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RAILROAD ACCIDENT REPORT

Collision of the State-of-the-Art Transit Cars with a Standing Car, High Speed Ground Test Center Pueblo, Colorado August 11, 1973

NATIONAL TRANSPORTATION SAFETY BOARD

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Washington, D.C. 20591

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15. Supplementary Notes

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16. Abstract

On August 11, 1973, the UMTA state-of-the-art rail rapid transit cars (SOAC's) collided with a standing railroad gondola car at the U. S. Department of Transportation's High Speed Ground Test Center near Pueblo, Colo. The SOAC's were being operated on the transit test track when they were inadvertently diverted through a switch onto an adjacent track and into the gondola. The motorman on the SOAC was killed.

The National Transportation Safety Board determines that the probable cause of this crash was the failure of a locomotive crewmember to aline a switch properly and the failure of the motorman to detect the open switch in sufficient time to stop the SOAC's short of a gondola standing on the track. Contributing to the accident were the failure of the Transportation Systems Center's representatives (UMTA's systems manager) to implement operating procedures that would secure the intended pathway and the absence of a systematic risk management program at the High Speed Ground Test Center.

This report examines the crashworthiness of the SOAC's and the institutional errors that led to the accident. Recommendations intended to prevent a recurrence of the accident and to improve crashworthiness of rail transit cars are directed to the Federal Railroad Administration and the Urban Mass Transportation Administration.

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FOREWORD

The accident described in this report was designated a major accident by the National Transportation Safety Board under the criteria established in the Safety Board's regulations. This action was taken after the Urban Mass Transportation Administration requested the Safety Board to conduct an investigation.

This report is based on facts obtained from the Safety Board's investigation. Cooperation in the investigation was received from the Federal Railroad Administration, the Urban Mass Transportation Administration, the Transportation Systems Center, Boeing Vertol Company, Kentron Hawaii, Limited, and the AiResearch Manufacturing Company.

The conclusions, the determination of probable cause, and the recommendations herein are those of the Safety Board.

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Washington, D. C. 20591

Railroad Accident Report

Adopted: May 1, 1974

Collision of the State-of-the-Art Transit Cars with a Standing Car, High Speed Ground Test Center, Pueblo, Colorado, August 11, 1973

SYNOPSIS

The Urban Mass Transportation Administration (UMTA) sponsored construction of two rail rapid transit cars to demonstrate the best state of the art in car design. The state-of-the-art cars (SOAC's) were being tested on UMTA's transit test track at the High Speed Ground Test Center near Pueblo, Colo. On August 11, 1973, the two SOAC's inadvertently were diverted through a switch onto an adjacent track and into a standing gondola car. The collision killed the motorman of the SOAC's and extensively damaged the lead car.

The National Transportation Safety Board determines that the probable cause of this crash was the failure of a locomotive crewmember to aline a switch properly and the failure of the motorman to detect the open switch in sufficient time to stop the SOAC's short of a gondola car standing on the track. Contributing to the accident were the failure of the Transportation Systems Center's representatives (UMTA's systems manager) to implement operating precedures that would secure the intended pathway and the absence of a systematic risk management program at the High Speed Ground Test Center.

The death of the motorman was caused by his remaining in the operator's compartment although he had time to evacuate after the brakes were applied.

FACTS

The Accident Circumstances

The collision. On August 11, 1973, two coupled rail rapid transit cars were being tested at the High Speed Ground Test Center (HSGTC) near Pueblo, Colorado. The cars had been constructed to demonstrate the best state of the art in car design. The state-of-the-art cars (SOAC's) began afternoon operation at 2:11 in a counterclockwise direction on the Urban Mass Transportation Administration (UMTA) transit test track. The SOAC's were operated by a motorman located in the operating compartment of the lead car. Four passengers, who were performing various test-monitoring functions, rode in the second car. One passenger was in the operator's seat at the extreme rear and the other three were at the forward end of the car, seated at right angles to the car's direction of travel.

The tests simulated conditions encountered during normal transit operations and included starting and stopping at 16 simulated stations spaced around the 9.1-mile oval test track. The SOAC's departed from the vicinity of station A after lunch and made 15 stops and starts without incident.

At 2:30 p.m., the SOAC's reapproached station A. The motorman was scheduled to make a service brake application at a preestablished location while the cars were traveling at 55 mph. The SOAC's were then supposed to stop at station A, where two persons were waiting to board. One of those persons waved to signal his intent to board as the SOAC's approached the station.

At a point 605 feet from the station, the SOAC's were diverted through a No. 15 turnout onto an adjacent track and collided with an empty gondola car that was coupled to an unmanned diesel-electric locomotive. The point of impact was 571 feet from the spot where the programmed braking for station A was to have been initiated and 159 feet short of a point opposite the station. Witnesses stated that the SOAC's had reduced speed before impact to about 25 to 40 mph. The accident area is shown in Figure 1.

Test activities. At the start of work on August 11, the two SOAC's were placed on the UMTA transit test track by a two-man locomotive crew using the diesel-electric locomotive and the gondola which was equipped with a special coupler. The gondola was then placed on a storage track and the locomotive traversed the test track loop for a security check. The test track was found to be secure, and the locomotive proceeded to the nearby Pueblo Army Depot via a track which connected with the transit test track.

During these test preparations, the test track security guard took his post at the gate and a second guard began to patrol around the transit test track in a truck. In patrolling, the roving guard used a road outside of and adjacent to the transit test track.

Because of a problem with the lighting and air-conditioning system on the SOAC's, testing did not start until after 11 a.m. A verbal clearance over the two-way radio by the roving guard and the previous security check by the locomotive crew were relied on to assure that the track was secure for testing.

The morning test consisted of two runs around the test track with stops at each of the 16 stations and two nonstop runs around the test track at 80 mph. Stops were accomplished as intended. Just before lunch, the locomotive crew contacted the SOAC crew via radio and requested that the SOAC's be parked north of the north access track switch during the lunch break to accommodate the return of the locomotive from the Pueblo

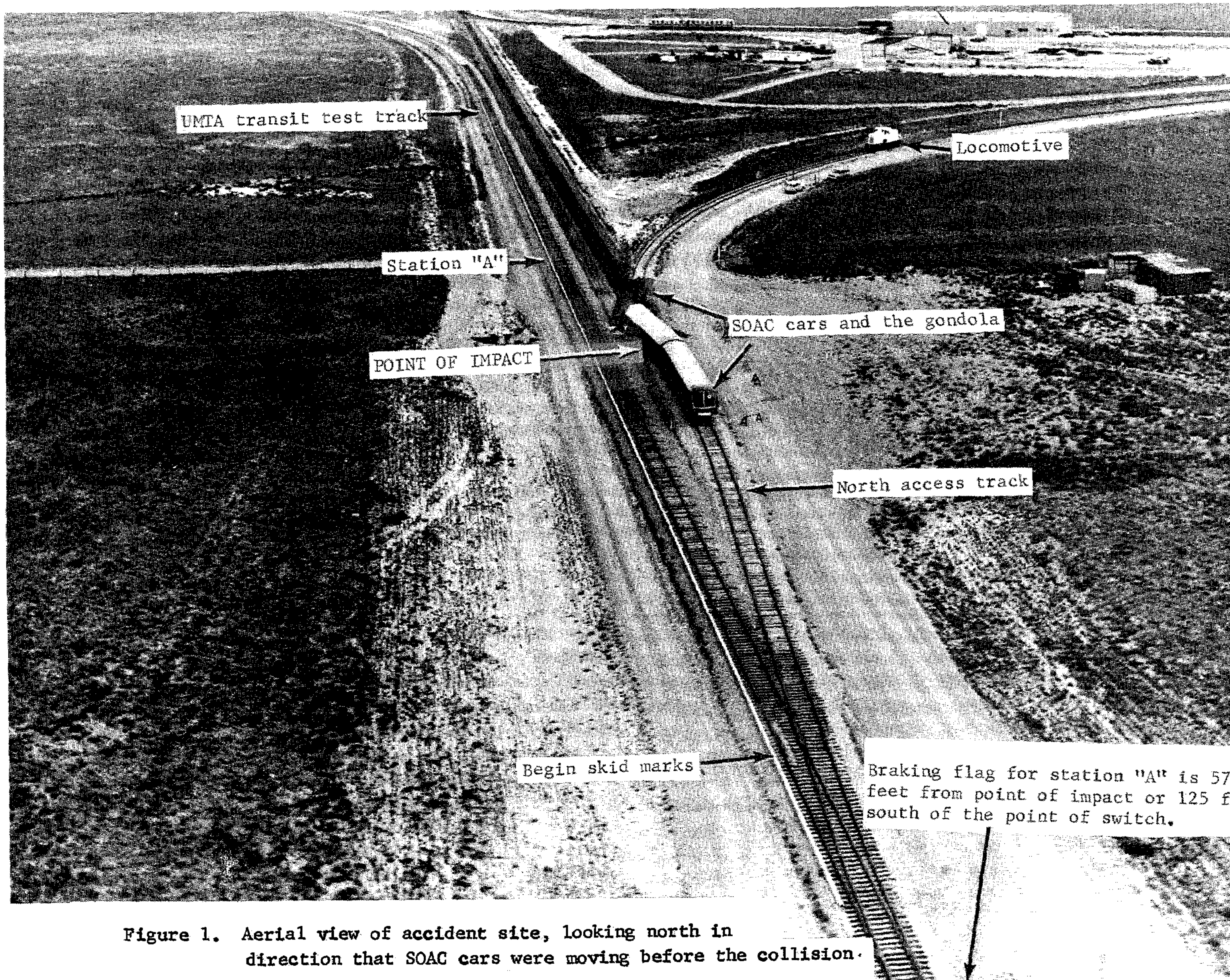


Figure 1. Aerial view of accident site, looking north in direction that SOAC cars were moving before the collision.

Army Depot. As a result, the SOAC's were parked approximately 300 to 400 feet north of the north access track switch. When the crew left for lunch at 12:30 p.m. no cars were parked on the track adjacent to the transit test track.

The locomotive crew operated both the locomotive used to go to the Pueblo Army Depot and another locomotive used to generate electric power for the transit track third rail. Accordingly, the crew had been given a truck for transportation to and from their duty assignments. When the test personnel went to lunch the locomotive crew drove to the depot to get the locomotive. During the trip back from the depot along the connecting track to the transit test track, one crewmember operated the locomotive while the other crewmember drove the truck from switch stand to switch stand.

The switch which allowed access to the UMTA transit test track was realined and locked after the locomotive moved onto the test track. The crewmember in the truck then proceeded to the north access track and manually opened the switch so that the locomotive could move from the transit test track to the north access track. The on-ground crewmember does not recall closing the switch after the locomotive passed through, although it was his responsibility to do so.

The locomotive moved onto the north access track and proceeded to the storage track to pick up the gondola used for coupling onto the SOAC's. The locomotive and gondola were then parked on the north access track, with the gondola on the south end for convenience in picking up the SOAC's after the afternoon testing was completed. The locomotive wheels were chocked for southward movement before the locomotive crewmembers went to lunch. The gate security guard maintained security during this time, and no other persons were observed near the north access track switch.

When the locomotive crew returned from lunch, they proceeded to the locomotive that provides electrical power for the transit test track. In doing so, they again passed the parked locomotive and gondola and the north access track switch. They did not observe the switch position at that time.

When the SOAC test personnel returned from lunch, they walked around the south end of the gondola on the north access track to get to the SOAC's. None of the test personnel recall looking at the position of the north access track switch at that time. The test controller had been told by the security guard that no one had come into the secured area during lunch. The controller understood from the locomotive crew that the switches were lined and locked for movement on the test track. He contacted the roving guard and was told that "everything was clear." The power was switched on, and the afternoon test was begun.

Collision dynamics. When the collision occurred the coupler of the lead SOAC engaged with the similar coupler on the gondola. The force of impact caused the coupler shear pins to fail. The anti-climber on the SOAC contacted the makeshift anti-climber of the gondola, and the gondola anti-climber yielded downward. The couplers on both cars jackknifed downward, and as the longitudinal structural members of the SOAC collapsed, the gondola overrode the underframe of the SOAC. The gondola penetrated the SOAC 6 feet on the motorman's side and 9 feet on the opposite side.

The force of the impact disengaged the coupler of the gondola from the locomotive coupler and knocked the locomotive about 575 feet rearward from its original location. The SOAC traveled about 69 feet after impact and the gondola moved rearward 73 feet. The gondola and the lead SOAC were derailed. The rear SOAC remained on the rails. (See Figures 2 and 3.)

Accident Site

The HSGTC is a field installation of the U. S. Department of Transportation (DOT) and is managed and operated by the Federal Railroad Administration (FRA). The mission of the HSGTC is the conduct of large-scale tests and evaluation of ground transportation experimental and developmental systems, subsystems, and components. The existing facilities on the 52.6 square-mile site include pathways for the testing of tracked air cushion vehicles, linear induction motor vehicles, rail transit cars, and conventional railroad equipment.

The UMTA transit test track was of conventional rail, crosstie, and ballast construction although some crossties were longer to accommodate the electrified third rail. Four turnouts diverged from the transit test track on the east side of the oval. Two of the turnouts were facing-point for a counterclockwise movement, while the other two were trailing-point. The transit test track was not equipped with signals.

All four turnouts could be operated manually by ground throw switch stands, two of which were also automatic. The automatic switch stands permitted the switch to be opened by the wheels of a car in a trailing-point movement when the switch was alined against that movement. In this use, the switch points remained in the position of the last trailing-point movement and the switch stand handle remained in the last position in which it was placed. The switch stand target moved with the switch points to indicate switch position.

The north access track switch was equipped with one of the automatic-type switch stands, with a low switch position target. (See Figure 4.) The switch stand handle could be secured in one position by the use of the chain and padlock which were connected directly to a head-block tie. Even when the handle was locked, however, the switch points could

Figure 2. Demolished operating compartment and the east side of the SOAC car. Derailed gondola car is at the right.

Figure 3. Damage to the west side of the SOAC .

Figure 4. North access track switch, looking north. Switch is in "open" position. The SOAC's are visible at the collision point in the background.

be realined by a trailing-point movement through them. Thus, a train could enter the test track from the north access track, exit by the same switch, and leave the switch open without any manual operation of the switch. The switch stand had neither latches nor padlock pedestals, nor were the switch points secured against the stock rail by any device. The SOAC motorman and the two locomotive crewmembers were the only HSGTC personnel assigned keys for the padlock.

Both the transit test track and the north access track ascended a northward 0.5-percent grade in the accident area. No derails or other appurtenances had been installed to prevent inadvertent movement onto the transit test track from the north access track or from other connecting tracks.

The general configuration of the transit test track was established by the Office of High Speed Ground Transportation of the FRA (now the Office of Research, Development, and Demonstrations) through consultation with UMTA. The track hardware and appurtenances were specified by the Transportation Systems Center (TSC) using the advice of engineering consultants. The contracts were prepared by the Federal Highway Administration, which also provided on-site engineering and supervision before and during construction.

Weather

Visibility was generally unrestricted at the time of the accident. Broken clouds were present, and the temperature was about 94° F.

Method of Operation

Organization. As manager and operator of the HSGTC, the Office of Research, Development, and Demonstrations of the FRA directed all organizational elements at the HSGTC, and, in doing so, was responsible to "provide safety program and equipment review and inspection ..." The responsibilities of the FRA were detailed in Department of Transportation Notice 1130.7 (DOT N 1130.7), pertinent portions of which are included in Appendix A.

Because the FRA staff at the HSGTC consisted of only 10 persons including clerical personnel, the FRA contracted Kentron Hawaii, Limited, to perform the operational and maintenance duties involved in the day-to-day operations at the HSGTC.

DOT N 1130.7 provided that sponsoring DOT administrations would conduct all testing and provide the facilities related to their programs. In the SOAC program, UMTA, as the sponsoring administration, provided both the transit test track and the cars. UMTA, however, had no employees at the HSGTC. Instead, UMTA retained TSC and the Boeing Vertol Company as their systems managers at the HSGTC.

TSC functioned as the systems manager for rail-supporting technology. TSC, a DOT organization which reports to the Assistant Secretary for Systems Development and Technology, was thus responsible for the design, construction, operation, and safety of UMTA's facilities at the HSGTC and had personnel permanently assigned to the center.

The Boeing Vertol Company, the second systems manager, was responsible for overseeing the design, manufacturing, and testing of the SOAC's, including overall planning and integration of the SOAC program. Boeing Vertol personnel were assigned at the HSGTC only during the SOAC testing program.

Prescribed operating procedures. The HSGTC had issued a number of policy orders and management instructions intended to establish basic operational organizations, concepts, definitions, and methods for conducting and coordinating the various test program activities. At least seven such documents were applicable and effective at the time of the accident. (See Appendix B.) These orders and instructions did not prescribe specific security measures and employee duties during individual tests. Instead, they stated that: "No test operations shall be scheduled or conducted until appropriate test documentation has been approved by the Project Monitor and concurred by the HSGTC Director."

Accordingly, Boeing Vertol submitted to the HSGTC operating procedures for the testing of the SOAC's. These procedures described the methods of operating the cars, the track security measures, and the test team organization that Boeing Vertol personnel understood as applicable at the time of the accident.

TSC, responsible for the conduct of testing on the transit test track, established its own set of operating procedures on February 1, 1973. The TSC document was modified by various notations of the project monitor, the test controller, and the motorman. The updated version of the document was dated August 24, 1973. (See Appendix C.) This document had not been distributed on August 11, 1973, although TSC's project monitor and the test controller stated that it was the agreed method of operation. These procedures differed somewhat from those submitted by Boeing Vertol even though they were intended to cover the same operation. HSGTC personnel had not reviewed all of the procedures described in the August 24 document.

A HSGTC document Railway System Rules Handbook also applied to operations on the transit test track. This document included approximately 350 rules and definitions extracted from standard railroad and transit operating and safety rules. Most of these rules were not pertinent to HSGTC operations but the handbook stated that the rules were established to govern all users, organizations, or agencies that operated, or had interest in an operation on the railway system at the HSGTC.

The HSGTC had established a safety program through Policy Order 5800.1. This program was to be implemented by a HSGTC safety officer whose duties were described in Management Instruction 3902.1. Excerpts from these documents are included in Appendix D. A Kentron Hawaii safety engineer was designated as the acting HSGTC safety officer in addition to his normal assignment.

Actual operating procedures. After the accident the Safety Board took statements from all of the test personnel. The statements provide the following description of the operating procedures at the transit test track on the day of the accident.

The SOAC's were operated both clockwise and counterclockwise on the oval transit test track. The movement of the cars was controlled by the motorman, except for "deadman" and fail-safe devices which could be activated automatically. The motorman was expected to be alert for hazards.

Before the third rail was energized or a test was run, track condition and security was to be assured. The test controller, the locomotive crewmembers, the roving guard, and the gate guard all had to verify that the transit test track was secure. However, the test controller was assigned overall operational control for a test. When he authorized a test to start, the track was assumed to be safe and secure.

The transit test track was surrounded by a barbed-wire fence. When a test was scheduled, all gates except one were closed. At the unlocked gate, the security guard controlled access. The guard had to request clearance from the test controller before he allowed any person to enter the test site, and he had to inform the test controller when any person left the area.

The roving guard patrolled the transit test track before a test began and, for the most part, when a test was in progress. The guard drove his truck at 25 to 30 mph on the service road. The roving guard on duty on August 11 understood that his duties included watching to assure that animals, debris, or unauthorized personnel were not on or near the track. He did not understand his duties were to include reporting switch position, nor had he received any instructions to that effect. A former roving guard stated that at one time the roving guard was required to check switch position, but that the practice had been discontinued.

The locomotive crew's role in assuring track security was to operate the locomotive around the transit test track in the morning before test operations commenced. The crewmembers were supposed to check that there were no obstructions on the track and no track defects and that the switches were alined properly. The inspection run was made at a speed of from 20 to 30 mph. If the locomotive crew used the switches during a period when testing was suspended, they were required before testing resumed to report the position of those switches they used. This report was to be made by the crewmember who actually handled the switch and did not have to be verified by anyone. One week before the accident, a switch had been left open by one of the locomotive crewmembers during a lunch break. The crewmember remembered the open switch during the security check, and the switch was realined before the SOAC's began testing.

The track security reports generally were made by radio to the test controller, who was located on the SOAC. Before he started a run, the motorman of the SOAC also was required to inspect the vehicle systems and to test the brakes and report to the test controller. The motorman on the day of the accident was also the "track security officer"; however, on August 11, he did not perform any duties that involved establishing track security.

Vehicles

Design concepts for the SOAC. Primary goals of the SOAC were to be passenger convenience and operating efficiency. The overall objective of the project, as set forth by UMTA, was to enhance the attractiveness of rail transportation to urban travelers by providing service that is as comfortable, reliable, safe, and economical as possible.

Specifications for the SOAC were based on Boeing Vertol's evaluation of currently available transit cars and subsystems. UMTA designated "state of the art" as that which was used on the Bay Area Rapid Transit (BART) system. Accordingly, a document, Detail Specification for State-of-the-Art Car, was prepared and released to the public. The specification follows the format of Guideline Specification for Urban Rail Cars, a document previously prepared for UMTA. Some paragraph numbers from the latter document were indicated as "not applicable" or "not specified" in the specification for the SOAC. A paragraph was "not specified", if the item to which it referred had not been called for in Boeing Vertol's contract with UMTA. In the final specification, crashworthiness criteria, certain reliability data, system safety data, and value and human-factor engineering data were classified as "not specified."

To meet schedule requirements, a car body with the strength requirements of the New York City Transit Authority's R44 transit car was selected as this was claimed to be compatible with using the BART system as the baseline for the state of the art. Both cars had undercar structures intended to provide plastic deformation and energy absorption in crashes. The structural integrity of the SOAC was specified in terms of traditional static end loads. The specifications called for the cars to withstand load tests of 250,000 pounds and the cars were designed for the application of 400,000-pound ultimate end loads.

The cars were designed to operate on the rail rapid transit systems in Boston, Chicago, Cleveland, New York, and Philadelphia. Demonstrations in these cities were scheduled to be conducted after the completion of testing on August 17, 1973.

General description of the SOAC. The two cars were each 75 feet long and weighed 90,000 pounds empty. They had been ballasted for a normal load weight of 105,000 pounds during testing. The basic car structure was of welded steel with stainlesss steel exteriors, except for car ends of molded fiberglass. The underframe was made of high-strength, low-alloy steel. A detailed description of the SOAC is included as Appendix E. The cars are shown in Figure 5.

The motorman's operating console included a digital speedometer, an air-pressure gauge, and a "P"-meter, which monitored the propulsion and the braking systems. Speed-maintaining buttons allowed the motorman to select various maximum car speeds. Once reached, the selected speed was maintained as long as the master controller handle was positioned properly. One of the speed-maintaining buttons was for 55 mph. The motorman could activate emergency braking by one of three methods: (1) depress the emergency-stop button on the right side of console; (2) move the master-controller handle through the emergency brake detent position; or (3) pull the emergency brake cord located directly overhead of the emergency stop button.

The cars were powered by a 600-volt direct-current system collected from a third rail adjacent to the transit test track.

Braking system on the SOAC. The braking system provided four different braking modes: (1) dynamic brakes, which normally supplied most of the braking effort for normal stops; (2) wheel-tread friction brakes, which supplied any braking effort not supplied by the dynamic brakes; (3) emergency brakes; and (4) a parking brake.

The dynamic brake system depended on the supply of electrical power to the cars. The service friction brakes were part of an air-brake system controlled per individual truck, which applied composition brake shoes to all wheels. The emergency brakes operated in essentially the same manner as the service friction brakes, except that no wheel-spin-slide protection was provided.

The SOAC's had been tested for braking during March and April 1973. The results are summarized below. The stopping-distance data include the effect of system time constants involved after the initiation of braking.

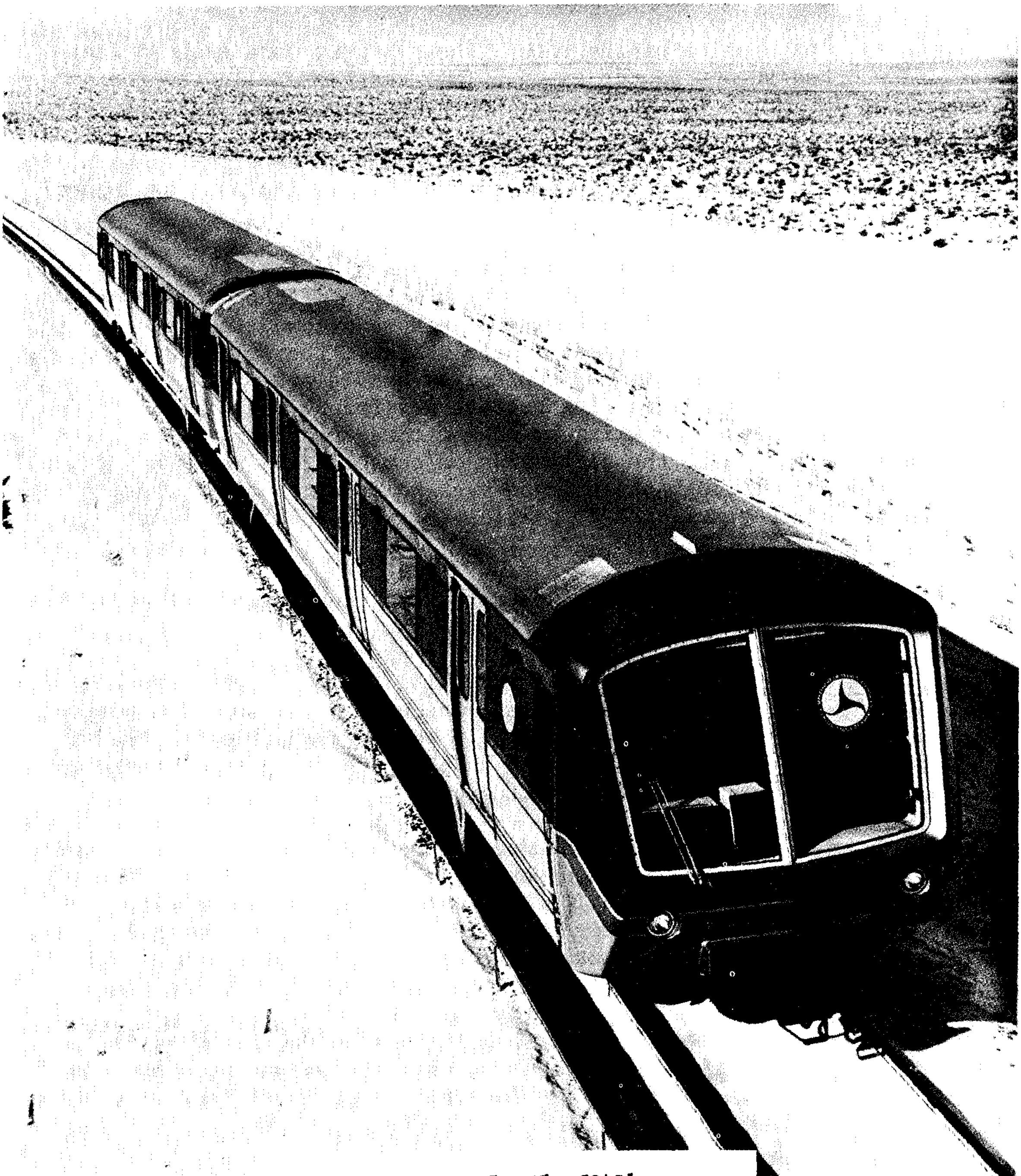


Figure 5. The SOAC's.

Braking (two 105,000-lb. cars)	SOAC Specification	Summary of Tests
Deceleration Rates (Peak)		
Blended Service	2.7 to 3.3 mph/sec	3.2 mph/sec
Dynamic Only	2.7 to 3.3 mph/sec	3.1 mph/sec
Service Friction	2.7 to 3.3 mph/sec	3.2 mph/sec
Emergency	2.88 to 3.52 mph/sec	3.5 mph/sec
Stopping Distances - 40 mph		
Blended Service	450 ft.	430 ft.
Service Friction	450 ft.	420 ft.
Emergency	425 ft.	335 ft.
Stopping Distances - 80 mph		
Blended Service	2,250 ft.	1,660 ft.
Service Friction	2,250 ft.	1,925 ft.
Emergency	2,200 ft.	1,635 ft.

Simulated dynamic brake failure during these tests resulted in the car's stopping within specification allowances with service friction brakes only.

The other vehicles. The empty gondola was 42 feet long, 10 feet wide and weighed 46,600 pounds. The gondola had been modified to accommodate the movement of rail rapid transit equipment by means of conventional railroad equipment. The modification consisted of the installation of a coupler and air service compatible with those on the SOAC. In addition, a gusseted steel platform was constructed on the end of the gondola. The gussets were connected with horizontal steel plates. This structure was intended to serve as a full-car-width anti-climber. A photograph of a similarly modified gondola is shown in Figure 6.

The locomotive coupled to the gondola was a General Electric diesel-electric steeple cab industrial type. The locomotive weighed 88,000 pounds.

Vehicle Damage

The SOAC's. The operating compartment of the lead car was demolished and the passenger compartment was heavily damaged back to the first side door. The side sills and draft sill of the underframe were twisted under the car. The fiberglass car end was shattered into many pieces. The windshield was dislodged and shattered but remained intact in two pieces. Both forward corner posts were torn from the side sills and bent aft from the top. The trailing door posts of both forward side doors were slightly bent. Minor buckles in the side skin were present behind the forward side doors. The car roof also was buckled moderately to the rear of the forward side doors.

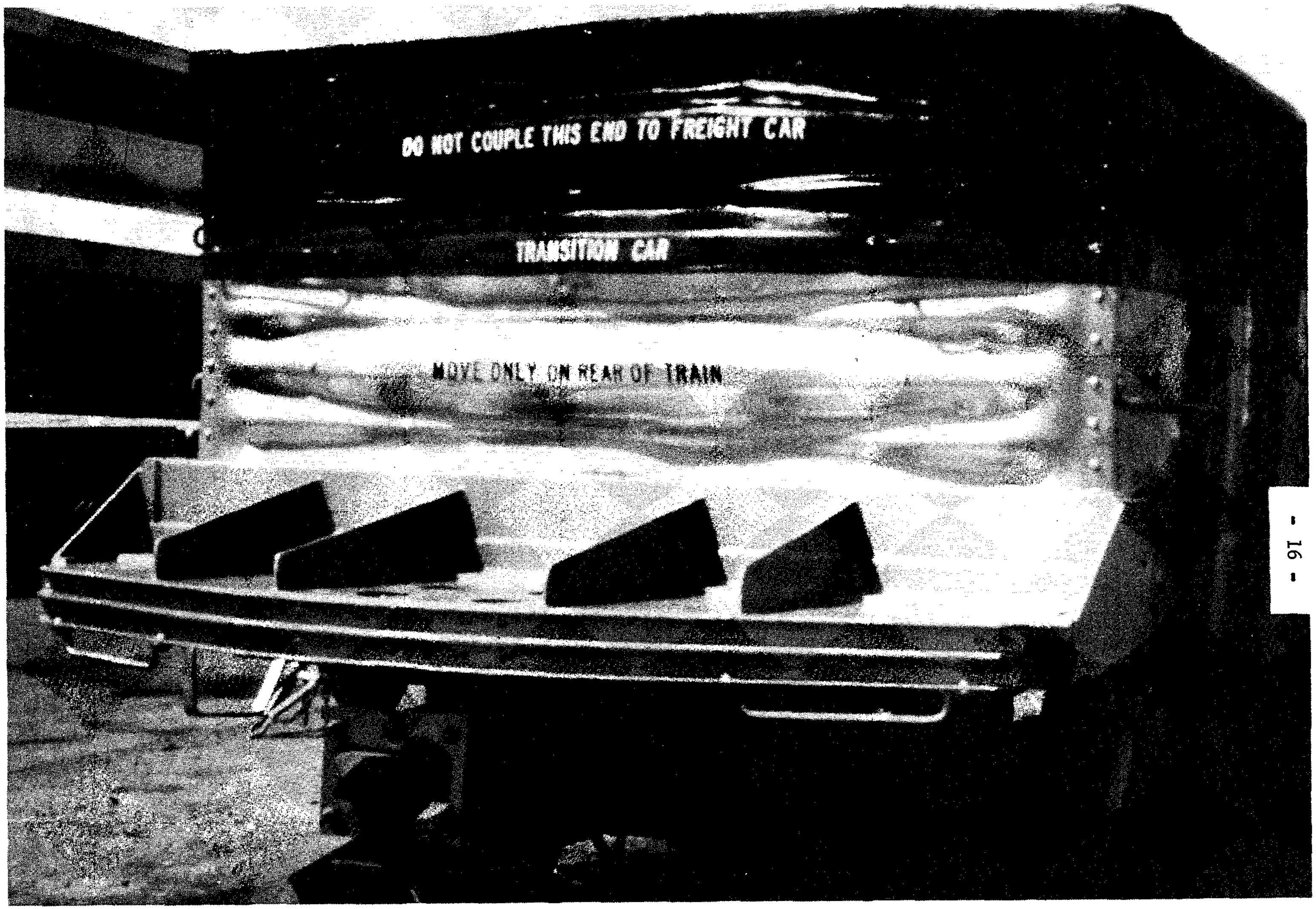


Figure 6. A gondola car modified to allow coupling with the SOAC's.

The two front passenger seats were dislodged, although one seat remained partially attached. These seats had been mounted longitudinally in the car, facing each other. All other seats in the first car were intact. The windscreens forward of the front side doors were sheared off, but those aft of the front doors had only minor impact marks or minor displacement. The two forward doors were jammed, but all other doors were operable.

The interior damage to the trailing SOAC was confined to two windscreens, which were slightly displaced and dented. The anti-climber between the cars was somewhat deformed, but the two cars had not overclimbed one another. The underframe of the rear car was not damaged, except that the shear pin in the coupler failed.

Flat spots were present on the four trailing wheels of the lead car and on four of the eight wheels of the rear car. The largest flat spot was approximately 4 square inches. All wheels showed that a heavy brake application had occurred.

The repair cost for the SOAC's was estimated at from $300,000 to $500,000.

Other vehicles. Damage to the gondola generally was limited to the anti-climber assembly, the coupler, and the end of the car that was impacted. The locomotive was essentially undamaged. All brakes on the locomotive were found released, and the knuckle of the south coupler was in the closed position.

Test Personnel

The motorman died of multiple injuries shortly after the collision. Three of the four passengers who were located in the rear car, were not injured. The fourth passenger incurred an arm abrasion and a stiff neck.

The SOAC test crew. The test controller was a TSC employee who had worked at the HSGTC for approximately 1½ years. He worked with TSC as a "transportation systems engineer." Before his employment with TSC, he had worked 10 years for the National Aeronautics and Space Administration as a test engineer. He had a B.S. degree in physics.

The motorman was employed by Kentron Hawaii as an "engineer/scheduler" on April 30, 1973, at which time he also came to the HSGTC. He had previously been engaged for 6 years in the testing of weapon systems and explosives. He possessed a B.S. degree in engineering and an M.S. degree in physics. He was 29 years old and had no known physical deficiencies. At the HSGTC he had functioned as "test controller" from time to time and had first operated the SOAC's 4 to 6 weeks before the accident. Four days before the accident, the Boeing Vertol project test manager asked him to act as motorman intermittently, because the regular operator was busy monitoring the SOAC test program. The motorman's training had included 2 days of supervised operation by the regular operator.

Kentron Hawaii indicated that the motorman was well versed in the HSGTC operational and safety procedures which related to the SOAC test operation and the HSGTC Railway System Rules Handbook. However, there was no examination for rule proficiency or qualification as a motorman.

The regular operator of the SOAC was one of the passengers on the day of the accident. This man was employed by the AiResearch Manufacturing Company, a division of the Garrett Corporation, as a laboratory technician. He was a college graduate and had worked for AiResearch for 1½ years. He was not formally trained for the motorman's duties but assumed them after observing other operators. He was not familiar with the HSGTC Railway System Rules Handbook or the Safety Support for Transit Track Operations. (See Appendix C.) He had not been furnished copies of HSGTC policy orders or management instructions.

An area supervisor for AiResearch was also monitoring test performance onboard the cars on the day of the accident. He had not been instructed on the HSGTC operating procedures and he was not familiar with the HSGTC Railway System Rules Handbook.

The third passenger on the SOAC's was a Boeing Vertol project engineer who was functioning as the chief test engineer. The project engineer was familiar with the operating procedures submitted by Boeing Vertol, and assumed that that document governed operations. He was not familiar with the HSGTC Railway System Rules Handbook or other HSGTC procedural documents.

The locomotive crew. The two locomotive crewmembers were employed by Kentron Hawaii as "senior train crewman." The two men alternated daily in operating the locomotive as no one man was in charge. The man who operated the locomotive on the day of the accident had worked as a locomotive engineer and fireman for 2 years before he started work at the HSGTC in August 1972. The other crewmember had 16 years of experience as a locomotive fireman and a roundhouse foreman. He had started work at the HSGTC in February 1973. Both men had been examined on the operation of locomotives by a representative of the Office of Safety, FRA. They also had passed written examinations on the HSGTC Railway System Rules Handbook. They had not been examined on SOAC operating procedures, but they had worked with the SOAC test program extensively.

The security guards. The gate guard and the roving guard were supplied by a local contractor. The gate guard had been employed for approximately 1½ months and the roving guard 2 months. Their duties at the HSGTC were explained to them by their supervisor. They had received no formal training or examination on procedural knowledge.

Postaccident Activities

Rescue. Immediately after the collision the on-scene personnel requested that the third rail power be shut down and that ambulances be sent. Electric power was suspended and an ambulance was dispatched to the scene from the nearby headquarters of the HSGTC. The motorman's body was on the track in front of the derailed SOAC with a portion of the emergency brake cord in his hand.

Inspections. The SOAC's were inspected after the accident. No defects or abnormalities were found which could have contributed to the accident. Continuous wheel skid marks were found on both rails of the north access track. These marks originated in the area of the turnout frog, 339 feet from the point of impact.

The north access track switch was found in an open position so that traffic was directed onto the north access track from the transit test track. The switch stand handle was in a position opposite to that of the chain and padlock. The padlock was lying on the top of a headblock tie and was open. The switch stand target displayed a red aspect for traffic operating on the transit test track. The switch points were in good condition and they fitted snugly against the stock rail when they were moved to either position. There were no unusual marks on the switch points or stock rails.

Visibility test. Sightings were made from the operating compartment of the undamaged SOAC to determine the distances from the switch at which the position of the north access track switch was visible. Visibility was unrestricted on the day the test was performed, and the switch was set in the open position. The red switch stand target was identifiable 756 feet from the switch and could be easily seen 456 feet away. The switch point alinement was recognized 270 feet from the switch. The flag that identified where braking was to be initiated for station A was 125 feet ahead of the switch and on the opposite side of the track from the switch stand. At that location, the view of the switch was unobstructed.

Regulations

Rail rapid transit vehicles such as the SOAC currently are not covered by regulations of the FRA.

ANALYSIS

Responsibility for the Collision

The locomotive crewmembers. The evidence indicates that the locomotive crewmember who operated the switches during the lunch break on the day of the accident did not close the north access track switch after he allowed the locomotive to pass. His use of a truck to travel from switch to switch may have influenced his oversight. With a truck, it was not necessary or expedient for the on-ground crewmember to wait for the locomotive to pass. However, this does not excuse his failure to act as required by the rules and in accordance with safe operating practice.

The HSGTC Railway System Rules Handbook requires that "the locomotive engineer must see that the switches near the locomotive are properly lined." However, this procedure was not commonly followed. The diffused responsibility of the two-man crew led each crewmember to believe that he was responsible only for his own actions. The operator of the locomotive was responsible for seeing that switches were positioned properly after use, but he did not do so.

One week before this accident a switch was left open by the same crewmember who forgot to close the switch on the day of the accident. That event should have served as a warning to the locomotive crew. It also should have caused the crew to question any reliance they might have in the roving guard to determine switch position. However, no changes in procedure were made as the result of that incident.

The motorman. The motorman was expected to operate the SOAC aware of all hazards, including open switches. Nevertheless, the clearances given by the roving guard, the gate guard, and the locomotive crew implied to the motorman that the switches were alined properly and that there were no obstructions on the track. Such an assumption would have been reinforced by the many trips around the test track without incident. Furthermore, the casual training afforded this motorman and the regular operator, particularly regarding operating procedures, suggested that safety was based on maintaining track security. This concept of safety was evidenced by the fact that the switch position was not identifiable within the stopping capability of the SOAC's when they operated at high speeds. Therefore, any reliance on the motorman's ability to observe hazards was not consistent with the actual operating practice.

In addition to watching for properly alined switches, the motorman had other duties. For instance, he was supposed to initiate the stop at station A exactly at the flag installed on the opposite side of the track from the switch stand target. The flag was 125 feet ahead of the switch, just in front of a grade crossing where a whistle signal was required. The motorman also had to monitor the "P"-meter on his console during the braking cycle. The motorman's attention may have been further distracted by the waving of personnel on the ground near station A, since these men were in an area that normally was secured.

Inattention or distractions, or both, may explain why the motorman did not identify the improperly alined switch until he was passing through it. This type of accident has been common on railroads, where there is no supposition of a secure pathway to dull an engineer's alertness.

Despite these extenuating circumstances, the motorman could have prevented the collision if he had applied either the service or emergency brakes when the switch stand target first became easily identifiable. Even after that time, he had sufficient opportunity to escape from the operating compartment. If the emergency brakes were applied while the SOAC's were traversing the turnout (as was indicated by the skid marks), then approximately 5 seconds elapsed before impact. Escape from the front of the train would have increased the motorman's chances for survival. The motorman, however, had not been trained to follow any particular escape procedure. Had he been so trained, the conflict between alternative emergency reactions would have been reduced and the possibility of the motorman's taking no action may have been eliminated.

The motorman also had been involved in overseeing some of the operating procedures that resulted in the lack of detection of the open switch. As the "track security officer", he should have known that the roving guard was not checking the position of switches and thus should have been aware of the possibility of an open switch. While he was operating the SOAC's the motorman could not perform the duties of the track security officer, but he could have looked at the position of the north access track switch when he returned from lunch. The motorman should have taken this simple precaution, especially since it was known that the switch had been used during the lunch period. He did not do so and instead relied upon the test controller's authority to proceed.

The test controller. The test controller was charged with controlling all traffic within the test area. He had a substantial role in preparing the operating procedures that were being used. In addition, as a representative of the TSC, he was partially accountable for the type of facilities that were used on the transit test track. He also had the opportunity to ride with the motorman in the operating compartment to monitor track security. Therefore, his responsibility seems clear and inclusive.

On the day of the accident, the operational clearances given by the roving guard, the gate guard, the locomotive crew, and the motorman led the test controller to conclude that the track was secure. Although such a conclusion might seem reasonable based on the information which he was given, the test controller, who had overall responsibility, should have realized the limitations of the operational clearances.

The test controller assumed that the roving guard's clearance implied that the guard had observed the position of the switches when he had not. The test controller assumed that the locomotive crew's clearance implied that they had physically inspected the switches when they had not. The test controller assumed that the track security officer's clearance implied that he had looked at the position of the north access track switch when he had not. A safe operation demands a clear understanding of duties, responsibilities, and actual employee performance. It does not result from assumptions.

Other SOAC test personnel. The other members of the test team relied on the test controller's authority to proceed as an indication that the track was clear, safe, and secure. As they returned from lunch, they had an opportunity to observe the position of the north access track switch, but did not. No one was assigned a specific responsibility to check the switch. The rule that "safety is the business of every individual" was inadequate to define responsibility position by position.

The roving security guard. Under the established operating procedures, the roving guard had an opportunity to check on the use of switches by the locomotive crew. This opportunity was lost through the diffused chain of command. The roving guard had not been instructed on the proper alinement of switches.

Pathway Securement

The switches. Automatic ground-throw switch stands were installed on a track that accommodated testing at speeds of 80 mph. Installation of that type of switch was inconsistent with safe operation on the transit test track for three reasons: First, the low switch stand target was the only means of identifying switch position until the switch points themselves became visible. This target, however, was not identifiable at the distance necessary to stop the cars from 80 mph. Second, the design of the switch stand allowed the switch points to be moved even though the switch stand handle was locked in place. An inadvertent trailing-point movement by train equipment on the north access track could have resulted in changing switch alinement even though the switch stand had been "lined and locked." Third, the switch stand accommodated automatic operation, but was not used in that manner. This type of switch stand generally is used to accommodate frequent switching operations in railroad yards, not high-speed main track operations.

In addition, the switch accommodated facing-point train movements, but there were no devices installed to secure the switch point against the stock rail. This again is not consistent with high-speed railroad operations where facing-point switches are avoided when at all possible. If facing-point switches are necessary, then generally the switch point should be locked against the stock rail, or protected to ensure that a train wheel does not split the switch.

Other pathway violations. Other violations of track security were possible. For instance, the north access track descended to the test track at a 0.5-percent grade, and train equipment was parked on that track regularly. Failure to secure equipment on a grade has been a frequent cause of train accidents on conventional railroads. At the test track not only were there no procedural checks to ensure equipment securement but there were no devices -- such as a derail -- to protect the test track from encroachment by vehicles.

The placement of train equipment on a track adjacent to a running track presented a hazard in the event of derailment or an obstruction of the motorman's vision. There was no need to park the train equipment at the point of impact. A systematic review of the accident possibilities before testing would have revealed the hazards. They could have been avoided by parking the train equipment beyond the switch a sufficient distance to allow the SOAC's to stop in the event of an improperly alined switch. It is significant that the hazards disclosed above could probably have been identified and the necessity for their correction analyzed by a formal process of hazard identification.

Operational Concepts

Operating procedures. TSC was responsible for establishing safety requirements and operating procedures at the transit test track. The TSC personnel indicated that the procedures dated August 24, 1973, were applicable. However, various members of the SOAC test team did not have a standard understanding of the procedures.

For instance, the motorman who was also track security officer did not verify that all switches were lined and locked, as required in the August 24 procedures. Likewise, he failed to conduct "a complete track surveillance/inspection." As a motorman he could not fulfill the duties of the track security officer prescribed in the August 24 procedures. The roving guard similarly misunderstood the August 24 procedures, as did the Boeing Vertol personnel who believed that the procedures which they had submitted were applicable.

The August 24 procedures thus were interpreted differently by the parties who were required to abide by the procedures. Furthermore, the HSGTC had not concurred in the adoption of these procedures.

Effective implementation of procedures requires that the duties of every individual be clearly defined. If procedures simply describe program goals and management functions, then ancillary documents which address individual responsibility should also be distributed. In the August 24 procedures, the track security duties of the locomotive crewmembers were dispersed throughout the document. The duties of motormen were mentioned only in the context of the "standard rules of conduct in railway operation." Since neither of the motormen who worked on the transit test track had railroad experience this definition of their duties was unrealistic. The August 24 procedures also listed many functions without stating who would be responsible for their performance.

Effective implementation of the operating procedures was made more difficult by the number of organizations involved and the chain of command.

The locomotive crew, the motorman, the test controller, and the roving guard were all responsible to different individuals outside of the SOAC test program. In testing experimental transportation systems, as the number of organizations involved increases, so do the opportunities for misunderstanding. The potential for errors can be reduced by a tight chain of command. For instance, the securement of the pathway would have been more manageable if it had been the complete responsibility of one organization familiar with all testing procedures at the HSGTC. All persons involved would then have been subject to the employer-employee relationship for maintaining understanding and discipline.

Operational philosophy. Some problems demonstrated by this accident originated in basic operational philosophy. For instance, the transit test track was of conventional construction with hardware manufactured for railroad use. Equipment operating on the track had conventional flanged wheels. Presumably for this reason, an extensive rulebook based on railroad operating rules was prepared. These rules were then applied to every individual at the HSGTC, even though the rules generally did not concern the type of operations at the site.

The only SOAC personnel who understood the principles of the railroad rules from experience were the locomotive crewmembers. Nevertheless, one of these men left the switch to the north access track open.

The opportunity for absolute pathway securement at the HSGTC was much greater than could be possible on normal railroad and transit systems. Even at the HSGTC, however, a thorough and systematic analysis of the means of achieving absolute pathway securement was necessary and should have been undertaken. Constraints that were influential in a railroad's adoption of operating procedures were not present at the HSGTC.

Safety in the development of the HSGTC. Railroad hardware was used at the HSGTC without resort to standard railroad safety practices. If railroad cars were expected to stop in advance of an open switch, the switch should have been identifiable before stopping distances were overrun. This could have been done without elaborate signal systems. Likewise, if facing-point switches were necessary, then switch points should have been secured against stock rails.

These hardware problems originated in the design stage of the HSGTC which involved a number of organizations. However, the Office of Safety, FRA, apparently had no role in reviewing design or construction, although that office is the authority on the construction and maintenance of conventional safe track.

The facilities at the HSGTC are complex and handle a variety of test operations. A disjointed approach to operational safety is particularly inappropriate when dealing with parties with diverse backgrounds. At the HSGTC, one organization should have overseen the merger of the many disciplines involved, e.g., engineering, testing, railroad, transit, highway, aerospace, and safety. This oversight function could be the responsibility of the HSGTC safety officer. Instead, the safety officer was primarily concerned with industrial safety. Although industrial safety is a worthwhile goal, catastrophic operating accidents can destroy the entire mission of the HSGTC.

On March 13, 1969, the Safety Board recommended to the Secretary of Transportation that FRA establish a systems safety capability within the Office of High Speed Ground Transportation (OHSGT) and develop in-house capabilities to administer and supervise systems safety programs in high-speed projects. In addition, the Board recommended that FRA establish an independent safety review committee, external to the FRA, to monitor all safety aspects of projects undertaken by the OHSGT, with special attention to identifying and evaluating hazards and to transferring safety standards and technology from other fields. This accident suggests that those recommendations were either not applied to the HSGTC or were not implemented effectively.

Collision Speed

To establish the speed at which the SOAC's impacted the gondola, Boeing Vertol analyzed the several possible braking situations. 1/ The analysis is summarized in Table 1.

All of the situations in Table 1 assume an emergency brake application before collision. With the exception of Case B, the distance of emergency braking is consistent with the length of the skid marks on the rail. The other variables are the total braking distances and the type of adhesion during braking.

The variety of assumptions was necessitated by the 730-foot distance between the braking flag and station A. For a 55-mph speed, braking tests indicated a stopping distance of about 810 feet. However, the braking flag had been positioned 730 feet away from the station after previous trials. The 785-foot stopping distance is thus based on the possibility that the motorman anticipated the braking flag and that the car stopped slightly beyond station A during trials.

Case B is not likely to have occurred, since there is no evidence to indicate that emergency braking was initiated 571 feet from impact. Therefore, the impact speed can be narrowed to a range of 28 to 40 mph, which is consistent with the witnesses' approximation of 25 to 40 mph.

1/ Boeing Vertol Company, Accident Report, State-of-the-Art Car, High Speed Ground Test Center, August 11, 1973.

TABLE NO. 1

Summary of SOAC Impact-Speed Analysis

Case	Stopping Distance (feet) Service braking from 55 mph to stop, 0.5 percent ascending grade	Distance in Assumed Braking Mode (feet) Service	Emergency	Total	Type of Adhesion in Emergency Braking Mode	Impact Speed (mph)
A	810	238	333	571	Good	35.3
B	810	-	571	571	Good	26.1
C	810	238	333	571	8 wheels sliding	40.3
D	785	266	333	599	Good	27.9
E	785	266	333	599	8 wheels sliding	34.4
F	730	238	333	571	Good	31.3

Boeing Vertol also estimated the impact speed based upon estimates of the energy expended in the crash. This approach resulted in an estimated collision speed of from 30 to 35 mph, which agrees with the range of speeds shown in Table 1. However, the calculation of crash velocities based on the dissipation of energy depends greatly upon the assumptions used.

The speed estimates suggest a problem in brake design and an opportunity for improvement. If the April 1973, braking performances are extrapolated for an initial speed of 55 mph, an ordinary service friction brake application should result in a 28-mph collision speed after 571 feet. A blended brake application, combining dynamic and friction braking, should result in a 31-mph speed under the same circumstances. These speeds do not take into account the interruption that would occur in traversing the third-rail gaps. However, they are in the range of impact speeds for emergency braking in Table 1. The application of emergency brakes thus may have adversely affected the impact speed, since the speeds in Table 1 either equal or are greater than the 28- and 31-mph speeds possible through normal braking.

This possibility seems even more persuasive in view of the flat spots on eight wheels of the two cars. Although the flat spots were small, they indicate that the wheels were sliding. Because of this sliding full adhesion between the wheels and rails could not have been realized. Protection against wheel-spin-slide was provided in the service braking modes, but not in the emergency mode. Thus, greater deceleration could have been obtained through use of the service friction brake. The motorman, of course, had no way of knowing this.

The braking tests of March and April 1973 showed better stopping ability in the emergency braking mode than in either service mode. These tests were made on smooth track with no discontinuities to initiate wheel sliding, whereas the accident occurred while the cars were passing over the discontinuities of a No. 15 turnout without electrical power. The discontinuities may have initiated wheel skidding which could not be halted. The tendency toward irreversible wheel sliding would have been increased if the track had been wet. The accident thus raises a general question about the effectiveness of various braking modes of the SOAC's under different operating circumstances.

SOAC Design Concepts

Boeing Vertol also extensively analyzed the sequence of crash events which led to the penetration of the SOAC by the gondola. Complete details are available in Boeing Vertol's accident report referenced above. Boeing Vertol's diagramatic description of the structural failure during the crash is included as Appendix F.

As in other rail car collisions investigated by the Safety Board 2/ the major structural damage in this accident occurred when one vehicle overrode and penetrated the other vehicle. When the dissimilar cars came together, the makeshift anti-climber on the gondola failed and the gondola overrode the SOAC. The override and penetration destroyed the operating compartment of the SOAC and crushed the motorman.

Since the anti-climber on the gondola was not standard, its failure and subsequent crash events do not entirely represent what might occur in a crash in day-to-day transit operations. Nevertheless, the events do indicate certain weaknesses in structural crash resistance which could recur in a crash between trains of similar design.

Any event in a crash which results in the vertical misalinement of end frames shown in Diagram 4 of Appendix F could deflect the couplers downward, because downward movement of the couplers is not restrained by any major structural element near the outboard end of the coupler shank. Factors which could permit such downward movement include design misalinement of the anti-climbers on two cars, failure of the anti-climbers to engage or loss of engagement because of derailing of one car, or lateral movement of frames, which might be induced by the convex plan-profile of the anti-climbers. The downward deflection of coupler shanks produced the akimbo misalinement of couplers which destroyed the potential of the engaged (but partially broken) coupler parts to hold a compressive load. In addition, the potential anti-climbing action of the engaged couplers, if structurally supported against downward deflection, was lost.

2/ National Transportation Safety Board, Collision of Illinois Central Gulf Railroad Commuter Trains, Chicago, Illinois, October 30, 1972, NTSB-RAR-73-5, and Penn Central Company, Collision of Trains N-48 and N-49 at Darien, Connecticut, August 20, 1969, NTSB-RAR-70-3.

Figure 3 and Diagram 5 in Appendix F suggest that once the end frames had overridden and bypassed each other, there were no substantial structures--such as the collision posts or the "main vertical members" required in Federally regulated rail cars--capable of resisting penetration by the opposing car frame. The next major resistive force which tended to limit penetration was the contact of the SOAC sill against the bolster on the gondola. The kinking of the sill shown in Diagram 9 of Appendix F indicates that a heavy force which retarded penetration was produced by this contact. However, the bolster contact point on the gondola would not have been as strong if the opposing car had been another SOAC and, thus, almost complete reliance is placed on ideal anti-climber action to prevent telescoping when cars of this design collide with each other.

The anti-climbers between the two SOAC's functioned as intended and the cars did not override. The second car was damaged only slightly. The two sets of anti-climbers were ideally alined; little or no lateral or vertical force was developed; and the forces required to be supported between the cars were much less than those required to be supported by the coupler and anti-climber at the end of the car which sustained the direct impact. The override and local collapse of the impacted end of the SOAC provided about 6 to 9 feet of cushioning for the remainder of the train. At the same time, the rearward movement of the standing gondola and locomotive indicated that the SOAC's did not lose all their velocity in the collision.

The effect of the continued integrity of the anti-climbers between cars was to make a rigid unyielding unit of the SOAC's and to prevent significant crash energy from being absorbed between cars. This meant that energy had to be dissipated almost entirely at the immediate impact point. Such a tendency to concentrate energy absorption at one point is not unusual and is the result of current design of rail cars. If the impact-resisting capability of couplers or anti-climbers is exceeded or bypassed, the operator's cab and some length of car is crushed on one or both trains. For practical purposes, the end of the car nearest the collision is thus sacrificed by crushing and serves as a cushion for the remainder of the train. This effect has not been a stated intent, but clearly occurred in this case.

If override at the point of collision is prevented, then the collision energy must be dissipated in another manner or the accelerations to which passengers are subject becomes severe. The analysis made by Boeing Vertol speculated that a collision between SOAC's would have produced different results. For example, hypotheticals were advanced involving a two car SOAC train colliding at 35 mph with a standing, unbraked SOAC. Boeing Vertol estimated that such a crash would crush approximately 4 feet of each impacting car if the anti-climbers functioned ideally and forces were dissipated equally. Average deceleration experienced by all the cars would be about 3 g.

It is difficult to envision the design maintaining anti-climber alinement and avoiding disruptive coupler action while the sills collapse over a distance of 4 feet. There is no apparent provision in the design for predictable collapse beyond the few inches permitted by coupler failure until sill ends meet. If 4 feet of predictable collapse distance with a compatible continuous engagement were provided at the end of each car, a 35-mph crash could be sustained with low g levels over the whole train. If the 4 feet were accounted for in the design and unoccupied during operation, the portion of the car which has been a de facto sacrifice cushion in the past could be invaded without loss of life.

On the other hand, if the motorman on the SOAC continues to occupy the 4 feet which may collapse in a 35-mph collision he is in danger. The danger, furthermore, is a condition of his work of which he apparently is not informed. The Safety Board's observation has been that most collisions are recognizable soon enough to allow evacuation if the motorman reacts quickly and if his exit is unobstructed.

In this accident the two forward passenger seats were dislodged and their immediate area was damaged extensively. If these seats had been occupied, the passengers would have been injured seriously and possibly ejected. Yet, the car was damaged only slightly aft of the forward side door posts. Since the doorway area is less likely to be occupied than are seats, the design of the SOAC needlessly exposes seated passengers by placing them in the area of greatest possible invasion during a collision. In some older designs, the forward door has been located ahead of all passenger seats. This design uses the doorway area or vestibule for energy absorption. Furthermore, the motorman could be placed in back of a 4-foot zone designed to provide crash collapse.

The SOAC's, scheduled to operate on five transit systems, will be exposed to other cars of various designs, to a variety of dissimilar crash circumstances, and to other conditions that are unique to individual transit systems. The fact that a variety of operating environments has received some consideration is evidenced by the anti-climber on the SOAC which can be adjusted vertically to match other types of transit cars. This adjustment, however, means that in collisions, bending forces would be produced. For instance, in this case, the anti-climbers of the SOAC and the gondola were alined vertically but one anti-climber was bent downward and rotated. Thus, compatibility between cars was not achieved in this instance. This suggests that other areas of incompatibility with other facilities of the various operating transit systems may exist.

In its reports on the Darien, Conn., and the Chicago, Ill., accidents referenced above, the Safety Board recommended to FRA and UMTA that research be undertaken to develop crashworthiness criteria for application in the design of commuter rail and rail rapid transit cars. This crash demonstrates once again the need for such research.

In addition, the Boeing Vertol analysis showing a 4-foot collapse of each SOAC in a 35-mph collision demonstrates that such analysis of design intent is clearly within the state of the art. The Board did not agree that the Boeing Vertol analysis of a crash between two similar cars assures a predictable mode of collapse with this particular design. However, such unpredictability is merely a problem in detailed design; the general state of the art in crash cushioning holds many examples of structural design for predictable collapse or cushioning effect.

One of the objectives which UMTA defined for the SOAC project was to provide the safest possible transit service. However, safety criteria were not specified or required by UMTA. Boeing Vertol considered safety as an internal matter and did not document its expectations for the SOAC in a crash. Thus, it is not possible to know whether UMTA's safety objective was attained.

CONCLUSIONS

1. The locomotive crewmember who operated the switches during the movement of the locomotive onto the north access track did not close the north access track switch.

2. The locomotive engineer did not fulfill his responsibility to see that the switches near the locomotive were properly lined.

3. Switch position on the transit test track could not be identified by an approaching motorman at a distance within the stopping capability of the SOAC's at normal operating speeds; however, if the motorman in this accident had made a brake application as soon as the open position of the north access track switch was identifiable, the SOAC's would have stopped short of the standing gondola.

4. The motorman had been conditioned to assume that the track was secure when operations were authorized by the test controller.

5. The motorman had time to evacuate the operating compartment after he recognized that an emergency existed, but he did not do so. His training apparently did not cover evacuation procedures.

6. The motorman and the rest of the SOAC test crew knew that the north access track switch had been used during the lunch break, but no one looked at the switch position when they all passed the switch as they returned from lunch.

7. The test controller did not fulfill his responsibility to see that the track was secure before he authorized operations. This failure may have resulted from his misunderstanding of the

duties of the personnel involved in establishing security and his failure to recognize other hazards.

8. The roving guard was not used to check switch position or to look for train or track defects.

9. Personnel responsible for securing the transit test track -- including the roving guard and the locomotive crewmembers -- had not been furnished copies of the applicable operating procedures nor did they understand them.

10. The use of an automatic ground-throw switch stand, although not involved causally in this accident, was incompatible with the intent to secure the pathway during high-speed operations.

11. The operating procedures relied for safety on the concept of a secured pathway when, in fact, the opportunity for violation of security existed in several areas.

12. The HSGTC had not concurred in the operating procedures being used, although the procedures apparently had been changed during the SOAC test program. Concurrence with procedures was required by HSGTC policy.

13. The absence of a clear chain-of-command between test-team individuals contributed to the general misunderstanding of individual responsibilities in track securement.

14. Many of the operating philosophies at the HSGTC were based on railroad practices, although the operating environment was not similar to that of a railroad.

15. The establishment of a facility managed and operated by FRA without a safety review by the FRA's Office of Safety was inconsistent with the stated mission of the HSGTC to develop effective safety standards.

16. The hazards found after the accident in HSGTC facilities and operating procedures suggest that the overall project had not been subject to a systems safety plan or review, which would have included hazard identification and analysis.

17. The collision occurred while the SOAC's were traveling about 30 to 35 mph.

18. The use of the emergency brake may have caused the collision speed to be higher than that which would have been obtained with service braking; however, this speed differential would have been slight.

19. The structural failure of the makeshift anti-climber on the gondola was critical in the sequence in which the gondola overrode and penetrated the SOAC; however, it is not clear that override would have been prevented if the crash had been between two SOAC's.

20. Passengers in the second SOAC escaped serious injury because a substantial proportion of the crash energy was absorbed in the deformation of the front of the first car and the two SOAC's did not override one another.

21. The operating compartment of the SOAC's is nonsurvivable in head-on or rear-end crashes where the total approach speed approximates 35 mph, whether or not override occurs, because the projected collapse distance, assuming no override, is 4 feet.

22. It is technically possible to develop rules, procedures, and equipment to provide for effective braking and timely escape of the motorman from his compartment.

23. Although postaccident calculations indicated that mutual crushing of two SOAC's colliding at a total approach speed of 35 mph would be limited to 4 feet for each car, it is not clear from available documents that this would happen in an actual crash. No crash tests had been performed.

24. The Detail Specification for State-of-the-Art Car does not set forth criteria regarding the state of the art in crashworthiness or systems safety.

25. Although safety was defined by UMTA as one objective of the SOAC project, the specific fields of safety or the specific level of safety to be attained were not defined. Therefore, the achievement of a "safe" transit car could not be assessed.

PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of this crash was the failure of a locomotive crewmember to aline a switch properly and the failure of the motorman to detect the open switch in sufficient time to stop the SOAC's short of a gondola car standing on the track. Contributing to the accident were the failure of the Transportation Systems Center's representatives (UMTA's systems manager) to implement operating procedures that would secure the intended pathway and the absence of a systematic risk management program at the High Speed Ground Test Center.

The death of the motorman was caused by his remaining in the operator's compartment although he had time to evacuate after the brakes were applied.

RECOMMENDATIONS

The National Transportation Safety Board recommends that:

1. The Federal Railroad Administration:

   (a) Conduct a systematic review of the overall operating procedures, rules, and facilities used in testing at the HSGTC in order to establish basic operating philosophies, clarify the chain of command, and strengthen risk management procedures. Rules should be developed which can be easily understood and followed by individuals of varying backgrounds who are employed by organizations which use the HSGTC. A system of ensuring effective implementation should follow. (Recommendation R-74-13)

   (b) Staff HSGTC safety positions with full-time personnel who are experienced in identifying hazards and in analyzing failure mode and effect. These employees should provide safety oversight for all HSGTC testing procedures. (Recommendation R-74-14)

   (c) Establish a systems safety capability in the Office of Research, Development and Demonstrations (the manager and operator of the HSGTC). This capability should be used to oversee and assist safety programs in all highspeed projects. (Recommendation R-74-15)

2. The Urban Mass Transportation Administration:

   (a) Establish safety goals or criteria within the detail specifications for development projects similar to the SOAC program so that attainment of crashworthiness and systems safety can be objectively determined. (Recommendation R-74-16)

   (b) Review the <u>Detail Specification for State-of-the-Art Car</u> and identify for all prospective users those areas of functional performance in which the specification does not actually require attainment of the full state of the art or in which the state of the art was not attained. (Recommendation R-74-17)

   (c) Conduct a systematic review to identify incompatibilities between the SOAC's and each different system upon which they are to be used, and assure compatibility before SOAC's are introduced on operating transit systems. (Recommendation R-74-18)

(d) Review the specific operating procedures, rules, and facilities in use at the transit test track of the HSGTC. If the track is to be operated on the "secure pathway" theory, then all possible violations of security should be examined. Resultant corrections should insure that specific safety functions are assigned to a specific individual and that all safety functions assigned to each individual are listed at one place in the operating rules and identified as that individual's responsibilities. (Recommendation R-74-19)

3. The Federal Railroad Administration and the Urban Mass Transportation Administration:

(a) Explore various technical approaches to crashworthiness of rail transit cars, such as determining neans of preventing override during crashes of similar cars and investigating the use of plastic deformation as a means of absorbing crash energy. Those technical approaches which appear practicable should be crash tested to insure that override would not occur and that a stated collapse cushioning effect will result as intended. (Recommendation R-74-20)

(b) Review past escapes of motormen and engineers from operating compartments of rail transit and commuter cars during crash situations in order to establish design requirements and definite procedures for an operator's escape during impending crashes. Take action to ensure that these requirements and procedures are put into effect by the transit and railroad industries. (Recommendation R-74-21)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JOHN H. REED
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

May 1, 1974

Department of Transportation
Office of the Secretary
Washington, D.C.

NOTICE

DOT N 1130.7

9-14-72

EXPIRES: 9-14-73

SUBJECT: HIGH SPEED GROUND TEST CENTER

1. PURPOSE. This Notice establishes the High Speed Ground Test Center, Pueblo, Colorado, and prescribes authorities, functions, operating procedures, and relationships with respect to the Center. The High Speed Ground Test Center is a field installation of the Department of Transportation (DOT), managed and operated by the Federal Railroad Administration (FRA).

2. MISSION. The mission of the High Speed Ground Test Center is the conduct of large-scale test and evaluation of ground transportation experimental and developmental systems (except motor vehicles), subsystems, and components by Government, industry, and contractor to:

   a. Determine technical and operational feasibility.

   b. Obtain quantitative experimental data to validate designs and analysis.

   c. Develop effective safety and maintenance standards.

   d. Provide an experimental basis for estimating costs, benefits and environmental impact (e.g., noise, electromagnetic and chemical emissions).

   e. Introduce experimental and developmental systems to representatives of the industry and public officials through demonstrations.

   f. Bring promising techniques and systems into operation at the least time and cost.

3. FUNCTIONS AND RESPONSIBILITIES.

   a. Under the overall management and technical direction of the Chief, Test Center and Demonstrations Division, Office of Research, Development and Demonstrations, FRA, the Test Center Director shall:

      (1) Provide management direction and leadership to all organization elements of the Test Center.

      (2) Provide and maintain the personnel complement and resources of the Test Center in the proper strength and balance to carry out both the current and long-range mission of the Test Center, determining and requesting the additional FRA personnel positions, funds and facilities required to do so.

DISTRIBUTION: All Secretarial Offices
All Operating Administrations
National Transportation Safety Board (info)

OPI: Office of Research, Development and Demonstrations, FRA

(3) Conduct testing of research and development components, subsystems, and systems pursuant to approved test specifications acceptable to the Test Center Director on programs which the sponsoring operating administration requests the Test Center to conduct in its entirety. The sponsoring operating administration is responsible for the conduct of all other testing.

(4) Ensure that Test Center operations meet the required DOT Safety Standards and take full account of potential environmental effect.

(5) Establish and maintain effective liaison and relations with other agencies of the Federal Government, private industry, educational institutions and with the public in general on matters related to the Test Center.

(6) Represent DOT in the general area of local public affairs in dealing with matters pertaining to the Test Center. Such activity will be coordinated with appropriate offices of DOT Headquarters, operating administrations, Secretarial Representatives, and Field Coordination Groups.

b. The Sponsoring Operating Administration shall:

(1) Be responsible for the conduct of all testing except that it requests to be handled by the Test Center.

(2) Provide whatever additional personnel beyond the Project Monitor and support personnel that may be required to conduct the test program.

(3) Provide to the Test Center, on a timely basis:

(a) Facilities requirements as related to their program.

(b) Detailed description of test program and associated hardware.

(c) Test requirements and test specifications.

(d) Test data requirements.

(c) Test articles.

(4) Ensure that test articles and test operations meet any required DOT Safety Standards and takes full account of their potential environmental effect.

APPENDIX B

APPLICABLE HSGTC INSTRUCTIONS ORDERS, AND NOTICES

1. Department of Transportation Notice, N 1130.7 - Establishes the High Speed Ground Test Center.
2. HSGTC Management Instruction 3902.1 - Duties and Authorities of HSGTC Safety Officer - Interim.
3. HSGTC Policy Order 5800.1 - HSGTC Safety Policy.
4. HSGTC Handbook 5800.3 - Railway System Rules.
5. HSGTC Policy Order 5882.5 - General Safety Requirements for the Operation and Control of Vehicles at the HSGTC - Interim.
6. HSGTC Policy Order 6371.1 - Framework for Conducting Test Operations.
7. HSGTC Management Instruction 6371.2- Scheduling Test Operations-Interim.

APPENDIX C

SAFETY SUPPORT FOR TRANSIT TRACK OPERATIONS

1. PURPOSE. The purpose of this Notice is to provide support safety requirements and operating procedures on the Rapid Transit Track at the HSGTC.

2. SCOPE. The provisions of this instruction apply to all agencies, organizations, or other federal employees, resident contractors and users associated with test programs using the Urban Mass Transit Administration Trasit Track. Appropriate provisions of this plan must be incorporated in the development of test operational procedures for transit car testing on the track.

3. DEFINITIONS.

   a. Program - An authorized and defined test or evaluation effort requiring the use of equipment, facilities or other resources at HSGTC. This may involve research, exploratory development, advanced development, prototype development, or preliminary operational demonstrations as defined by DOT Order 4200.9. Before authorization of a program at the HSGTC, a Program Summary and Support Request will be forwarded to the HSGTC Director. This Support Request will be used as a basis for developing the case-by-case Memorandum-of-Understanding required by DOT Notice 1130.7.

   b. Program Summary and Support Request (PSSR) - A document prepared by the Sponsoring Operating Administration and presents a summary of the proposed test program and support requirements as provided for in DOT Notice 1130.7 dated September 14, 1972 paragraph 3b (3). The instructions for the development and format for the PSSR are presented in DOT Order 4200.9. These instructions also delineate the content, format, and submittal timing for program test plans and procedures.

   c. Contracting Officer's Technical Representative (COTR) - An individual appointed by the responsible Contracting Officer in accordance with appropriate authority as his authorized representative for specific actions, such as inspections-engineering, technical direction or expediting, to assist in the administration of a contract which involves work at the HSGTC.

   d. User - Any individual, contractor, or government organization authorized to conduct a program at the HSGTC.

   e. Project Monitor (PM) - An individual, in residence at the HSGTC, assigned by the Sponsoring Operating Administration to direct a test program at the HSGTC. He will receive administrative guidance from the Test Center Director and receive technical direction from the Sponsoring Operating Administration. He is responsible for representing his test program in obtaining necessary support and in developing with the O & M Contractor the case-by-case Memorandum-of-Understanding. In addition, he is reponsible for User development and implementation of the Test Program Plan, Test Procedures, and the Test Schedule Request Summary. The COTR and PM responsibilities may be assigned to one individual.

f. Test Controller (TC) - An HSGTC individual, either government or O & M Contractor employee, assigned support responsibility and operational control for a test. He will control traffic, personnel or other movements within the prescribed safety area during a test. He informs the Project Monitor of any problems or changes affecting the test and gives final clearance to the Chief Test Engineer to proceed. He has authority to stop any test because of undue hazards or unsafe conditions.

g. Test Project Manager (TPM) - The senior representative of a Test Center User in residence at the HSGTC. Responsible for team management, planning, preparation and attainment of data acquisition.

h. Test Support Engineer (TSE) - A representative of the O & M Contractor responsible for providing agreed-to support services.

i. Chief Test Engineer (CTE) - A representative of the User, responsible for vehicle operation and achieving the objectives of a specific test. He receives clearance for the vehicle to proceed from the TC. He has authority to abort any run in the event that the test objective will not be achieved or because of any unsafe vehicle conditions.

j. Track Security Officer - The individual assigned the responsibility to provide for the safety of personnel and equipment during any transit test operations. He will initiate and maintain track inspection and surveillance prior to any start up of test operations and after reporting the status of the track to the Test Controller he will assume the function of the rover.

k. Test - This term means the use of a vehicle authorized by an HSGTC Test Schedule Request for purposes of accomplishing a task specified in the PSSR, the Test Program Plan, and implemented in accordance with the approved Test Procedure. A Test may or may not involve the physical movement of a vehicle along a track or guideway. No test operations shall be scheduled or conducted until appropriate test documentation is approved.

l. Test Schedule Request Summary (TSRS) - The form authorizing the use of a vehicle to perform a test. The Test Schedule Request Summary shall include the day and time of vehicle tests, duration, location of the Test Controller and test procedures to be followed. It will show the names of the Test Controller and Chief Test Engineer and contain a check list of required support. Schedule revisions shall be coordinated by the Project Monitor.

m. Static Test - Any test not involving the physical movement of a vehicle along a track or guideway.

n. Run(s) - Any test involving movement of a vehicle along a track or guideway.

o. Test Program Plan - A document provided by either a COTR as part of a contracted project or by the program director for a project implemented by the Government which sets forth the overall objectives of the project. The Program Plan describes test and evaluation activities to be measured, instrumentatior and data collection required, and outlines the general schedule for these activities. The User shall identify the Program Plan by a letter-numeric designation for cross referencing to corresponding Test Procedures.

p. Test Procedure - A document initiated by a User as a prerequisite to scheduling a test. It references the Test Program Plan and provides the step-by-step outline, profile and control list for implementing a specific test from the time of scheduling until completion of that test. Each procedure shall outline the stations to be manned; key times and distances along the track or guideway; speeds, data recording and essential instrumentation; special checklists and special safety measures such as: functional checks of emergency or backup systems, arresting gear, track clearances, and sentry stations as may be necessary for the test described. Normally, a Test Procedure will describe key jobs by title, but not by an individual's name; time spans, calendar dates or clock times.

q. Monthly Program Schedule - A tentative monthly schedule, published prior to the beginning of each month, for each particular vehicle and program. This document will be prepared and published by the O & M Contractor.

r. Weekly Test Schedule - The official, consolidated vehicle test schedule normally published each Friday when operations are planned for the following week. This document will be prepared and published by the O & M Contractor upon approval of the Test Center Director.

4. BASIC SAFETY REQUIREMENTS:

a. Track Security - Track security must be established along the entire transit track to: (1) Ensure control of vehicular traffic around the track and (2) Provide for the safety of personnel and equipment during the test operations.

The following minimum security measures are required before and during a test run or test series or any activity requiring third rail excitation. Reference the HSGTC Plot Plan; Appendix A.

(1) Lock all rail gates and vehicle access gates except the east entrance (Station C).

(2) Post a security guard at Station C and control traffic at this point. Note: No thru traffic is permitted. Vehicular traffic along the transit track service roads must be limited to traffic in direct support of test operations or as authorized by the Test Controller.

b. Track Inspection and Surveillance - Before energizing the third rail or prior to a test run or run series, a complete track surveillance/inspection must be conducted by the track security officer to insure that the track is clear and to verify that track security is in effect. The initial test day inspection survey must be accomplished by driving either a motor maintenance crew car or a locomotive around the transit track. Subsequent inspections may be accomplished by a motor vehicle around the transit track access road. As a minimum requirement, the transit track inspection survey must be accomplished before the first third rail excitation, test run or run series of the day, and after any extended break in the track security such as the lunch break. The inspection survey must verify the following:

(1) Track Conditions - Assure that the track is clear and free of debris and all switches are lined and locked for the test run condition established by the Chief Test Engineer. NOTE: UPON COMPLETION OF THIS VERIFICATION OF TRACK CONDITIONS, NO SWITCHES WILL BE OPERATED WITHOUT DIRECTION FROM THE TEST CONTROLLER.

(2) Track Security - Service road is free of all vehicular traffic except vehicles associated with the test operations or those authorized by the Test Controller. All unauthorized traffic must be reported to the Test Controller and cleared from the service road before the start of a test.

(3) A roving patrol around the transit track is required during any period of third rail excitation or runs with a test car. A minimum of one vehicle on the service road is required. The roving patrol will maintain a continuous

patrol around the UMTA loop. The rover will report on the presence of any unauthorized personnel or equipment or any other information which could affect safety or operations i.e. open switches, dragging equipment, etc. The rover will also be responsible for setting up and securing the red flashing lights at the main entrance roads. The roving patrol will not leave the area unless authorized by the Test Controller; if relief is required, a replacement guard will be provided. The roving patrol complete loop inspection must be performed and reported on prior to third rail excitation after any extended break in track security or after any switching operation or after any other situation which may have changed the safety integrity of the transit loop.

(4) Guard Station C (Charter Station) - Thirty minutes prior to any test operation on the UMTA loop, the guard at station C will maintain a secure test loop. The guard will stop and identify all personnel.and request clearance from the Test Controller prior to their entry. The Test Controller will also be informed when personnel leave the area.

Personnel requesting permission to enter the inside of the test loop will be required to carry a radio with them. "C" station will then request permission for these people and or vehicles to enter or leave the loop from the Test Controller.

The actual track grade crossing will be coordinated with the test vehicle operator and the Test Controller.

c. Third Rail Excitation - The DOT 001 Locomotive provides power for the third rail and is stationed on the siding along the transit track. The locomotive is controlled by a train crewman under the direction of the Test Controller during all test operations. As a general safety requirement, the third rail should be powered only as required for system checkouts or during a run. The third rail should be deenergized during any unusually long standby periods. The following procedure shall be used to power the third rail:

(1) Five minutes before energizing the third rail from the locomotive, the Test Controller shall direct the DOT 001 Locomotive Operator to sound the first warning, i.e., five one-second blasts of the locomotive horn. Immediately before energizing the third rail the Test Controller shall direct the DOT 001 Locomotive Operator to sound the second and final warning which is three one-second blasts of the locomotive horn.

NOTE: THE LOCOMOTIVE OPERATOR SHALL NOT ENERGIZE THE THIRD RAIL UNTIL DIRECTED BY THE TEST CONTROLLER.

After the second warning is completed, the Test Controller shall direct the DOT 001 Locomotive Operator to apply power to the third rail. The Test Controller radios the security guards at the first warning and the second warning. The security guards, prior to the five minute warning must have verified to the Test Controller a safe track status, 2nd after third rail excitation they must acknowledge that the track is energized to the Test Controller.

(2) At the direction of the Test Controller the DOT 001 Locomotive Operator shall de-energize the third rail. The DOT 001 Locomotive Opeator shall sound one continuous five second blast on the locomotive horn to indicate that power is off. The Test Controller shall notify and receive acknowledgement from the security guards that the third rail is de-energized. All stations must acknowledge and shall not leave their stations until dismissed by the Test Controller.

Note: In the event of an emergency situation, any person may direct that the power be removed from the rail.

(3) Several portable power generating systems are available for third rail excitation in the event of failure of the DOT 001 locomotive power system or to back up the locomotive power system. The auxiliary units may be stationed anywhere around the track as required to support the system. On days when they are scheduled to be used, they will be operated on stand-by status (diesels operating but main power switch off) until placed in service as directed by the Test Controller. A five minute warning and a warning just prior to turn on will be given by the Test Controller to the portable power generator operators prior to third rail excitation. At such times when these generators and in standby or on line they shall be manned full time and in radio contact with the Test Controller.

d. Safety Warning - Signals and Devices - The third rail is covered by a protective board approximately four inches above the rail to act as a barrier which will prevent personnel and equipment from falling onto the third rail. In addition, High Voltage signs are placed along the rail at regular intervals to alert and warn personnel of potential danger.

(1) Other protective and warning devices such as insulated covers, boots, flags, warning signs, flashing lights, etc., may be used or displayed as required for test operations.

(2) The test car operator must observe standard rules of conduct in railway operation where applicable.

(3) During the time that the transit track is being secured for testing and after ensuring that all switches are properly lined and locked, verified by both the locomotive engineer and security officer, security personnel will set up track protection devices and warnings signals as required.

Note: In accordance with standard rules of the HSGTC and standard rules of railroad, only the person placing warning signals may remove them.

e. User Agency Test Team - The user agency is responsible for the development of his test team and assignment of duty stations. The number of personnel required for the test team is dependent upon a number of factors; however, a minimum number of duty stations must be designated and manned during any test run or run series. These stations include: (1) The Chief Test Engineer (CTE), (2) The Test Vehicle Operator, Other stations may be required such as on-board instrument monitors, observers etc., wayside instrumentation personnel, Data Acquisition Systems, Telemetry stations, etc. Prior to the first run, run series, or operational checkout of the day for a test vehicle, the user agency Chief Test Engineer shall convene a pretest meeting with all members of his test team, the HSGTC Test Controller, the Project Monitor, and the HSGTC Safety Officer in attendance. The Chief Test Engineer shall distribute a written run/operational plan of that day's activities to all attendants. The Chief Test Engineer shall review the run plan and discuss the planned objectives, the vehicle configuration, operating conditions, planned run speeds, instrumentation and data requirements, potential hazards and other aspects of the run plan.

The Chief Test Engineer shall further prepare a written assignment sheet wherein the individuals assigned to a specific task or duty station is defined and the responsibilities of these individuals are defined and discussed. These duty assignments are for all test team members including any High Speed Ground Test Center support services such as fire, emergency and security services. The Chief Test Engineer must discuss his plan for ensuring the safety of personnel and equipment in the event of a fire or other emergency during the planned test activities.

During the course of the conduct of the test program, the Chief Test Engineer is ultimately responsible for the control of the test vehicle, the acquisition of data, and other activities related to the test runs or run series. The Chief Test Engineer is required to communicate with the Test Controller and advise him of the current status of the test vehicle and test program. The Chief Test Engineer is required to receive clearance from the Test Controller prior to any movement of the test vehicle. He is further required to inform the Test Controller each time the test vehicle stops or comes to rest. In the event it becomes necessary for any personnel on board the test vehicle to deboard the vehicle for whatever purpose, the Chief Test Engineer is required to first obtain authorization from the Test Controller before deboarding. The Chief Test Engineer is further required to assign an individual from his test team as ground observer. The ground observer shall be in voice (radio) contact with the vehicle operator and shall coordinate all activities between the ground crews and those on board the test vehicle. The Chief Test Engineer shall receive clearance from the ground observer after ground work has been completed.

Upon completion of the day's test activity, the Chief Test Engineer is required to convene a post-test meeting with all members of his test team, the HSGTC Test Controller, the Project Monitor, and the HSGTC Safety Officer in attendance. The Chief Test Engineer shall review the actual accomplishments as compared with the planned objectives, discuss porblem areas, and, in general, review all facets of the test activity. The meeting shall be open for general comment and discussion of problem areas from all attendees.

f. Communication - It is mandatory that an effective communication network be established for control of all test operations. It is the responsibility of the Test Controller to define requirements for the communication network and to establish key stations required for the conduct of the test program. In addition to any intercom system that may be installed on the test cars, portable radios are available and should be used as required for communication between various stations designated by the Test Controller. The Test Controller shall be stationed at a site which he considers most advantageous to conduct the tests.

Stations which must be designated are:

(1) Test Controller

(2) DOT 001 Locomotive operator and or standby diesels

(3) Chief Test Engineer

(4) Test Car Operator

(5) Track Security.

Other stations may be established by the Test Controller and Chief Test Engineer as required in support of the test operations.

g. Radio Communications - Generally accepted rules of conduct applicable to test control and operations with a communication network shall be followed, i.e.:

(1) Stations must identify themselves to the Test Controller as soon as they assume their assigned station and remain on the network.

(2) All stations must be manned and remain on the network until relieved or dismissed by the Test Controller.

(3) Stations must identify themselves before making transmissions, i.e., "Test Controller from Station C".

(4) Transmissions must be limited to essential communication related to test operations.

(5) Observe common courtesy, i.e., do not interrupt transmission sequence. Only in the event of an emergency is it permissible to break in on a transmission sequence.

(6) Never use profanity on the network.

(7) Exercise extreme care in the operation and utilization of the radio instruments.

(8) All personnel involved in the test program or in the transit track testing area will have radios which are set on channel 1 (one) which is a frequency of 165.3125 MHZ.

5. HIGH SPEED GROUND TEST CENTER PLOT PLAN - A Plot Plan is attached to aid in identifying the locations described in this instruction (Attachment A).

APPENDIX D

Excerpts from HSGTS Policy Order 5800.1
Subject: HSGTC Safety Policy

4. POLICY. It is the policy of the HSGTC to ensure that the Test Center operations meet the required DOT Safety Standards and take full account for the occupational safety and health of personnel and the protection of material resources. Although the Test Center must conduct test operations inherently more hazardous than those conducted with previously developed equipment, every possible effort must be exerted to prevent incidents which could lead to personal injury, damage to property or other events which could adversely affect the Test Center's mission. Included are mishaps involving visitors or the general public and their property when at the Test Center. In more conventional activities such as construction and logistics operations, existing industry safety standards will be applied. In development test operations, where specific safety standards are not yet available, precedents evolved through railroad, rapid transit, aerospace or other safety experiences will be applied insofar as is practicable. Appropriate safety plans, standards, and operating rules will be issued for these purposes.

Excerpts from HSGTC Management Instruction 3902.1
Subject: Duties and Authorities of HSGTC Safety Officer -Interim

4. BACKGROUND. Reference a. establishes the basic mission of the Test Center and assigns responsibilities to both the Test Center Director and Sponsoring Operating Administrations for safety. Reference b. promulgated the Test Center safety policy consistent with other DOT Orders and sets forth the broad areas of responsibility for the Safety Officer and Project Monitors. From these directives, it should be noted that each Project Monitor, acting for the Sponsoring Operating Administration through the User, is responsible for safety within his Test Program, and that he may formally request assistance from the Test Center.

5. FUNCTIONS. The HSGTC Safety Officer Shall:
   a. Be a federal employee on the staff of and directly responsible to the Test Center Director.
   b. Vigorously implement and administer the Test Center Safety Program.
   c. Ensure that all resident contractors and users are acquainted with and implementing the provisions of the Occupational Safety & Health Act of 1970 (OSHA).
   d. Serve as advisor to the HSGTC Director and act as Secretary of the Safety Steering Committee.
   e. Conduct inspections and review of project activities at the Test Center as may be requested by the cognizant Project Monitor or Construction Supervisor.
   f. Review general Test Center maintenance, operating and safety procedures.

APPENDIX E

Excerpts from Boeing
Vertol's "Accident Report,
State-of-the-Art Car,
High Speed Ground Test Center
August 11, 1973"

1.3.1.1 Exterior

The stylized exterior (Figure 4) features smooth, brush-finished stainless steel materials and molded fiberglass ends. The basic car structure is of all-steel, welded construction. Four 50-inch wide sliding doors per car side are designed to safely handle maximum passenger interchange within the desired 20-second station stop dwell time. Safety features of the door system include propulsion system interlock, restricted push back leaves, soft door edges and a 3-second warning chime prior to door closing.

1.3.1.2 Car Structure

The underframe is fabricated of high strength, low alloy steel with full-length side sill channels, formed cross-bearers between bolsters and rolled section crossbearers near the car ends. Sides and roof are fabricated of stainless steel skins spot-welded to steel frames. Local reinforcement has been provided for support of the pantograph and for car jacking.

The anticlimber and the coupler mounting are integrated into an end weldment assembly (Drawing No. 2D31000) which is built up around two 8" draft sill channels spaced 26" apart. The anticlimber, which is built up by welding two 3" channels together and was modified near the ends with welded flange extensions and gussets between flanges, extends 7.5" beyond the draft sill at each side. From the ends of the anticlimber, 6" "intermediate" draft sill channels extend just over 2 feet aft to the end floor support beam, which consists of rolled angles welded together to form an 8" box beam between the side sill ends and the draft sills and between the draft sills.

Behind the anticlimber is a .375" center shear plate between the draft sills, extending to the end floor support beam; a .125" bottom shear plate extending to the coupler radial bar support channel; and a .125" top shear plate spanning the intermediate draft sills to the end floor support beam and the draft sills aft to the bolster. Secondary floor support structure, consisting of end and corner sills (6" formed channels) and .082" corner (top) plates complete the forward end of the end assembly.

Aft of the floor support beam, a .50" plate reinforced with .50" vertical transverse stiffeners is welded to the bottom flange of the draft sills to provide the mounting for the coupler anchor. Aft of the coupler anchor, the draft sill height tapers to 5.88" (by cutting the web, bending up the lower flange and welding) and the sills are spanned by a .25" shear plate extending aft to the end of the weldment assembly.

The body bolster assembly (Drawing No. 2D35003) provides the primary load path from the anticlimber and coupler through the end weldment into the side sills. The bolster weldment consists of two 6" wide flange "I" beams spaced just under 3 feet apart, joined together (at approximately mid-web) by .31" base (shear) plates which extend 29" from each end. Numerous vertical and horizontal plate members plus four 6" rolled channels also join the "I" beams and provide local stiffening for the lateral bumper brackets and the safety straps. The inboard channel members are spaced the same as the draft sill channels.

Above the car floor on the aft face of the fiberglass end fairing are two shear panel assemblies, located 17" on either side of the car centerline (Drawing No. 2D35019). Each assembly consists of a .188" plate, 20" high by 6" (at the bottom) to 12" (at the top) wide plate with an integral aft flange and welded on 2 x 2 x .188" angles on the other three edges. This assembly is welded to a .50 x 6" plate extending its full height and through the end weldment top plate. At the car body forward corner, the corner post structure consists of a 1.56 x 4 x .188" formed angle with the 4" leg parallel to the car centerline (Drawing No. 2D35019) butt welded to the lateral (2") leg of a 1.5 x 2 x .188" angle at the forward edge of the car side.

1.3.1.3 Interior

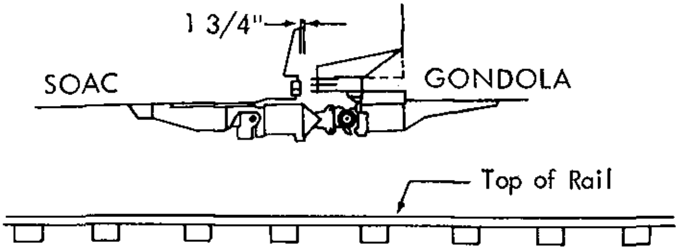
Two different car interiors have been developed. The first car has 64 cushioned, upholstered seats designed for maximum comfort. Four different interior arrangements are demonstrated with the objective that passenger preference data can be obtained as part of the demonstration program. Maximum capacity of this "low-density" car is 220 passengers.

The second car has 72 seats and more floor space for standees. One-piece molded fiberglass seats are fitted with padded cushions. Maximum capacity for this "high-density" car is 300 passengers.

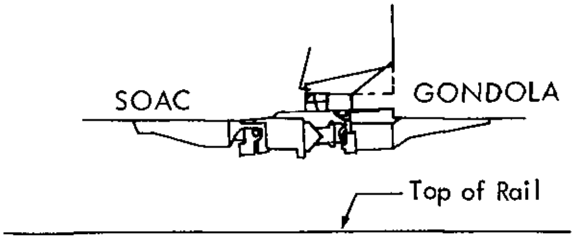
Seat materials of both cars can be readily cleaned and are resistant to vandalism. Floors are completely carpeted. During design, emphasis was placed on use of fire retardant materials throughout the car (meeting FRA 302 Specification as a minimum).

Inward swinging cab doors are provided. These doors were removed from both SOAC cars at Pueblo to facilitate testing.

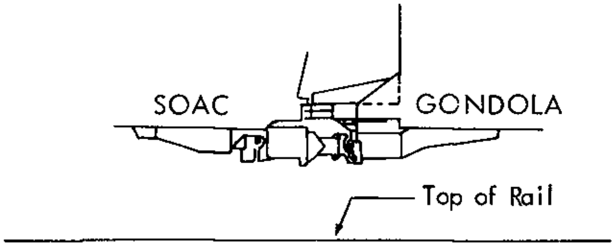
(1) Couplers Engage. Load in Couplers.



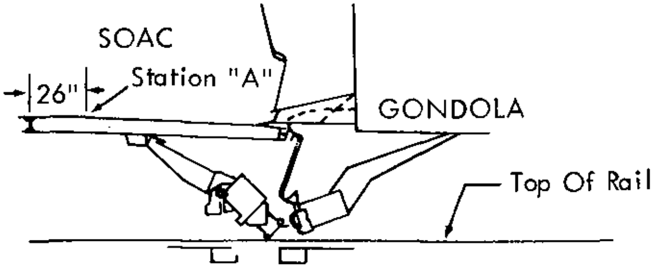
(2) Coupler Emergency Release Shears, Couplers Foreshorten Total 7.50 in. Under a Buff Load in Excess of 225.000 lb. Anticlimbers Engage, Load Shared With Anticlimbers.



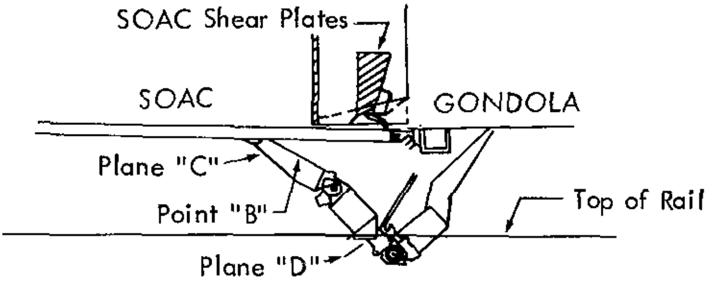
(3) Anticlimber on Gondola Peels Downward off the Gussets. Load Transfers Back to the Couplers.



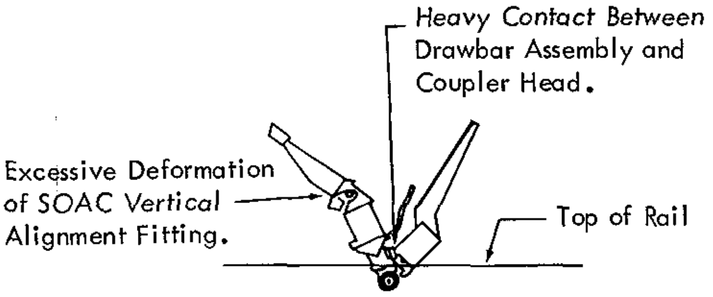
(4) Down Load in Gondola Coupler Pulls Down the Coupler Carrier and the Plate it is Mounted to, Pulling the Anticlimber Face of the Gondola Further Down, This Permits the Gondola to Override the SOAC Anticlimber.



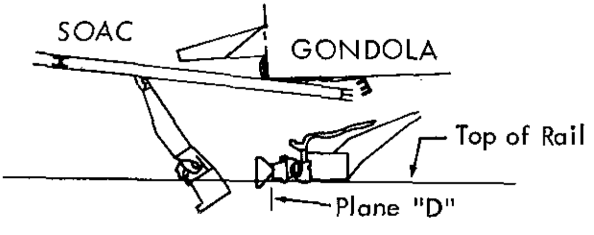
(5) Anticlimber Gussets Puncture Top Plate of the SOAC End Weldment. End of the Gondola Impacts Top of Center Sill, This Causes Contact Between SOAC Coupler Shank and Anchor Casting at Point "B" Resulting in Shear Failure of the Shank at Plane "C". The SOAC End Weldments (Between Side and Center Sills) Were Torn Off by the Outer Gussets, Penetrate Past Shear Plates and Corner Angles, Into Motorman's Area. SOAC Anticlimber Drives Gondola Anticlimber Into Coupler Attachment Area Forcing Coupler Downward. Step at Side of Gondola Rides Upon SOAC Side Sill.

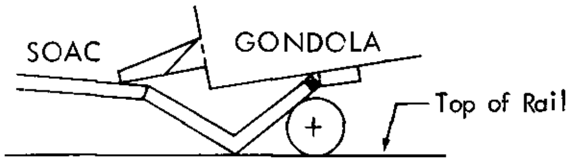


(6) In the Same Sequence Extreme End Load and Misalignment Causes Rotation of Coupler Heads Resulting in the Damage Observed.



(7) The Couplers Hit Rail and Disengage. Both Couplers Are Sheared Off and the Rear of the SOAC Coupler is Jammed Into the Right Side of the Draft Sill.



8	The SOAC Coupler Hits the Right Hand Rail Causing Deformation and Gouging of the Face Plate Corner the Coupler is Dumped Between Rails Where it is Dragged Along Before Coming to Rest.
9	SOAC Anticlimber Contacts Gondola Bolster Area. SOAC Draft Sill is Crumpled by Central Load. Side Sills Intact the Gondola is Detrucked and the Truck is Pushed up the Track. 
10	The Gondola Coupler had Been Failed at the Eye. The Coupler Then Fell to the Rail or was Driven to the Rail by the Kink in the SOAC Draft Sill.
11	The Gondola in the Raised Position Completes the Elbow in the Center Sill, Then Overrides Into SOAC Cab to a Depth of 9 Feet. Overriding Allows the Gondola Aft Truck to be Disengaged. This Truck Slews Sideways on the Right-of-Way. The Gondola Traps the Aft Truck on the Ties Causing Heavy Damage to the Ties.
12	During this Sequence Both Cars are Approaching a Common Velocity. The SOAC Forward Truck is Forcing the Coupler Carrier Along the Right Hand Rail. This Continues Until the Broken End (Assembly) is Stopped by the Rail Splice Plate. The Truck is Pole Vaulted Laterally Into the Left Side Ballast Causing a More Rapid Deceleration Than That of the Gondola. The Forward Truck Imbeds Deeply Into the Ballast. The Drawbar Assembly is Freed and Drops Between the Rails.

(13) The Yawing Action of the SOAC Imparts an Opposite Yaw Motion to the Departing Gondola, Which Comes to Rest - 11.4 Feet From the SOAC.

(14) Body Separation Allows the SOAC Underframe to Spring Back, Some Extent Under the Action of Stored Strain Energy. Also Separation Friction Would Pull the Folded Center Sill Into a More Extended Position.

(15) Body Separation Allows the Trapped Loose Items of Demolished Structure and Equipment to Fall Out Onto the Right-of-Way. The Operator was also Ejected at This Time.

*As depicted by the Boeing Vertol Company in their Accident Report - State of-the-Art Car - High Speed Ground Test Center - August 11, 1973

APPENDIX F

BOEING VERTOL'S

SKETCH SHOWING COLLISION DYNAMICS*

GPO 875-755