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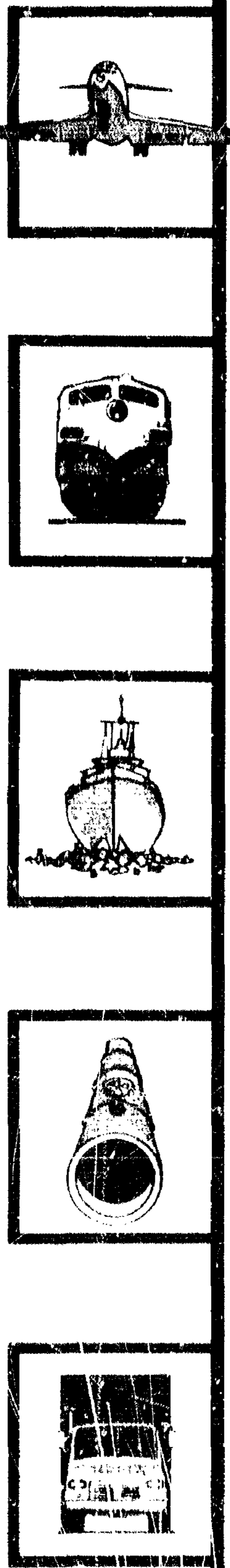

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

REAR-END COLLISION OF CONRAIL COMMUTER TRAINS PHILADELPHIA, PENNSYLVANIA

OCTOBER 16, 1979

NTSB-RAR-80-5

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB-RAR-80-5	2. Government Accession No.	3. Recipient's Catalog No. PB80 [illegible] 182
4. Title and Subtitle Railroad Accident Report— Rear-End Collision of Conrail Commuter Trains, Philadelphia, Pennsylvania, October 16, 1979		5. Report Date May 12, 1980
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Accident Investigation Washington, D.C. 20594		10. Work Unit No. 2824-A
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594		13. Type of Report and Period Covered Railroad Accident Report October 16, 1979
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

On October 16, 1979, about 8:19 a.m., northbound Consolidated Rail Corporation (Conrail) train No. 1718 collided with the rear end of standing Conrail train No. 0714 and caused it to move forward and collide with standing Conrail train No. 716 on track No. 1 of Conrail's West Chester Branch, just north of the Angora station at Philadelphia, Pennsylvania. Of the 525 persons who were injured, one crewmember of train No. 0714 died 6 days after the accident. Equipment damage was estimated at $1,940,312.

The National Transportation Safety Board determines that the probable cause of this accident was the engineer of train No. 1718 operating at a speed above that authorized by the block signal indication which did not allow for his stopping the train before it collided with a standing train. Contributing to the accident was the engineer's improper operation of the train brakes and the failure of a supervisor and traincrew personnel in the operating compartment of the locomotive to monitor the train's operation adequately and to take action to insure that the train's speed was reduced or that it was stopped when its speed exceeded that authorized for the signal block.

17. Key Words Rear-end collision, decelostat, slide protection, rail adhesion, deadman control, No. 8 vent valve, automatic brake valve, emergency brakes, throwover seats, conductor's valve		18. Distribution Statement This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161	
19. Security Classification (of this report) UNCLASSIFIED	20. Security Classification (of this page) UNCLASSIFIED	21. No. of Pages 37	22. Price

NTSB Form 1765.2 (Rev. 9/74)

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

Adopted: May 12, 1980

REAR END COLLISION OF CONRAIL COMMUTER TRAINS PHILADELPHIA, PENNSYLVANIA OCTOBER 16, 1979

SYNOPSIS

On October 16, 1979, about 8:19 a.m., northbound Consolidated Rail Corporation (Conrail) train No. 1718 collided with the rear end of standing Conrail train No. 0714 and caused it to move forward and collide with standing Conrail train No. 716 on track No. 1 of Conrail's West Chester Branch, just north of the Angora station at Philadelphia, Pennsylvania. Of the 525 persons who were injured, one crewmember of train No. 0714 died 6 days after the accident. Equipment damage was estimated at $1,940,312.

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INVESTIGATION

The Accident

Conrail train No. 712, consisting of nine cars, departed Media, Pennsylvania, at 7:27 a.m., on October 16, 1979, after the required brake test had been performed. The brake test disclosed no defects, and the brakes operated properly en route to Suburban Station until three undesired emergency applications occurred: one at the Media station, one at Morton-Rutledge, and one just north of Angora, Pennsylvania, about milepost 3.7. As the train moved north away from milepost 3.7, it stopped again. Inspection disclosed that the coupler had been pulled out of the north end of the eighth car. The passengers in the eighth and ninth cars were moved into the forward cars; the two rear cars were uncoupled and left standing on track No. 1; and train No. 712 proceeded into Suburban Station in downtown Philadelphia.

Conrail train No. 716, also consisting of nine cars, departed from Media at 7:43 a.m. When it approached wayside signal B-56, the signal displayed an "approach" aspect. The next signal, B-42, 3,924 ft north of signal B-56, displayed a "stop-and-proceed" aspect because the block was occupied by train No. 712. Train No. 716 had no difficulty in slowing to comply with the indication of signal B-56 or in stopping at signal B-42. After moving past signal B-42, train No. 716 stopped on track No. 1 about 50 ft behind the two cars from train No. 712. After receiving instructions to couple the standing cars and to push them into Suburban Station, the crewmembers complied and prepared to make an air brake test.

Conrail train No. 0714, consisting of two cars, departed West Chester, Pennsylvania, at 7:14 a.m., en route to Suburban Station. When train No. 0714 passed signal B-56, it displayed an "approach" aspect, and the next signal, B-42, displayed a "stop-and-proceed" aspect. Train No. 0714 stopped and then proceeded past signal B-42 at restricted speed until it was stopped about 20 ft behind train No. 716. The engineer reported no difficulties in stopping at any point.

Train No. 1718, consisting of four cars departed Elwyn, Pennsylvania, at 7:50 a.m. A special duty trainmaster boarded the train at Media and rode in the operating compartment. Train No. 1718 passed Cane Tower, milepost 9.1, at 8:09 a.m., and made its last scheduled stop on the West Chester Branch at Secane, Pennsylvania, 0.7 mile north of Cane Tower. In all instances south of Secane braking was satisfactory and the engineer did not have any trouble stopping or starting the train at the stations. From Secane, train No. 1718 was scheduled to be operated as an express train into the 30th Street Station. After leaving Secane, the engineer of train No. 1718 said that he applied the train brakes on several occasions to slow the train in accordance with slow speed orders. He also said that the speed of the train at signal B-56 was about 30 mph, which was in compliance with the "approach" aspect displayed by that signal, and that he maintained this speed until his train had passed over a 30 mph-crossover located about 1.8 miles south of signal B-42. The rates of speed were estimates given by the engineer, because the speedometer was not operable.

Shortly after train No. 1718 passed signal B-56, the conductor joined the engineer and the special duty trainmaster in the operating compartment and began counting and recording his tickets. He did not remember engaging in any conversation with the two men, seeing the wayside signals, nor calling them as required by Rule 34. (See appendix A.)

After clearing the 30 mph-crossover, the engineer released the brakes on the train and allowed the train to increase speed as it rolled down a grade toward the Angora trestle. As it approached the trestle, the engineer made a light brake application and the train's speed slowed in response to the application.

Shortly after the train crossed the trestle, a trainman entered the operating compartment to give the conductor tickets collected from the other cars and to check on an odor of burning wire insulation about which the passengers were complaining. The conductor opened an electrical cabinet behind the engineer and examined it for fire. The engineer stated that there had been an electrical problem on the car within the past few days which had caused some wiring to be heated, but they found no fire or heat at that time.

The engineer estimated the train's speed to be about 20 mph as it approached the point where he normally made a brake application when he was expecting to stop at signal B-42, and he made a light brake application. Shortly thereafter, he saw the "stop-and-proceed" aspect displayed by signal B-42. About the same time, the trainman, who was standing on the left side of the operating compartment, looked forward and saw the rear end of train No. 0714 and shouted three times, "hind-end, drop it." No one in the operating compartment remembered calling the aspect of signal B-42; however, the engineer and the special duty trainmaster said that they heard someone call it but that no one acknowledged the call as required by the operating rules.

The engineer did not see the rear end of train No. 0714 when it became visible to the trainman because of a righthand curve and the bank of a cut in which the train was standing. He did not see the rear headlight on train No. 0714, but he saw a red marker light and immediately released the master controller handle, which should have caused an emergency brake application. At the same time, he moved the automatic brake valve handle, which he had been moving toward the suppression position, to the emergency position. (See figure 1.) He said he heard an air exhaust, but to him the train did not appear to decelerate as it should have from an emergency brake application. He said that he was not alarmed because he believed that there was still sufficient distance for the train to stop, and since he had not experienced any braking difficulties, he thought the brakes would become effective and stop the train. When the train passed signal B-42, moving about 20 mph, the engineer said that he realized that they were going to collide with the train ahead. During that time, he sensed the brakes retard momentarily and then release. He said that when the closing distance had decreased to about 80 feet with no decrease in the train's speed, he left the operating compartment, closed the compartment door, held it closed with his foot, and braced himself for the crash. The special duty trainmaster, the conductor, and the trainman, in that order, left the operating compartment ahead of the engineer as soon as the trainman shouted an alarm. About 8:19 a.m., while moving at a speed estimated by the engineer to be 20 mph, train No. 1718 struck the rear of train No. 0714. (See figure 2.) The impact force moved train No. 0714 forward and caused it to collide with the rear of train No. 716.

Trains Nos. 1718 and 0714 collided 375 ft north of signal B-42. Train No. 716 was moved forward 55 ft, and train No. 0714 was moved forward 39 ft. After the collision, the two trains, Nos. 0718 and 0714, were separated by 5 ft. At the time of impact, brakes were not applied on the 11 cars of train No. 716.

Cars Nos. 305 and 304 in train No. 0714 derailed and moved toward the west a sufficient distance to block track No. 2, but they remained upright and in line. Cars Nos. 265, 221, and 255 in train No. 1718 derailed but remained upright and in line with the track. Although the catenary structure was not damaged and power was not disrupted, power was cut off at 8:22 a.m., as a safety precaution. (See figures 3 and 4.)

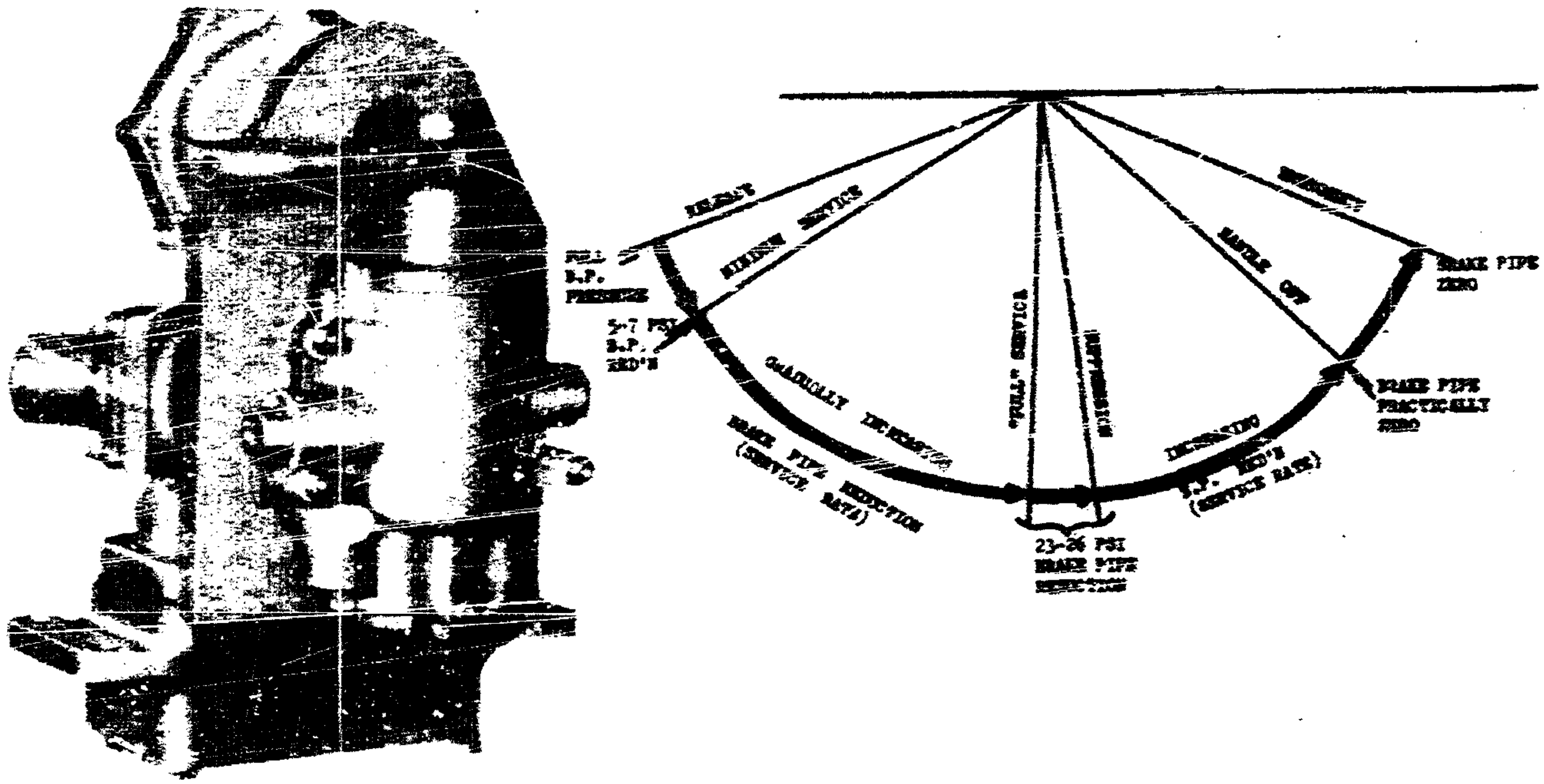

Figure 1.—26-B-1 automatic brake valve.

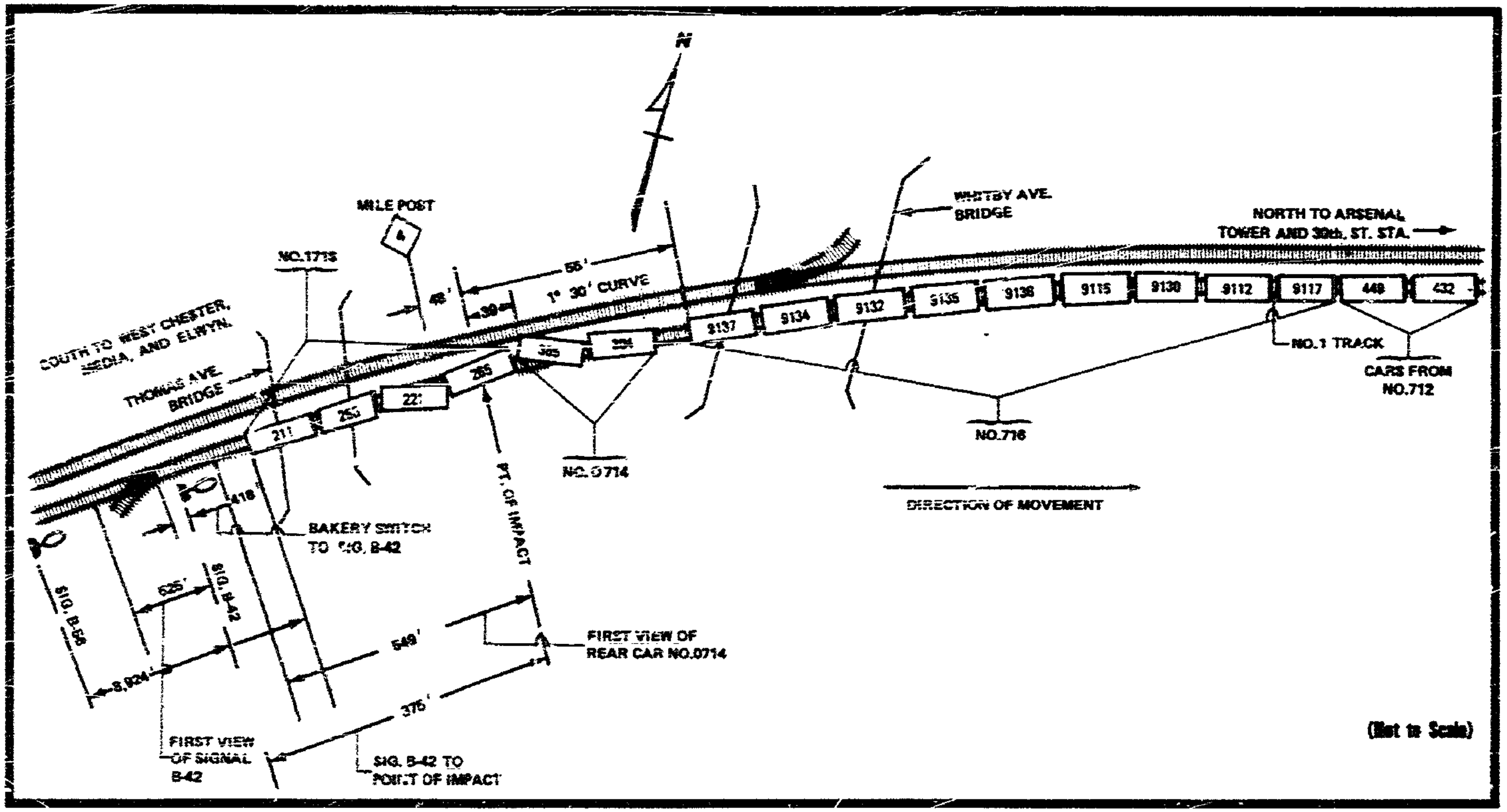

Figure 2.—Plan view of accident site.

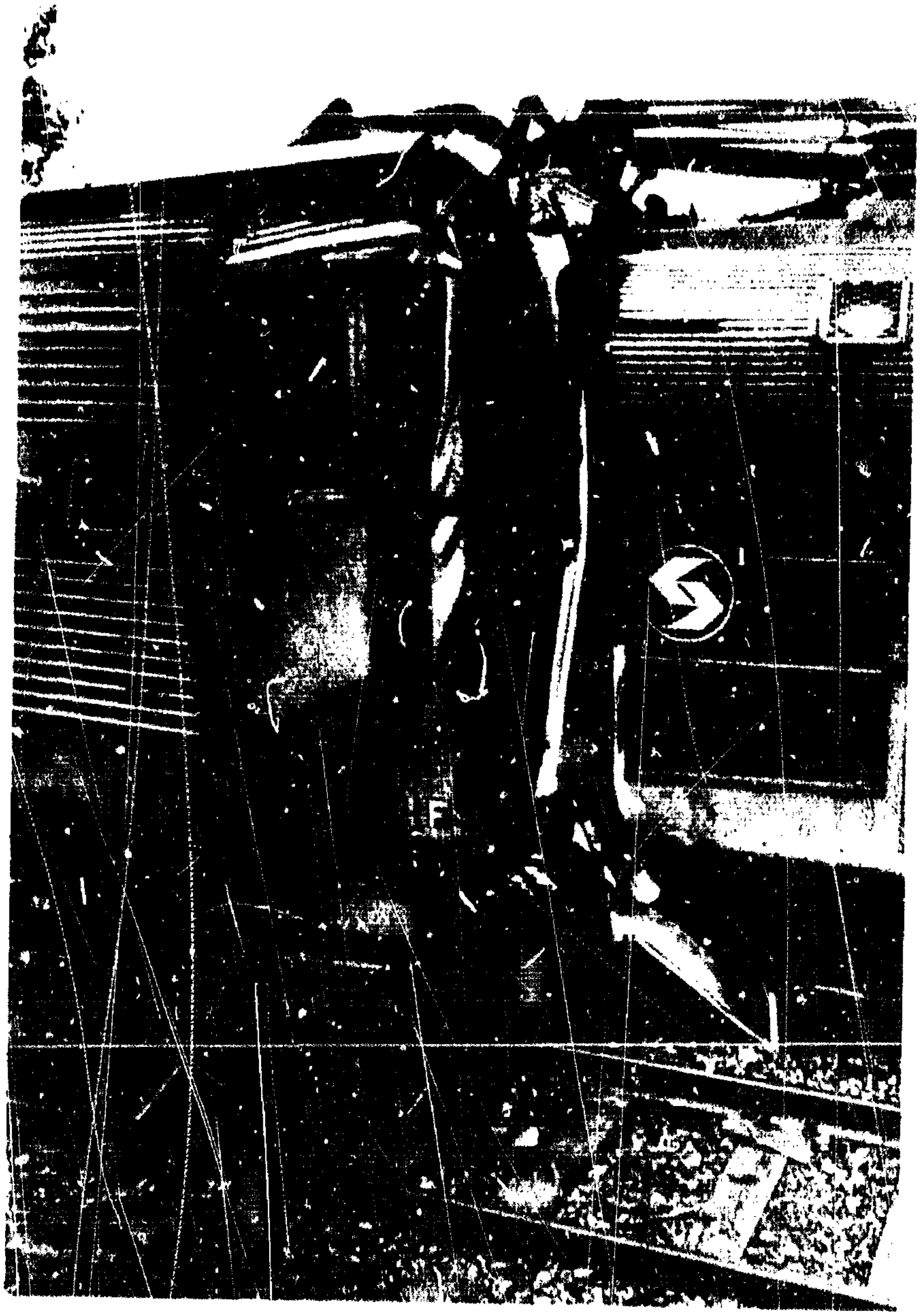

Figure 3.--Left-rear car No. 0714, right-lead car No. 1718.

Figure 4.--Train No. 0714; view is south.

Injuries to Persons

Injuries[1/]	Train No. 716 Crew	Train No. 0714 Crew	Train No. 1718 Crew	Passengers	Total
Fatal	0	1	0	0	1
Serious	0	2	1	25	28
Minor	0	0	3	431	434
None	4	0	2	Unknown	6+
					469+

Medical and Pathological Information

Sixty-two persons were treated for lacerations, contusions, and back, facial, leg, knee, neck, head, arm, and chest injuries at a nearby temporary emergency center and were released. Of the 463 persons who were treated at 23 area hospitals, 29 were admitted with concussions, laryngeal, edema, fractures of noses, hips, and ankles, and abdominal injuries.

An autopsy revealed that the crewmember died of multiple abdominal injuries, which included a lacerated liver and spleen.

Damage

The two standing cars detached from train No. 712 train were damaged only slightly. The Hale and Kilburne throwover type-seats had numerous seat cushions displaced, but there was no serious internal damage. No exterior car damage resulted from the accident.

The equipment in trains Nos. 716, 0714, and 1718 had damage that varied from slight to heavy. The damage consisted of broken piping to the emergency air reservoirs, broken couplers, bent end-posts and frames, buckled side skin, buckled buffer plates, and broken glass. The ends of the cars where impact occurred were damaged severely. On several cars, the end doors were inoperable because of the distortion of the underframe caused by high compressive forces.

The seat bases of some of the Haywood-Wakefield seats in car No. 265 of train No. 1718 pulled loose from the floor. In some instances, the seat bases were detached from the seat. These bases bent or broke from passenger contact and, in some instances, contributed to the injuries.

1/ For the purposes of this chart, severity of injury is determined as follows: "serious" includes only those who were admitted to a hospital; "minor" includes those who were reported to have been seen and/or treated and released.

Crewmember Information--Train No. 1718

The engineer reported for duty at Media on October 16, 1979, at 5:30 a.m., after having been off duty since 5:25 p.m., October 15. He reported that he had rested well during his off-duty period. He operated train No. 702 from Media into Suburban Station, and then train No. 1705 back to Elwyn, and departed Elwyn operating train No. 1718. No one with whom he had worked during the time before the accident took any exceptions to his behavior or train handling. He had operated commuter trains on the West Chester Branch for about 9 years, and his record indicated no prior disciplinary action.

The conductor reported for duty on October 16, 1979, at 5:30 a.m., at Media, and he had made one roundtrip into Suburban Station before his tour of duty as conductor on train No. 1718. His record indicated a reprimand for failing to comply with a company notice after a passenger caught his arm in a door.

The front brakeman was assigned to the second car when he reported for duty at Media at 7:45 a.m. His record indicated several disciplinary actions before December 1974, but since that time, his record was clear.

Another brakeman and a flagman were at their duty stations in the third and fourth cars and had no foreknowledge of the collision.

A special duty trainmaster occupied the operating compartment between Media and the collision site. It was his first day on that assignment. He was a qualified engineer, but he was not qualified on the West Chester Branch. He was riding in the operating compartment primarily to qualify on that portion of the railroad. He had worked other assignments as a special duty road foreman beginning May 1, 1979. His record indicated no disciplinary action. (See appendix B.)

Track Information

The railroad in the area of the accident consists of two main tracks built of 130-pound, continuous welded rail (CWR) laid on crushed stone ballast. The two tracks extend through a cut in a 1° 30' right-hand curve. The grade changes from 0.18 percent ascending northward to 0.21 percent descending northward, 200 feet south of the collision site.

Train Information

Commuter trains, electrically powered from a catenary system, are operated between Suburban Station, Philadelphia, and West Chester and intermediate point.

Cars Nos. 449 and 432, left near milepost 4 by train No. 712, were built by the Pennsylvania Railroad Company between 1912 and 1914. The 64-ft 5 3/4- in. cars seat 72 passengers and weigh 141,570 pounds. Car No. 449 is owned by the Southeastern Pennsylvania Transportation Authority (SEPTA), and car No. 432 is owned by the New Jersey Department of Transportation (NJDOT). Neither car was equipped with emergency tools or first aid kits, but both were equipped with a 30-pound CO 2 fire extinguisher. Neither car was equipped with a train radio.

The nine cars of train No. 716, classified as type RER-13, were built by the Bethlehem Steel Company in 1931. The 72-ft 11 1/2-in. cars weigh 130,000 pounds and seat 86 passengers. The cars are owned by the city of Philadelphia. The cars are not equipped with emergency tools or a fire extinguisher, but first aid kits (dry bandages) were available. None of the cars was equipped with a train radio.

The two cars of train No. 0714, classified as type MA1F, are owned by SEPTA. The 85 ft-long cars, built by the General Electric Company in 1974, seat 127 passengers and weigh 120,600 pounds. The cars were equipped with train radios, emergency tools and fire extinguishers, but no first aid kits. The rear car of train No. 0714 was equipped with red marker lights and a headlight. These lights were illuminated at the time of the accident.

Earlier on the day of the accident, the equipment used in train No. 1718 northward had been operated southward to Elwyn, Pennsylvania, as train No. 1705. A brake test was made at Suburban Station, and no exceptions were taken. The train responded well to braking requirements southward, and no difficulties were experienced in making accurate station stops.

At Elwyn, the engineer moved from the south end of the equipment to the north end for the return trip to Suburban Station, as train No. 1718. The engineer and flagman made a brake test, which included an emergency brake application initiated by the deadman control and the automatic brake valve, and no problems were detected.

Cars Nos. 265, 255, and 211, classified as type MA1B MP85 in train No. 1718, are owned by the city of Philadelphia. They were built by the Budd Company in 1963. They weigh 104,000 pounds, are 85 ft long, and seat 127 passengers. Car No. 221 was built by the St. Louis Car Company in 1967, and it is also owned by the city of Philadelphia. It weighs 105,540 pounds, is 85 ft long, and seats 122 passengers. Each car was equipped with a train radio and fire extinguishers, but they did not have emergency tools or first aid kits. The MA1B MP85 cars are equipped with a 26R-type airbrake system, a 26B1 brake valve, cab signals, and train stop equipment; cab signals and train stop equipment are not in service on the West Chester Branch because the branch line is not equipped with the wayside facilities. Car No. 265 was equipped with a Vapor Mark IV speed indicator which was inoperable on the day of the accident.

In addition to the auxillary equipment, the cars of train No. 1718 were equipped with wheel slide protection and a deadman safety device. The wheel slide device is activated by a Westinghouse valve known as a "decelostat." The deadman control puts the brakes in emergency when it is activated by releasing the master controller handle. This action nullifies the wheel slide protection. Placing the automatic brake valve in the suppression position makes a full service application, but nullifies the deadman control feature. An emergency brake application can be made with the automatic brake valve, by a single unit brake control if the train separates and the brake pipe pressure is depleted, and by a conductor's emergency valve located inside the passenger compartment. If the main reservoir pressure drops between 70 and 8[illegible] pounds, the car's emergency brakes automatically apply.

The "decelostat" valve is activated if a wheel slides during a brake application. When a sliding wheel is detected, the action of the "decelostat" valve vents the brake cylinder pressure and releases the brake only on that truck 2/ on which the slide is occurring. The recovery time for brakes to be effective again can be several seconds. The "decelostat" action for each truck is independent of all other trucks in the train. The "decelostat" valve would not be activated if all wheels on a truck slid simultaneously. Activation of the "decelostat" valve is dependent on a differential in axle rotational speed between axles on the same truck.

The brake cylinder pressure gage, which is located in front of the engineer's position, only indicates the brake cylinder pressure on the truck immediately under the engineer. The engineer has no means of determining the [illegible] cylinder pressure on other trucks in the train. Therefore, he can only [illegible] hen the "decelostat" valve has vented the brake cylinder pressure on the truck beneath him because it will indicate a reduced pressure.

The conductor of train No. 712 was forced to use a commercial telephone to inform his superiors about the trouble with his trains and to receive instructions about how to handle the situation.

Southbound train No. 709 arrived at milepost 3.7 on track No. 2 immediately after trains Nos. 1718 and 0714 collided. Since train No. 709 was equipped with an operable radio, the conductor of train No. 716 used it to relay information relative to the accident, and the engineer of train No. 709 continued to communicate information concerning the accident to Arsenal Tower.

Method of Operation

Trains are operated through the area of the accident by an automatic block signal system. The double main tracks run north and south and are numbered east to west as Nos. 1 and 2. The current of traffic is northbound on track No. 1 and southbound on track No. 2, and the maximum authorized speed for passenger trains is 50 mph.

The approach signal, B-56, for signal B-42 is 8,924 ft south of signal B-42. Signal B-42 is 395 ft south of the point of impact. (See figure 2.) The position light signals can display the following aspects:

2/ The wheel and axle assembly at each end of the car on which the body of rail equipment is carried.

Aspect	Name	Indication
Three horizontal yellow lights displayed over a single light	Stop and proceed	Stop; then proceed at restricted speed
Three diagonal yellow lights to the right	Approach	Proceed prepared to stop at next signal. Train exceeding medium speed must at once reduce to that speed.
Three vertical yellow lights	Clear	Proceed
Three diagonal yellow lights to the right over three vertical yellow lights	Approach medium	Proceed approaching next signal at medium speed.

Normally, signal B-42 can display an "approach medium" and a "clear" aspect in addition to "approach" and "stop-and-proceed"; however, the least restrictive aspect that signal B-42 could display at the time of the accident was an approach aspect because of changes made to facilitate signal cable repairs between signal B-42 and Arsenal Tower. Tests conducted on the signal system following the accident indicated that it was operating properly.

Operating Rule 285 governed movements past signal B-56 and Rule 291 governed operation past signal B-42. Rules 34, 106, 108, 400N-1, 400N-2, and 400N-3 governed the operational procedures leading to the accident. These rules assign responsibilities to crewmembers, such as calling signal indications, responsibilities to insure safe movement of the train, speed of a train relative to signal indications, and the responsibilities of each crewmember according to his assignment. (See appendix A.)

There are no supervisors assigned to a specific location on the West Chester Branch, but supervision is accomplished by roving supervisors. Traffic density on the line is about 1 1/2 roundtrip freight trains per day and about 30 passenger trains each way per day, except on Saturdays, Sundays, and holidays.

The commuter service in the Philadelphia area is supplied by SEPTA, and the equipment used in the service is owned either by SEPTA, the NJDOT, or the city of Philadelphia. SEPTA provides funding, equipment, and schedule information to Conrail which then operates the trains over its trackage with Conrail crews. SEPTA does not issue operational directives to Conrail, but occasionally it will make a recommendation relative to the operation of the service. It also monitors and works with Conrail in the maintenance program for the commuter equipment.

The commuter trains operating on the West Chester Branch operate over a dedicated line between Arsenal Tower and 30th Street Station which belongs to the National Railway Passenger Corporation (Amtrak) and over SEPTA tracks from 30th Street Station into Suburban Station.

The special duty trainmaster took no exceptions to the behavior of the engineer of train No. 1718 or to his operating procedures en route from Media to the point of the collision. While he was in the cab, the engineer called out the restrictive signal aspects, except for signal B-42. According to the special duty trainmaster, the train was handled properly between stations and station stops were made with no problems. He recalled hearing brake pipe air exhaust when the brakes were applied to slow for the crossover at Fernwood; for the approach to the Angora trestle; for the approach to signal B-42; and when the brake application was made after the alarm was given that a train was ahead. He had no criticism of the engineer's train handling as it approached signal B-42. In his opinion, the engineer had done all that he could to stop the train, and he did not consider him to be negligent in his responsibilities.

Meteorological Information

On the morning of the accident, the weather was clear with good visibility and no wind. The temperature was 40° F with a dewpoint about 38° F. During the hours before sunrise, dew was reported on the railheads, but it dried shortly after sunrise at 7:13 a.m. At 8:00 a.m., the sun was 8° above the horizon with an azimuth of 108° from true north.

Survival Aspects

Passengers were thrown from their seats, forward or backward, depending on the direction in which they were facing. They complained of failed seatbacks, seat cushions hitting them, no restraint devices to keep them in their seats, hitting the top portion of the seatbacks or chair arms with their faces, and being pinned on the floor by someone thrown on top of them or by a dislodged seat.

Some of the newer cars were equipped with emergency windows set in pullout rubber mountings, but only two or three of them were removed. One or two end doors could not be opened because of damage; however, the passengers were able to leave through the vestibule side doors. When passengers attempted to move through the cars, seats which had broken loose impeded then. Rescue personnel had some difficulty removing passengers on stretchers because the aisles were too narrow to permit stretcher passage. Stretchers had to be lifted over the seatbacks and carried laboriously to the ends of the cars.

The city of Philadelphia and the counties of Bucks, Chester, Delaware, and Montgomery participate jointly in the "Philadelphia Regional Emergency Medical Disaster Operation Plan (PREMDOP)." The function of PREMDOP is to provide emergency medical support and assistance in the area when and where it is needed.

The development of the plan was begun after World War II by the Philadelphia Civil Defense Council, which is currently the Office of Emergency Preparedness of the Philadelphia Fire Department. The current plan was made effective in April 1973. Because PREMDOP had conducted a mock drill/rehearsal of a disaster involving the plan in early October, the preparedness of all units was exceptional.

The total emergency response effort at the scene of the accident was provided by three supervisors, 10 district cars, 39 emergency wagons, and 8 rescue units, staffed with 21 emergency medical technicians.

Those passengers who were not considered seriously injured were treated at a triage center set up and operated in the Harrington School gym. All casualties had been removed from the accident site by 9:34 a.m.

Tests and Research

Following the accident, an inspection of the operating controls of train No. 1718 indicated that the brake valve was cut in, with the handle in the handle-off position. The master controller handle was missing but the handle receptacle indicated that the controller was in the center or emergency position. The control plug, which activates the car's controls, was inserted.

The cars in train No. 1718 were examined at the site and again after they were moved to the shop; no flat spots were found to indicate that the wheels had slid. No marks were found on the railheads ahead of the point of impact which would indicate sliding wheels.

A series of sight and stopping distance tests was conducted at the accident site on October 21, 1979. Tests determined that a standing passenger coach could be seen by the engineer while standing on the right side of the operating compartment when the train was 549 ft from the point of impact. Signal B-42 could be seen by the same engineer from 525 ft. The same points were visible from the left side of the operating compartment at 616 ft and 568 ft, respectively.

Once signal B-42 was sighted, it did not pass from sight because of any visual obstructions. The position of the sun did not affect visibility. The rear of the standing train was visible 375 ft from signal B-42. The wayside marker used unofficially by the engineer of train No. 1718 when he was planning to stop at signal B-42 is a track switch leading into a bakery. It is 418 ft in front of signal B-42. It was near this point that the engineer began increasing his applied brakes and someone shouted an alarm.

Brake tests were conducted on the cars of train No. 712, and one car had a defective train-stop magnet valve which was determined to be the cause of the undesired emergency brake applications.

The brakes of cars Nos. 211 and 255, the second and third cars of train No. 1718, were tested and functioned correctly except at location L-3 on car No. 255. The failure of the L-3 package brake assembly was determined to be caused by a displaced cylinder lever pin which had moved laterally from its position as a pivot shaft between the piston rod and the lever body. Its shifted position prevented the proper operation of the brake. The wheel at location L-3 was the only cold wheel detected when the wheels of train No. 1718 were inspected at the accident site. All other wheels were warm because of the brake applications.

When the brake pipe pressure was charged to about 110 psi and a service brake application was made, the brake cylinder pressure on car No. 255 was 65 psi and 68 psi on car No. 211. All of the brakes released properly. When an emergency application was made with the same brake pipe pressure, the brake cylinder pressure registered 82 psi and 80 psi on cars Nos. 255 and 211, respectively. Tests conducted using the master controller handle (the deadman feature), the conductor's valve, and the single-car main reservoir emergency brake all indicated proper responses.

At different times, car No. 221 was coupled with cars Nos. 255 and 211. The same tests were made and the results were satisfactory. The brake cylinder pressure on car No. 221 registered 65 psi when a full service application was made with a brake pipe pressure of 110 psi.

Car No. 265, the first car of train No. 1718, was damaged so severely that it could not be tested. However, the 26B1 brake valve equipment was removed from car No. 265 and installed on car No. 255 for testing. A brake pipe leakage test conducted at 110 psi brake pipe pressure indicated a 4 psi per minute leakage. A 6-pound reduction with a brake pipe pressure of 110 psi gave a brake cylinder pressure of 25 psi, and a full-service reduction gave a brake cylinder pressure of 65 psi and a brake pipe pressure of 85 psi. Further testing of the system indicated that all brake demands were met with no discrepancies noted.

In addition to the service testing on car No. 255, the 26B1 brake valve and other brake equipment were disassembled for inspection. No defects were found. A "DB" electronic printed circuit board associated with the control of the "decelostat" valve was checked for faults and none were found.

Braking capability tests were made at the accident site on October 21, 1979. After the accident, the cars in the consist of train No. 1718 were not serviceable; therefore, similar cars were used. Cars Nos. 264, 261, and 209, built by the Budd Company, and car No. 236, built by the St. Louis Car Company were placed in the test train to represent the car manufacturers and the relative positions of the cars so that they corresponded to the consist of train No. 1718. The cars were loaded with brakeshoes to simulate passenger load and the brake unit at location L-3 of car No. 261 was made inoperative except for three tests. Every effort was made to simulate exactly the operation of train No. 1718 and the conditions that prevailed at the time of the accident. Since several trains had preceded train No. 1718 on October 16, 1979, the test train made several movements through the area in an attempt to condition the surface of the rails to approach the same surface conditions that prevailed on October 16. Even so, there was still some water on the railheads at the time of the brake tests. Speeds were observed from the speed indicator of car No. 264, which had been calibrated and was known to be correct, and from a wayside portable radar unit. (See appendix C for a brake unit efficiency determination based on six measurements obtained from cars Nos. 209, 264, and 221, which shows the effective brake effort.)

When the tests were started about 8:20 a.m., the weather was slightly hazy and misty; however, the sun began to shine about 10:30 a.m., and the railheads dried. (See table 1.)

Other Information

A mathematical analysis of the impact forces was made by the Transportation Systems Center (TSC) at Cambridge, Massachusetts, to determine the speed of train No. 1718 at the time of the collision. Using parameters obtained from the accident, such as the equipment deformation, the railhead condition, the distance the equipment was moved, and the weight of the equipment, it was determined that the speed at the time of impact was not less than 28 mph. TSC expressed a high degree of confidence in this value. The calculated speed differs from the speed estimated by the engineer, who said that train No. 1718 was traveling about 18 to 20 mph at the time of impact. (See appendix D.)

ANALYSIS

Brake System

The engineer testified that he had no trouble starting or making stops with train No. 1718's equipment on the trip southbound. When he operated the equipment northward as train No. 1718, the train's scheduled stops were made with no difficulty. The train responded satisfactorily to the braking demands for the slow orders at Fernwood and at the Angora trestle. When the light brake application was made as the train approached the "bakery" switch near signal B-42, the engineer and the special duty trainmaster said that they heard the brake pipe air exhaust which would have indicated a measure of applied brakes. According to the engineer's testimony, when the alarm was shouted, he released the master controller handle and, almost simultaneously, moved the automatic brake handle toward the emergency brake position. He reported that the anticipated retardation did not occur and he assumed that the brakes released even though an emergency brake application had been initiated by two separate actions.

The engineer said that he had made an effective light brake pipe reduction near the "bakery" switch, because he was expecting a stop-and-proceed aspect on signal B-42, and he wanted to be prepared to stop. As the train approached the signal, he was moving the automatic brake handle toward suppression, and it is possible that he could have stopped it in that position. If such were the case, when he released the master controller handle, that action would not have applied the emergency brakes automatically because of the designed bypass function. It would have taken him several seconds to become aware of this, time which he could not spare because train No. 1718 was rapidly closing the distance to the rear of train No. 0714. When he realized that the emergency brakes had not been applied, he may have attempted to make an emergency application with the automatic brake handle; however, under the stress of the situation, he could have become excited and failed to move it to the emergency position. If his actions were as just described, he probably never made an emergency brake application with the automatic brake valve. Support is given to this action because the brake handle was found in the handle-off position. When the brake handle was moved

Table 1.

Results of Tests

Test No.	Location* Brake - applied	Type Brake application**	Speedometer Indication (mph)	Radar Indication (mph)	Time To Stop (Sec)	Distance to Stop (Ft)	Brake Cyl. Press. (psi)	Wheel Slide
1.	2	Service	20	NA	10.45	177	65	No
2.	3	Service	19	NA	10.89	183	60	No
3.	3	Service	30	28	14.97	374	61	No
4.	3	Service	45	40	20.44	735	65	2
5.	2	Emergency	20	18	7.86	121.8	[illegible]	No
6.	2	Emergency	30	27	10.53	238.4	85	No
7.	2	Emergency	45	41	15.82	540	85	No
8.	2	Service	35	33	16.93	496.5	62	No
9.	2	Emergency	35	33	10.69	292.9	85	No
10.	2	Service	30	29	13.65	362.2	85	No
11.	2	Emergency	30	29	8.99	218.5	85	No
12.	3	Service	31	29	14.29	380.7	61	No
13.	3	Service	29	28	13.68	351	61	No

14. At Location No. 3, a full service brake was applied, followed by an emergency application at Location No. 2.

*Location Brake Applied: 1 Point of impact; 2 Point rear of 0714 first visible to test train; 3 Point where signal B-42 first became visible to test train

**Type Brake Application: S-Service, full; E-Emergency (Controller).

Train 1718 probably was dispatched and operated the day of the accident with only 31 of the 32 package brake units working, or 96.87 percent of its maximum braking capability. Train stop distance tests were performed using 31 of 32 braking units (tests 1 through 9) and 32 of 32 braking units (tests 10, 11 and 12). The stop distance for an emergency stop from 30 mph with one brake unit inoperable increased 19.9 ft or 9 percent of the total distance when compared to stop distance with all 32 package brake units functioning.

from the suppression to the handle off position, releasing the master controller handle would apply the emergency brakes but too late to become effective. With the automatic brake handle in the handle off position, until the master control handle was released, the brakes would have only applied with a full-service application. In either event, the brakes were not applied in sufficient time to stop the train short of collision. The automatic brake handle quadrant has detents, cams, and stops to identify the several positions, but these would not have been a distraction under normal operating conditions. If the train had been operated at a reduced speed of 30 mph prepared to stop at the next signal, it could have been controlled properly and stopped, using a full service brake application because the stress situation would not have developed.

The brake tests performed on cars Nos. 211, 255, and 221 failed to disclose any faults that would have contributed to a brake failure. When various brake cylinder pressures were used, the brakes applied with sufficient force to be effective. The effectiveness of the brakes was also supported by the fact that there was no evidence to support a failure. The testing of the key brake system components on car No. 265 failed to reveal a fault that would have caused a brake failure. Also, the lack of any detected faults in the "DB" card eliminated the possibility of a faulty "decelostat" on the lead truck, which was the only "decelostat" action the engineer could have detected since the brake cylinder pressure gage indicates pressure variations only in respect to the brake cylinder on that truck.

The wheels on train No. 1718 were examined immediately following the accident, and they were all found to be warm to the touch, except for the wheel at L-3 on car No. 255 where the failed brake package was found. The heat indicated that the brakes had been applied. The loss of the brake at position L-3 on car No. 255 was not a factor in the failure of the train to stop short of a collision, as it would have reduced the overall braking efficiency by about 3 percent. The engineer had made a number of stops and brake applications without this being a factor.

The commuter cars used on the West Chester Branch have several means by which they can be stopped if there is a mechanical failure of the brake system. For example, if the main reservoir pressure is reduced to a predetermined minimum value, the brakes will be applied automatically. The only protection against an engineer's failure is the deadman control, which provides protection in the event he becomes incapacitated. Activation of the deadman control is dependent upon the engineer's releasing the master controller handle so that it is free to return to its center position and raise up under a spring load. If the master controller handle is blocked so that it cannot return to its center position or if the automatic brake valve handle is in the suppressed position, the deadman control feature will not operate; therefore, the deadman control is not always a positive control.

Some safety features can be nullified if the automatic brake handle is moved to the suppression position. Such nullifying capabilities are designed into the operating controls to provide flexibility and operating expediency; however, they can become detrimental if the engineer is not fully alert to his operational situation and needs, and if he does not understand the operation of the system. The engineer on train No. 1718 may not have remained fully alert to his speed and location.

The traffic density on the West Chester Branch is high during the morning and evening rush hours. The safe movement of the trains is entirely dependent on the alertness and ability of the engineer. There are no control devices on the locomotive which will limit the speed of the train in a signal block that is governed by a restrictive signal indication. Neither will the engineer get an alarm or a penalty brake application if he passes a signal in excess of the allowable speed for the signal aspect. The newer equipment used in trains Nos. 0714 and 1718 is equipped with cab signals and automatic train stop. However, the West Chester Branch of Conrail does not have the requisite wayside facilities to permit the use of the onboard control equipment.

The engineer should be given every advantage possible to eliminate distractions and to insure that his performance will be at maximum efficiency. The engineer of train No. 1718 did not have the benefit of privacy in the operating compartment on October 16, 1979. The three other employees in the cab may have been discussing topics other than the operation of the train and all may have been distracted from their duties. Apparently, it is not unusual for other employees to ride with engineers on the West Chester Branch. This may have been a factor in the accident.

The Safety Board believes that commuter service on the West Chester Branch and elsewhere should have the benefit of some of the available safety appliances to reduce the accident potential and to provide more positive support for engineers.

Repeated operation of the "decelostat" valve could conceivably prolong stopping if the railheads were in a condition to reduce adhesion and promote sliding because of the short time required for the system to cycle. If the sliding persisted repeatedly and a number of wheels were involved, stopping might be prolonged. However, the condition of the railheads did not appear to be such that adhesion would be a problem. Even if the "decelostat" operated, it is not likely that the valves on all four cars (eight valves total) would be operated at the same time. The wheel treads were checked twice for flat spots or evidence of sliding and no indications were found. The railheads had no scars or marks which would have indicated sliding wheels. None of the tests conducted revealed any defect or problem that would support a brake failure or a total slide. It is a known fact in the railroad industry that a sliding wheel will not stop as quickly as one that is not sliding. One factor in this phenomena is that friction causes a thin deposit of molten metal to develop which acts as a lubricant on the rail.

The low pressure safety feature built into the main reservoir air system provides protection so that if a "decelostat" valve was operated continually and the main reservoir air pressure was reduced to the 70 to 80 psi limit, the brakes would have applied in emergency. Even if the engineer had depleted his air through repeated brake applications and releases, the low pressure main reservoir feature should have stopped the train.

As a result of a special study, 4/ on February 7, 1972, the Safety Board issued the following recommendation to the Federal Railroad Administration:

> "Develop a comprehensive program for future requirements in signal systems . . . that will require as a minimum:
>
> a. that all mainline trains be equipped with continuous cab signals in conjunction with automatic-block signals;
>
> b. that all passenger trains be equipped with continuous automatic speed control (train control);
>
> * * * * *
>
> d. that a system be devised to protect trains which stop within 1,000 feet after entering a block from being struck by following trains; . . . ."
>
> * * * * *

If parts a, b, and/or d had been implemented on the West Chester Branch, it is almost certain the accident of October 16, 1979, would not have happened. Automatic train control (ATC) would have required the engineer to observe the 30 mph or less speed limit in the signal block governed by signal B-56, and the train would have been stopped when it passed signal B-42, if he had not stopped or further reduced the train's speed.

<u>Impact Speed</u>

The mathematical approach used to determine the impact speed is quite reliable. There is a possibility that the brakes were set on train No. 716 to some degree before the impact since the air line had been connected from train No. 716 to the two cars from train No. 712. The sudden release of air from No. 716 could have caused a light brake application. Nevertheless, the impact force was sufficient to move the standing equipment a considerable distance forward. The deformation of the equipment on all cars at the points of impact indicates the absorption of high energy. The conservative value of impact speed, 28 mph, substantiates the high energy that would have been required to produce the damage to the standing equipment and to have moved both trains, Nos. 0714 and 716, forward. The conservative calculated speed of 28 mph is far more realistic than the 18 to 20 mph estimated by the engineer because it is based on, among other things, the strength of materials, the damage done, and the distance the two standing trains were moved forward. A higher impact speed more readily accounts for the distance trains Nos. 0714 and 716 were moved.

4/ Special Study, Signals and Operating Rules as Causal Factors in Train Accidents, December 2, 1971 (NTSB-RSS-71-3).

Test results indicate that the brakes were operable and effective. Therefore, the Safety Board must conclude that the train was being operated at a speed greater than the 20 mph estimated by the engineer for the resulting damage to have occurred.

The following conclusions can be drawn from figure 5.

- The 40-mph curve indicates that, if a decision was made to stop and a full-service brake application was made, the train's speed would be reduced to the computed collision speed, 28 mph, in approximately 460 ft (points A to B).

- Allowing time for a decision to stop and make a full-service brake application; the 30-mph curve indicates that impact would have occurred at a lower speed, 18 mph, after traveling approximately 350 ft (points C to D).

- Under the same conditions for the 20-mph curve, the 20-mph curve indicates that train No. 1718 would have stopped before hitting train No. 0714 (points E to F).

Operable Radios

The lack of operable radios on all the equipment used on the West Chester Branch was a handicap in the events of the accident. The older equipment is not expected to be used much longer and the railroad claims that it would be costly to equip it with radios. However, because of the traffic density on the Branch, a good responsive radio system would be invaluable in keeping all trains informed on the current status of operations. Since the radio on train No. 1718 could not be tested after the accident, it is not known whether or not it was operable. However, if all locomotives had been equipped with radios and they had been operating properly, and the radio system had been designed and maintained for maximum coverage, the engineer of train No. 1718 may have heard the radio conversations relative to the move taking place at milepost 3.7 and avoided the accident.

Crewmember Responsibilities

Either the special duty trainmaster was not fully aware of what was occurring in the operation of the train, or he chose to ignore some of the occurrences. Rule 34 does not exempt clear signals from being called, and the trainmaster should have insisted that the engineer call all signals. The trainmaster did not correct or reprimand the engineer when he operated the train in an approach block at a speed that was apparently greater than 30 mph. The lack of an operable speedometer may have contributed to his operating at this speed. It is difficult for most persons to estimate speed accurately, and a speedometer would assist an engineer greatly in maintaining the proper speed. The fact that a trainmaster, who was a qualified engineer, was in the operating compartment should have prompted the engineer of train No. 1718 to be particularly alert and conscientious in observing the rules. Conrail should impress supervisors that subordinates must comply with the rules. The lack of assigned supervision along the Branch also could lead to a lax operation on the part of operating employees.

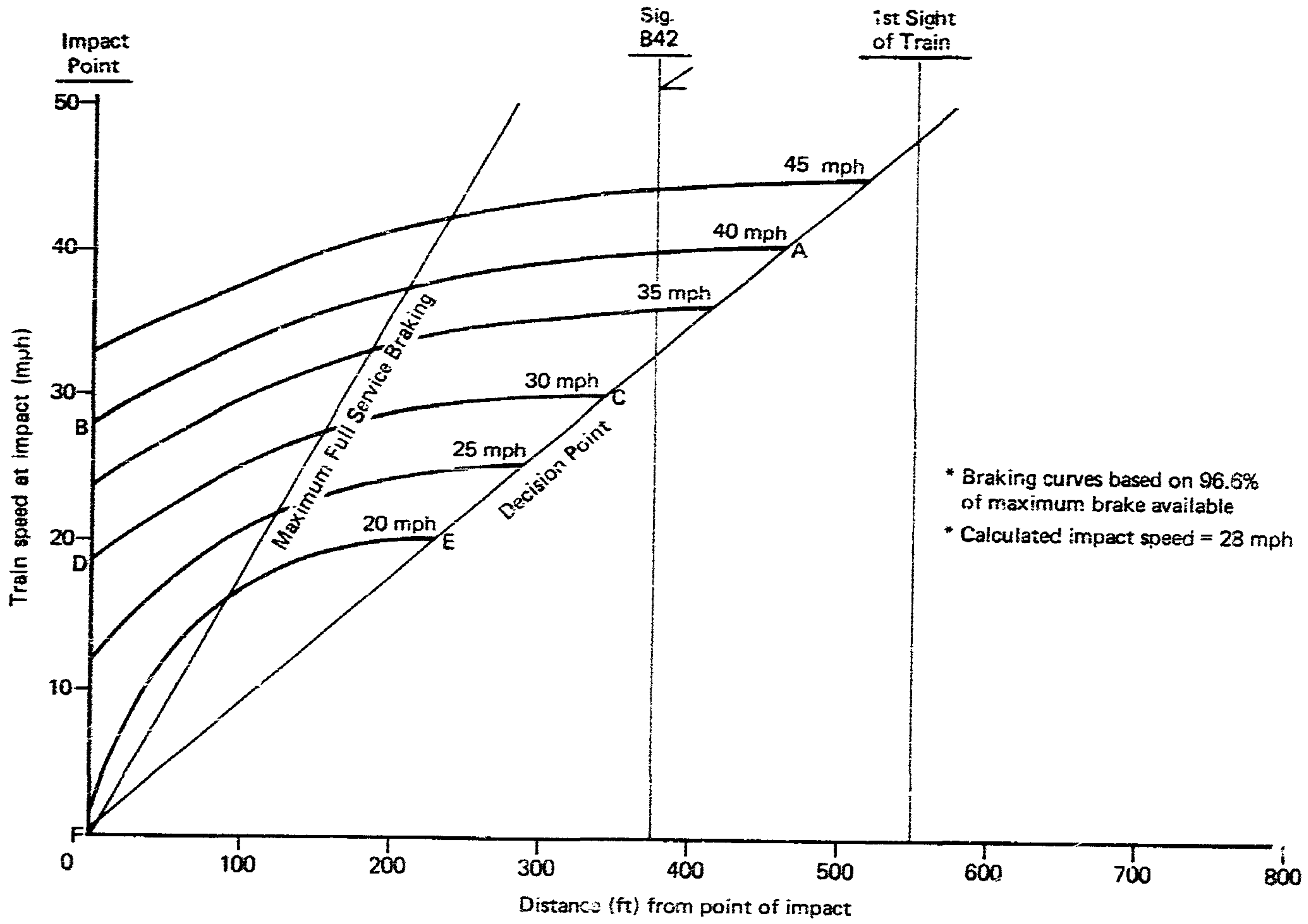

Figure 5.—Impact speed vs. train speed (mph).

The attention of the engineer needs to be focused completely on the handling of the train; the presence of other persons in the operating compartment can prove to be distracting despite the engineer's efforts to ignore it. Most railroads discourage the practice of allowing nonessential employees to be in the operating compartments of locomotives. In situations, such as that existing on the West Chester Branch, where trains operate on close headway with almost no support safety devices, nonessential crewmembers should not be allowed to occupy locomotive operating compartments. An effective supervisor or a trainee should not be considered nonessential crewmembers, but if they are familiar with their jobs, are alert, and perform supportively and instructively, which would lead to an engineer's improved performance, they could be a safety asset.

CONCLUSIONS

Findings

1. Train No. 1718 was being operated at a speed in excess of that allowed by the approach signal aspect displayed by signal B-56.

2. There was no failure of the signal system.

3. The presence of three other persons in the operating compartment could have caused undue commotion and confusion which could have distracted the engineer.

4. The "decelostat" valve system did not malfunction, and thus, did not create a condition that would make it impossible to stop the train.

5. The brakes on the train did not malfunction, except on one wheel.

6. The condition of the railheads did not contribute to the failure to stop.

7. The engineer failed to operate the automatic brake valve handle correctly and, thus, failed to stop the train before it collided with the standing train.

8. There was no operable speedometer on the control locomotive unit and the engineer estimated the speed at impact to be 18 to 20 mph. The train's speed at impact was at least 28 mph.

9. Cab signals and automatic train control could have prevented the accident.

10. Operable radios on all equipment being used on the West Chester Branch would help avert disasters and improve operations.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the engineer of train No. 1718 operating at a speed above that authorized by the block signal indication which did not allow for his stopping the train before it collided with a standing train. Contributing to the accident was the engineer's improper operation of the train brakes and the failure of a supervisor and traincrew personnel in the operating compartment of the locomotive to monitor the train's operation adequately and to take action to insure that the train's speed was reduced or that it was stopped when its speed exceeded that authorized for the signal block.

RECOMMENDATIONS

As a result of its investigation of the accident, the National Transportation Safety Board reviewed a recommendation issued on February 7, 1972, recommendation R-76-24, issued on July 30, 1976, 5/ and recommendation R-79-73, issued on November 1, 1979. 6/ Numerous accidents have been investigated which indicate the need for such actions. Therefore, the Safety Board reiterates the following recommendations to the Federal Railroad Administration:

> "Develop a comprehensive program for future requirements in signal systems . . . that will require as a minimum:
>
> a. that all mainline trains be equipped with continuous cab signals in conjunction with automatic-block signals;
>
> b. that all passenger trains be equipped with continuous automatic speed control (train control);
>
> * * *
>
> d. that a system be devised to protect trains which stop within 1,000 feet after entering a block from being struck by following trains;
>
> * * *
>
> "Establish regulations that would require all trains operating on a main track to be equipped with an operable radio. (R-79-73)
>
> "Establish regulations on mainlines used by passenger trains that will require trains to stop if the block in front of them is occupied. (R-76-24)"

5/ Railroad Accident Report—Collision of Penn Central Transportation Company-Operated Passenger Trains Nos. 132, 944, and 939, Near Wilmington, Delaware, October 17, 1975 (NTSB-RAR-76-7).

6/ Railroad Accident Report—National Railroad Passenger Corporation Head-end Collision of Train No. 111 and Plasser Track Machine Equipment, Edison, New Jersey, April 20, 1979 (NTSB-RAR-79-10).

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PATRICIA A. GOLDMAN
Member

/s/ G. H. PATRICK BURSLEY
Member

May 12, 1980

APPENDIXES

APPENDIX A

EXCERPTS FROM RULES FOR CONDUCTING TRANSPORTATION

Rule D. Person Employed In Any Service On Trains Are Subject To The Rules And Special Instructions.

34. All members of the crew must, when practicable, as soon as the next signal ahead affecting the movement of their train or engine becomes clearly visible, communicate the indication to each other by name, and thereafter continue to observe the signal and call any change of indication until it is passed.

If train or engine is not operated in accordance with the signal indication, or other condition requiring speed be reduced, other members of the crew must communicate with crew member controlling the movement at once and if necessary stop the train.

106. The conductor, enginemen, and pilot are responsible for the safety of the train and the observance of the rules, and under conditions not provided for by the rules, must take every precaution for protection.

This does not relieve other employes of their responsibility under the rules.

108. In case of doubt or uncertainty, the safe course must be taken.

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APPENDIX A

Rule 291

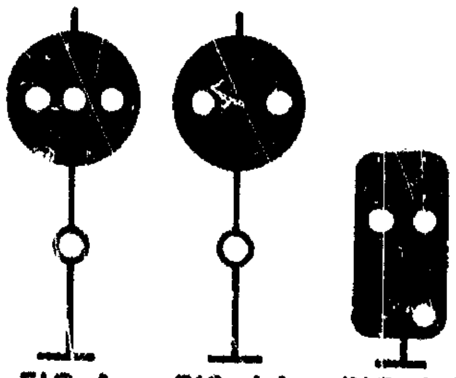


FIG. A FIG. AA FIG. A-1

Aspect Displayed by Signal B-42

INDICATION--Stop; then proceed at Restricted speed.

NAME: Stop and proceed.

Rule 285

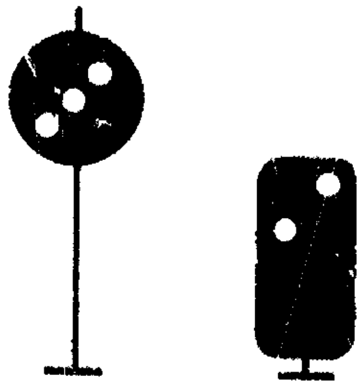


FIG. A FIG. A-1

Aspect Displayed by Signal B-56

INDICATION– Proceed prepared to stop at next signal. Train exceeding Medium speed must at once reduce to that speed.

NAME: Approach.

APPENDIX A

CONDUCTORS

400N-1. .... Conductors have general charge of the train to which assigned and all persons employed thereon are subject to their instructions. They are responsible for the prompt movement, safety and care of their respective trains and the passengers and commodities carried, for the vigilance and conduct of the men employed thereon and for the prompt reporting to the Superintendent of conditions that interfere with the prompt and safe movement of trains.

They must know that members of crew providing protection as required by Rule 99 are familiar with their duties and that their trains are properly equipped and inspected; also that Air Brake Rules have been complied with and that the prescribed signals are displayed.

Passenger conductors must familiarize themselves with the location of the conductor's valve, (emergency brake valve), hand brakes and communicating signal appliances. ...

TRAINMEN AND BRAKEMEN

400N-2. .... They are responsible for the display of train signals, the proper protection of trains, the handling of switches, the coupling and uncoupling of cars and engines, the manipulation of brakes and for assisting the conductor or engineman in all things requisite for the prompt and safe movement of their train. ...

ENGINEMEN

400-3. Report to and receive instructions from the Superintendent or other designated officer. They will be governed by current mechanical, electrical and air brake instructions pertaining to the safety, inspection, preparation, and operation of trains and engines. They must comply with the orders of the Road Foreman of Engines, Trainmaster or other designated officer within their jurisdiction.

They must obey the instructions of Station Masters, Station Agents, Yard Masters, and Operators within their jurisdiction; and the conductor in charge of their train as to general management of their train, unless by so doing they endanger its safety or commit a violation of the rules.

They must be qualified on type of engine to which assigned including any devices or auxiliaries attached thereto. At a point where no mechanical forces are on duty and except on through trains, they will check the prescribed form in the cab to be sure that the unit or units of the engine consist have been inspected within the previous 24 hour period for road service or within one calendar day in yard service.

APPENDIX A

If the engine unit or units are not within date they will make an inspection. After making inspection, they will then record date, time and location on the prescribed form in the cab and prepare and sign regular work report.

At points where mechanical forces are employed and on duty, they will accept the inspection of the mechanical forces, except air brake test as to the condition of the engine.

They will at the end of the trip make written report on the prescribed forms.

They will be responsible for the observance of all signals controlling movements accordingly and the regularity of speed between stations, exercise discretion, care, and vigilance in moving the engine with or without cars to prevent injury to persons, damage to property, and lading, avoiding collisions and derailments. While acting as pilot they will operate the engine unless otherwise instucted and when in charge of the engine to which no qualified conductor is assigned or is disabled they must perform the duties of and conform to the rules relating to conductors. They will require the assistance of crew members in any duties relative to the prompt and safe movement of their trains, engine and cars, promptly reporting irregularities or failures.

They must not allow any member of the crew to operate the engine except under their personal supervision. They will be responsible for the proper operation of the engine and must not leave it while on duty except in case of necessity in which case the engine must be secured.

They must, if anything withdraws attention from constant lookout ahead, or weather conditions make observation of signals or warnings in any way doubtful, at once so regulate speed as to make train progress entirely safe.

When a train has more than one engine the rules apply alike to the engineman of each engine, but the use of the engine bell, whistle and air brake except in emergency must be limited to the leading engine.

The engineman is responsible for the vigilance and conduct of other employes on the engine. He will see that they are familiar with their duties and instruct them if necessary.

APPENDIX B

PERSONNEL INFORMATION
TRAIN NO. 1718

Lester A. Shank, Engineer

Lester A Shank, 47, was employed by the Pennsylvania Railroad Company on July 1, 1959. He was promoted to engineer on June 1, 1966. Until October 16, 1979, his disciplinary record was clear. He was examined on the company operating rules on December 12, 1978, and on the operation of air brakes on March 31, 1978. He passed his last medical examination on September 20, 1979.

Richard J. Hanratty, Conductor

Richard J. Hanratty, 58, was employed by the Pennsylvania Railroad Company on July 12, 1941. He was promoted to conductor on February 1, 1944. He passed an operating rules examination on December 13, 1978, and a medical examination on September 9, 1977.

William R. Gibson, Front Brakeman

William R. Gibson, 50, was employed by the Pennsylvania Railroad Company on June 14, 1955. His personnel records do not indicate when or if he was promoted to conductor, or when he passed his last operating rules examination. He passed his last medical examination on April 29, 1976.

Anthony A. Dilauro, Special Duty Trainmaster

Anthony A. Dilauro, 40, was employed by the Penn Central Transportation Company on January 14, 1970. He was promoted to engineer on November 1, 1971. He passed a company operating rules examination on December 29, 1978, an air brake examination on April 1, 1974, and a medical examination on September 20, 1978.

APPENDIX C

BRAKE UNIT EFFICIENCY

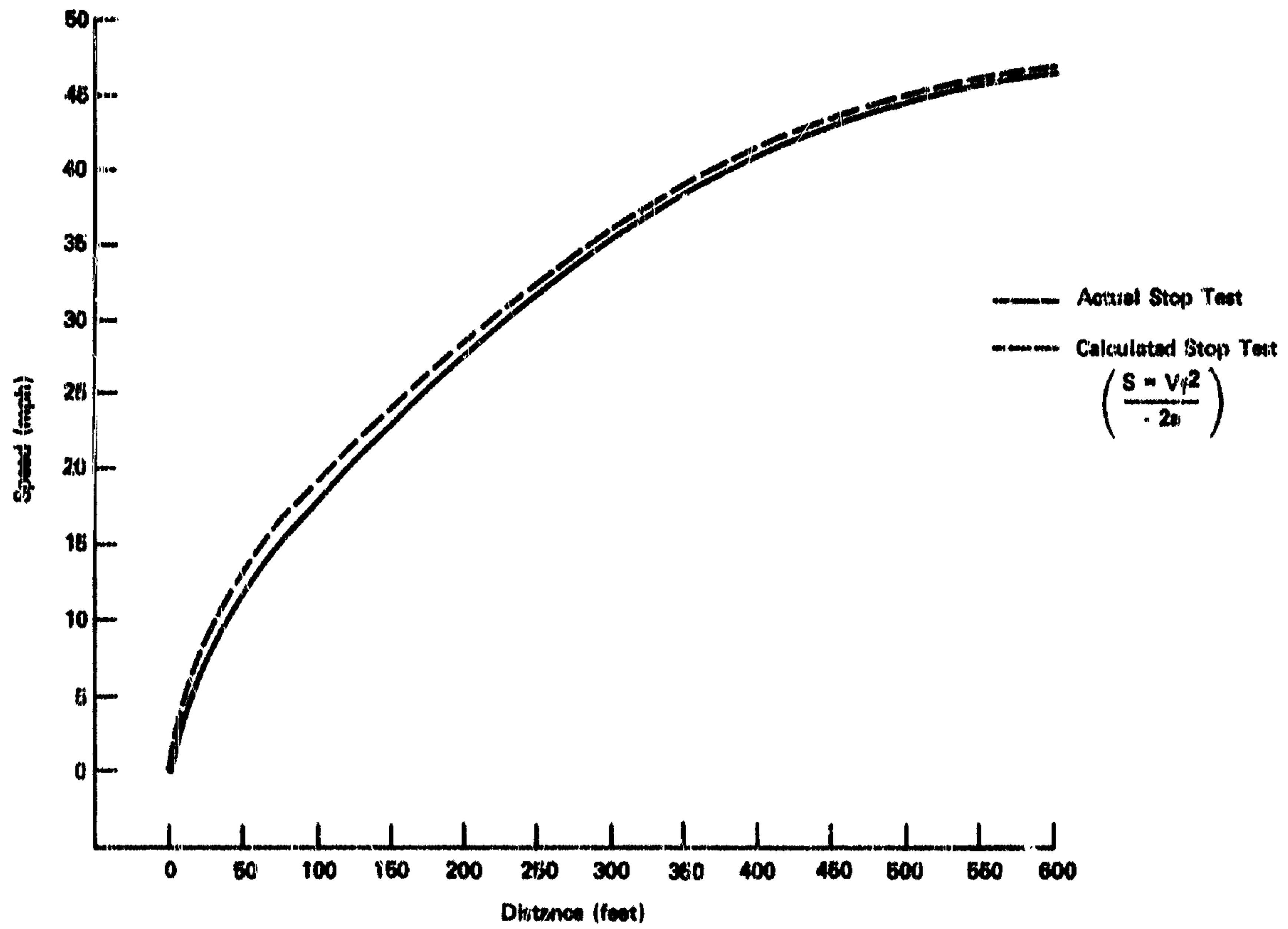
Unit Type: WABCO Model GJ 5 1/2 Tread Brake Unit
Piston Area = 23.758 in. 2
Lever Ratio = 3.97 : 1
Formula to determine theoretical shoe force
Shoe Force (SF) = (BCP-3) x Piston Area x Lever Ratio x .94

BCP psi	Measured Ave. SF-lb.*	Calculated Theo. SF lb.	% Eff.	Remarks
10	551	620	89	Unreliable at Low Press.
20	1416	1507	93	
30	2270	2393	95	
40	3125	3280	95	
50	4067	4167	98	
60	4848	5053	96	
62	5083	5230	97	Full Service Press.
70	5723	5940	96	
80	6572	6915	95	
85	7003	7215	97	Emergency Press.
90	7435	7713	96	
100	8309	8600	97	
58	4700	4886	96	Average

(*) Force = average of 6 units measured

APPENDIX C

Stopping Distance Chart



APPENDIX D

MATHEMATICAL ANALYSIS OF IMPACT FORCES

SYMBOL	EXPLANATION	NUMERICAL VALUE
W_1	Total weight of Train 1718 including 46,000 lbs. for passengers' weight	463,000 lbs.
W_2	Total weight of Train 714 including 23,000 lbs. for passengers' weight	264,000 lbs.
W_3	Total weight of Train 716 and two cars from Train 712 including 83,000 lbs. for passengers' weight	1,537,000 lbs.
U	Coefficient of Adhesions (Reference 2)	0.08
F	AAR Compression Spec.	800K lbs.
B	Passenger Load Factor	0.65
V_0	Speed of First Impact	
V_1	Speed of Second Impact	
S	Total Crush Distance	72 inches
d	Distance travelled by the Eleven-Car Train	55 feet

APPENDIX D

The energy dissipated in moving the eleven-car consist can be calculated as:

$$E_1 = M \times W_3 \times d$$
$$= 0.08 \times 1{,}537{,}000 \times 55$$
$$= 6.76 \times 10^6 \text{ ft.-lbs.}$$

The energy dissipated in crushing of cars 304, 305 and 265 may be estimated as:

$$E_2 = \tfrac{1}{2} F \times S$$
$$= \tfrac{1}{2} \times 800{,}000 \times 72'' \div 12$$
$$= 2.4 \times 10^6 \text{ ft.-lbs.}$$

The kinetic energy of Train No. 1718 and No. 714 before the second impact is:

$$E_0 = \frac{V_1^2}{2} \sum_{i=1}^{2} W_i$$
$$= \frac{V_1^2}{2 \times 32.2} (727{,}000)$$
$$= 11{,}289 V_1^2$$

To obtain the lower bound of the second impact speed, only forty percent of the energy dissipated in crushing the three cars was used in calculations, i.e.,:

$$E_0 = E_1 + 0.4E_2$$
$$V_1 = 26.1 \text{ ft./sec.}$$
$$= 17.7 \text{ mph}$$

During the first impact, from momentum therein, one has:

$$W_1 V_0 = (W_1 + W_2)\, V_0^{1}$$

where V_0 denotes the speed of Train 1718 prior to impact and V_0^{1} denotes the the speed of the combined Train 1718 and 714. With numerical values from Table 1, one obtains:

$$V_0^{1} = 0.637 V_0$$

APPENDIX D

It is obvious that the combined Train 1718 and 714 has to travel a short distance to strike the eleven-car train, i.e.,

$$V_0^1 > V^1$$

Again, to estimate the lower bound impact speed, one assumes

$$V_0^1 = V^1$$

From Eq. (1), it is found that the initial impact speed of Train 1718 is:

$$V_0 = 27.8 \text{ mph}$$

The estimate agrees quite closely with the brake test data which results in a second impact of 12 mph for a braking distance of 55 feet.