full-service brake application but was unable to stop his train short of the B train.

As a result of the impact, the rear car 4259 of the B train penetrated the lead control car 4918 of the M train about 3 feet (see figure 3), and the B train moved forward about 10 feet. The third car 4939 of the M train partially blocked track D3/4 after the collision. (See figure 4.)

Injuries*

Type	B Train Crew	M Train Crew	Passengers	Total
Minor	3**	1	11	15
None	0	0	139	139
Total	3	1	150	154

*Based on the injury criteria (49 Code of Federal Regulations [CFR] 830.2) of the International Civil Aviation Organization, which the Safety Board uses in accident reports for all transportation modes.

**Includes off-duty employee.

Figure 3--Rear car 4259 of B train penetrating lead car 4918 of M train.

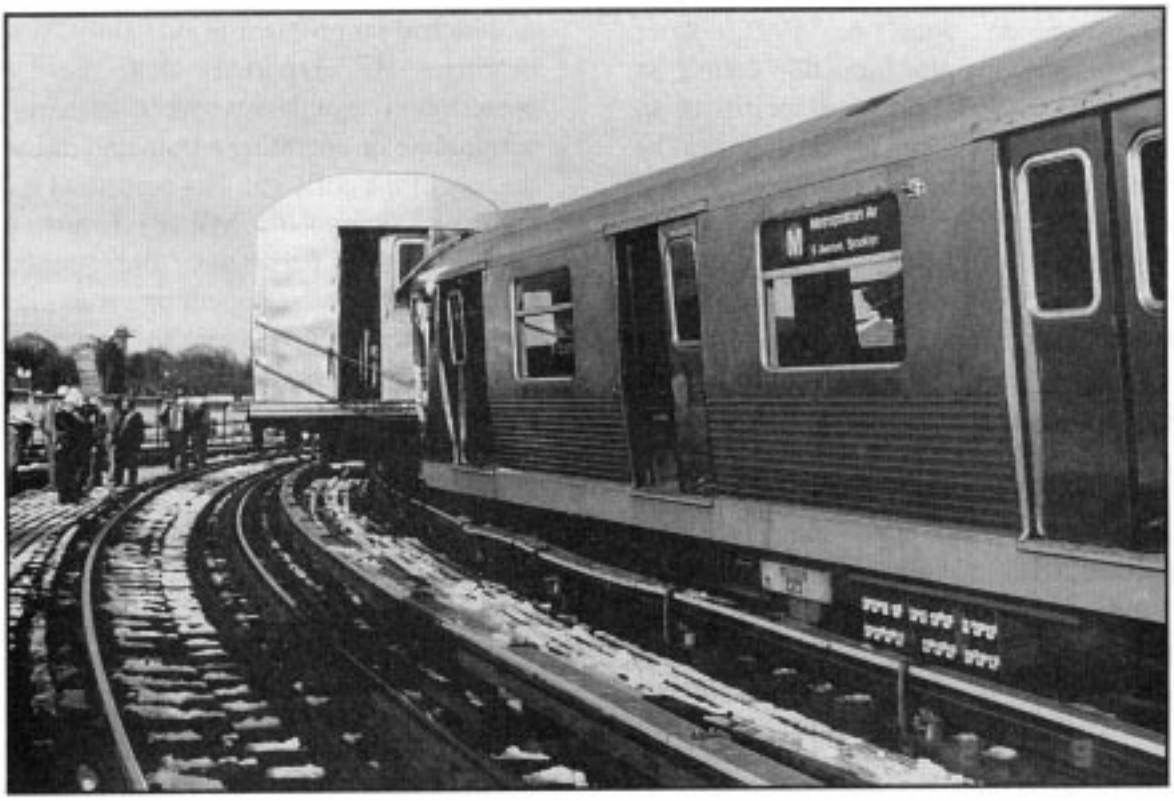

Figure 4--Third car 4939 of M train blocking D3/4 track.

Damages

The rear five cars of the B train and the first five cars of the M train received damages, according to the NYCT, in excess of $1.5 million.

Personnel Information

B Train Crew--Appendix B provides information about the professional background and experience with the NYCT of the 31-year-old operator and the 39-year-old conductor who were the crew of the B train.

M Train Operator--The 28-year-old operator reported for duty with the NYCT as a conductor-in-training on November 27, 1989. He worked as a conductor on subdivisions A and B before being promoted to operator on June 6, 1993. After concluding the operator induction course on October 21, 1993, he was certified to perform all duties of an operator. The operator had successfully completed the course series of written examinations on NYCT operating rules and during interviews with Safety Board investigators had correctly described the provisions of rule 39 (i) that apply to light train operation (see appendix C). The operator had no regular duties and was assigned from the extra list working in the yard, relay trains, and passenger service. He stated that during his 16-month experience as a certified operator, he worked "anywhere they needed me, except work trains [used for track maintenance], that's the only thing I'm not qualified for." In the 2 weeks before the collision, he had operated primarily in passenger service but had relayed trains 1 day.

The operator's personnel file contained two disciplinary cases: absence from his post and on an undocumented emergency in May 1991 and June 1992, respectively. Also in the file were two operating employee evaluations in which he received an overall rating of acceptable in April 1994 and of good 8 months later. A search of the NYCT evaluation data base found two additional evaluations for overall ratings of good on January 24 and February 8, 1995.

The most recent NYCT medical examination[4] of the train operator was on April 12, 1994, in which he was assessed fit for full work. Describing his health as good, he said that he worked out at the gym as much as possible accommodating his irregular work schedule. The operator noted that he had no problem or difficulty with his hearing. He reported that he wore prescription eyeglasses when driving an automobile or operating a train and did so on the day of the collision. His personnel record card was stamped "MWG" (must wear glasses); the personnel file contained evidence that the operator was issued prescription safety glasses in August 1992 and that the evaluating train service supervisors observed him wearing prescription glasses at least twice.

Safety Board investigators reviewed the operator's time and payroll records for the

[4]NYCT requires train operators and all other employees whose duties regularly require them to be on or near tracks or right-of-way to have periodic medical examinations (every 2 years and annually for employees under and over age 50, respectively).

30 days before the collision. He was on vacation between January 10 and 14, 1995, and then worked 7 consecutive days on his return to duty before taking January 22 and 23 as his regular days off. During each of the next two 5-day work weeks, he worked about 42 and 41 hours, respectively. The investigators then reconstructed the activities of the operator for the 72-hour period before the collision from NYCT records and operator interviews. Although February 6 was a regular day off for the operator, he accepted an assignment that began at 10 p.m. the night before and ended at 6 a.m. on February 6. He said that he returned home at 7 a.m., slept until about 2 p.m., was up for 3 or 4 hours, and then napped from 6 to 10 p.m. in anticipation of his midnight reporting time. The NYCT records indicate that he worked from midnight until 2 p.m. on February 7. The operator said that he then went to the gym, returned home for dinner, retired about 8 p.m., and rose about 3:30 a.m. on February 8. His work hours that day were from 4:57 a.m. until 2:02 p.m. The operator reported that he had lunch at home before going to the gym, returned home for dinner, and retired between 10 and 11 p.m. On February 9, he rose about 7:30 a.m., ate breakfast, began work at 8:45 a.m., and was on duty about 6 hours at the time of the collision.

Train Information

The equipment involved in the collision was built by the St. Louis Car Manufacturing Corporation. The self-propelled cars, operated in two-car pairs with control compartments on opposite ends, are powered by a contact, attached to each car truck, collecting current from a "third-rail" distribution system. The 10 R-40 type cars (numbers 4351, 4350, 4275, 4274, 4329, 4328, 4347, 4346, 4258, and 4259) of the B train were built in 1968 and 1969 and were modified in 1987 and 1989 by Sumitomo Corporation of America. The control ends of each car were angled. The eight R-42 type cars (numbers 4918, 4919, 4939, 4938, 4917, 4916, 4915, and 4914) of the M train were built in 1969 and 1970. The control ends of each car were the conventional flat-end shape.

Representatives of the Safety Board, the Office of the Inspector General (Metropolitan Transportation Authority), the New York State Public Transportation Safety Board (NYSPTSB), and the NYCT inspected the equipment after the collision and found no defects. The trip cock[5] from the lead car of the M train was examined and showed no evidence of strike marks. During its testing, the trip cock operated as designed. The maintenance records of all cars involved in the collision were also reviewed. These records indicated normal maintenance standards, and no collision-related maintenance conduct was discovered.

Safety Board investigators performed air brake and power tests of the collision-involved M train cars on March 3, 1995, at the Coney Island train yard. The brakes and brake rigging were checked and operated as designed. After the brake valve on the lead car was removed, it was bench tested and also operated as designed. The power test to check the traction motors in forward and

[5]Device mounted on each car that places train in emergency braking when it strikes stop arm near track.

reverse indicated that the cars operated as designed.

Speedometers--The M train was not equipped with a speedometer. No Federal, State, or local regulations require NYCT trains to have speedometers. Instead of the trains being equipped with speedometers, according to the senior director of Operations Support and Review for Rapid Transit Operations (RTO), the operators are taught the relationship between the speed and the master controller three points of power (switching, series, and parallel). The assistant chief mechanical officer explained that a master controller has four positions: off; switching (one point of power), for speeds up to 10 mph; series (two points of power), for speeds between 10 and 20 mph; and parallel (three points of power), for speeds as great as 55 mph, depending on the grade. (See figure 5.)

The senior director further stated that allowable speed is a judgment for operators "because right now, they don't know how fast they're operating without the speedometer. They're guesstimating." He added that as an operator becomes more experienced, the operator knows how fast he is going. Answering the question of how he estimated or determined speed, the M train operator stated, "well, the series on a train of two points is told to me to be estimated between 15 and 18 mph. Three points of power is full speed, whatever that could be - 35, 40, depending on the grade, or whatever."

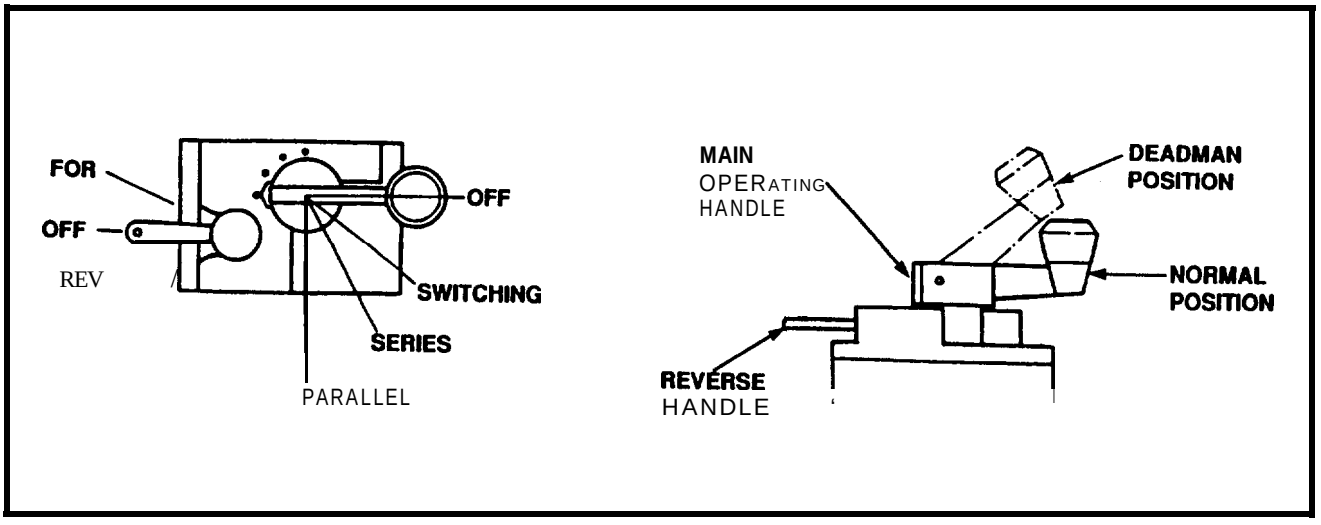

Figure 5--Master controller.

Event Recorders--Neither the B nor the M train were equipped with event recorders. No Federal, State, or local regulations require NYCT trains to be equipped with event recorders. In an April 1995 interview with Safety Board investigators, the assistant chief mechanical officer said that new NYCT cars, expected to arrive by 2000, will be equipped with event recorders that will monitor several train line functions, including speed.

Radios--The NYCT rule 20 (b) that applies to the possessing and testing of radios (see appendix C) states, "Each train must be equipped with an operable Train-to-Wayside Radio." In addition, the NYCT bulletin number 45-94, which was issued in June 1994 and was in effect at the time of the collision, provided for train-to-wayside communication. It directed that "all trains using main line tracks, for any reason and for any distance, must have an operable train to wayside radio (either a train radio or conductor's portable may be used)."

The assistant chief mechanical officer stated that the only subway cars equipped with built-in radios are on the new technology trains and that older cars have a bracket behind the operator's seat into which an operator plugs a radio. The operator must bring a radio onto the train. He added that operators and conductors also may use portable radios. During an interview with Safety Board investigators, the M train operator denied that he had either been issued a radio or had one at the time of the collision. The NYCT supervisory personnel stated that the operator was given a radio; however, the NYCT was unable to produce documentation to that effect.

Track and Signal Information

The collision occurred on NYCT elevated track about 23.5 feet above 10th Avenue between 40th and 41st Streets in Brooklyn. Tracks D1, D3/4, and D2 are on the west side, in the center, and on the east side of an open-deck, steel structure, respectively. Trains traveling in a southward and a northward direction use tracks D1 and D2, respectively. Bidirectional train movements are on track D3/4.

The track has a 0.7-percent ascending grade in a northward direction. Its alignment curves to the right with a 270-foot radius (21^{o} 13') from about 430 feet north of the Fort Hamilton station to about 53 feet beyond the point of impact (POI). A 15-mph speed restriction sign in advance of the curve is posted on the east side of the track about 262 feet north of signal D2-532. A building near the middle of the curve obscures the line of sight through the curve. (See figures 2 and 6.)

NYCT track personnel who were first on scene observed that the rail surface was dry and that skid marks on the rail head started between 100 and 150 feet south of the POI. Safety Board investigators detected no preexisting track anomalies during their postcollision track inspection.

The NYCT signal system consists of automatic block wayside signals and consecutive signal blocks governed by automatic and interlocking signals. Operating as a train control system, it provides train detection and separation as well as movement through interlockings. Four light signals control northbound movement on track D2 from the south end of the Fort Hamilton station to the Ninth Avenue station.

Signal D2-541, located about 300 feet south of Fort Hamilton station (see figure 7), displays either a red (stop) or a yellow (proceed with caution, be prepared to stop) aspect. Train occupancy of the track ahead determines the signal aspect displayed. If a

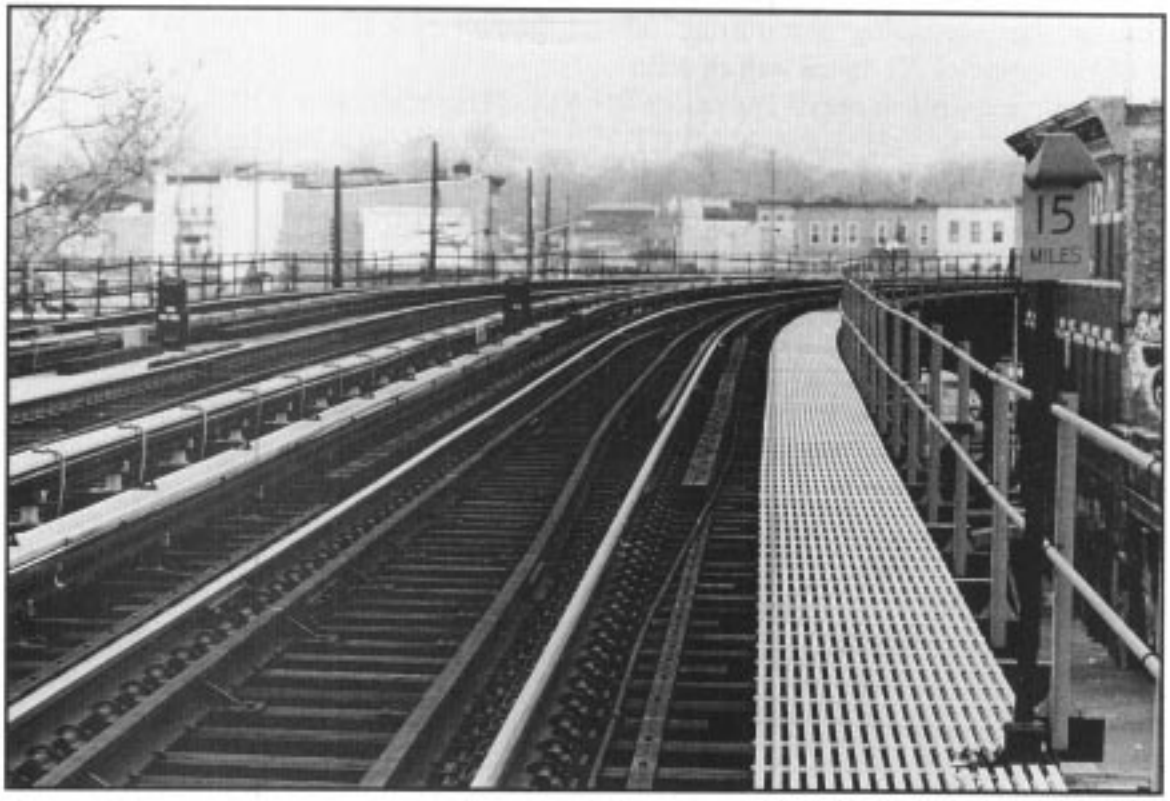

Figure 6--15-mph speed restriction sign approaching curve.

train is on track D2 within the next two signal circuits, D2-541 displays a red aspect until that train clears the signal block. If the track is unoccupied, then D2-541 displays a yellow aspect that permits a train to enter the signal block. A green (proceed) aspect cannot be displayed from D2-541 because the next signal (D2-532), a grade time (GT) controlled signal,[6] enforces a predetermined speed (on descending grades or at other locations) and trains exceeding such speed are automatically stopped.

Signal D2-532, located about 34 feet north of the Fort Hamilton station (see figure 8), displays either a red, a yellow, or a green aspect. The time-controlled signal requires the passage of time for a change in aspect and, therefore, remains red until such time is used by a train approaching it. The timing device is actuated when a train enters the timing circuit at the station's south end, which has a time setting of 20.4 seconds and a circuit length of 638 feet. Therefore, trains approaching at 20 mph or less meet the time

[6]Always preceded either by "T" sign, which indicates beginning of time-controlled territory, and second sign that denotes allowable speed in miles per hour, which indicates proceed at such speed, or "GT" sign that denotes allowable speed, which indicates beginning of grade timing section.

Figure 7--Signal D2-541.

requirement. The signal then changes to a yellow or green aspect as the time requirement expires and should the track ahead be unoccupied.

The NYCT system has 636 one-shot[7] GT signals of which 423 signals have a lunar white aspect[8] and 213 signals, including signal D2-532, have no lunar aspect. An NYCT electrical systems manager told Safety Board investigators that GT signals without a lunar aspect "are probably old installations that were built way before we adopted the new design standard of providing lunar lights." The manager said that new installations are equipped with lunar aspects on any signal that has a one-shot GT control, but a retrofit of the existing signals, which lack lunar white aspects, is not currently planned.

[7]Single GT signal employed to enforce predetermined safe train speed at specific locations; series of GT signals is also used along certain territory.

[8]When lunar white aspect is illuminated together with stop indication, signal may be cleared by train approaching at predetermined speed. Lunar white light does not illuminate when track ahead is occupied by trains.

Figure 8--Signal D2-532
(left arrow indicates automatic stop arm; right arrow indicates sign installed after collision).

The stop arm is outside of the left rail opposite[9] the D2-532 signal. (See figure 9.) A yellow-painted insulated-joint (IJ) marking acts as stop marker in the approach of the signal. The stop arm is up in the tripping position (see figure 10) when the signal is red, and if a train passes the red signal, the stop arm will strike the trip cock. This action places the train in emergency braking.

A "key-by"[10] feature, activated by a train properly stopping in approach of an automatic signal or an approach signal, is associated with signal D2-532. When activated, it lets the stop arm lower to the clear position. This feature[11] enables the NYCT to keep trains moving during emergencies or delays. The NYCT system

[9]Stop arm location on subdivision B; however, stop arm location on signal side on subdivision A.

[10]Term is hold-over from time when key was used to manually lower stop arm.

[11]Three other systems, the Port Authority Trans Hudson, operating between Newark, New Jersey, and Manhattan; the Chicago [Illinois] Transit Authority; and the Toronto [Canada] Transit Commission, have similar automatic stop arm manual features.

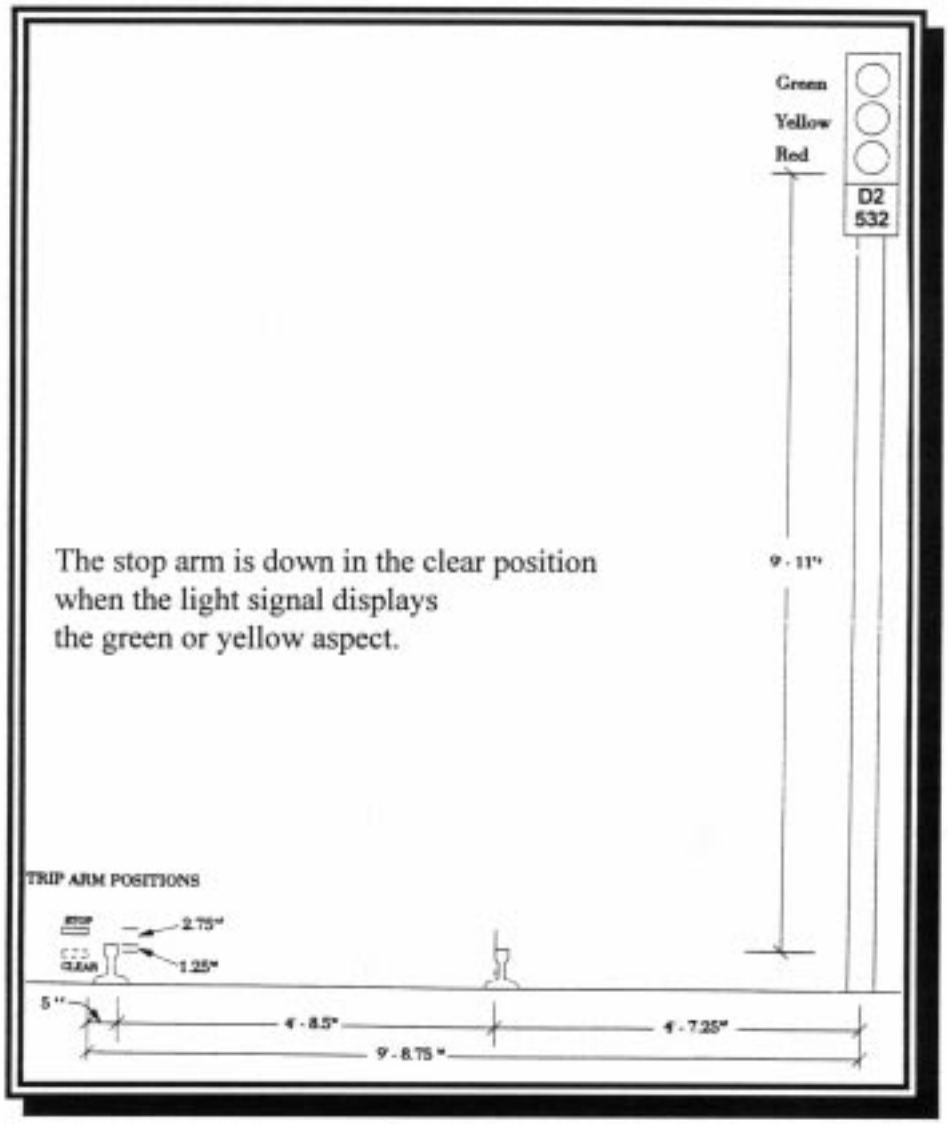

Figure 9--Illustration of stop arm and signal D2-532.

has been equipped with stop arms since a gradual installation began in 1927. The stop arms as originally installed could not be automatically keyed by; however, modifications on the system in the 1950s converted many signals with an automatic key-by feature.[12] After a 1970 train collision caused by an operator keying by a signal, all operators were required by rule to obtain authorization before keying by a red automatic signal. The operator, as directed

[12]R.B. Shaw, *A History of Railroad Accidents, Safety Precautions and Operating Practices*, Vail-Ballou Press, 1978.

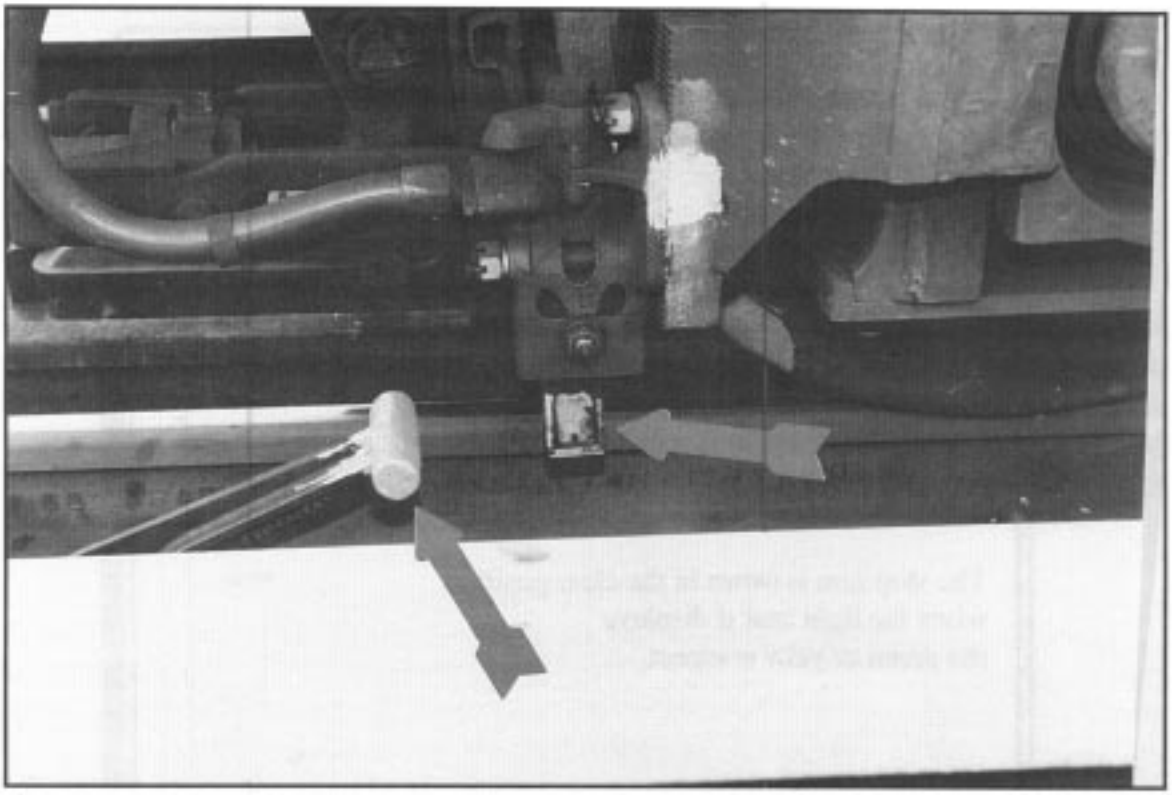

Figure 10--Automatic stop arm in tripping position and trip cock on car (left and right arrows, respectively).

by NYCT Rule 40 (m) (see appendix C), must stop his train short of the signal or at the IJ (yellow stop marker) and receive permission from the command center before activating the key-by feature. The train either stops between the IJ (the yellow stop marker) and the stop arm or moves at less than 5 mph to lower the stop arm to the clear position. (See figure 11.) This key-by feature does not change the aspect of the signal, which remains red (stop).

The rear of the stopped B train at the time of the collision was about 220 feet south of the third signal D2-522 (see figure 12), which is about 949 feet north of signal D2-532. The posted 15 miles on signal D2-522 indicates the allowable speed for trains approaching the next signal, which is D2-518.

The fourth signal D2-518, located about 476 feet north of signal D2-522, is a GT signal equipped with a lunar white light. (See figure 13.) The front of the stopped B train was about 75 feet south of this signal at the time of the collision.

Safety Board investigators completed a postaccident collision site inspection of the signal system, stop arm, and key-by feature on February 10, 1995. The investigators

found during their inspection that signal D2-532 and its corresponding circuits as well as the relays, stop arm, and signals operated as designed. Signal cyclic maintenance records for the 13 months before the collision were also reviewed and indicated repairs were made within NYCT maintenance requirements. The 12-month incident record disclosed no reportable signal incidents.

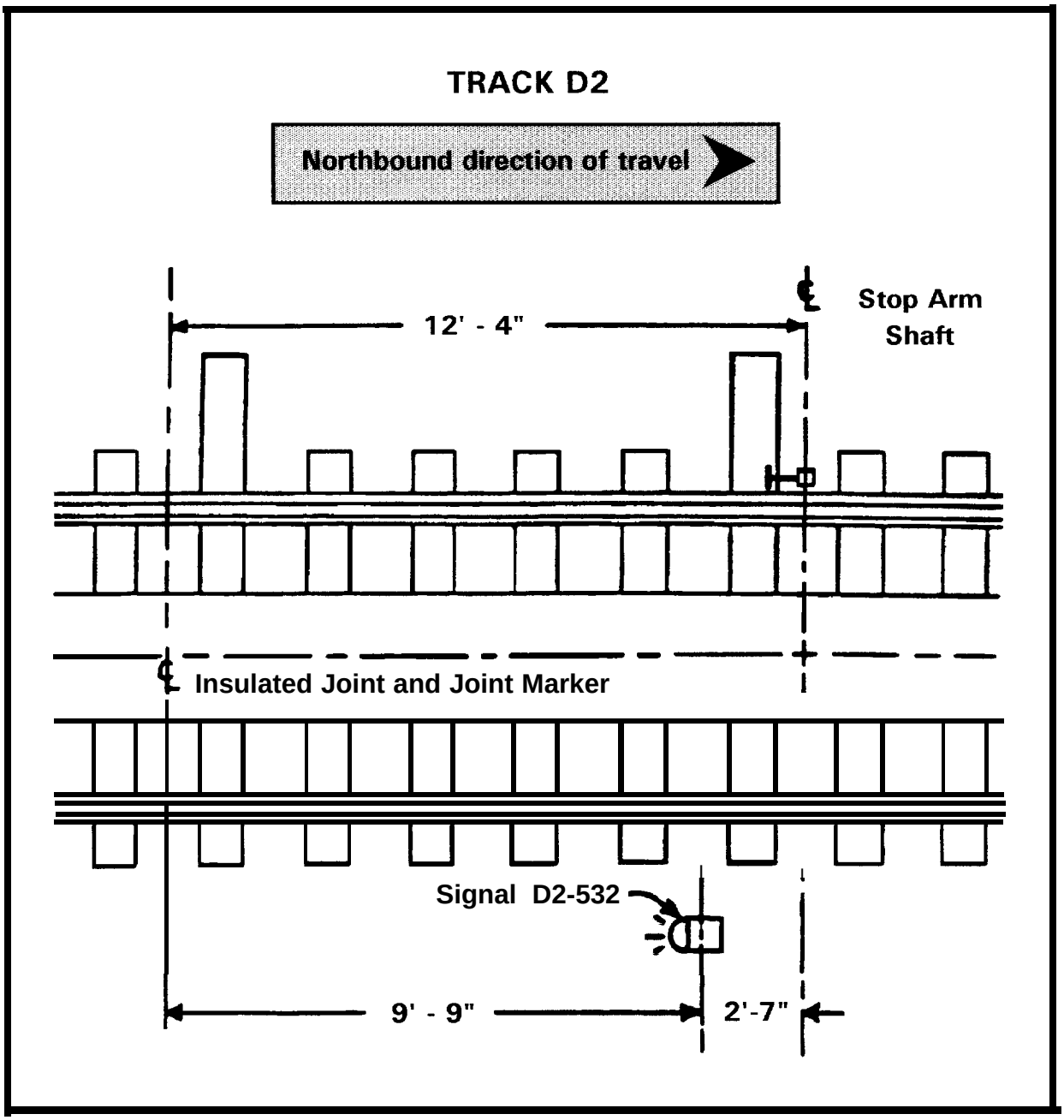

Figure 1 l--Layout of insulated joint, signal D2-532, and automatic stop arm.
(Source: Adapted from New York City Transit drawings. Not to scale.)

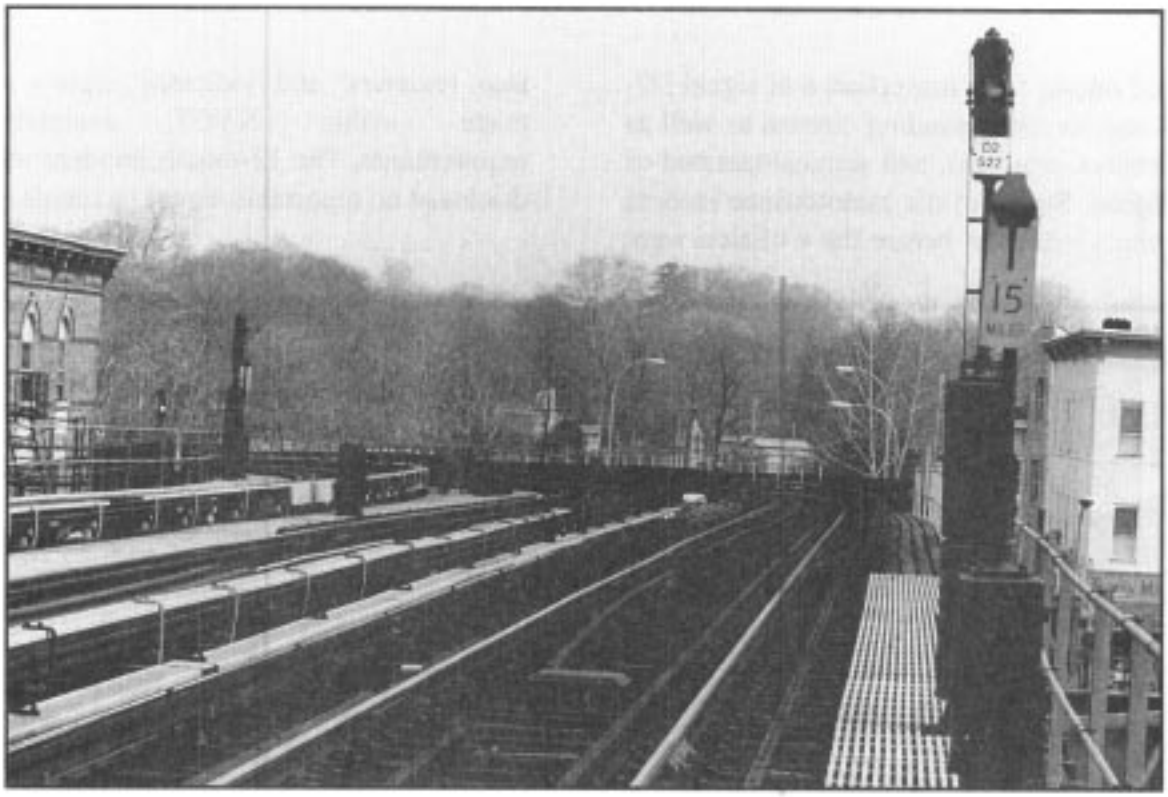

Figure 12--Signal D2-522.

Figure 13--Signal D2-518 (arrow indicates lunar white light).

Operations Information

The NYCT system consists of 25 lines, identified by either letters or numbers. The NYCT 1994 data indicated that its annual ridership was approximately 1.8 billion. An average of 3.4 million passengers rode on weekdays and half that number on Saturday and Sunday. Scheduled train trips, according to the 1994 data, totaled about 2.2 million, and 6,568 scheduled trips occurred daily.

Subway trains in passenger service are crewed by an operator and a conductor. The NYCT employs 2,841 operators and 2,408 conductors. The operator works the train from the control compartment of the lead car. The conductor is required to ride in the center of the train.

The RTO control center coordinates all train movement, governed by the *Rules and Regulations Governing Employees Engaged in the Operation of the New York City Transit System* (revised 1992), the timetable, the schedule, general orders, and bulletins. The RTO reported that on-time train performance as of February 1995 was 88.7 percent.

Train dispatchers and employees at the control center communicate by radio with operators. Safety Board investigators reviewed the RTO control center radio tapes from the day of the collision. No conversations were recorded between control center personnel and either the M train operator or the B train crew. In addition, no conversations were taped between the crews of the M and of the B train.

Meteorological Information

The weather at the time of the collision was clear and sunny, and several inches of snow covered the ground. The ambient temperature was 29^{o} F.

Toxicological Information

In compliance with the Federal Transit Administration regulations on toxicological testing for transit workers in safety-sensitive positions, both train operators provided breath and urine samples for toxicological testing. An evidential breath testing device, which prints the date, the time, and the test results, was used in the breath alcohol tests. The results for both operators were negative (0.00 grams of alcohol per 210 liters of breath). MetPath, Inc., a federally approved laboratory, tested the urine specimens provided by both operators for the presence of amphetamines, cocaine, marijuana, opiates, and phencyclidine. The laboratory reported that the test results for both specimens were negative.

Emergency Response

The collision was reported at 2:39 p.m. to the Fire Department of New York (FDNY) emergency response dispatch center. FDNY units were dispatched at 2:41 p.m., and the three engine and two ladder companies and two rescue vehicles arrived on scene at 2:45 p.m. After an initial assessment by the on-scene commander, additional assistance was requested. (Ten emergency medical service officers, 15 city police officers, and 10 NYCT rescue unit officers responded.) At 2:53 p.m., the FDNY requested confirmation

that the NYCT had shut off the power to the third rail. The NYCT confirmed at 2:56 p.m. that the power was shut off. FDNY personnel with the assistance of the transit police completed the evacuation of approximately 150 people from the B train at 3:15 p.m. The FDNY had established a mobile unit command post, and the NYCT had used a standard city bus as its command post.

Crashworthiness and Control Compartment Survivability

The lead car 4918 of the M train underrode the anticlimber of the rear car 4259 on the B train, causing extensive damage. The anticlimber was pushed in 5 to 6 feet and had the deepest penetration slightly to the right of the center (facing forward). The inner fiberglass was destroyed with the left side deflected outward to the first door. The interior floor of car 4259 was penetrated and buckled upward and inward.

The third car 4939 of the M train derailed and had displaced sideways. The car had exterior damage to its right rear and had interior panel displacement. The passenger compartment had no interior car body penetration.

The fourth car 4938 of the M train also was derailed and displaced. The collision post on the right side was bent about 1 foot inward and over and was torn on the bottom from the horizontal member. A break was partially, but not completely, on the weld. The interior of car 4938 had some penetration at the right rear, and its ceiling was displaced downward and backward.

The control compartment in lead car 4918 of the M train was constructed of structural grade sheet metal and had angular corner framing reinforcements. A full-sized, outward swinging, hinged access door and a sliding window were to the operator's left and right, respectively. The lower half of the door was compressively wedged and distorted between the jambs. The M train operator stated during an on-scene interview that he was able to climb out of the damaged compartment through a small opening in its door. The door was warped inward about 1 foot at the top corner, and this warpage created a triangular opening in the rear wall that measured about 10 inches at the top and tapered to zero at the bottom. The rear bottom corner of the compartment was displaced aft approximately 2 inches.

The rear car 4259 of the B train was compressed against the front of the control compartment, whose windshield was shattered but remained within its frame. The exterior car body panel below the windshield was intact but distorted. The right front cornerpost was displaced aft, and the right front collision post (adjacent to the car end door) was displaced aft about 2 feet. The 2-foot-wide operator console was displaced aft on the left side, and its kick panel had the left front edge of the operator seat frame embedded slightly into its surface. The rear wall of the compartment behind the seat frame was distorted aft. The right side of the operator console appeared only negligibly displaced aft. This displacement created a triangular survival space that measured 6 inches on the right side and tapered to zero on the left. The displaced compartment floor left wiring and piping exposed. The compartment ceiling remained intact and did not collapse.

In addition, small indentations and scratches were found on the inside surface in the center of the control compartment window. The window was open about 2 inches and could not be pushed aft into its pocket. The operator stated that he removed his control handle and attempted to break the window. He gave up after striking it several times and replaced the handle on the console.

Postaccident Tests

Safety Board investigators conducted visibility, sight-distance, stop arm, key-by and stopping tests on February 11, 1995, at the collision site. Equipment similar to that of the trains in the collision was operated during the tests. The weather conditions were comparable to those on February 9, 1995.

A visibility test was performed about the time the February 9 collision occurred when the sun was reported to be shining over the left shoulder of the M train operator as he approached signal D2-532. As the test M train approached the south end of Fort Hamilton station, the sun was behind the train approximately at the 7 o'clock position. No ghost or phantom reflections were observed from the three vertical color light lenses on the signal.

Two sight-distance tests were completed: the test operator in the M train was standing during the first and sitting during the second. The rear car of the test B train was placed at the approximate POI. The test M train was then operated from the Fort Hamilton station northward, and its operator was instructed to call out as soon as the rear car of the B train came into sight. The test results recorded the line of sight from the standing and the sitting positions was 200 and 207 feet, respectively.

A stop arm test was done to determine whether the raised stop arm would strike the trip cock of the train and cause the train to stop. The test operator was instructed to pass the train over the stop arm moving at least 5 mph to ensure that the train did not activate the key-by feature. Because the train was not equipped with a speedometer, a radar gun was used to indicate the speed (11 mph) when the train reached the stop arm. The stop arm did strike the trip cock, and the action placed the train in emergency braking and stopped the train within 55 feet.

The key-by feature of the stop arm was also tested. As the test M train moved toward the stop arm at less than 5 mph, the operator observed the stop arm in the up position. When the operator passed the IJ (stop marker) and neared the stop arm, she saw the stop arm move to the down position, and the train was then stopped to determine the operator's visibility of signal D2-532. The test operator was directly across from the signal, and she stated that she could not see the signal aspect from the normal sitting or standing positions. Signal D2-532 was observed from the station platform, and it displayed a red (stop) signal.

Five tests were performed to determine stopping distances of the test M train. The operator was sitting during all tests, and a radar gun was again used to determine the speed. The test B train was removed from the collision site, and red flags were placed to mark the position of the B train rear car. A yellow flag marked the sight distance point of 207 feet from the POI.

The first, second, and third stopping distance tests were carried out at 15, 20, and 25 mph, respectively. When the train reached the yellow flag during all three tests, the operator applied a full-service automatic brake application. The train stopped in tests one, two, and three, respectively, 107.5, 71, and 10.5 feet short of the POI. During test four, the operator placed the train at 25 mph in emergency air braking at the yellow flag, and the train stopped 2.5 feet beyond the POI.

The final test was done to verify the collision speed estimated by the NYCT brake systems engineering manager, who considered in his calculations the 100 feet of intermittent skid marks on the rails and the 10.5 feet of forward movement of the B train rear car. (See appendix D.) He calculated that the speed of the train where the skid marks began and just before impact was between 21 and 26 mph and between 13 and 17 mph, respectively. Using these calculations, the operator accelerated the test train to 25 mph and, allowing for brake reaction time, placed the train in emergency braking 40 feet before the skid marks began. The test train passed the POI at 14 mph while decelerating and stopped 30.5 feet beyond the POI.

Other Information

Operating Rules Compliance--Safety Board investigators questioned the senior director of operations support and review for the RTO in April 1995 as to whether the NYCT is monitoring speeds at the 103rd Street station, at the fixed 15 mph speed limit sign north of the Fort Hamilton station, or at any location on the system. The senior director responded, “there is no program that we're going to go out there and actually do speed checks with radar guns at this time.” He also said that the NYCT had no formal written efficiency testing program; however, unannounced testing was done at the Grand and Graham Avenue stations on the L line. He added that tests were conducted at only these locations. The L line supervisors observed 291 trains at stop signals between October 1994 and March 1995. On the 6th day of testing, a train was seen keying by and passing a stop signal without permission, which was the only stop signal violation reported during the testing period.

Safety Board investigators also interviewed NYCT managers and line superintendents in April 1995 about the NYCT methods used to ensure the operators are complying with operating rules. The line superintendents stated that among the methods followed daily are: documented critiques in which safety rules and regulations are discussed with operators and fitness-for-duty assessments of reporting crews by crew dispatchers. The NYCT additionally uses bulletin boards to convey operation and procedure changes and safety concerns, and the operators receive 15 minutes to review them at the beginning of each assignment. All operators also receive a 3-day rules and regulations review course every 2 to 3 years.

In addition, a train service supervisor (TSS) observes the on-board performance of an operator at least once every 6 months and records the operator’s performance on the “B-Form” (Operating Employee Evaluation Check List). (See appendix E.) The TSS receives classroom directions for completing the form; however, no written instructions

are provided for the TSS. The B-Form uses the rating system of good, acceptable, or unacceptable, indicating the level of competency for the 18 subjects listed that the TSS believes is warranted for each. Only the overall operation rating is recorded in the NYCT computer data base.

The Safety Board has reviewed other transit agencies' oversight policies concerning speed, signal, and operating rule compliance. The Los Angeles Metropolitan Transit Authority (California) and the Massachusetts Bay Transit Authority (Boston metropolitan area) conduct unannounced proficiency testing for speed, signal, and operating rules compliance by operators. In Ohio, the Greater Cleveland Regional Transit Authority (GCRTA) has a written policy that outlines management oversight for the training and testing of operators to ensure rules compliance. In a May 1995 letter, the GCRTA informed the Safety Board that supervisors are

> responsible for the conducting of and documentation for a prescribed series of safety tests which are as follows:
>
> o The daily ride check inspections,
> o daily proficiency testing of operators for compliance to signal rules (red signal test), and
> o speed limit compliance on the Light Rail will be checked at least bi-weekly by a Rail Supervisor using radar.

Rear-End Collisions Involving Keying By Signals--The August 1995 NYCT publication *Williamsburg Bridge Collision: Interim Action Plan to Address Safety Issues* lists seven rear-end collisions, injuring 115 passengers and employees, that occurred between July 1990 and February 1995. The NYCT reported that six of the seven collisions were caused by operators keying by stop signals without permission.

The Safety Board investigated a rear-end collision in October 1993 between two NYCT trains at the Graham Avenue station in Brooklyn.[13] Two crewmembers and 64 passengers sustained minor injuries, and total damages were estimated to exceed $150,000. A train operator keyed by a stop signal without permission and collided with a stopped train. The Safety Board determined that the probable cause of the collision was the failure of the operator to control the speed of his train and to stop in compliance with a stop signal.

Directives and Bulletins Concerning Keying By Signals--In the March 1995 interim NYCT report of this collision to the senior vice president in the Department of Subways, the assistant vice president in the Office of System Safety (OSS) stated, "The signal system governing the movement of trains system wide is dependent on operators complying with standard operating rules." The OSS director of field operations also told Safety Board investigators that the system

> is heavily dependent on operators adhering to the rulebook when they see signals and are interpreting signals and how they operate their

[13]Railroad Accident Report--*Rear-End Collision of Two New York City Transit Authority Trains, Graham Avenue Station, Brooklyn, New York, October 7, 1993* (NTSB/NYC-94-FR-002A/B).

> train. ...the system is pretty much dependent on that blue book over there [NYCT rule book] for its operation, and the best you can do is remind.

One method that the NYCT used to "remind" operators about keying by red automatic signals was a series of directives and bulletins.

The NYCT published Positive Compliance Directive No. 90-01 (08/01/90) after a July 1990 rear-end collision in which a light M train operator keyed past a red automatic signal and collided with a stopped B train. This directive stated, "all employees are re-instructed as to the contents of these rules [rules 37 (m) and (n)[14] concern stopping for red automatic signals and subsequently asking for permission to proceed by at restricted speed]."

Bulletin No. 21:91 (01/25/91) was issued after a chain-reaction collision involving three work trains that occurred when a train operator, without authorization, keyed by a red automatic signal, was unable to stop, and collided with a second train, which then collided with the rear of another train. The bulletin reminded operators that "they must stop for a RED Automatic Signal" and after receiving permission to pass that signal, "proceed with RESTRICTED SPEED and EXTREME CAUTION."

Bulletin No. 39-94 (06/03/94) was published in response to the NYSPTSB recommendation that after the October 1993 rear-end collision at Graham Avenue station, the NYCT issue a safety bulletin concerning the seriousness of passing red signals, specifically grade time controlled signals. The bulletin stated, "Historically, a number of collisions have been caused by train operators keying by red automatic signals improperly and without authorization. In light of this, train operators are reminded of Rules 40(m) and 40(n)." The bulletin also restated the rules for stopping at red automatic signals and then proceeding at restricted speed after permission had been granted as a reminder to operators of their duties.

The NYCT distributed Bulletin No. 35-95 (03/22/95) after the February 9 Brooklyn collision. The bulletin repeated to operators that "[h]istorically, a number of collisions have been caused by train operators keying by red automatic signals improperly and without authorization" and reiterated the requirements of rules 40(m) and 40(n).

Automatic Stop Arm Strike Mark Survey--Stop arm strike marks indicate that the trip cock of a passing train has struck a raised stop arm in conjunction with a red (stop) signal. The strike leaves a discernible mark on the stop arm; NYCT Policy/Instruction No. 11.006.2 requires the arms to be inspected every 30 days and repainted, if necessary.

As a result of the Graham Avenue rear-end collision, the NYCT surveyed the L line stop arms for evidence of strike marks, which was found on:

- 43 stop arms or 17 percent of the 252 inspected signals,

[14]Revised rule book, effective March 1993, renumbered rules 37 (m) and (n) as 40 (m) and (n).

- 25 stop arms or 45 percent of the 56 grade time signals, and
- 18 stop arms or 9 percent of the other 196 automatic signals.

Key-By Feature Deactivation--The NYCT senior vice president in the Department of Subways attended the sight-distance tests on February 11, 1995. While at the collision site, he directed NYCT employees to deactivate the automatic key-by feature of signal D2-532, and the work was completed by the next morning. A bulletin advising operators that the automatic key-by feature had been deactivated was issued on February 14, 1995. (See appendix F.)

In September 1995, Safety Board investigators queried the RTO about operations at signal D2-532 for the 7-month period after the key-by feature had been deactivated. The RTO responded that:

- The deactivation of the key-by feature on signal D2-532 has not caused any delays to service on the B line.
- Only one console dispatcher could recall an incident in which an operator requested permission to key by signal D2-532, and in that instance, the signal cleared before the request was granted.
- No problems have been encountered since deactivation of the key-by feature at signal D2-532.
- Inspections have detected no strike marks on the stop arm at signal D2-532 as of September 12, 1995.
- Although no documentation is maintained, the RTO estimates that on a typical day, systemwide, about 15 to 24 train operators call the command center for permission to proceed past a red signal. Approximately 50 percent of the requests are granted.

ANALYSIS

General

The weather at the time of the collision was clear and sunny and did not adversely affect train operation. The postaccident equipment inspection did not indicate any equipment failure, and the operator reported no mechanical problems while the M train was en route. During the pre- and postaccident inspections, no defects were found in the track, and the signal system as well as the stop arm functioned as designed and modified. The Safety Board therefore concludes that neither the weather, the train equipment, nor the track either caused or contributed to the collision.

A review of the crewmembers' work records and their postaccident interviews indicated no evidence of fatigue. All crewmembers had passed the NYCT medical examinations and had the necessary initial training to competently perform their duties. The toxicological tests for alcohol and drugs were negative for both operators. Consequently, the Safety Board concludes that no crewmember fatigue was indicated, that crewmembers had the necessary initial training to competently perform their duties, and that neither alcohol nor drug use was a factor in the collision.

Accident

As the M train operator approached signal D2-541 south of the Fort Hamilton station, the signal was yellow, instructing him to proceed and to be prepared to stop at the next signal at the north end of the station. However, he knew, as he had correctly answered NYCT examination questions on rule 39 and had also correctly described provisions of that rule to Safety Board investigators, that as the operator of a light train, he was not permitted by rule 39 to stop in the station. The operator told investigators that he could see the next signal (D2-532) showing red with a white light illuminated at the bottom as he entered the station; however, signal D2-532 was not equipped with a lunar white light. He said that he thought if he approached the signal at the allowable speed, it would clear. The operator likely slowed his train while entering the station because he presumably anticipated that signal D2-532 would clear on time. The operator conceded in subsequent interviews that signal D2-532 is not equipped with a lunar white light. The Safety Board therefore concludes that because the operator was able to key by signal D2-532, he had slowed his train eventually to less than 5 mph and passed the stop marker.

The difference between GT signals that are and are not equipped with a lunar white light may account for the operator misidentifying signal D2-532. An illuminated lunar white light indicates that a GT signal invariably will clear on time if approached at the allowable speed. A light train operator can therefore enter a station with confidence that he will not be stopped in that station. GT signals not equipped with

lunar white lights, however, provide ambiguous information because the signal may or may not clear on time, depending on track occupancy. The NYCT system has 213 one-shot GT signals similar to signal D2-532 without a lunar aspect. The electrical systems manager told Safety Board investigators that although new installations provide lunar white lights at any signal that has a one-shot GT control, the NYCT had no plans to retrofit the 213 existing signals with lunar white lights. To eliminate any ambiguous information about whether a signal will clear on time, the Safety Board believes that the NYCT should ensure that each existing one-shot GT signal is equipped with a lunar white light.

The M train operator told Safety Board investigators that as his train neared signal D2-532, he remembered looking at the stop arm but not the signal and that he saw the stop arm go down and continued to proceed. The stop arm being outside of the left rail opposite signal D2-532 may explain, in part, the M train operator's assertion that he did not remember viewing the signal when he observed the stop arm go down. In the key-by feature test conducted after the collision, the test M train operator slowly passed the IJ (stop marker) to key by the signal. When she observed the stop arm move down, the test train was stopped, and the operating compartment was directly across from the signal. The test operator could not see the signal aspect from the normal sitting or standing positions. In addition, the stop arm and the signal have a 10-foot separation horizontally and vertically. When the M train crossed the IJ about 9.75 feet in approach of the signal, the arm and signal, as viewed from the operator's position, were separated visually by a 45^{o} angle, which made it difficult to keep the arm and the signal both in focus at the same time. The visual angle increased as the train approached. Therefore, the Safety Board concludes that had the M train operator seen the stop arm go down, as stated, he would have been unable to readily determine the signal aspect from the normal standing or sitting positions of an operator in the control compartment, even had he looked.

Safety Board investigators next considered whether the operator's unauthorized key-by action was deliberate. The operator had no history of operating rules violations. He described the provisions of the operating rules applicable to light train operation during the investigative interviews. When he passed signal D2-532 at 2:38 p.m., he was less than 2 minutes away from the Ninth Avenue station traveling at the allowable 15-mph speed. Because the M train he was relaying was not scheduled to depart the Ninth Avenue station until 2:46 p.m., he unlikely considered himself pressed for time. He had three additional scheduled trips to make that day and, therefore, likely would not be rushing to an off-duty activity. Finally, had he deliberately keyed by, he would have known that the signal was red and a train was ahead and would not conceivably have accelerated the speed of his train as he did. The Safety Board concludes that the M train operator keyed by signal D2-532 when he erroneously assumed the stop arm had gone down because the signal had cleared. Whether the operator deliberately or unintentionally keyed by the signal, the stop arm design that enabled an operator without authorization to key by a red (stop) signal was a significant factor in this collision. The Safety Board further concludes that had the

operator not been able to key by the stop signal, the collision would have probably not occurred.

The Safety Board investigation identified two major safety issues: the effectiveness of automatic stop arms to ensure compliance with stop signals and the adequacy of NYCT oversight to ensure compliance with operating rules. The analysis will discuss those issues as well as safety issues relating to speedometers, radios, positive train separation, crashworthiness and occupant survivability, and emergency response.

Effectiveness of Automatic Stop Arms to Ensure Compliance with Stop Signals

Because the M train operator was easily able to key by the stop arm at signal D2-532 and to bypass an important safety device, the NYCT may be placing undue reliance on the operation of stop arms as currently implemented. The 1971 NYCT *Standard Procedures Manual No.7.71.011* describes the following purpose of stop arms:

> The train stop is used to ensure observance of and compliance with the stop indication of the signal. Failure of the motorman to comply with the rules regarding STOP signal indications results in stopping the train. Brake application on the train is completely automatic and entirely independent of any action on the part of the motorman.

The failure to comply with the rules regarding stop signal indications, as asserted in the manual, does not invariably result in stopping the train, as demonstrated in this collision. The stop arm can be bypassed as currently implemented, and it can be done by an operator who passes the stop marker at less than 5 mph approaching the signal, which causes the stop arm to go down while the signal remains red.

Excluding either an electrical or a mechanical malfunction, a stop arm is in a raised position for only two reasons: the track ahead is occupied by another train; and at GT signals, the striking train has approached and passed the signal at excessive speed. Each strike mark therefore is evidence that a train has been operated at risk of collision or derailment. The Safety Board is concerned, as the NYCT L line survey found, that 17 percent of the inspected stop arms had been struck at least once within the past 30 days, which averages 1.4 strikes a day. Because GT signals enforce a predetermined speed on descending grades or at other safety critical locations, the Safety Board has an even greater concern that nearly half of GT signal stop arms had been struck. The percentage of stop arm strikes (45 percent) at GT signals was five times greater than the percentage of strikes (9 percent) at other automatic signals, indicating a disproportionately greater frequency of strikes at GT signals. The disproportion may be caused by display differences since stop arms at GT signals and at other automatic signals, respectively, are normally up until a train approaches at a predetermined speed and down unless the track ahead is occupied. However, the disproportion is more likely because the operators have acquired, with experience on the transit system, certain expectancies and habits. The 88.7-percent

on-time train performance reported by the RTO as of February 1995 indicates that trains are moving without delay most of the time, and presumably operators become accustomed to that flow of traffic. The GT signals usually clear on time as operators approach, and trains proceed without delay; however, the operators' routine expectancies occasionally are not met, and the signal does not clear on time because of track occupancy. The strike arm survey indicates that on some of those occasions, the operators do not stop the train before striking stop arms and passing stop signals, particularly the safety-critical GT signals.

The NYCT has issued a series of directives and bulletins since 1990, each after a rear-end collision, reminding operators to obtain permission before keying by signals. Six rear-end collisions between July 1990 and February 1995 have been attributed to operators keying by signals without permission. The continuation of rear-end collisions demonstrates a lack of compliance with published operating rules. Therefore, the Safety Board concludes that the NYCT directives and bulletins were inadequately administered to ensure operator compliance with stop signals to prevent subsequent collisions.

A few days after the collision, the NYCT deactivated the automatic key-by feature at signal D2-532. The NYCT reported that since the deactivation, no strike marks have been detected on the stop arm at signal D2-532 and no delay in service on the B line has occurred. Therefore, the Safety Board concludes that the safety of operations at signal D2-532 has been enhanced by the deactivation of its automatic key-by feature. Consequently, the Safety Board believes that the NYCT should deactivate the automatic key-by feature at every one-shot GT signal.

Adequacy of NYCT Oversight to Ensure Compliance with Operating Rules

The principal duty of the NYCT management to guarantee the safety of its 3.4 million daily passengers is to ensure operating crew compliance with the NYCT published operating rules. The management oversight procedures, considering this and past collisions on the NYCT lines, have been examined. The Safety Board reviewed the July 26, 1990, NYCT rear-end collision that involved keying by without permission and in which the track, signal, and trains were the same as addressed in this report. One employee and 37 passengers were injured, and equipment damage was estimated at $63,735. The RTO was informed by memorandum after the NYCT investigation that the collision was caused "by the failure of the operator, operating the M train, to adhere to the operating rules relative to passing red signals, and failing to pay proper attention to the operation of the train" and was issued a safety recommendation by the OSS to "instruct local supervisors to increase their observation of operator's performance in their areas of responsibility as a deterrent to improper train operation." In addition, the Safety Board is investigating the June 5, 1995, NYCT collision on the Williamsburg Bridge in New York City, New York, which will further detail operational oversight.

According to the M train operator, he could not remember the aspect of signal D2-532 when he passed it without stopping.

Signal D2-532 will display a red (stop) signal when a train is ahead in the block. The signal worked properly during the stopping distance tests conducted with the test train after the collision, which indicated that signal D2-532 was working as designed. The Safety Board, therefore, concludes that the M train operator failed to comply with published operating rules that require stopping at a red signal and requesting and obtaining RTO permission to proceed.

The M train was not equipped with a speedometer; however, its operator was required to comply with different speed restrictions. The south end to the north end of Fort Hamilton station and the curve before the collision site were restricted to 20 and 15 mph, respectively. When asked how he determined the train speed, the operator replied that he used the controller positions to estimate the speeds. The RTO operations support and review senior director affirmed that without a speedometer, an operator is "guesstimating" his speed and relying on experience.

Three postcollision stopping distance tests, using a full-service brake application at speeds of 15, 20, and 25 mph, resulted in the train stopping short of the POI. In two other stopping distance tests, the test operator placed the train at 25 mph in emergency braking, and the test M train passed the POI. The Safety Board concludes that based on these stopping distance tests and the 10-foot forward movement of the B train after impact, the operator had accelerated the M train to at least 25 mph before he placed the train in emergency braking. Had the train been traveling at the posted 15-mph speed restriction, the collision might not have occurred.

The Safety Board investigated a rear-end collision on March 10, 1989, between two NYCT trains at the 103rd Street station[15] in which 3 crewmembers and 38 passengers were injured. The estimated damage was $360,000. After its investigation, the Safety Board determined that contributing to the severity of the accident was the operation of train 428 into the 103rd Street station at a speed in excess of the posted speed, in part, as a result of the failure of the NYCT management to furnish a reasonable means for operators to determine speed. The Safety Board issued Safety Recommendation R-90-2 urging the NYCT to provide speed indicators on each car in service on the system to allow operators the ability to properly determine speed. The NYCT responded in April 1991 that a speed indicator test program was being conducted and that it would retrofit the R-44 fleet (280 cars) beginning in 1992. Additional car classes would be retrofitted following a 1-year evaluation of the R-44 fleet. In May 1993, the NYCT announced that the installation of speedometers on the car fleet was in its proposed budget between 1992 and 1998. The Safety Board classified Safety Recommendation R-90-2 "Open--Acceptable Response" in August 1993.

The NYCT assistant chief mechanical officer in April 1995 advised the Safety Board that all new cars will be equipped with speedometers and that the NYCT is retrofitting its entire fleet of cars, except the 1,400 oldest, with speedometers. The older cars will be removed from service when new

[15]Railroad Accident Report--*Rear-End Collision of Two New York City Transit Authority Trains, 103rd Street Station, New York, New York, March 10, 1989* (NTSB/RAR-90/01).

cars begin arriving in 2000. The remaining 4,379 cars are scheduled for retrofit completion in 1996; however, 2,246 cars have been retrofitted as of January 14, 1996. The Safety Board recognizes the efforts of the NYCT and will monitor the progress of this project to enhance the safety of the NYCT system.

Also after the March 10, 1989, rear-end collision at the 103rd Street station, the Safety Board asked the NYCT in Safety Recommendation R-90-4 to conduct random testing, using radar guns, of train speed, with special emphasis given to those locations where speed restrictions are in effect. The NYCT responded that "operators are regularly monitored for their adherence to posted speed limits; we will, manpower permitting, intensify our efforts to ensure that speed restrictions are strictly obeyed." The Safety Board classified Safety Recommendation R-90-4 "Closed--Acceptable Action" in December 1990.

In the April 1995 interviews with NYCT line superintendents, only the superintendent of the L line stated that he conducted unannounced testing. The NYCT also has no oversight compliance program that includes either speed checks with radar guns or formal written efficiency testing. NYCT operators are passing stop signals without permission and not adhering to the speed restrictions. The NYCT has no unannounced, oral or written, operating rule compliance testing program. Therefore, the Safety Board concludes that the NYCT lacks an adequate oversight testing program to ensure operator compliance with critical speed and signal operating rules. An NYCT operational testing program that includes frequent unannounced speed and signal tests as well as radio communication procedure testing to monitor operator performance would not only detect violations but also instruct operators.

The NYCT TSSs use the B-Form check list to document operator performance. The NYCT provides no written standardized instruction to them for either filling out or grading the 18 items found on the form, which allows possible subjective performance evaluations. An overall rating is filed on the computer data base and may not adequately reflect the operator's compliance with critical speed and signal rules. The Safety Board believes that the NYCT should revise the Operating Employee Evaluation Check List to effectively determine compliance with operating rules and instructions and include, at a minimum, unannounced speed and signal tests and radio communication procedures. The NYCT should also provide standardized written instructions for administering and grading the evaluation check list.

Radio Procedures

Rule 20 (b) of the *Rules and Regulations Governing Employees Engaged in the Operation of the New York City Transit System* requires that each train must be equipped with an operable train-to-wayside radio. Additionally, NYCT rule 40 (m) requires operators to obtain radio permission to key by and pass a stop signal. However, the M train in the collision was not outfitted with a permanent radio. The M train operator stated during a Safety Board interview that he neither had been issued nor possessed a radio at the time of the collision.

He, consequently, could not request permission to key by and pass a stop signal as required by the NYCT rules. The NYCT lacked any documentation that would confirm it had provided a radio to the M train operator. Therefore, the Safety Board concludes that the NYCT failed to have procedures for radio accountability at the Ninth Avenue station to document compliance with rule 20 (b) of its published operating rules to ensure the M train operator was provided with a radio during his tour of duty.

Since the collision, according to the senior director of Operations Support and Review for the RTO, the relay operator now uses the radio of the train operator who controls the train to the Ninth Avenue station. After the train is relayed, he returns the radio to the train operator who provided it.

Positive Train Separation

The Safety Board has long been an advocate of train control systems that provide positive train separation (PTS) and has included PTS on its list of "Most Wanted Transportation Safety Improvements." The PTS system provides an automatic means of backing up the actions of the train operator by monitoring the performance of operator and train when approaching the limits of a signal or speed restriction. Should the operator or the train fail to apply the proper brake action, the PTS system will assume control, automatically apply the brakes, and stop the train. The newer transit agencies in San Francisco, California; Atlanta, Georgia; and Washington, DC, use PTS systems to control train speed and separation.

The NYCT relies on the stop arm to prevent collisions as well as on the operator's understanding of and compliance with operating rules. The collision just south of the Ninth Avenue station demonstrates the limitations of this NYCT control system. The Safety Board concludes that the track section on which the collision occurred lacked a true PTS system because the automatic stop arm did not prevent the M train from passing signal D2-532. Therefore, the Safety Board believes that the NYCT should include overspeed protection and PTS in the modernization of its signal system.

Crashworthiness and Occupant Survivability

Municipal subway systems are not subject to the Federal Railroad Administration (FRA), and the subway cars are constructed according to municipality-prepared specifications. Consequently, the car construction is not obliged to comply with FRA crashworthiness design requirements at 49 CFR 229.141, which address the minimum performance standards of structural components, such as collision posts, anticlimbers, and truck securements. The NYCT now follows a design philosophy in which equipment crashworthiness is considered. Its R-68 type car procurement specification stipulates that carbodies be constructed to include engineered primary and secondary collision posts, progressive crush resistance, carbody stress analysis, and truck securing devices. Incorporation of these design features places the NYCT in

voluntary compliance with the current FRA crashworthiness design requirements. However, the economics of construction and operation in the late 1950s resulted in a lightweight stainless steel carbody design of which the R-40 and R-42 type cars were typical. The refurbishment by Sumitomo Corporation of America included the running gear, the air conditioning, and carbody cosmetics but not a retrofit of crashworthiness structural features.

The R-40 and R-42 cars did provide reasonable protection to the occupants in this collision. A postrecovery analysis of the damage indicated that the end and corner posts of both type cars, being secured to the floor and roof structure, successfully minimized carbody telescoping as the posts pulled the roof and floor structures together in an inward folding action. Given the estimated collision speed and the amount of telescoping damage observed, the effectiveness of the carbody-end structure post is not unreasonable. The anticlimber effectiveness may have been exceeded because the collision occurred on curved track and the forces of impact may have caused one of the cars to lift. An impact occurring at such an angle may result in one car end being slightly elevated above the other corresponding car end. Because of the curved track, the impact was off center and biased to the side opposite the operator control compartment. Such a bias, in which collision forces are partially directed in a lateral direction, causes the cars to pivot and skew at the coupler connections. This lateral component of force dissipated the kinetic energy of the collision in a transverse direction. Collision forces on tangent track are substantially linear and normally absorbed into the carbody-end structures, which results in compressive collapse and crush zone intrusion.

The B train held 153 occupants, of whom only 14 people sustained minor injuries, and none of the occupants were in the intrusion "crush zone." The injuries described by emergency responders are consistent with those typically sustained when standing occupants are thrown to the floor and seated occupants are pitched rearward against hard obstacles during a low-speed, nonintrusion, rear-impact collision. The M train was not occupied except for the operator, who was in the control compartment and sustained only minor injuries. Given the amount of collision crush that was observed, the operator apparently benefited by being positioned within a small "survival space" cavity that was created during the collapse of the carbody-end structure.

Emergency Response

The collision was reported, the FDNY units were dispatched, these first units arrived on scene, and the train was evacuated at 2:39, 2:41, 2:45, and 3:15 p.m., respectively. Five emergency response agencies, municipal and private, responded with equipment and manpower to the collision site. The 15 reported injuries were minor. The Safety Board concludes that the local emergency response personnel reacted promptly to and acted effectively at the collision site.

CONCLUSIONS

1. Neither the weather, the train equipment, nor the track either caused or contributed to the collision. No crewmember fatigue was indicated, crewmembers had the necessary initial training to competently perform their duties, and neither alcohol nor drug use was a factor in the collision.

2. Because the operator was able to key by signal D2-532, he had slowed his train eventually to less than 5 mph and passed the stop marker.

3. Had the M train operator seen the stop arm go down, as stated, he would have been unable to readily determine the signal aspect from the normal standing or sitting positions of an operator in the control compartment, even had he looked.

4. The M train operator keyed by signal D2-532 when he erroneously assumed the stop arm had gone down because the signal had cleared.

5. Had the operator not been able to key by the stop signal, the collision would have probably not occurred.

6. The Metropolitan Transportation Authority/New York City Transit directives and bulletins were inadequately administered to ensure operator compliance with stop signals to prevent subsequent collisions.

7. The safety of operations at signal D2-532 has been enhanced by the deactivation of its automatic key-by feature.

8. The M train operator failed to comply with published operating rules that require stopping at a red signal and requesting and obtaining Rapid Transit Operations permission to proceed.

9. Based on the postcollision stopping distance tests and the 10-foot forward movement of the B train after impact, the operator had accelerated the M train to at least 25 mph before he placed the train in emergency braking. Had the train been traveling at the posted 15-mph speed restriction, the collision might not have occurred.

10. The Metropolitan Transportation Authority/New York City Transit lacks an adequate oversight testing program to ensure operator compliance with critical speed and signal operating rules.

11. The Metropolitan Transportation Authority/New York City Transit failed to have procedures for radio accountability at the Ninth Avenue station to document compliance with rule 20 (b) of its published operating rules to ensure the M train operator was provided with a radio during his tour of duty.

12. The track section on which the collision occurred lacked a true positive train separation system because the automatic stop arm did not prevent the M train from passing signal D2-532.

13. The local emergency response personnel reacted promptly to and acted effectively at the collision site.

PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of the rear-end collision between the two subway trains was the inadequate oversight and compliance program of the Metropolitan Transportation Authority/New York City Transit to ensure that train operators comply with the published operating rules. Contributing to the collision was the design modification to the automatic key-by feature of the automatic stop arm that enabled the operator of the M train to pass a stop signal contrary to the published operating rules that require stopping at a red signal unless permission to pass is granted by Rapid Transit Operations.

RECOMMENDATIONS

As a result of its investigation, the National Transportation Safety Board makes the following recommendations:

--to the Metropolitan Transportation Authority/New York City Transit:

Ensure that each existing one-shot grade time signal is equipped with a lunar white light. (Class II, Priority Action)(R-96-8)

Deactivate the automatic key-by feature at every one-shot grade time signal. (Class II, Priority Action)(R-96-9)

Revise the Operating Employee Evaluation Check List to effectively determine compliance with operating rules and instructions and include, at a minimum, unannounced speed and signal tests and radio communication procedures. Provide standardized written instructions for administering and grading the evaluation check list. (Class II, Priority Action)(R-96-10)

Include overspeed protection and positive train separation in the modernization of the signal system. (Class II, Priority Action)(R-96-11)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES E. HALL
Chairman

ROBERT T. FRANCIS II
Vice Chairman

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Member

JOHN J. GOGLIA
Member

GEORGE W. BLACK, JR
Member

March 19, 1996

APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

The National Transportation Safety Board was notified at 3 p.m. on February 9, 1995, of a rear-end collision between two New York City Transit subway trains in Brooklyn, New York. The investigator-in-charge and other members of the Safety Board investigative team were dispatched from the headquarters in Washington, D. C., and the regional offices in Chicago, Illinois, and Los Angeles, California. Investigative groups studied operations, track, signals, mechanical, survival factors, and human performance.

The Office of the Inspector General (MTA), New York State Public Transportation Safety Board, New York City Transit, New York City Transit Police, New York City Fire Department, New York City Police Department, and New York City Emergency Medical Service assisted in the Safety Board investigation.

Safety Board staff conducted a deposition hearing as part of its investigation on April 4, 1995, at which 10 witnesses testified.

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APPENDIX B

B TRAIN PERSONNEL INFORMATION

The train operator was employed as a cleaner by the NYCT on March 11, 1985. He was promoted to train operator on September 6, 1987. His regular assignment was on the B line working the 1405 to 2200 tour of duty. After being off on February 4 and 5, 1995, he worked his regular tour on the subsequent days leading up to the collision.

The operator passed his last periodic medical examination on June 14, 1993. During the year preceding the collision, he received six operating employee evaluations: the check list items were rated "good" or "acceptable" on a rating scale of good, acceptable, unacceptable. He had no records in the Rapid Transit Operations "Disciplinary Action History" data base.

The train conductor was employed as a cleaner by the NYCT on December 30, 1987. He began working as a conductor in subdivision B on July 5, 1988. He worked the 1405 to 2200 tour on the B line as his regular assignment. He was out sick on February 5 and 6, 1995, and then resumed his regular tour of duty up to the collision.

The conductor had his last periodic medical examination on November 15, 1994, and was assessed fit for full work. He received three operating employee evaluations during the year preceding the collision. His most recent evaluation on January 15, 1995, rated him "good" on all check list items. The conductor's personnel file contained eight disciplinary action cases, which were for administrative violations (undocumented emergency absence, AWOL, and late submission of sick forms).

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APPENDIX C

NYCT RULES APPLICABLE TO REPORT

Rule 20

(b) Each train must be equipped with an operable Train-to-Wayside Radio. Train Crews must test their radios, prior to leaving a terminal or yard for operation on the mainline, by transmitting their call sign to the Train Dispatcher or Yard Dispatcher; the reception of his/her response will indicate that the radio equipment is functioning properly. Any train having a defective radio and/or radio bracket must have that equipment exchanged; the train crew must have an operable radio before proceeding on an over the road movement.

Rule 39

(b) A Train Operator is prohibited from passing a STOP SIGN OR STOP SIGNAL or going over a switch that is set the wrong way.

(i) The train will enter the stations being bypassed at the normal speed for the area; the Train Operator will then begin to decelerate gradually, ensuring that the train does not go faster than fifteen (15) miles per hour as it leaves the station. The Train Operator must blow the horn or whistle at the entering and leaving end of the station.

Unless ordered by the Command Center or an RTO Supervisor, Train Operators operating LIGHT trains must not enter stations, unless they can get their whole train beyond the station platform without making a stop. On stations that have grade time signals, either within the station, or at the leaving end, the Train Operator must regulate the speed of his or her train so that the signals will clear without the train coming to a stop. In no event must speed exceed 15 miles per hour.

The only exception for LIGHT trains shall be in those stations that require the Train Operator to punch in to indicate the requested route or train identification and where this can not be done prior to entering the station.

APPENDIX C

Rule 40

NOTE: effective with NYCTA RTO Bulletin No. 17:93 Red Automatic Signals dated March 4, 1993, the last paragraph of rule 40(m) is changed and reads as follows.

(m) A Train Operator must STOP for a RED AUTOMATIC SIGNAL.

He/she must stop fifteen (15) feet short of the signal, or at the yellow joint marker plate on the contact rail protection board. He/she must NOT MOVE until the light turns to YELLOW or GREEN, UNLESS:

1. The signal has an "AK" sign; or
2. The signal is on a storage track or in a yard; or
3. An employee whom the Train Operator KNOWS is an authorized RTO or Electrical (Signal) employee gives a signal to go ahead which the Train Operator KNOWS is meant for him/her; or
4. The Train Operator calls the Command Center Desk Superintendent by radio and is told to proceed with RESTRICTED SPEED AND EXTREME CAUTION.

The Train Operator must call the Command Center Desk Superintendent immediately via radio. If Command Center does not acknowledge the transmission and there is no train visible ahead, he/she must wait two (2) minutes before using the wayside telephone. If after ten (10) minutes and there is a train visible ahead and Command Center still has not acknowledged the radio transmission, the Train Operator must then use the nearest wayside telephone.

(n) When he/she is permitted to move past a RED Automatic Signal, the Train Operator must pull up to the signal, Stop and make sure that the Automatic Stop Arm goes down. If the signal has a "K" sign, the Train Operator must use the Automatic Stop Arm Manual Release lever, button or special key to make the Automatic Stop Arm go down. The Train Operator must then proceed with RESTRICTED SPEED AND EXTREME CAUTION to the next signal.

APPENDIX C

Rule 59

Signal colors have the following meanings:

(a)	**RED**	STOP.
(b)	**YELLOW** (including flashing lights)	PROCEED WITH CAUTION, BE PREPARED TO STOP.
(c)	**GREEN**	PROCEED.
(d)	**BLUE**	Indicates the location of an Emergency Alarm Box, Emergency Telephone and Fire Extinguisher, or an Emergency Telephone only.
(e)	**LUNAR WHITE**	Indicates that the fixed signal on which it is displayed may be cleared by a train operating at a predetermined speed. Also used for train orders. Two horizontal white lights means no orders to be received.

Rule 66

(a) TIME-CONTROLLED SIGNAL

A fixed signal having a time element in its control which requires the passage of time for a change in aspect.

(b) GRADE TIME CONTROL OF SIGNALS

Is intended to cause a train to run through grade time territory at a predetermined speed. Trains exceeding such speed are automatically stopped.

(d) TIME CONTROL "T" SIGN

A fixed signal bearing the letter "T" located at the point of entrance to time-controlled territory.

APPENDIX C

(e) GRADE TIME "GT" SIGNAL

A fixed signal used to enforce a predetermined speed on descending grades or at other locations; this signal is always preceded by a Time Control "T" Sign and a sign designating the allowable speed in miles per hour or by a "GT" Sign.

(h) LUNAR WHITE SIGNAL

A fixed signal bearing a lunar white aspect which when illuminated together with a STOP indication, indicates that the signal may be cleared by a train approaching said signal at a predetermined speed.

Rule 68

(a) AUTOMATIC STOP

A device used in conjunction with a fixed signal to cause an emergency application of the air brakes of a train passing that signal when it indicates STOP.

Some Automatic Stops are operated as "BLIND" stops without any signal being opposite. In this case the Automatic Stop is cleared by the train passing at a predetermined speed. (Used on both Subdivisions A and B; Williamsburg Bridge, reverse running.)

(b) AUTOMATIC STOP ARM

The part of an Automatic Stop which engages a device on a car to apply the train air brakes in emergency. It is located outside the running rails.

Rule 70

(b) SPEED LIMIT SIGN

A fixed signal located at the entrance to a section of track on which trains are required to run at a reduced speed; it indicates the maximum speed at which trains may be operated on said section of track. (PROCEED AT SPEED INDICATED "10" DENOTES MILES PER HOUR.)

APPENDIX D

MEMORANDUM AND SPEED CALCULATIONS FROM NYCT BRAKE SYSTEMS ENGINEERING MANAGER

New York City Transit Authority
Metropolitin Transportation Authority

Memorandum

Date: February 16, 1995

To: Keith Falk, Director Car Systems Engineering

From: George Feinstein, Manager Brake Systems Engineering

Re: COLLISION OF FEBRUARY 9, 1995 N/O 9TH AVE. (BMT)

Following the subject collision I was requested to inspect the accident site and determine the speed of the moving train at the instant of impact based on the physical evidence

A light, moving eight car R42 train (M service) with brakes applied collided with a stationary ten car R4C train (B service) with brakes applied. The R40 train had an unknown number of passengers.

Skid marks indicated that the last car (4259) of the R40 train was moved forward 10.5 ft. The first car (4351) of the R40 train was moved 1.5 ft. The cars in between were moved various distances between 1.5 and 10.5 ft. There were approximately 100 ft. of intermittent skid marks on the running rails behind the last car (4914) of the R42 train.

There was extensive damage to the two cars (4259 & 4918) directly involved in the collision. The two cars telescoped into each other approximately 5.5 ft. Heavy damage, including broken drawbass and cars leaving the center castings of the truck, was observed on several cars in each of the trains.

Considering the motion of the individual cars, and the damage to the various cars it was taken that the total energy absorbed by the two trains after the collision is represented by an average motion of the two trains of 10.5 ft. after the collision.

Based on the above considerations, the calculated speed of the R42 train just before the collision was 13 to 17 mph. The calculated speed of the train at the start of the skid marks was 21 to 26 mph. See attached sheets for the calculations.

Attachment

APPENDIX D

2/14/95
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Speed of two trains after collision

$V_i = \sqrt{2as}$ $\quad a = 3.0 \pm 0.5$ mphs
$\quad s = 10.5 \pm 1.0$ ft.

① For $a = 2.5$, $s = 9.5$
$V_i = 5.69$ mph

② For $a = 3.0$, $s = 10.5$
$V_i = 6.55$ mph

③ For $a = 3.5$, $s = 11.5$
$V_i = 7.40$ mph

Using conservation of momentum considerations, the speed of the R42 train just before the collision was:

$$V_o = \frac{V_i\,(10 \times 74{,}400 + 8 \times 68{,}200)}{(8 \times 68{,}200)}$$

$$= 2.36\,V_i$$

① $V_o = 13.43$ mph ② $V_o = 15.46$ mph ③ $V_o = 17.46$ mph

Say 13 to 17 mph

For the speed of the R42 train at the start of the 100 ft skid mark see below:

Deceleration distance prior to collision:

$100 \text{ ft} - (10.5\text{ft} + 5.5\text{ft}) = 84\text{ft}$

$$V = \sqrt{V_o^2 + 2a(s - s_o)}$$

$a = 3.0 \pm 0.5$ mphs

① For $V_o = 13$ mph & $a = 2.5$ mphs
$V = 21.3$ mph

② For $V_o = 15$ mph & $a = 3.0$ mphs
$V = 23.8$ mph

③ For $V_o = 17$ mph & $a = 3.5$ mphs
$V = 26.3$ mph

Say 21 to 26 mph

APPENDIX E

NYCT B FORM
OPERATING EMPLOYEE EVALUATION CHECK LIST

NEW YORK CITY TRANSIT AUTHORITY
RAPID TRANSIT OPERATIONS DEPARTMENT

OPERATING EMPLOYEE EVALUATION CHECK LIST

NAME _____ PASS _____ TITLE _____

DATE _____ TIME _____ DIVISION _____ DIRECTION _____

CAR NO. _____ INTERVAL/LINE/TERMINAL _____

JOB NO. _____ REGULAR JOB NO. _____ RDO _____

YEARS IN TITLE _____ BRAKE VALVE HANDLE NO. _____

WEARING SAFETY GLASSES? YES NO

PRESCRIPTION GLASSES REQUIRED? YES NO

WEARING PRESCRIPTION GLASSES? YES NO N/A

CONDUCTOR	CODE	TRAIN OPERATOR
UNIFORM	____	UNIFORM
APPEARANCE		APPEARANCE
SAFETY EQUIPMENT		SAFETY EQUIPMENT
P.A. CHECK AT TERMINAL	____	P.A. CHECK AT TERMINAL
USE OF PUBLIC ADDRESS	____	USE OF PUBLIC ADDRESS
COMMUNICATIONS BOOK	____	COMMUNICATIONS BOOK
USE OF RADIO	____	USE OF RADIO
KNOWLEDGE OF RUNNING TIME	____	KNOWLEDGE OF RUNNING TIME
BOARDING TRAIN AT TERMINAL	____	BOARDING TRAIN AT TERMINAL
CAB DOOR POSITION	____	CAB DOOR POSITION
SIDE SIGNS	____	SIDE AND END SIGNS
DOOR OPERATION	____	BRAKE TESTS: STANDING, ROLLING, RUNNING
OBSERVING PLATFORM	____	JUDGMENT OF SPEED AND DISTANCE
PLATFORM DUTIES	____	STATION STOPS
FLAGGING DUTIES	____	REACTION TO SIGNALS
PASSENGER RELATIONS	____	SPEED OVER SWITCHES
		PROPER OPERATION, PASSENGER SERVICE
	____	PROPER OPERATION, YARD/LAY UP TRACKS
OVERALL OPERATION		OVERALL OPERATION

MARK WITH APPROPRIATE CODE: GOOD (G), ACCEPTABLE (A), UNACCEPTABLE (U)

REMARKS _____

_____

_____

REPORTED BY _____
(TITLE) (NAME) (PASS)

ORIGINAL TO LINE SUPERINTENDENT, COPY TO EMPLOYEE

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APPENDIX F

NYCT BULLETIN NO. 15-95
DEACTIVATION OF KEY-BY FEATURE - SIGNAL D2-532

MTA NEW YORK CITY TRANSIT
DIVISION OF RAPID TRANSIT OPERATIONS

BULLETIN

BULLETIN NO.: 15-95

TO: ALL EMPLOYEES February 14, 1995

SUBJECT: **DEACTIVATION OF KEY-BY FEATURE - SIGNAL D2-532**

An subdivision "B" Train Operators are advised that effective Sunday, February 12, 1995, you arc no longer able to key-by Automatic Signal D2-532, located at the north end of the northbound platform (Track D-2) at the Fort Hamilton Parkway Station, in the manner prescribed in Rule 40(n). The automatic key-by feature associated with Automatic Signal D2-532 has been deactivated. Should it be necessary for a train Operator to move past this signal when it is at danger (RED), they MUST proceed as follows:

- The Train Operator will call the Command Center via wayside radio or telephone and ask for permission to proceed past the red signal according to Rule 40(n).
- When given permission by the Command Center to proceed past the red automatic signal, the Train Operator must pull up to the signal and stop. Any further movement will result in an emergency application of the air brakes
- After stopping, the train Operator must descend to the roadbed and step on the stop arm and make sure that it retains

  NOTE: If the stop arm does not retain Use Train Operator must inform the Command Center immediately and be governed by their instructions.

- Having done this, the train operator will board the train and proceed with RESTRICTED SPEED AND EXTREME CAUTION to the next signal.

Line Managers and Train Service Supervisors will ensure that all train Operators are aware of and strictly comply with this directive.

Nathaniel Ford
Chief Transportation Officer
Rapid Transit Operations