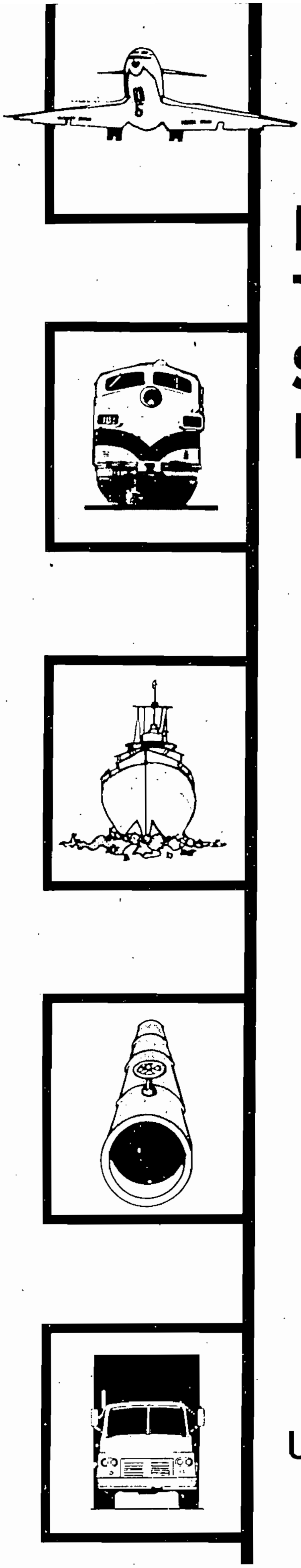

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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

**COLLISION OF
PORT AUTHORITY OF ALLEGHENY COUNTY
TROLLEY CAR NO. 1790 AND BUS NO. 2413
PITTSBURGH, PENNSYLVANIA
FEBRUARY 10, 1978**

REPORT NUMBER: NTSB-RAR-78-5

UNITED STATES GOVERNMENT

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16. Abstract About 8:03 a.m., on February 10, 1978, a trolley car and a bus owned by the Port Authority of Allegheny County collided in Pittsburgh, Pennsylvania, when the trolley car suddenly turned into the path of the oncoming bus. Four persons were killed, 37 persons were injured, and damage was estimated to be $48,000.

The National Transportation Safety Board determines that the probable cause of this accident was the operator's inadvertent and untimely operation of an unprotected track switch, which caused the trolley car to be routed into the path of the approaching bus. Contributing to the accident was the operator's operation of the car at a speed too great to permit stopping when he detected the turning movement of the car, and the lack of protective devices to control the switch operation.

Two recommendations were made to the Port Authority of Allegheny County, Pennsylvania, about the means by which the track switch can be operated from the trolley car and about providing protection against the switch operating when another vehicle is in a danger zone.

A recommendation was also made to the Governor of the Commonwealth of Pennsylvania, urging the State to encourage communities that have emergency response facilities to establish emergency procedures for disasters.

17. Key Words Trolley car; trolley pole; electromagnetic switch machine; track switch; catenary; contactor; magnetic track brakes; black rail; PAT BUSWAY; dedicated right-of-way.		18. Distribution Statement This document is available to the public through the National Technical Information Service, Springfield, Virginia 22151	
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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D. C. 20594

RAILROAD ACCIDENT REPORT

Adopted: August 17, 1978

COLLISION OF PORT AUTHORITY OF ALLEGHENY COUNTY TROLLEY CAR NO. 1790 AND BUS NO. 2413 PITTSBURGH, PENNSYLVANIA FEBRUARY 10, 1978

SYNOPSIS

About 8:03 a.m., on February 10, 1978, a trolley car and a bus owned by the Port Authority of Allegheny County collided in Pittsburgh, Pennsylvania, when the trolley car suddenly turned into the path of the oncoming bus. Four persons were killed, 37 persons were injured, and damage was estimated to be $48,000.

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INVESTIGATION

The Accident

Port Authority Transit (PAT) Bus No. 2413, route No. 41D Brookline, entered the dedicated PAT BUSWAY about 7:58 a.m. on February 10, 1978, en route to downtown Pittsburgh with at least 39 passengers. About 8:02 a.m., the bus left that portion of the busway used exclusively by buses, and continued its trip northbound on a section of right-of-way that is used jointly by trolley cars and buses. As it approached a track switch, which gave trolley cars in the outbound trolley track access to the Palm Garden Loop track, a southbound trolley car traveling on the outbound track suddenly entered the curved track leading into the loop and crossed into the path of the bus. (See figure 1.) The busdriver turned his vehicle to the right to avoid the trolley car, but the trolley's left front corner and the bus' left front side collided.

The outbound trolley car, No. 1790, route No. 42/38 Dormont, had departed the South Hills Junction area about 7:58 a.m. with no passengers. The car operator was following about 200 feet behind another trolley car. The operator of car No. 1790 and the traffic dispatcher had discussed via radio whether the trolley had enough time to go to the end of the line for an 8:13 a.m. departure back to Pittsburgh. Although car No. 1790 was running 5 to 7 minutes late, the dispatcher told the operator to make the scheduled run and that he had time to reach Dormont Junction and depart that point on time.

The operator stopped near an employee car stop about 450 feet from the point of the accident because the car ahead had stopped. He then applied just enough power to attain a speed of about 15 mph and allowed the car to coast toward the Palm Garden Loop track switch. According to the operator, the car approached the contactor 1/ for that switch while moving at an estimated 3 mph. At that time he said he assumed the operating stance required by the operating rules, i.e., his left hand on the gong switch, his right hand on the sander switch, his left foot on the deadman pedal, and his right foot on the brake. He was aware of the trolley car ahead and he knew it had continued straight at the switch. As he approached it, he said that the switch was lined for the straight track. The operator testified that he coasted through the contactor because he did not want to change the switch's alignment. He continued coasting after the car's trolley pole 2/ was clear of the contactor and approached the switch point at an estimated 1 to 3 mph.

He continued to watch the switch as he moved toward it, and he stated that it was still lined for the straight track until it passed from his view under the front of the car. When the lead wheels of the front truck entered the switch, the car began to turn left onto the Palm Garden Loop track. When he became aware of the car's turning movement, he immediately applied the brakes in emergency, but the car continued to move forward into the path of the No. 41D Brookline bus.

Several passengers who were on the bus estimated that the busdriver was traveling at speeds ranging from 20 to 35 mph approaching the point of impact. The passengers testified that the trip had been uneventful and that the driver was operating the bus in a usual manner. Witnesses testified that the trolley car speed ranged from "almost stopped" to 10 mph. They also said that the trolley seemed to push the bus after the impact.

Injuries to Persons

Injuries	Bus Operator	Trolley Operator	Bus Passengers	Trolley Passengers	Other
Fatal	1	0	3	0	0
Nonfatal	0	1	36	0	0
None	0	0		0	0

1/ A switch in the catenary that is actuated by the trolley pole to enable the operator to operate an electrical track switch.

2/ The propulsion power collector which extends from the trolley car to the catenary. The contact is via a roller on the end of the pole that moves along the catenary.

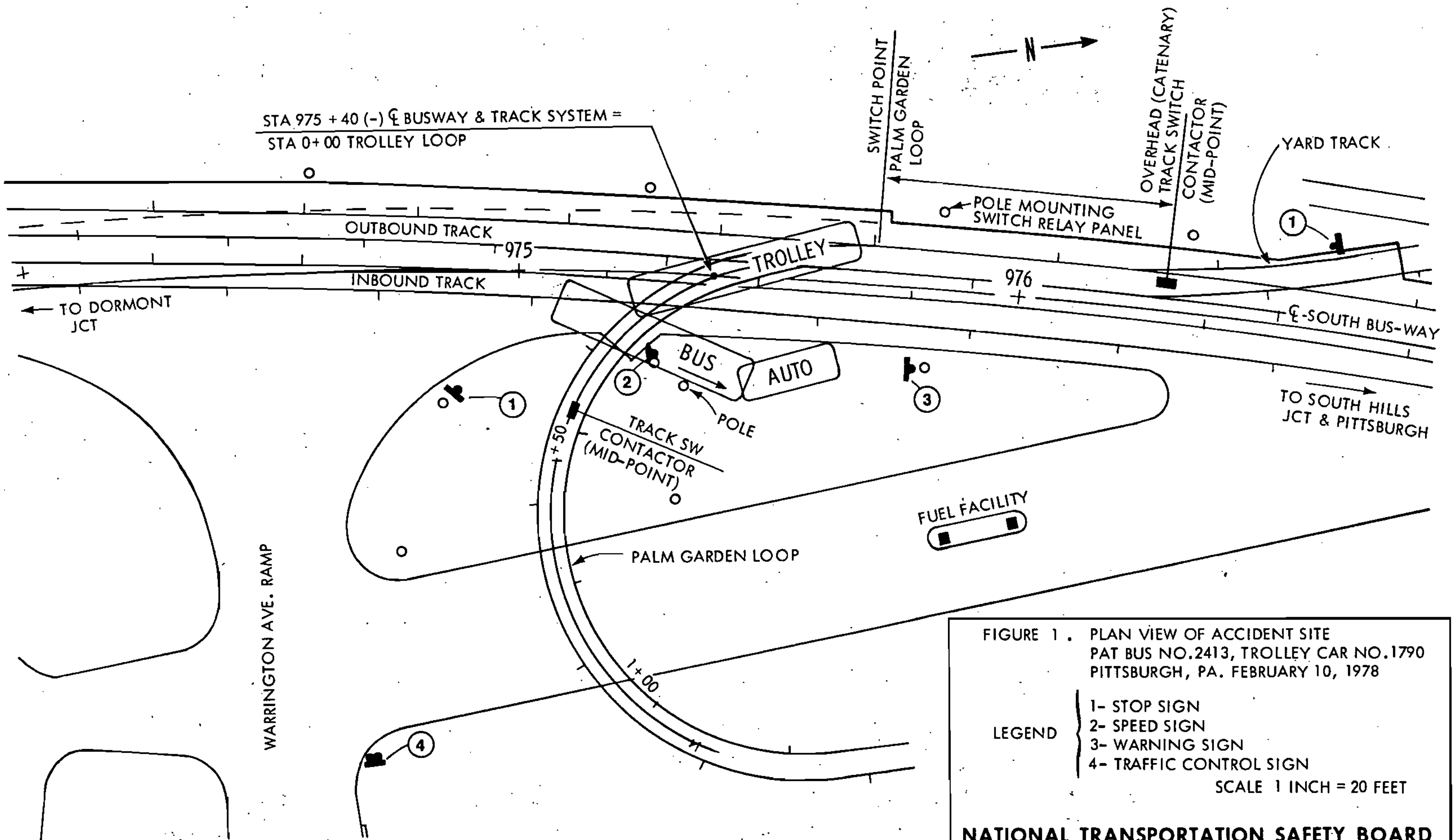

FIGURE 1. PLAN VIEW OF ACCIDENT SITE
PAT BUS NO.2413, TROLLEY CAR NO.1790
PITTSBURGH, PA. FEBRUARY 10, 1978

LEGEND
1- STOP SIGN
2- SPEED SIGN
3- WARNING SIGN
4- TRAFFIC CONTROL SIGN

SCALE 1 INCH = 20 FEET

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Damage

The trolley car struck the bus on the left front corner. The upper section of the bus was displaced rearward approximately 5 feet and downward 3 feet. The roof structure above the windshield frame was displaced to the left 2 feet, and the windshield was missing. The trolley car penetrated into the bus about 3 feet at the deepest point. Major deformation was evident along the left side for almost 15 feet. (See figure 2.)

An 11-inch-wide indentation on the rim of the left front wheel contained deposits of red paint where the trolley car's anticlimber hit the wheel. The bus came to rest against a catenary pole, which contacted the bus on the right front side causing the two front side windows to jam.

The bus instrument panel was damaged extensively. The steering wheel drive mechanism was inoperable. Seats and stanchions on the left side from the front of the bus through seats L-8-9 were detached and bent to varying degrees. The backs of several seats behind L-8-9 were bent forward. There was minimal damage to the interior on the right side of the bus. Some damage was caused by rescue personnel during their efforts to evacuate the injured.

The trolley car was damaged on the left front corner. Damage to the outside of the body and the interior was minimal. The left half of the windshield was broken out. The operating console was damaged, and some of the operating handles to control switches were broken off, including the handle to the "track switch" control. The foot-operated controls were bent and inoperable. The operator's seat was displaced, and its platform was damaged.

Several automobiles parked beside the inbound lane were damaged when they were struck by the bus as it veered from the roadway. The automobile drivers used the catenary poles as clearance guides and because they provided protection from the busway traffic.

Personnel Information

The busdriver was employed by the Brentwood Motor Coach Company on January 9, 1945, as a bus operator. He continued as a driver when PAT acquired the company. No record of his training was available, but performance evaluations made by riding supervisors gave him predominantly above average ratings. He had received many passenger commendations during his 33 years of service, and he was the recipient of the PAT Safety Operator of the Month Award in September 1971. His last medical examination on October 13, 1977, determined that he was in good health. His uncorrected vision for both eyes was 20/25. At the time of the accident he was working run No. 2201, Route No. 41D from 4:31 a.m. until 1:46 p.m.

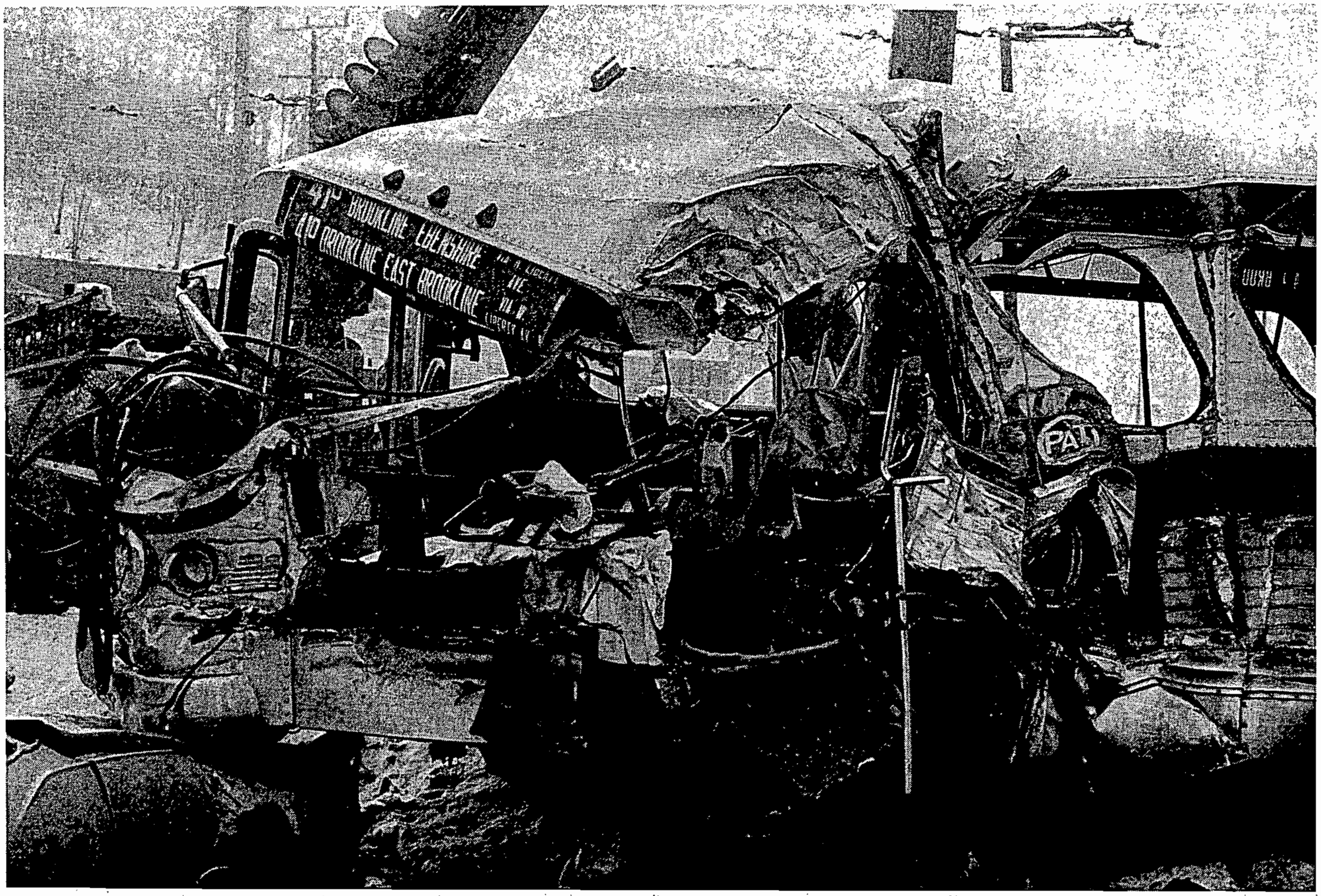


Figure 2. PAT bus No. 2413.

The trolley car operator was employed by PAT on August 30, 1964, as a bus operator. He worked in that capacity for 13 years. He was promoted to Staff Instructor on August 1, 1976, but on October 30, 1977, after a reduction in force, he transferred from his position as a supervisor to that of a trolley car operator. He received about 7 weeks training and was qualified in that position. His record as a busdriver showed that he had received some retraining, and his record improved over the years. He was given above average ratings on ride checks on November 15 and 22, 1977, while he was operating a trolley car. His last medical examination on November 3, 1977, determined that he was in good health. His uncorrected vision for both eyes was 20/15. At the time of the accident his assignment was a split shift, Monday through Friday. The day of the accident he was operating run No. 423, routes 42/38/35 from 6:29 a.m. until 6:00 a.m. with a 3-hour break during the day.

Track and Roadway Information

The PAT BUSWAY extends about 3.5 miles from Glenbury Avenue through South Hills Junction and the Mt. Washington Tunnel to Carson Street. The portion of the busway that is used exclusively by buses ends at the north end of the Palm Garden Bridge, about 3/4 mile from South Hills Junction. From this point the busway is used jointly by buses and trolley cars. The roadway is concrete with two 12-foot-wide lanes and no separating median. The roadway is slightly elevated from west to east.

There are two main tracks which run north and south through the accident area. The west track is the "outbound" track and the east track is the "inbound" track. The two tracks are embedded in concrete, thus permitting the surface to be used as a roadway. The roadway is on a 3-percent descending grade outbound. The roadway curvature varies to a maximum of 5° to the left outbound through the Palm Garden Loop switch area. There are no pertinent sight impediments near the switch. (See figure 1.)

The Palm Garden Loop track switch is in the outbound track and provides access to a loop track which is used as a terminus for some scheduled runs and by maintenance personnel from the nearby shop to turn trolley cars. The loop crosses the inbound track and enters that track about 400 feet north of the crossing. The switch and loop were relocated about 3 years ago and the protective devices provided at the original location, which prevented the switch from being operated if conflicting traffic was present, were not reinstalled. The original installation also included governing signals.

The functional components of the track switch circuit consist of an electromagnetic switch machine, which is essentially a large solenoid, a relay assembly (mounted on a catenary pole), and a contactor switch mounted in the catenary system 57 feet from the switch point.

The switch has one movable point which is operated by the electromagnetic switch machine. (See figure 3.) The switch machine consists of two coils which, when separately energized, lines the route for either a straight movement or for the curve. There is no positive locking device, and the switch is held in either position by spring pressure. Power to energize and operate the switch machine and the relay panel is obtained from the 600-volt d.c. catenary.

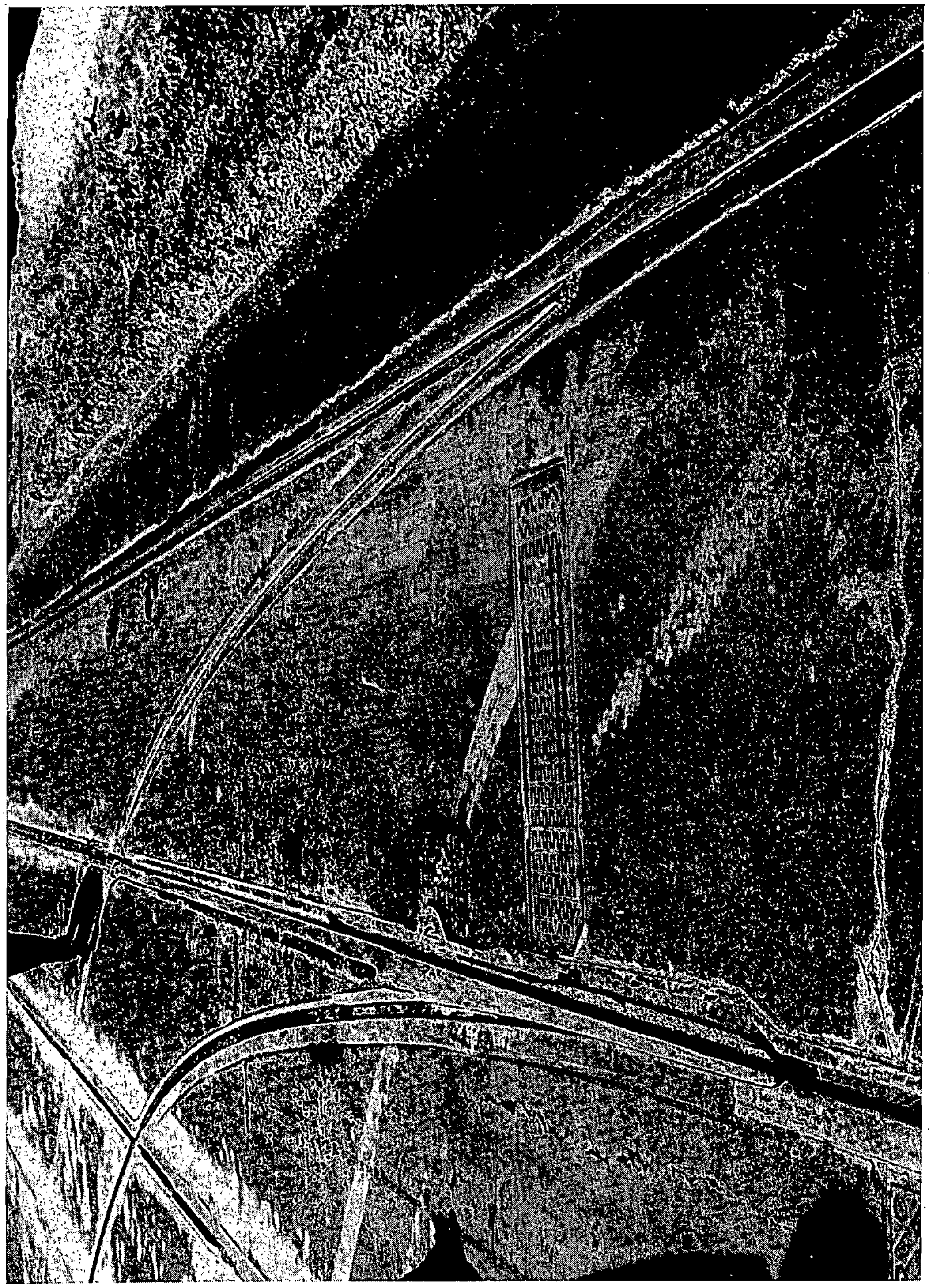
The relay panel consists of two relays, identified as "KL" and "B," and miscellaneous components. The position of relay "KL" determines whether the switch point will be positioned for the curve or straight track. The "KL" relay operates on 60 amperes d.c. current or more. The "B" relay has to operate for the switch to assume either position. (See appendix A.)

The contactor consists of a 2-foot bar hinged at the receiving end relative to the direction of travel of the trolley pole. When the trolley pole contacts the contactor bar, an upward pressure closes the single contact and energy is fed to the switch relay panel to operate the "B" relay. The "B" relay operates on a very low d.c. current.

The contactor is located 57 feet from the switch point so that an operator will have time to stop his car if the switch does not respond properly. The closest the operator can see the ground ahead is 6 to 8 feet because of the car overhang. When the trolley pole is just engaging the contactor, the point of the switch is 12 feet from the front of the car, which gives the operator about 4 to 6 feet ground view of the switch point. After the trolley pole clears the contactor, the operator's ground view of the switch point would still be 2 to 4 feet. The front of the car would be about 10 feet from the switch point, and this distance, if extended to the heel of the switch, would be about 16 feet. (See figure 4.) Movement of the switch point can be observed throughout its 6-foot length.

The switch is normally positioned for a straight movement. The desired route over the switch must be selected by the trolley operator. The design of the circuit is such that the switch point cannot be operated electrically by the trolley operator by any means except when the trolley pole is in contact with the 2-foot contactor. When this condition exists, the operator can cause the switch to line for the curve in one of two ways.

A spring-loaded, single-throw, toggle switch located on the control console is identified as the "track switch." If the operator operates the switch while the car's trolley pole is on the contactor, it causes a current flow of 60 amperes or more and the trackside relay control panel will respond to line the switch point for the curve. The operator can also operate the switch by applying power with the power pedal and cause the switch point to line for the curve. This action effectively draws



Figures 3. Track switch.

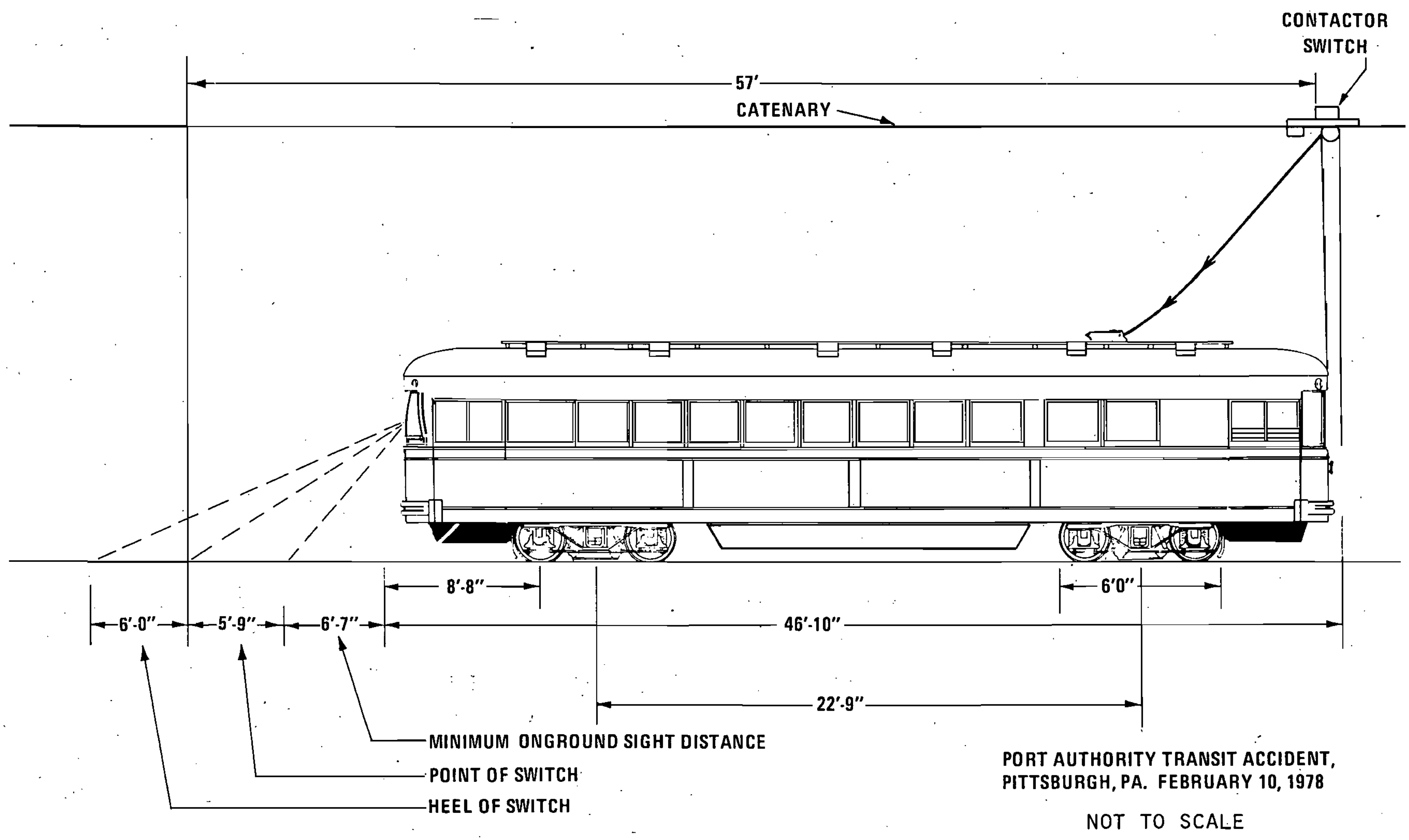


Figure 4. Trolley car dimensions and some average sight distances for a typical operator.

in excess of 60 amperes which causes the relay panel to respond. Company rules prohibit operators from operating the switch in this manner.

If the switch is lined for the curve or if it is lined for the straight track and the operator wants it to remain for the straight track, he must allow his car to coast with no propulsion power applied while the trolley pole is in contact with the contactor.

Trolley operators do not have positive identifying markings to let them know when the trolley pole is on the contactor. Through experience, they listen for a "thump" that is transmitted through the car as the pole leaves the contactor. This is their only indication of the trolley pole's location relative to the contactor, other than using an estimated distance from the front of the car to the switch point.

Equipment Information

Trolley car No. 1790 is 46 feet long over the anticlimbers, 8 feet 4 inches wide and 10 feet above the top of the rail. It has an all steel underframe, and a seating capacity of 54 persons. The trolley car is driven by four 50-horsepower 600-volt d.c. electric traction motors mounted two each on two 4-wheel trucks. The trolley car has a combined air and dynamic brake system with an emergency magnetic track brake. The cars weigh 18 tons unloaded, and they are not provided with speedometers. The center line distance between front and rear trucks is 22 feet 9 inches. The car was manufactured by the St. Louis Car Company about 1947, and was remodeled by PAT several years ago, but the electrical characteristics were not changed. The full current load for the car's auxiliary power units could not be measured but this value for a similar car was 29.6 amperes. The track switch drew 60 amperes when operated, and the traction motors drew more than 100 amperes.

The bus was manufactured by the GMC Truck and Coach Division of General Motors Corporation in 1971. The front door was fully air-operated, and the side door was the push type with an emergency release mechanism. The side window frames glazed with safety glass were hinged at the top and could be pushed out from the bottom for emergency use. The design weight of the vehicle was 23,536 pounds which included an allowance for fuel and the weight of an average-sized operator.

Method of Operation

There are no automatic block signals in the accident area. Traffic signs indicating the maximum speed, and stop and yield points govern all traffic operations. Movement of the trolley cars is by visual observation. Trolley car operators are instructed to maintain about 40 feet of separation between cars for each 10 mph of speed. There is considerable traffic consisting of trolley cars, buses, automobiles, and trucks through the accident area.

A traffic dispatcher is responsible for the movement of cars on the system. In the event of delays, trouble, or unusual circumstances, he directs the operation. He has two-way radio facilities with which to contact most of the buses and the trolley cars.

At some locations on the system, speed is maintained by time-distance restrictions. For example, through the Mt. Washington tunnel the maximum speed is 18 mph. Instructions stipulate that not less than 2 1/4 minutes must be used to travel between the tunnel portals. Instructions were in effect before the accident that prohibited two trolley cars traveling in opposite directions from passing each other at an electric switch, except in downtown areas. This did not apply to a bus and a trolley car before the accident, but since the accident, the rule has been expanded to include a bus and a trolley car.

Trolley cars are governed by local city ordinances and the traffic laws of the Commonwealth of Pennsylvania. Trolley car operators are not required to possess a Pennsylvania motor vehicle operator's license. The PAT operation over the joint-use right-of-way is considered by PAT officials to equate to an on-the-street operation.

On February 14, 1978, the track switch for the Palm Garden Loop was made to operate semi-automatically. An operator entering the Palm Garden Loop now has to stop his car and position the switch for the curve manually. It will then restore for a straight move automatically after a trolley car passes a closure contactor in the loop catenary. Specific instructions are given for operating a trolley car over an electric switch. (See appendix B.)

Meteorological Information

The 8:00 a.m. temperature on February 10, 1978, was 11° F. Visibility was described as good. The track or rail condition was indicated to be "bad," which is referred to by PAT employees as a "black" rail condition caused by a thin film of oil or water. The rail can be expected to be slick under such conditions.

Medical and Pathological Information

Most of the injured passengers were treated in hospital emergency rooms and released; six injured passengers were admitted to the hospital. The injuries included fractured bones, bruises, lacerations, broken or lost teeth, hematoma of one or both eyes, concussions, sprains, and neck and back injuries.

The autopsy of the four fatalities indicated that: One died from blunt force injuries of the head, chest, and extremities, two died from blunt force injuries of the chest, abdomen, and head, and one died from blunt force injuries of the head, thorax, and abdomen.

Survival Aspects

The damage to the trolley car would not have been detrimental to the evacuation of passengers. The operator apparently was thrown from his seat and escaped serious crushing injury that would have resulted from the impact with the bus and by the windshield of the bus penetrating the trolley car's windshield. The operator was able to leave the car unassisted.

The bus passengers' injuries were caused by their striking seats and stanchions, being thrown into the floor, and probably by striking each other. The passengers immediately behind the driver were crushed by the deforming metal and thrown into the aisles. The driver was thrown from his seat and one of his legs was pinned by the crushed seat. There were no seatbelts for passengers. The front door was jammed, but PAT personnel who first arrived on the scene forced it open. The side door was inoperable, but it was kicked open by passengers and several exited through the door. Some passengers escaped through the emergency side windows, which opened from the bottom. However, the two right front side windows were jammed when the bus lodged against the catenary pole, and those two windows had to be removed to facilitate the removal of several injured passengers through the windows. All of the passengers were removed from the bus by 8:50 a.m.

The first PAT employees to arrive on the scene immediately began to evacuate passengers and give first aid. The Allegheny County Sheriff's Department arrived about 8:10 a.m. The Pittsburgh Police and Fire Departments were notified about 8:09 a.m. and arrived shortly thereafter. Thirty-six police and fire department vehicles were sent to the accident scene.

The Pittsburgh hospitals were alerted to receive the injured and they implemented their emergency disaster plans without incident. The city's emergency forces apparently have no plan for coordinating operations at the scene of a major accident. No one assumed command and established a central authority or command post at the accident site, although the Fire Chief of the Fourth District did assume some control of activities.

Other Information

The operator of another trolley car testified that on February 14, 1978, 4 days after the accident, and before the Palm Garden Loop switch was made to operate semi-automatically, he was preparing to stop just beyond the switch to discharge an employee. To follow his planned route would have required that the switch be lined for the straight track. He testified that the switch was properly lined, that his speed was below 5 mph, and that he was coasting as he passed through the contactor. He further testified that after his trolley pole was clear of the contactor, but before the switch disappeared from his view, he saw the switch change position and become lined for the curve. Since he was in the required position with his foot on the brake, he was able to stop in about 2 ft before entering the curve. The employee who was preparing to get off the car was standing in the front doorwell, and he did not see or hear the switch move.

The operator then backed the car through the contactor and coasted through it a second time. He said the switch still did not operate for the straight track. Once more he backed through the contactor, and the third time he coasted through it, the switch operated to line the route for the straight track. The employee riding with him testified that the switch was lined for the curve when the car first stopped, that it did not line for the straight track the second time the operator tried it, but that the third time it positioned itself properly for the straight track. He did not observe specifically each time the operator had backed through the contactor that the trolley pole was clear of it, but he felt that the operator had moved back far enough to conform to the operating requirements. Following this occurrence, the switch was made to operate semi-automatically.

A yard track enters the outbound track about 40 ft north of the Palm Garden Loop switch. When cars are reversed so that their trolley pole passes through the junction of the siding catenary lead to the main wire, the pole tends to follow the siding lead. This displaces the trolley pole relative to the car, and if the car is reversed too far, the pole will jump off the catenary. This limits the facility with which the operator can back his car without assistance.

Tests and Research

The trolley operator involved in the accident testified that the car was operating properly before the accident except for the passenger signal buzzer, and one section of the front door. Both of these equipment circuits operate from an onboard battery and would not have affected the operation of the track switch.

On the day of the accident, PAT officials made several test runs through the switch with a car similar to the one in the accident. The switch performed correctly during all of the tests. Later, additional tests were made on the switch and its associated equipment, and no defective conditions were detected. The leads to the switch machine and all internal wiring for the relay panel were tested and no faults were found. The contactor was inspected and operated manually several times; it operated properly.

On February 12, 1978, the trolley car involved in the accident was tested electrically for conditions that would impose an overload on the switch circuit and cause it to operate, but none was found.

The left front wheel contour and flange were found to be in good condition with no marks to indicate that the wheel "picked" 3/ the switch. The switch point had no marks to indicate it had been picked. The switch point fitted the stock rail, and it did not roll or raise when a car moved over it.

The relay assembly that was in use on February 10, 1978, was replaced with a similar panel while the original panel was being tested. This replacement panel was being used on February 14, when the second reported failure occurred. Both panels were tested but no faults were found. Tests of the individual components of the relay panel involved in the accident disclosed no faults, and all component values checked close to specifications.

Bench tests of the contactor that was in service at the time of the accident showed a slight breakdown in insulation between the upper contact and lower arm assembly; however, this would not have caused the switch to have operated as claimed. During subsequent tests, to simulate a failure of the contactor in the operated position, the switch still operated properly. On February 16, 1978, all switch components and all leads coming from the catenary were tested again. Once again no faults were detected.

On May 7, 1978, after the controls of the damaged car had been repaired, operation tests were performed through the switch at Palm Garden Loop. The contactor and the relay panel that were in use at the time of the accident were reinstalled. During these tests, no abnormal voltage was observed in the "KL" relay circuit and the current values for a full electrical load, using all of the onboard auxiliary components (lights, heaters, etc.) with no propulsion power applied, were well below the level necessary to operate the "KL" relay. No malfunctions were detected during the series of tests conducted.

For several days between February 10, 1978, and the tests on May 7, 1978, a recording voltmeter was used in the relay circuits in different configurations to check for impulse or stray voltage and current. None of the checks indicated any abnormal conditions.

Stopping charts for the trolley indicate that it should be capable of stopping within 3.32 ft from a speed of 5 mph. The deceleration rate for an empty car on a 3-percent downgrade is 5.53 mph/sec. Experience and tests indicate that the cars will stop in 1 or 2 ft from a speed of 1 to 3 mph. Based on physical evidence, investigators calculated mathematically that the trolley car was traveling faster at impact than the operator estimated, and the bus was moving about the authorized speed limit.

The bus was inspected and tested to the extent possible for mechanical defects, but none were found. The rear brakes were found to operate properly and the brake drums, brakeshoe linings, and tires were in good condition.

3/ A switch point forcibly moved to the wrong position by a wheel flange.

PAT has no records of reports of similar occurrences of switches arbitrarily operating for the wrong route. The manufacturer of the relay panel reported that such reports had been received at times but that investigations of the incidents indicated the failures were human error.

ANALYSIS

The testimony presented by passenger witnesses indicates that the busdriver was operating his bus normally. He was apparently alert and attentive to his driving, because he attempted to avoid a collision by turning the bus when the trolley car turned into his path without warning. It is not surprising that estimates of the bus' speed given by several passengers ranged from 20 to 35 mph because this is a difficult judgment to make. Therefore, the Safety Board concludes that the busdriver was operating his vehicle consistent with the rules and in a safe manner.

The trolley operator had recently completed his training to operate a trolley car, and he had been working in this position for only 2 months. Because of his recent training, the operating procedures should have been fresh in his mind. According to his testimony, he was complying with the operating rules as he approached the Palm Garden Loop track switch at 1 to 3 mph.

Witnesses reported that the trolley car veered quickly to the left as it entered the switch, and that it seemed to push the bus after the impact. This indicates a collision speed greater than 1 to 3 mph. With the small differential in weight between the two vehicles, the trolley car might have been reversed in its direction of travel or stopped, but there was no indication of this.

When the trolley operator felt the car enter the curve, he said he immediately applied the brakes in emergency. His reaction time should have been greatly reduced because, as he testified, his foot was already on the brake pedal. Tests and computations estimate that the car should have stopped within 3 feet if moving at 1 to 3 mph. However, the car traveled onto the loop track, and when it stopped, the wheels of the rear truck were completely in the turnout. This means that the car traveled more than 25 feet after the operator was aware that the car was turning onto the loop track. The "black rail" condition would not have adversely affected the stopping distance to this extent. The operator who reported the switch failure on February 14, 1978, was moving from 1 to 3 mph when the switch moved in front of the car. He reacted to the irregularity and was able to stop in about 2 feet. Therefore, the Safety Board concludes that the trolley car involved in this accident was moving at a speed greater than the 1 to 3 mph reported by the trolley operator.

The design of the switch operating circuit is such that the switch cannot be electrically operated unless the car's trolley pole is on the contactor. The tests could not reproduce a switch failure. Similarly, the inspection and testing of components in the switch circuitry and on the trolley car revealed no malfunctions.

The switch would only have operated if there was a "sneak" or fault circuit or if the operator initiated the action. Since the failures could not be reproduced during the postaccident tests, the operator must have caused the switch to operate. There are several factors which support the probability that he inadvertently caused the switch to line for the curve: He was about 5 to 7 minutes behind schedule; he had just stopped while the car ahead stopped to discharge an employee, which may have delayed him further; and he was concentrating on the car ahead, attempting to close up as much as possible and yet maintain a safe separation.

When these factors are considered, it is possible that he thought his trolley pole was clear of the contactor, and he may have made some move that caused the switch to operate. The circuit is fast acting and the entire sequence of operation could occur in an instant. Also, the operator claims the switch did not line for the curve until after it disappeared from his view under the nose of the car. At this time the trolley pole would have been from 2 to 4 feet past the contactor. If the speed of the car increased about the time the pole was leaving the contactor, his speed would have been such that he would have covered the 5 to 7 feet almost instantaneously, and it would have appeared to him that the switch did not operate until he had lost it from view.

The relay panel is the "heart" of the switch operation. The reported switch failures occurred with two different relay panels in service. Both failures reportedly occurred after the car's trolley pole had passed clear of the contactor. All operations of the switch were proper when the control relays were operated manually. Tests were made with several different cars, including car No. 1790, in an attempt to produce an undesirable response and none occurred. In summmary, no failure of the switch was observed during tests, the switch operated properly from February 10 to February 14 without a failure, and the performance history of this switch circuit lends credence to its reliability.

The malfunction of the switch on February 14, 1978, also could have been the result of the operator's preoccupation with making a discharge stop. Once more the operator said that the switch did not operate until the car's trolley pole was clear of the contactor. If the operator had caused a high flow of current by some action while the trolley pole was on the contactor, the switch would have lined for the curve. For example, he could have applied power if the car needed a little more momentum to reach his projected stopping point, and he could have done this before the trolley pole cleared the contactor.

The operator was undoubtedly aware of the yard track switch behind him and he knew that if he reversed the car too far, the trolley pole might jump off the catenary because of the diverging line. He may have been too cautious in backing toward the contactor because of this constraint, and therefore, failed to position his car properly with respect to the contactor for correct track switch operation. A visual check on the relationship of the pole to the contactor was not made by the employee on the car because he did not alight.

If the operator had backed through the contactor, the car would have drawn current so that the "KL" and "B" relays would have operated properly, causing the switch to remain positioned correctly for the curve. When he stopped, if he had not cleared the contactor and had applied power to move forward, the switch would have remained lined for the curve. If the trolley pole remained on the contactor when he stopped, the "B" relay would have dropped out, the "KL" would have been de-energized, and even though he coasted forward, the switch point would not have operated.

The same series of electrical events took place when he reversed the car for a second time. However, if when moving back for the second time, he moved back far enough for the trolley pole to clear the contactor, he could have given a quick burst of power to move forward before the trolley pole moved onto the contactor, and this action would not have affected the switch circuit. Then, by allowing the car to coast through the contactor, the switch would have operated and lined for the straight track. Therefore, the Safety Board concludes that the switch was operating properly, and that there were no discrepancies in the switch circuit or in the components on the day of the accident or on February 14, 1978.

Operators of trolley cars would not be required to concentrate so intently on positioning a switch if they had some means of knowing when their trolley pole was on the contactor. Such a marker would be helpful at all times, but it would be especially helpful to trolley operators when they must back their cars through and clear the contactors. Additionally, the operation of the track switch to the curve should be limited to operation by the onboard toggle track switch only. The track switch should not be operable with the foot accelerator pedal.

When the Palm Garden Loop switch was relocated, even if its use was expected to be on a temporary basis, some form of protection should have been included. Switch protection could have been provided even for rubber-tired vehicles, because the state-of-the-art is such that detection of a vehicle is not limited to a track circuit that is shunt actuated. Because the switch is located on a grade and because of the heavy density of traffic at that point, the switch circuit should be arranged so that it cannot operate the switch if another vehicle is within a predetermined range. If this switch circuit had incorporated such a feature, this accident probably would not have occurred.

The rule change since February 10, 1978, to prohibit a bus or trolley car from passing another trolley car at a switch is good and it provides a measure of protection, but it does not provide the positive protection that a mechanical or electrical lock would provide. Also, since company vehicles use these bus/trolley facilities, they should be included in the procedure.

Even though the operation on the PAT BUSWAY is equivalent to an on-the-street operation, it is a dedicated thoroughfare and operators might be lulled into a false sense of security that would not prevail on city streets. Therefore, safeguards should be taken to guard against human error. This becomes especially important through the accident area, since there are no detection or speed control appurtenances in service.

The automobiles that were damaged during the accident undoubtedly were parked along the right-of-way with due consideration for clearance from the PAT BUSWAY traffic by using the catenary poles as guides However, the presence of the catenary poles, though necessary, and the parked vehicles so close to the traffic lanes does not give moving vehicles ample space for evasive action if it becomes necessary. The PAT should consider the elimination of such hazards alongside the busway and in similar congested areas.

The trolley car struck and penetrated the left side of the bus with virtually no penetration resistance, and because of the relative motion of the two vehicles, the penetration was effectively extended along the side. This action caused the greatest amount of energy to be absorbed in the immediate area occupied by the driver and the three passengers who were killed. The driver was not using his seatbelt, but even so it would not have prevented his injuries nor would seatbelts have helped the passengers. All of the fatalities received their injuries because of the impact crushing of their occupiable space. The deforming metal and left front axle/wheel assembly absorbed much of the kinetic energy and thus reduced the potential for injury to passengers outside of the "crush zone." If the impact had been head-on, or if the left front side had been more resistant to crushing, more of the impact energy would have been transmitted through the bus body and there may have been more injuries.

The PAT employees who were the first on the scene did a commendable job in evacuating the passengers and administering first aid. Rescue vehicles had difficulty reaching the area because of congestion. If a preparedness plan had existed and one individual had assumed command, he could have directed the rescue activity and lessened the confusion. Someone should be designated to take command of an emergency situation. All municipalities that have an emergency response capability should have a preparedness plan to cope with emergencies. In an emergency there is not time to organize and still be effective in handling the situation. The foresight of the hospitals and the manner in which they operated is indicative of the benefits to be derived from preparedness.

CONCLUSIONS

Findings

1. The busdriver was operating his vehicle in a manner consistent with acceptable operating practices.

2. The busdriver took evasive action to avoid colliding with the trolley car but it was not effective.

3. During tests on the track switch for the Palm Garden Loop, it could not be made to operate except by a proper operating procedure.

4. The trolley car operator approached the switch contactor conscious of the car ahead and observing the position of the switch.

5. The trolley car operator must have inadvertently caused the switch to line for the curve by some operating action before the car's trolley pole was off of the contactor.

6. The trolley car's speed was greater at impact than the operator estimated.

7. The incident on February 14, 1978, was probably caused by the operator inadvertently performing some operating action before the trolley pole cleared the contactor.

8. The track switch did not align properly on February 14, 1978, because the operator did not at first properly operate through the contactor.

9. Switch protective devices or the implementation of the no-passing rule for buses and trolley cars before the accident probably would have prevented it.

10. Lack of a preparedness plan by the emergency forces of the Pittsburgh Police and Fire Departments and a lack of a central control authority caused unnecessary confusion at the accident site.

11. Even if available, the use of seatbelts by the busdriver or by the passengers who were killed would not have prevented their injuries because of the vulnerable point at which the impact occurred.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the operator's inadvertent and untimely operation of an unprotected track switch, which caused the trolley car to be routed into the path of the approaching bus. Contributing to the accident was the operator's operation of the car at a speed too great to permit stopping when he detected the turning movement of the car, and the lack of protective devices to control the switch operation.

RECOMMENDATIONS

As a result of its investigation of this accident, the National Transportation Safety Board recommended that:

...the Port Authority of Allegheny County, Pennsylvania:

> "Disable the inherent feature of the trolley car that permits the operation of an electric switch movement by depressing the power pedal. (Class II, Priority Action) (R-78-49)
>
> "Provide switch-operating protection to prevent the Palm Garden Loop and similar switches from being operable when an opposing vehicle is within a danger zone. (Class II, Priority Action) (R-78-50)"

...the Governor of the Commonwealth of Pennsylvania:

> "Encourage and assist municipalities that have emergency response facilities to develop emergency procedures in a disaster plan that includes the designation of a controlling, onscene officer. (Class II, Priority Action) (R-78-51)"

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ FRANCIS H. McADAMS
Member

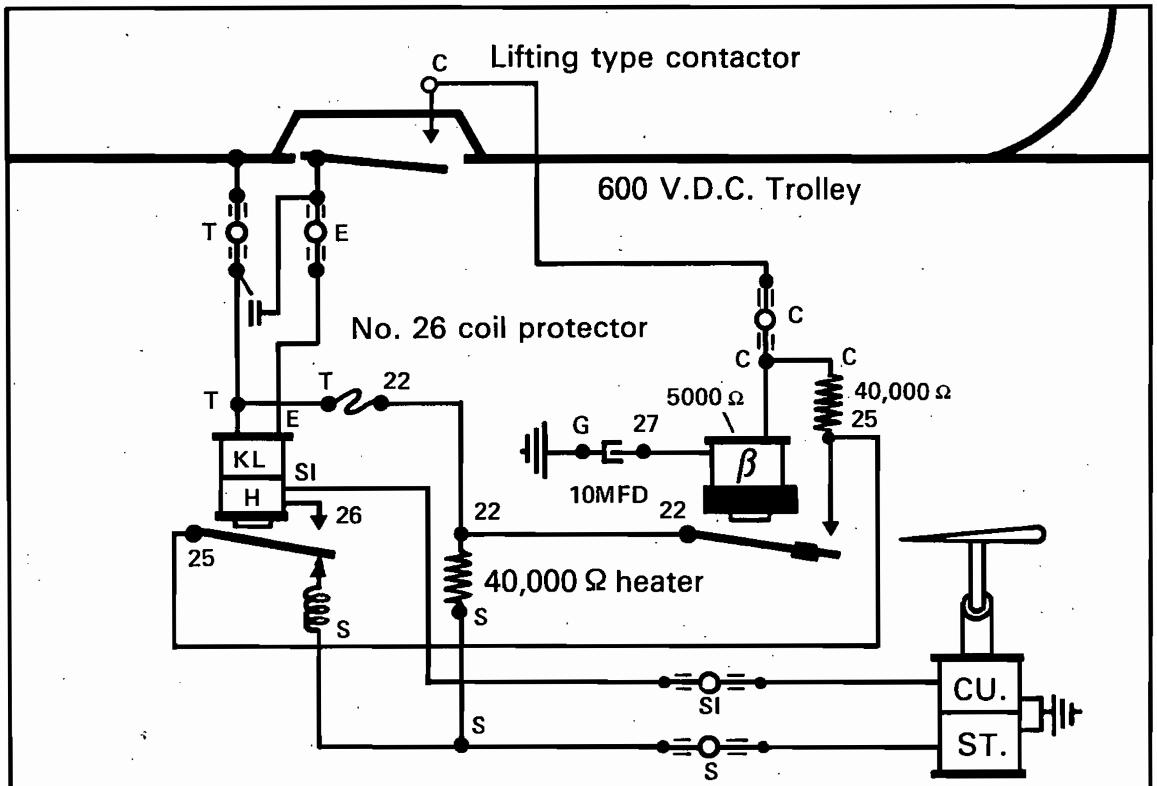
/s/ PHILIP A. HOGUE
Member

/s/ ELWOOD T. DRIVER

August 17, 1978

APPENDIX A

SWITCH RELAY CIRCUIT



CIRCUIT DIAGRAM

Note: Arcing will occur on contacts of K.L. relay if coils are connected otherwise than shown.

CAUTION: BE SURE THAT CONDENSER IS DISCHARGED BEFORE HANDLING PANEL BY JUMPING THE TERMINALS OF THE CONDENSER ("27"-"G").

OPERATION OF SWITCH RELAY CIRCUIT

Circuit is shown at rest. To operate switch for straight track: Contactor is closed by trolley pole, "B" relay is energized momentarily by energy through closed contact in contactor, over "C" lead, through "B" relay winding, over 27 lead, through capacitor and "G" lead to ground. At the same time, current flows over "T" lead, over 22 lead, through closed contact of "B" relay, over 25 lead, through down contact of "KL" relay, over "S" lead to energize coil "ST" and position switch straight.

To operate for curved track: Contactor is closed by trolley pole (operator has track switch operated on car or power pedal depressed), current flows over "T" lead, through "KL" relay winding, over "E" lead, through contactor bar, through trolley pole and trolley circuitry to ground (this draws the 60 amps needed to energize "KL" relay). Simultaneously "B" relay is energized as before. When relays "KL" and "B" are energized, current flows over "T" lead, over 22 lead, through closed contact of "B" relay, over 25 lead, through closed upper contact of "KL" relay, through contact 26 and holding coil "H" of "KL" relay, over S1 to energize coil "CU" and position the switch to the curve.

APPENDIX B

PAT OPERATING ORDER NO. 30

PAT TRANSPORTATION DEPARTMENT

OPERATING ORDER

OO #30
May 2, 1973

Subject: OPERATION AT FACING SWITCHES

To: Operating Employees and All Concerned

The following instructions will govern operators in the operation of cars at facing switches.

1. Upon approaching an electric switch operators must reduce the speed of their cars so that the speed between the contactor and the switch point will not exceed five (5) miles per hour, which is approximately the speed a man can walk at a rapid pace. Approaching the switch at this speed will permit stopping the car short of the switch point should it fail to operate, fail to close completely, or be obstructed by foreign matter.

2. Likewise upon approaching any non-electric facing switch operators must reduce the speed of their cars so that the speed in the fifty foot section short of the switch point will not exceed five (5) miles per hour.

3. At every facing switch operators will be expected to have the power off when the front wheels of their cars reach the switch and will not reapply power until the rear truck has passed over the switch, excepting where an upgrade or curve makes this impossible. Even where the grade or curve requires the application of power to move the car over the switch operators will limit the speed of operation to five (5) miles per hour or less.

4. Operators should be alert when the rear trucks reach switch for indications of improper tracking, i.e., "splitting the switch," and fully prepared to act promptly to bring the car to a stop.

5. A car should not be moved over a facing switch point while an opposite bound car is passing, except at those busy intersections in the Downtown area, where traffic congestion in the peak hours would result from so doing. Where it is necessary to pass opposite-bound cars at a switch location each car should be moved at a speed not greater than five (5) miles per hour.

6. Operators must not attempt to move a car over any facing switch which is covered with snow, slush, or water or is for any reason obstructed from full view without first determining that it is set for the desired movement and is completely closed. In order to determine that the switch is properly lined and completely closed under such conditions, the operator should get off his car and probe the switch with the switch iron.

7. When switches which are ordinarily not used, are used in some unusual operation, the operator in charge of each car using such a switch is required to see that the switch is returned to its normal position and properly locked or plugged, before proceeding.

Bear in mind that the instructions outlined above referring to all facing switches include electric switches, spring switches, dead switches, plugged switches and the Korn locking-type switches.

/s/ G. C. Steitz
Manager of Transportation