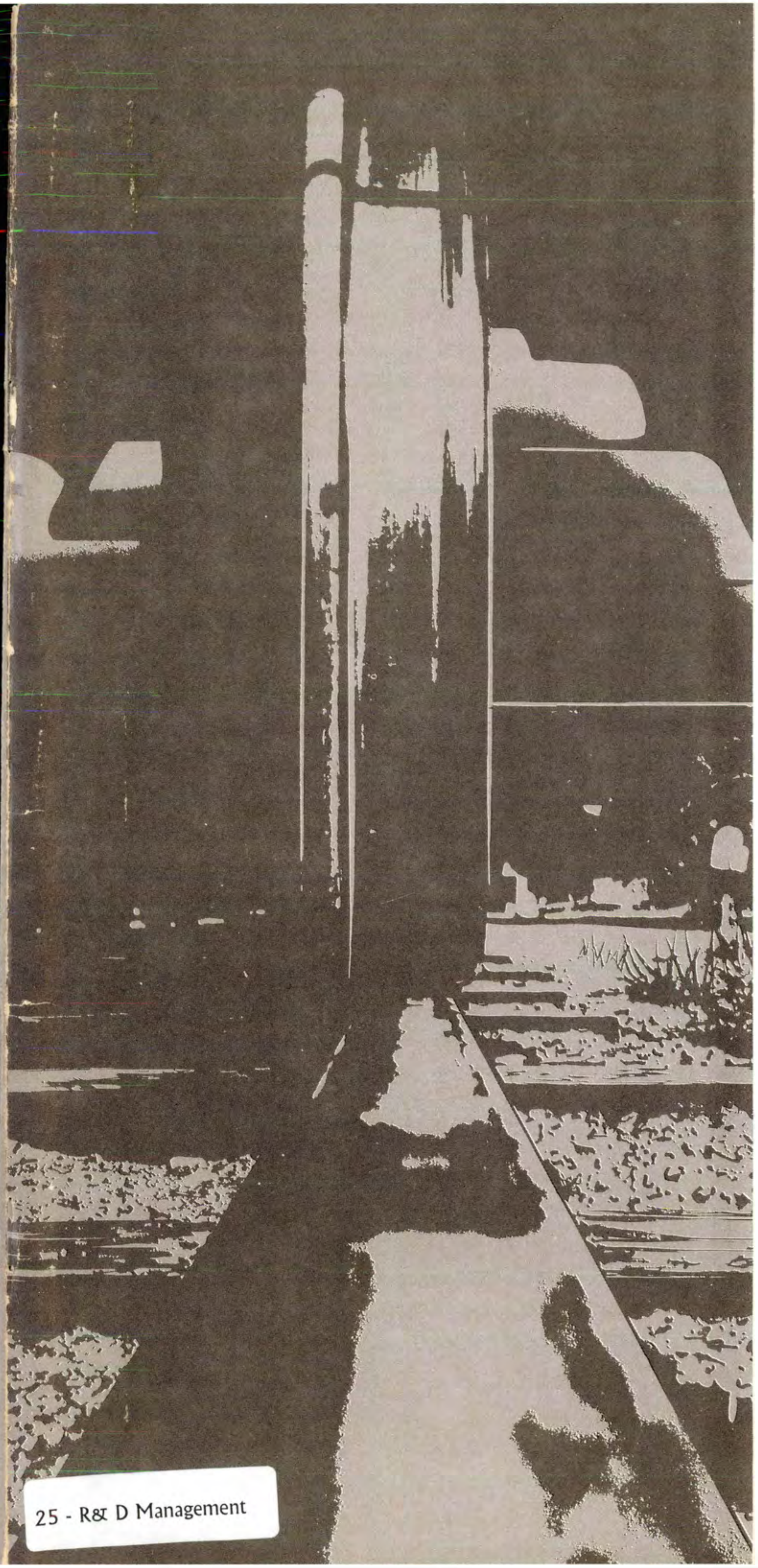

NINTH REPORT ON THE RAILROAD TECHNOLOGY PROGRAM 1975

BY THE SECRETARY OF TRANSPORTATION TO THE PRESIDENT, THE SENATE, AND THE HOUSE OF REPRESENTATIVES

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16. Abstract

A report on the Federal Railroad Administration's activities carried out under the High Speed Ground Transportation (HSGT) Act of 1965 as amended and extended, for the Secretary of Transportation to report annually to the President and the Congress on activities performed under the Act.

This report covers the HSGT-funded research, development and demonstrations programs administered by the Office of Research and Development (OR&D) and the Transportation Test Center (TTC) of the Federal Railroad Administration (FRA) in accordance with Section 10(a) of the Act and also encompasses related work performed under appropriations for advancing railroad technology and safety including the activities of the Transportation Test Center. The report covers program activities for the period October 1, 1974, to September 30, 1975.

The report is designed to serve as a source of information for those having an interest in FRA's research, development and demonstration activities. A limited number of copies are made available to Committees of Congress, other Department of Transportation (DOT) organizations, academicians, prospective contractors, industry organizations and others who have an interest in FRA's R&D results.

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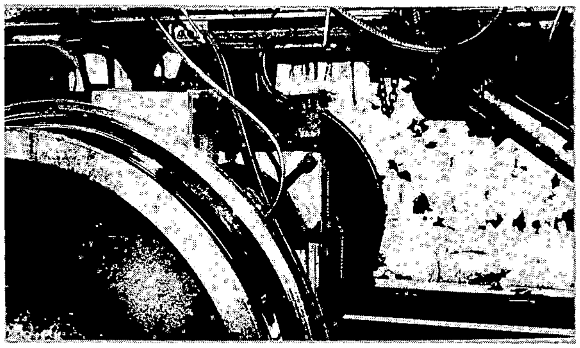

PREFACE

The Secretary of Transportation is required to report annually to the President and the Congress on the activities carried out under the High Speed Ground Transportation (HSGT) Act of 1965 as amended and extended. This Ninth Report covers the HSGT-funded research, development, and demonstrations programs administered by the office of Research and Development (OR&D) of the Federal Railroad Administration (FRA) in accordance with section 10(a) of the Act, and also encompasses related work performed under appropriations for advancing railroad technology and safety.

Earlier reports have also contained a full bibliography of reports published in conjunction with railroad research, development, and demonstrations efforts. The Rail Research Information Service, operated by the National Research Council and sponsored by FRA, has incorporated all references to FRA reports in its bibliography which is updated through published bulletins at six-month intervals and is now available on a subscription basis. (See Section 7.0 for information on subscription procedures and bibliography searches.)

The annual reports continue to serve as an information source for those having a technological interest in FRA's research, development, and demonstrations activities. A limited number of copies are made available to committees of Congress, other Department of Transportation (DOT) organizations, academicians, prospective contractors, industry organizations and others who want or need to know about results obtained. General public distribution is made through the National Technical Information Service, Springfield, Virginia 22151.

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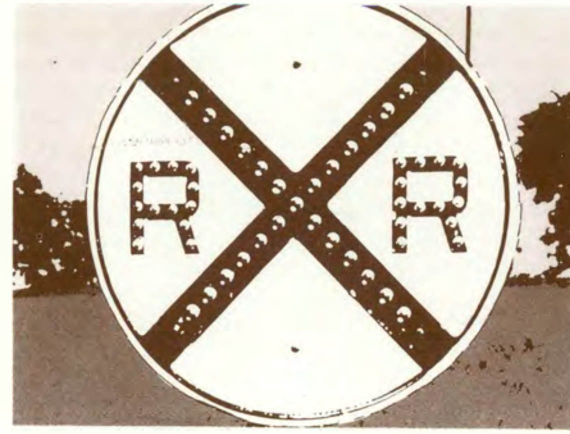
1.0 OVERVIEW AND HIGHLIGHTS



This Ninth Report from the Secretary of Transportation to the President and the Congress covers results and progress by the Federal Railroad Administration (FRA) Office of Research and Development (OR&D) in carrying out the provisions of the High Speed Ground Transportation Act of 1965 (as amended) during the year ending September 30, 1975. The report also covers corresponding and interrelated work carried out under the annual appropriation for railroad research and development. Activities funded from both of these sources involved facilities of the Department of Transportation's Transportation Test Center (TTC) operated by FRA at Pueblo, Colorado.

FRA's technological research has been redirected to focus more sharply on near- and intermediate-term conventional rail problems. Consistent with this redirection, the R&D office was reorganized. Efforts in this area have already resulted in significant program changes. As part of this reorganization, FRA has separated most passenger and freight systems R&D activities to assure that unique customer needs are addressed and mechanisms established to promote early incorporation of proven R&D results into the rail industry. FRA continues to place highest priority on safety and has developed efficient internal coordination among rule making, inspection, and technical R&D support personnel. In the passenger systems area, FRA is emphasizing developments which will help Amtrak reduce its operating costs and improve the service. In the past, FRA developed advanced systems such as the Linear Induction Motor Research Vehicle (LIMRV) and the Tracked Levitated Research Vehicle (TLRV). While these have provided extensive and useful data, their use in operational systems is still many years away. Therefore, FRA is now concentrating on developing moderate improvements upon existing technology so that Amtrak and other rail passenger systems can implement these results quickly and efficiently to achieve lower operating and maintenance costs. FRA's freight R&D activities are focusing on two phases of product evolution, leaving product development and implementation to the private sector. FRA has strengthened its relationship with both the railroad users and the supply industry and has become involved in many joint feasibility-type activities to demonstrate to railroads the technical improvements possible. The railroads, in turn, through advanced performance specifications, can then attract the supply industry to invest in product development. FRA's second major thrust is to provide railroads and suppliers with useful test and evaluation capability at the Transportation Test Center (TTC). During the past year, many of FRA's facilities at TTC have been modified to make them more representative of the actual railroad environment.

In order to insure maximum return from R&D dollars, FRA cosponsored with the Association of American Railroads (AAR) a railroad research study conference at Woods Hole, Massachusetts, in June and July 1975. Experts from the railroad industry, railroad suppliers, government, and academic institutions were invited to deliver papers and discuss the needs and priorities of research areas. The objectives of the conference were to identify problem areas affecting the health of the rail industry and to identify and assign priorities research areas responsive to these problems. Preliminary conclusions from the conference proceedings indicate that a major portion of FRA's R&D programs in conventional systems are highly responsive to the critical needs of the industry and will provide major benefits to the industry on a near-term basis.

Congress has expressed interest in the economic impact of government expenditures for rail research and development. This report includes in Appendix A a listing of contract obligations incurred in FY 1975 together with the names of the contractors and their places of business.

The missions, goals/objectives, and significant accomplishments for each technological area through September 30, 1975, are summarized below.

Rail Freight Systems R&D

The Office of Freight Systems R&D was established in the recent reorganization to respond to the critical research problems confronting the railroad industry in rail freight transportation. Current programs include those related to classification yards, trailer-on-flatcar (TOFC) evaluations, freight car management systems, freight car components, and the development of the Rail Dynamics Laboratory (RDL). The highlights for 1975 are as follows:

Improved Rail Freight Service

• An analytical model for estimating fuel consumption in rail transportation has been completed. This model is presently in the process of being validated through actual field fuel consumption measurements. Validation will permit the use of the simulation model in assessing alternatives for routing and/or rail operations that are most energy efficient.

• In response to a rail industry request for technical assistance, FRA completed an investigation into the problems associated with low readability of the rail industry's standard optical automatic car identification (ACI) system. This effort systematically specified parameters that delineated the actual problem sources.

• FRA completed Phase I of the Truck Design Optimization Project (TDOP), a performance evaluation of general purpose freight car trucks, and conducted an industry briefing on the early findings. Four technical reports were published describing test parameters, and an economic methodology was developed for assessing truck ownership costs based upon improved designs or modifications. Results of a comprehensive literature search were made available in a three-volume report.

• An industry-government project continues to evaluate two lightweight trailer-on-flatcar (TOFC) and container-on-flatcar (COFC) cars and compare their performance with that of a heavier and more conventional TOFC/COFC car.

• The first experiment utilizing the single-ended vertical shaker in the Rail Dynamics Laboratory (RDL) was initiated, using a flatcar and trailer combination, to examine and improve the environment of typical goods shipped by rail in the TOFC configuration. Reducing damage to goods will increase the profitability of rail freight service as well as encourage new business through more reliable and safer operations.

• Phase I of the Track Train Dynamics Program was completed successfully; the findings have received wide acceptance throughout the rail industry. Sponsored jointly by FRA, AAR, the Railway Progress Institute (RPI), and the Transportation Development Agency (TDA) of the Canadian Ministry of Transport, the program is designed to investigate the dynamics of train operations.

• The Transportation Systems Center (TCS), working with railroad companies, conducted fuel consumption tests on intermodal trains consisting of TOFC and COFC equipment. The data obtained will be used to validate a computer simulation model previously developed to assess energy efficiencies of different types of operations.

• FRA, with assistance from TSC, initiated development of a TOFC/COFC wind tunnel test to determine aerodynamic drag characteristics of various existing equipment configurations. The results will be used to establish energy trade-off data between TOFC and COFC and the effects of streamlining and the spacing of loads.

Rail Dynamics Laboratory

• The Rail Dynamics Laboratory (RDL) Program was redirected from a Rail Dynamics Simulator facility to a Vibration Test Unit (VTU) and Roll Dynamics Unit (RDU) so that the RDL could be completed in a timely fashion, relatively free of technical risk, and with minimum cost.

• A vertical shaker at the RDL is operational. The shaker will study the response characteristics of truck assemblies and total vehicles subjected to vertically applied periodic and random excitation.

• The RDL Integrated Computer Subsystem Network, Communication System, and Analog Data Acquisition and Control Subsystem (ADACS) have been accepted by the government and will be reconfigured to support the VTU and RDU systems. The ADACS and Communication System are currently being utilized in the vertical shaker system.

Rail Safety R&D

The Office of Rail Safety R&D was formed in FY 1975 under the FRA reorganization. The mission of the office is to plan, sponsor, and implement research and development programs designed to improve rail safety. The broad goals of the office are to reduce the number and severity of the accidents through the application of research results. To realize these goals, the office conducts research in three main areas which are:

• Improved track structures

• Rail vehicle safety

• Safety inspection, defect detection, and testing of track and rail vehicle components and systems.

There are three divisions within the Office of Rail Safety R&D, each of which is responsible for one of the above research areas.

The office coordinates its planned and outgoing research efforts with the potential users of the research outputs, e.g., FRA Office of Safety and the Office of Northeast Corridor Development, Amtrak, and the railroad industry. In some instances, projects are sponsored jointly by the FRA and these users. The highlights for 1975 are as follows:

• Facilities constructed during the previous reporting period were used to test tank car thermal shields and relief systems and for evaluating the effectiveness of such measures for tank cars engulfed in fire and the destructive effects of bursting tank cars.

• Louisiana Tech University completed a tank car structural stress analysis and the National Bureau of Standards completed a metallurgical analysis of steel plate samples taken from tank cars involved in accidents in order to develop tank cars with stronger tank car shells.

• Progress in FRA's program to improve rail vehicle occupant protection included the development of a locomotive-caboose collision model, the formulation of occupant protection guidelines, and the completion of eight rear-end collision tests.

• Two FRA contractors completed studies aimed at acquiring an understanding of safety-critical railroad jobs.

• The Naval Ammunition Depot, Crane, Indiana, completed a study to identify and describe the principal tasks performed by conductors and brakemen during over-the-road operations.

• A study was completed of minimum experience qualifications for enginemen, conductors, brakemen, and dispatchers.

• The Transportation Systems Center (TSC) completed evaluations of three train-handling aides—the Draft-Buff Indicator, the Power Force Indicator, and the L/V Hazard Detector, used to measure the ratio of lateral to vertical forces.

• TSC completed an evaluation of several commercially available portable wheel-inspection units.

• FRA completed the grade crossing inventory project.

Improved Track Structures

• Lateral track stability tests were completed on the main line track of the Chessie System at Sabot, Virginia.

• An AAR contract produced a preliminary conceptualization of a Facility for Accelerated Service Testing (FAST), from which life-cycle cost and performance data can be accumulated in compressed time.

• The nine-section Kansas Test Track was opened to in-service traffic.

Automated Track Inspection

• TSC completed an evaluation of a rail flaw detection vehicle.

• FRA R&D has moved into the operational mode in the Automated Track Inspection Program, which is directed toward providing the Office of Safety with an automated track inspection capability. Two surplus U.S. Army hospital cars were acquired and are being refurbished and converted into track inspection vehicles to supplement the existing track test cars:

• To date FRA's track inspection vehicles have inspected 15,548 miles of track for compliance with safety standards.

Passenger Systems R&D

The Office of Passenger Systems seeks to develop technology to support and enhance Amtrak's mission in intercity passenger service. The program investigates and develops improved equipment alternatives for operations and demonstrations by Amtrak. The main technology areas under investigation include traction and propulsion, suspension, braking, equipment, controls, train evaluations, and systems developments. The highlights for 1975 are as follows:

Systems Analysis and Technical Assessment

• The Metroliner Improvement Program was completed during the reporting year. The objective of the program was to improve those components that had been responsible for a high failure rate and high maintenance cost. Four modified cars, two of which were equipped with General Electric propulsion and control equipment and two with Westinghouse Electric equipment, have completed a 25,000-mile (40,225 km) road test which verified that the modifications are effective and reliable. The results of this program have been made available to Amtrak for its use in improving the fleet of Metroliner cars.

• At the end of the reporting year, a program was being planned to acquire in-depth knowledge of existing passenger train systems, components, and subsystems that could be used in the United States in the near future. The information is intended to provide a baseline for the acquisition of improved passenger equipment.

• Another program which was in the planning stage at the end of the reporting year was the passenger-car truck test program. This program will collect performance and ride quality information on different passenger-car trucks. Also aimed at improving passenger service is a planned signal, control, and communication study which will concentrate on methods for achieving faster schedules at a minimum cost by improving existing signaling systems.

• Passenger car ride quality, acceleration, and noise data were recorded during the year. The goal of this program is, ultimately, to develop ride quality criteria and specifications for improved passenger cars.

Supporting Technology

• A power conditioning unit with variable-voltage/variable-frequency capability is now undergoing testing in the Tracked Levitated Research Vehicle (TLRV). This represents the most powerful and most advanced system for potential locomotive use to date.

• FRA conducted a series of Linear Induction Motor (LIM) tests over the entire speed range of the Linear Induction Motor Research Vehicle (LIMRV) to determine electrical characteristics of the motor and to establish significant correlation with mathematical models.

• Other LIMRV tests completed were in the areas of braking, motor edge effects, electromagnetic wake, wheel-rail adhesion, and noise.

Advanced Systems

• FRA, in cooperation with UMTA, has developed the world's first all-electric Prototype Tracked Air Cushion Vehicle (PTACV). The 60-passenger vehicle is being tested on a 5.7-mile (9.2 km) inverted-tee guideway at the Transportation Test Center. On May 9, 1975, the vehicle reached a speed of 102 mph (163 km/h), a speed record for levitated vehicles in this country.

• The LIM and the power conditioning unit were installed in the TLRV.

• Conceptual designs were developed for the repulsion and attraction concepts of revenue-service Maglev vehicles.

Transportation Test Center

Significant developments at the Transportation Test Center (TTC) during the past year included changing the name of the test center from the High Speed Ground Test Center (HSGTC) to the Transportation Test Center; changing the mission statement and table of organization; and shifting emphasis from advanced vehicle testing to conventional railroad and transit equipment testing in order to attract more use of the center by the private sector. The highlights for 1975 are as follows:

• The Center Services Building and the Operations Building were completed and occupied.

• The electrical distribution system was completed.

• Construction of 5.7 miles (9.2 km) of railroad track for the northern segment of the High Speed Track and "Balloon Loop" was completed; construction was begun on 8.3 miles (13.4 km) of track to complete the High Speed Track, two miles (3.2 km) of which will be bolted track which could have built-in perturbations to simulate actual or "real world" track conditions.

• The Canadian Light, Rapid, Comfortable (LRC) Train ran more than 20,000 miles (32.130 km) during 29 tests on TTC tracks.

• FRA/AAR/RPI completed a two-month series of Long Train Stability (L/V and Lateral Stability) Tests, an element of the Track/ Train Dynamics Research Program, Phase I.

• FRA completed the Train-to-Train Impact Test series, simulating rear-end train collisions at speeds up to 30.4 mph (49 km/h).

• FRA completed high speed tests up to 120 mph (193 km/h) to qualify new Budd Company "AM" coaches for high speed Amtrak service.

• The Prototype Tracked Air Cushion Vehicle (PTACV) exceeded 100 mph (160 km/h) on a test run.

• TTC personnel assisted in conducting the FRA-sponsored Eleventh Railroad Engineering Conference in Pueblo, which included a tour of TTC facilities.

•TTC public affairs efforts included assistance in filming test center activities for the NBC *Today Show* and for the United States Information Agency; official dedication of the newly paved 17-mile (27.4 km) test center access road by Deputy Secretary of Transportation John W. Barnum (including a test center open house for the general public); and hosting government, industry, and news media people at the 30.4 mph (49 km/h) Train-to-Train Impact Test.

• More than 6,500 people visited the test center during the period of this report, including representatives of American and foreign government and industry.

International Cooperation

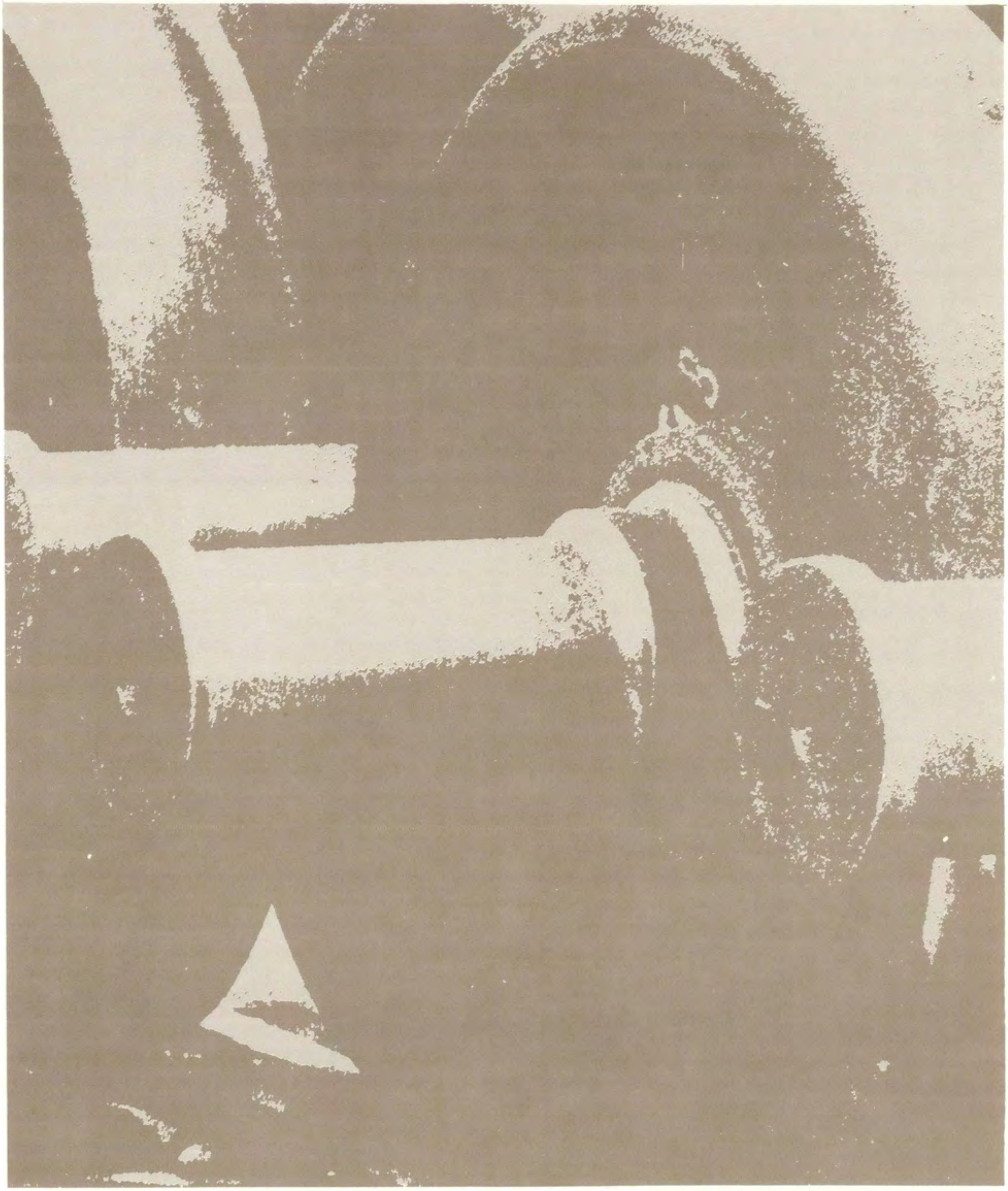
Greater impetus was placed on international cooperation during the past year as a method for conserving R&D resources and avoiding duplicative research. The Department of Transportation (DOT) has 10 bilateral agreements with foreign countries in which FRA is involved. The most significant one is the agreement with the Soviet Union, which is the most rail-intensive country in the world and which has reached a high degree of development in railroad technology. The highlights for 1975 are as follows:

• The US-USSR bilateral agreement for cooperation in the field of transportation resulted in an agreement at the fourth working group meeting on railroad technology exchange held in Moscow in September 1975 whereby the Soviet Union is to provide the United States with 10 prestressed concrete crossties for testing and evaluation in this country and the United States is to furnish the Soviets with an American draft gear for freight cars for tests and evaluation in the Soviet Union.

• FRA participated in the proceedings of the joint Soviet-American meetings in Moscow during August-September 1975. The meetings related to the third meeting of the Joint Transportation Committee and the Joint Working Group Meetings on Transport of the Future and on Railroad Transportation.

• A U.S. delegation visited the Soviet Union from May 26 to June 5, 1975, to study Soviet railroad electrification technology.

• FRA participated in a three-day railroad seminar on June 3-5, 1975, at the U.S. Trade Center, Mexico City, with technical papers delivered by members of the U.S. railroad industry and the government.



2.0 RAIL FREIGHT SYSTEMS R&D

2.1 IMPROVED RAIL FREIGHT SERVICE

The purpose of the Improved Rail Freight Service Program is to promote research and development efforts within the government and the rail industry which are responsive to the critical problems confronting the railroads in the transportation of freight and goods. The program is structured to attract industry participation and cost sharing in R&D efforts. It is designed to stimulate a level of R&D activity essential to sound capital investment decisions which will be necessary as the upgrading of the nation's railroads proceeds in the years ahead. This need is highlighted by the fact that government and industry agencies are forecasting a doubling of demand for railroad services in the 1980s. Such an increase in service will require significant capital investments in relatively long-lived facilities and equipment—facilities and equipment that will be expected to remain in service well into the next century.

Much of the research heretofore in the rail industry can be characterized as evolutionary in nature—often founded on empirical data and experience gained over a long period of time. This tedious and costly process must be accelerated if the railroads are to meet expected future demands. To this end, a multipronged attack has begun on identified problem areas.

During the past year there has been significant progress in the development of cooperative research projects involving the railroads, manufacturers and suppliers, and the Federal Government. At the same time, the Federal Railroad Administration (FRA) initiated a number of foundation studies to determine what railroad problems might be resolved through research into innovative concepts. FRA also examined existing technology applicable to the movement of goods by railroads in the interest of reducing development lead times.

In order to respond to the nation's need for a more efficient and effective rail freight transport system, the Improved Rail Freight Service Program has been divided into four major functional subprograms:

- Systems Analysis/Technology Assessment
- Classification Yard Technology
- Equipment Performance Analysis
- Intermodal Freight Systems Technology

The broadly based Systems Analysis/Technology Assessment subprogram covers those areas that deal with railroad productivity in general. Research in this area often leads to identification of a problem that is subsequently addressed in another functional program area. In this subprogram, FRA, through the Transportation Systems Center (TSC), has begun an effort to analyze and measure fuel consumption in rail freight service. Noise and locomotive exhaust emission characteristics are also being investigated.

Under the Classification Yard Technology subprogram, research efforts are committed, in the near term, to provide more reliable and efficient performance in yard and terminal operations. FRA anticipates that this research will stimulate industry to develop improved systems of specialized equipment and yard configurations which will increase the efficiency of the classification process and the overall handling of railcars. The classification yard has long been recognized as the principal obstacle to improved rail transport service and capability.

Research in this subprogram has concentrated on an assessment of classification yard technology in order to establish existing and anticipated needs for hardware development and on a study of the Automatic Car Identification (ACI) system, an important component of freight car management and control systems. The electro-optical ACI system has been under considerable technical scrutiny, and FRA has participated in a cooperative effort with the AAR and RPI to identify problems and suggest improvements for the system.

The Equipment Performance Analysis subprogram is devoted primarily, in the near term, to defining the characteristics of existing rail freight car equipment and systems. It is intended to determine the potential for improvement of this equipment through minor modifications which can prove economically beneficial to the railroads in terms of reduced maintenance and operation costs or loss and damage claims.

A crucial first step, however, is a characterization of the performance of existing equipment, much of which has evolved on the basis of empirical judgment. Therefore, current performance must be evaluated prior to attempting assessment of new designs and developments. A significant accomplishment in this area was the completion of the first year of the Truck Design Optimization Project (TDOP), a multiyear, applied research program designed to define thoroughly the performance of existing general purpose freight car trucks. The results of this research will lead to economically feasible improvements in truck suspension systems. Similar investigations which were initiated involve assessment of the potential for modifications and improvements in freight car braking and coupling systems.

The Intermodal Freight Systems Technology subprogram, begun in 1974, is directed toward developing technologies to facilitate the establishment of an efficient land-based transport system employing truck-rail-truck handling of containerized freight between origin and destination. The goal of this subprogram is to develop system components which will produce a more efficient intermodal network capable of accommodating the projected transport market increase over the next two decades.

The major accomplishments of the Improved Rail Freight Service Program in 1975 are examined in a further discussion of specific projects.

Fuel Consumption of Rail Transportation

Rail freight transportation accounts for only a small percentage of the petroleum fuel used for transportation in the United States and has generally been accepted as one of the most energy-efficient modes of transportation. To date a detailed knowledge of fuel consumption of trains has not been available, although estimation of this quantity typically has been a by-product of railroad computer simulations used to predict schedule and motive power requirements in planned operations. Recent developments, however, including a significant increase in fuel prices, have given major impetus to developing more fuel-efficient operations.

A first step in this direction is the accurate determination of actual fuel consumption in various rail transportation operations. For most modes of transport, operations are well defined, and a relatively simple physical model supported by a small number of measurements can provide reasonable estimates of fuel consumption. However, rail freight operations are characterized by diversity. Power-to-weight ratio can vary from less than unity to greater than 10. Speeds can range from 10 to 80 mph (16 to 29 km/h) over a wide variety of terrain. Aerodynamic characteristics can differ markedly for different types of freight cars and train configurations.

In order to shed light on this uncertain area, the FRA has supported a TSC effort to analyze and measure fuel consumption in rail freight service operations. Utilizing an analytical model based on the physics of train movement developed in FY 74, TSC conducted a study on a variety of operations, including branch lines, general freight, and passenger systems. A computer program based on this model was used to examine the sensitivity of fuel efficiency to various factors—speed, grade, power-to-weight ratios, load, etc. This study has been documented in a formal report, "Railroads and the Environment—Estimation of Fuel Consumption in Rail Transportation" (Vol. 1—Analytical Model), FRA-OR&D-75-74.1 (NTIS Document PB 244 150/AS).

For this model (and others) to be of maximum utility, it must be validated through comparison to actual cases. In addition, accurate measurements for particular cases are, in themselves, of value for policy formulation. Thus, FRA/TSC has undertaken a program of fuel consumption measurement for several types of service. To have meaning and credibility, this endeavor must be carried out within the framework of revenue operations of cooperating railroads.

During the past year measurements were collected from a typical branch-line operation, and arrangements were initiated or

Figure 1. Research technician from the Transportation Systems Center records fueling of a diesel-electric locomotive during the conduct of fuel consumption measurements of various train operations.

completed for collection of data from several railroads on other types of operations. The data to be collected ranges from highly detailed (measured car weight, fuel and speed every 10 miles (16 km), etc.) to gross values (total fuels, estimated weight).

The current emphasis in the measurement program is on trailer-on-flatcar/container-on-flatcar (TOFC/COFC) operations—a class of service for which the uncertainty is particularly great and accurate data are necessary for the analysis and systems engineering essential to developing an efficient and practical intermodal transportation system. This type of operation will be examined on at least four railroads. Fuel consumption data are also being gathered for unit coal trains and general freight. It is anticipated that the final results of this research will lead to new operating techniques and optimum performing equipment for use by railroads.

Railroad Noise Abatement Research

As part of its responsibilities under the Noise Control Act of 1972 (PL 92-574), the Office of Noise Abatement, U.S. Department of Transportation, requested the support of FRA/OR&D, TSC, and AAR in developing a comprehensive research program on railroad noise. This work augments research undertaken by the railroads on noise in railroad operations. The initial cooperative effort currently under way is directed at identifying the sources of noise on a typical line-haul diesel-electric locomotive.

With the cooperation of AAR and the Burlington-Northern (B-N) Railroad, an SD-40 locomotive was selected for the tests and B-N facilities were made available to an acoustic consultant firm to perform the noise study. Moving and stationary measurements have been conducted, data reduction and analysis are currently under way, and a final report was scheduled for completion in November 1975. The results of this program will be coordinated closely with research under way to evaluate a muffler installed on the same locomotive used in the source identification research.

Another significant source of noise in the railroad environment is the hump track in classification yards, where car retarders are used to control the speed of free-rolling cars during the classification process. When the retarders are applied to the car wheels in a clamping fashion, a loud squeal is created which is audible quite some distance from the yard. The actuating mechanism of the

Figure 2. SD-40 locomotive used to identify noise source components. Microphone can be seen in foreground. Also noticeable is acoustical tape around engine compartment doors and specially fabricated box housing used to isolate engine air intake noise.

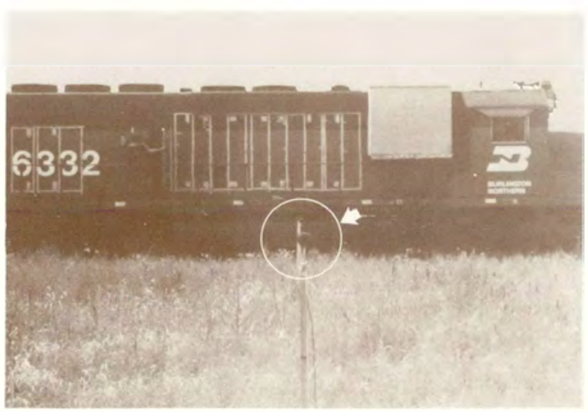


Figure 3. View of Burlington Northern's Northtown Yard at Fridley, Minn. In the foreground can be seen acoustic barriers used to attenuate the noise generated by the master retarders when controlling railcar rolling speed. Project is to evaluate the effectiveness of different acoustic barriers.

retarder also creates an irritating noise. Besides disturbing nearby communities, the noise associated with retarder operation creates an unsafe environment for railroad operating personnel in the vicinity. It can mask both control communications and the sound of an approaching car and adversely affect the health of the employees. A joint investigation is now under way to find an effective way to minimize the perceived sound generated by master and group retarders in hump classification yards.

These noise source investigations are expected to result in recommendations on how to control the sources of noise more effectively.

Classification Yard Technology Assessment

One of the major factors affecting the speed and reliability of rail freight service is the enroute classification of freight cars to make up trains for onward destinations. This has long been recognized as a costly but necessary operation. An assessment of classification yard technology is necessary to help determine existing and anticipated needs for technology development, especially that which will be required to meet future operational demands. This study, initiated this past year, is to be of sufficient depth to delineate clearly the research areas which most warrant Federal R&D support of the rail industry and the specific benefits that can be expected. This effort will include a comprehensive review of existing yard technology with a characterization of present-day performance and direct/indirect costs. It will also include an assessment of the impact of various railroad operating policies and practices. A data base on classification yards will be established in order to evaluate expected benefits and overall system impacts associated with alternatives for improving classification yards. This effort will provide a solid framework on which to formulate and assess R&D needs.

Initial activities have focused on the collection of all currently available data concerning the U.S. yard population, development of categorization criteria, and the preliminary assessment of yard operations and technology. Information has been gathered from United States Railway Association (USRA) studies and data, Interstate Commerce Commission (ICC) listings, a 1960 Department of Defense (DOD) yard census, and interviews with regional directors of the FRA Office of Safety. To complete the data base a questionnaire will be used to survey railroads on their classification yards.

Other activities now in progress include consideration of the effects of railroad network operations on yard activities and assessment of the impact of various technological features of yards.

Information developed from this assessment will be available to both government and industry. This information will assist in planning for the future needs of classification yards in both technology development and new or modified operating policies and practices.

Freight Car Management and Control in Yards

A major component of freight car management and control systems is the Automatic Car Identification (ACI) system which provides real-time information so that timely management and operating decisions can be made. ACI can be considered as the front end of the information system used to identify and control cars. However, there has been considerable criticism of the performance of the optical ACI system since its adoption by U.S. railroads. At the request of the Association of American Railroads (AAR), FRA, through TSC, sponsored laboratory research to provide technical support to the AAR Ad Hoc Technical Task Force for ACI Improvement.

The investigations in the TSC laboratory provided quantitative measurements of the readability of different ACI labels ranging from extremely dirty to brand new. This work also included the measurement of electronic signal strength and characteristics of ACI scanners supplied by two different manufacturers while scanning all categories of labels.

In May 1975, because of readability problems being experienced in the industry, the AAR Operating-Transportation General Committee requested that the AAR Research and Test Department report all supporting data, both technical and economic, to the commit-

Figure 4. Test site (Proviso Yard, East-Chicago) used to evaluate potential improvements that can be made to increase the readability of optical automatic car identification (ACI) labels. One conventional scanner (left background) was compared to two improved scanners (foreground) from each of the two scanner suppliers. Data collection equipment was housed in trailer and motor van.

tee at its November 1975 meeting so that a decision could be made relative to continuing optical ACI as the industry standard. In view of these new developments, the laboratory effort described previously was held in abeyance, and FRA proposed to the industry an expeditious ACI field test to confirm preliminary laboratory findings. This field test was endorsed as a cooperative AAR/RPI/FRA effort to demonstrate the ACI system capability and determine the potential readability limit of the system.

Both standard and modified ACI systems were used in this test, with the modified systems including improvements suggested in the laboratory research findings. This test has been completed and its objective achieved—establishing system performance and determining readability limits of the system. The test results, which were reported to the industry, are expected to provide railroad management with the data required to make a decision regarding the future of the optical ACI system. Pending the industry decision, FRA stands ready to assist in improving the optical ACI system or, if warranted, to participate in the development of a second-generation ACI system.

Truck Design Optimization Project

The freight car suspension system, or truck, has been around in its present form for several decades. It has long been recognized as a contributor to derailments, lading loss and damage claims, and railroad operating and maintenance costs for both rolling stock and track. In recent years, greater demands for performance, both in speed and freight capacity, have been placed upon the system and, consequently, associated costs have increased. Many stop-gap measures have been introduced over the years to combat new problems which arose, such as "harmonic roll" (car rock and roll), and "hunting" (truck fishtailing motion). Although the industry has established standards for the various components of freight car trucks, these standards apply mainly to interchangeability of parts for maintenance purposes rather than to the performance of the system. This is not meant to imply that nothing has been done to improve performance. However, most new hardware developments have been directed to specific components designed to solve a particular problem rather than to improvement of the total system's performance.

Figure 5. Two ACI test scanners reading ACI label on passing freight car. Five thousand cars passed the test site during the evaluation.

Recognizing the need to develop performance and testing specifications for freight car trucks (as a system), FRA initiated the Truck Design Optimization Project (TDOP) in July 1974 as its first major research effort in the area of equipment performance analysis. This multiyear applied research project is designed to: (1) define thoroughly the performance of existing freight car trucks, (2) depict potential improvements in present-day truck suspension systems, and (3) stimulate economically feasible modifications and new designs which will result in improved performance of trucks in the future. FRA's sponsorship of this comprehensive program makes it possible to obtain results more rapidly and at less cost than if individual railroads were to attempt such research with their limited resources and insures availability of results to the entire industry.

To insure industry-wide acceptance of the research results, FRA has provided for industry involvement by directing the prime contractor (Southern Pacific Transportation Co.) to utilize expertise from railroads and equipment suppliers. Phase I, about two-thirds of which has been completed, has produced mathematical models and initial performance characteristics for the conventional three-piece truck. The test trucks used in this study were instrumented with various standard components and adjustments and evaluated over a wide range of operating conditions in an effort to establish the dynamic range of performance experienced in present truck designs.

Preliminary conclusions derived from early Phase I efforts include:

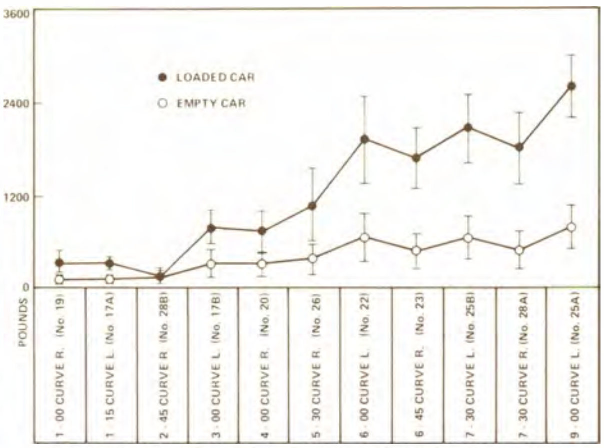
• Continuous welded rail afforded a more stable ride.

• By order of magnitude, the test car was more stable in the loaded configuration than in the empty.

• Nominal gib (lateral movement stops on bolster) clearance produced a more stable ride than a closer clearance.

• More side bearing clearance is necessary on jointed rail, regardless of load configuration, than on welded rail to provide the more stable ride.

Mathematical models developed during this phase are being used in conjunction with field tests to determine the extent to which performance may be improved by varying the physical characteristics of the springs and side bearings or by adding accessory damping devices. The end product of the Phase I research will be a General Purpose Truck Performance and Testing Specification for industry use in evaluating modified or new design trucks. These specifications will be reviewed periodically, and suppliers will be encouraged to take full advantage of technological advances as they occur.



Total Axle Lateral Force - Over Equilibrium Speed Over Various Curves
L&N Hopper Car, Class H-100-30, ASF Ride Control Truck

Figure 6. Example of data presentation, computer derived and plotted in engineering units, from the Truck Design Optimization Project.

Advanced Braking Concepts

The basic concept on which modern freight train braking systems are based was first introduced to practice a century ago. Since that time, these systems have been refined and developed to provide what has been considered effective and reliable performance. However, experience in recent years involving ever-increasing demands on braking systems indicates that improved performance would offer major benefits.

The standard air brake uses a single pressurized air line to charge reservoirs on each car and to actuate and release brake applications by means of changes in brake line pressure. Several disadvantages are inherent in this concept. Once applied, braking can only be released completely or increased, not moderated. Accidental braking can occur, as can unintended release, and only a limited number of successive applications can be made without recharging the system. Since brakes can be actuated only sequentially, cars further back from the locomotive are braked later, contributing to long stopping distances and severe forces and shocks between cars at various points in the train. Other operating problems include delays in charging and inspection of trains prior to departure from terminals, difficulty in charging the system in cold weather, and wheel wear and thermal cracking resulting from the large quantities of energy dissipated during hard braking.

In response to this clearly defined problem, FRA is, with the support of TSC, examining the possibility of achieving a major advance through development of an alternative concept or modified system concept. As an initial step a study was initiated in late FY 75 for an evaluation of advanced freight train braking concepts measured against existing technology. The major tasks include: (1) characterizing performance and direct and indirect costs of conventional systems, (2) conducting a survey and engineering/economic analysis of improved and alternative technologies and concepts in order to provide a baseline, and (3) making recommendations for further R&D activity, if required.

Automatic Coupling Concepts

The basic automatic coupler in use in North America was invented in 1873 and first adopted as a standard in 1888. The version now in use became standard in 1934. Although this coupler does couple automatically under most circumstances, uncoupling must be performed manually by an operator on the ground while the coupling is not in draft (or tension stretched). And while the train's air brakeline pulls free if stretched, detaching automatically, the same air brake line requires manual coupling when making up a train. Thus, the process of assembling cars into trains and breaking them down in rail yards involves substantial human effort, with concomitant costs and associated physical hazard to crew members.

The need for increased operational efficiency and safety led in 1968 to the formation by FRA and AAR of the Joint Study Group on Advanced Coupler Concepts. The resulting program contains both economic and technical elements. AAR is currently sponsoring a major study of economic benefits which could derive from functional changes. In coordination with the AAR effort, FRA is now conducting a review and engineering analysis of alternative coupling concepts. This technology assessment, being carried out through a TSC contract, includes: (1) a thorough survey of existing concepts, (2) an examination of sufficient detail to permit meaningful estimation of performance characteristics and costs of promising new approaches, and (3) recommendations for further research activities as warranted. This effort is being coordinated closely with the AAR Advanced Coupling Concepts Steering Committee.

Intermodal Freight Systems Technology

The Intermodal Freight Systems Technology R&D efforts over the past year have concentrated on establishing the supporting technology which is a prerequisite to systems engineering for developing a more efficient rail-based intermodal system in the United States.

Working in close coordination with the economic research efforts of FRA, the Office of Freight Systems Research and Development has continued research and planning for a major systems engineering effort which will define, establish as technically feasible through testing and evaluation, and demonstrate the economic feasibility of the technological improvements that could be made to the components of the present-day intermodal system. This work draws heavily upon the FRA-sponsored National Intermodal Network Feasibility Study and other supporting technology efforts already under way, including the fuel consumption and equipment performance analyses discussed elsewhere in this report.

Another cooperative industry-government project which is moving toward implementation involves operational testing and evaluation of two existing lightweight TOFC and COFC cars and comparison of their performance with that of a heavier and more conventional TOFC/COFC car. Cooperating supporters of this project include two freight car truck manufacturers, a car builder, a car leasing company, and a railroad company, all of which are working with FRA, TSC, and the FRA contractor to develop a test plan and furnish the required equipment and services

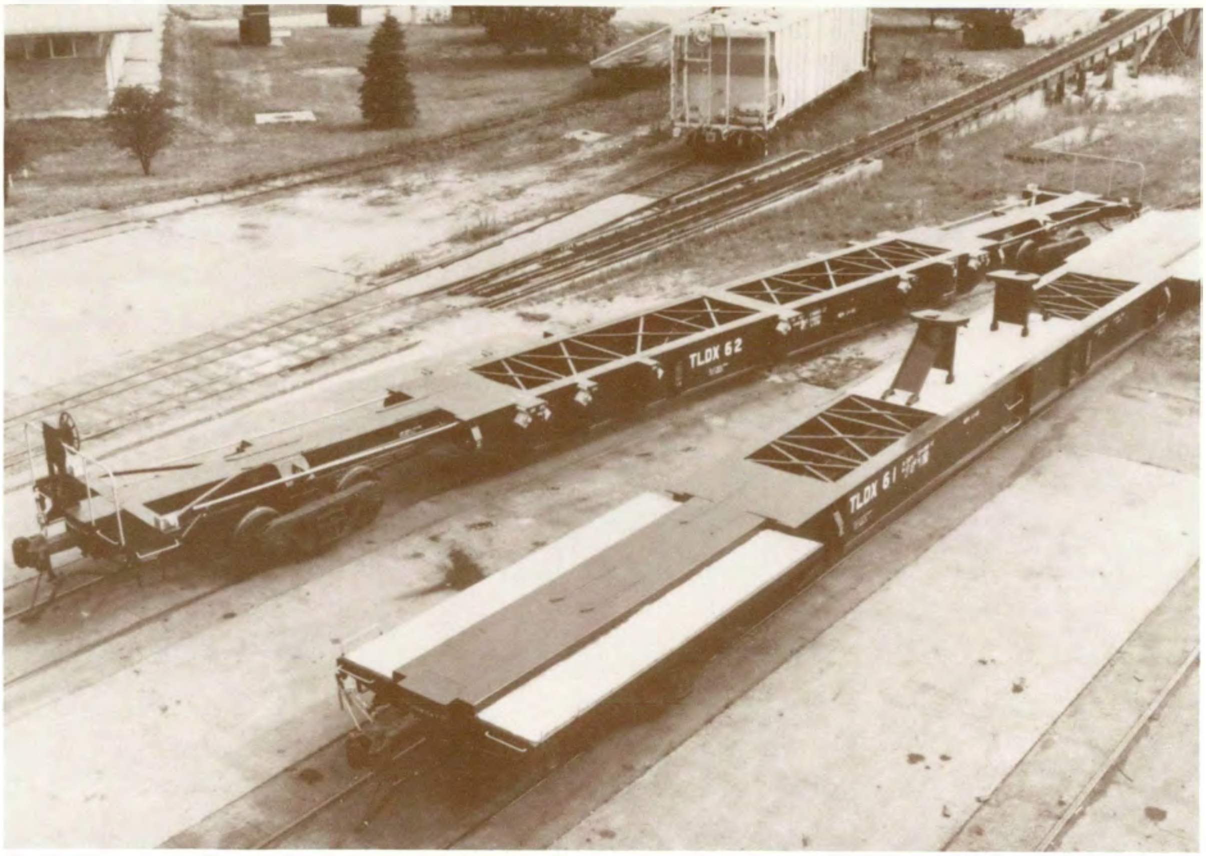
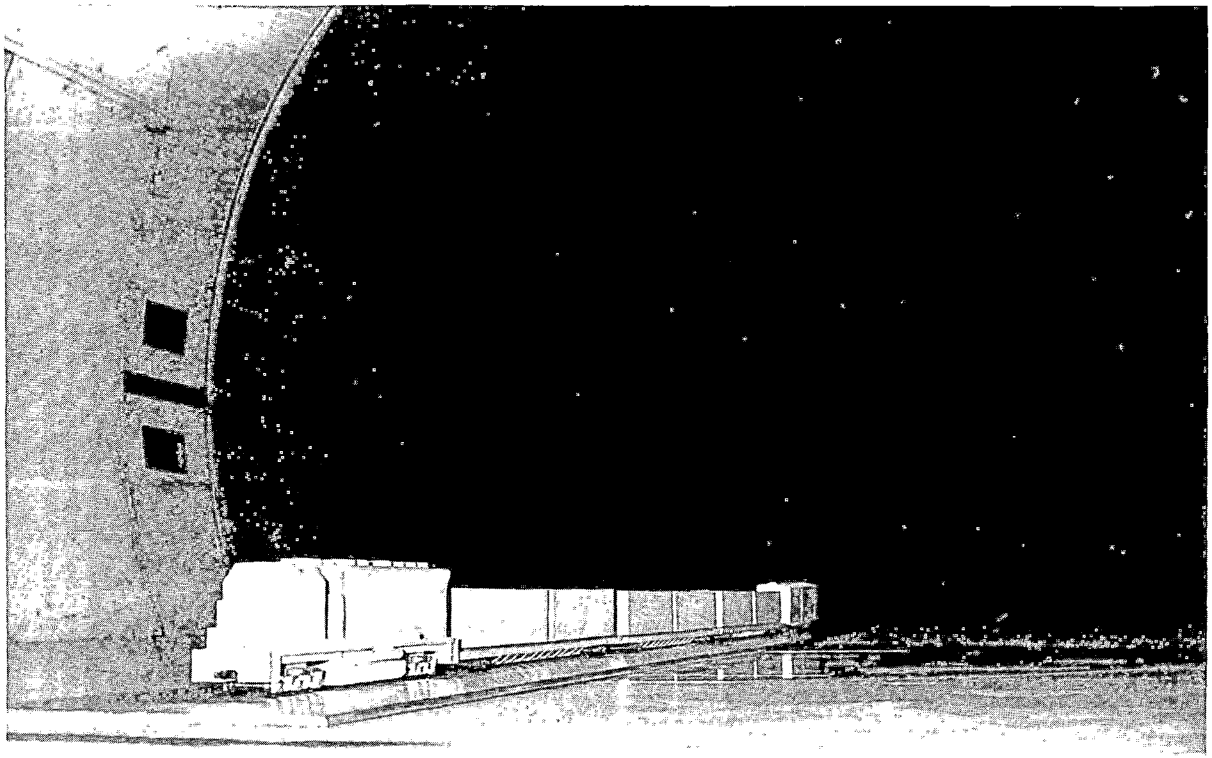


Figure 7. Lightweight flatcars to be operated in revenue service in order to evaluate dynamic performance and maintenance characteristics. Using two different types of trucks during 150,000 miles of operation a container car (TLDX 62) and a piggyback car (TLDX 61) will be studied to determine performance as compared with a conventional all-purpose flatcar.

necessary to conduct the research. Each participating company has agreed to accept those expenses associated directly with its respective degree of participation in the project. The results of this research are expected to indicate the feasibility and economic worth of lighter-weight car construction as well as the relative merit of two different categories of suspension systems.

During the past year FRA initiated an investigation into the aerodynamic drag characteristics of intermodal equipment when it was found that only limited information was available concerning the role this factor plays in total train resistance. The relatively unstreamlined shape of a flatcar carrying trailers suggests high aerodynamic drag, and past empirical measurements have tended to verify this. In order to quantify this characteristic in a meaningful way and to establish a methodology for considering possible design improvements, FRA, again through TSC, began a program of analysis involving the use of scale models in a wind tunnel. As a result of a contract effort, a critical literature search has been conducted and an experimental design established. Wind tunnel tests were scheduled to begin in November 1975.

These wind tunnel tests will measure the effects on drag of many variables, including: (1) trailers versus containers, (2) open space between cars and containers, (3) simple streamlining, (4) various flatcar configurations, and (5) the effect of open load spaces on a car. Testing will be done with a model train consisting of a locomotive, three flatcars, and a caboose. The size of the consist being used is restricted by the wind tunnel dimensions. Following the wind tunnel tests, full-scale validations of the analytical findings will be undertaken.



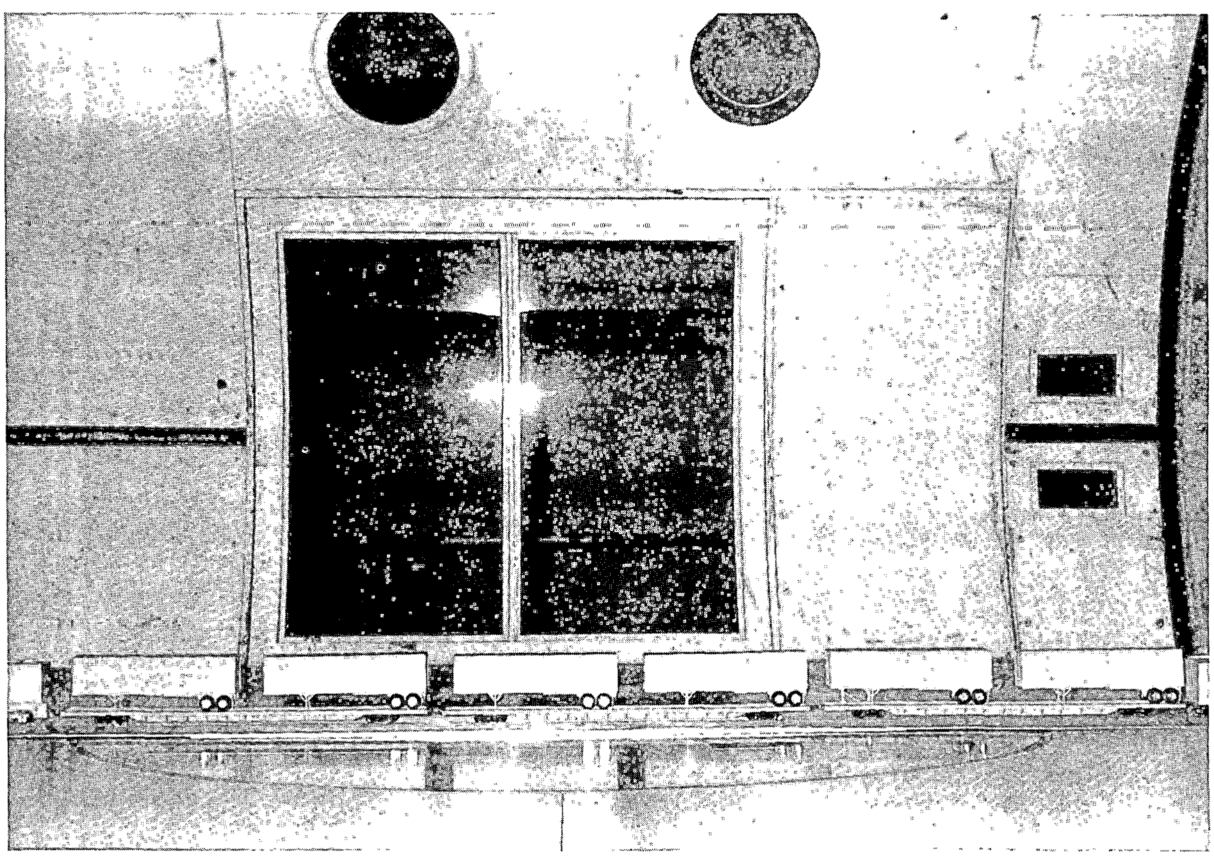


Figure 8. Top left; View of 1:43 scale model container (COFC) train in 10-foot subsonic wind tunnel at the California Institute of Technology, Pasadena, Calif. used to determine the aerodynamic drag characteristics of intermodal equipment.

Figure 9. Bottom left; Side view of a trailer-on-flat-car (TOFC) train during wind tunnel testing at Cal Tech, Pasadena, Calif. Various combinations of loading and equipment configurations were studied. Shown here are three conventional Trailer Train flatcars loaded with four standard smooth-side trailers and two outside vertical post trailers. Data was collected on the drag experienced by the center car of the train consist (makeup) with relative wind attack angles up to 30 degrees from the train's centerline.

The supporting technology investigations mentioned will all carry over into next year and will support the initiation of a comprehensive systems engineering effort designed to increase the efficiency of the nation's total intermodal system.

The purpose of this new effort is to develop the systems engineering which will: (1) define the technological problems involved, (2) formulate concepts to resolve those problems, (3) develop performance specifications for the implementation of solutions, and (4) provide for their test, evaluation, and demonstration over two adjoining line-haul segments of a theoretical national rail intermodal network with the potential for as many as 130 terminal locations. The work involved will encompass the determination of specific improvement requirements for efficient intermodal terminal configurations (both gateway and intermediate) under varying traffic demand situations and for intermodal equipment, including highway vehicles, rail rolling stock, container transfer handling, and propulsion and control systems. In future years this program will include testing, evaluation, and demonstration of the products evolving as a result of the systems-engineered approach.

Railroad Vehicle Dynamic Analysis and Evaluation

The efficient use of the R&D resources of FRA and the industry requires a balance of R&D tools. These tools include mathematical models, component tests, simulation tests, and full-scale tests under actual operating conditions. These R&D techniques are particularly appropriate for the dynamic analysis and evaluation of freight cars, subsystems, and components. Hence, the goal of this program area—the development of comprehensive mathematical models and test facilities that are easily utilized at a low cost.

Scientists and engineers in government and industry have long recognized this R&D approach and the appropriate use of models, computers, component tests, etc. To date, however, most of the mathematical models, characterization tests, validations, and experiments have been project- or problem-oriented, involving, for example, a model of a freight car truck or particular track infrastructure. Assumptions made for the parameters seemingly are outside the sphere of interest, i.e., track inputs for a track model or wheel loads on a track model. A review of the literature will reveal a considerable number of models available for specific problems with specific outputs that, generally, cannot be applied to other similar problems. More specifically, the models and tests do not address the function of wheel-rail dynamics or the wheel-rail interface which is the most critical interface in determining vehicle or track design or maintenance criteria.

Therefore, the objective of this program area is to conduct the dynamic analysis and evaluation of freight cars, systems, components, and track infrastructure and to bring about the development of a complete set of analytical and test tools for use by government and industry researchers. (Prior to this report period, FRA had not designated a program area to address this specific functional area; thus, models and tests were developed within each of the other program areas in OR&D.) Program output ultimately will be utilized by equipment manufacturers, car builders, and track designers. The major accomplishments of the analysis and evaluation program in 1975 are described below.

Trailer-on-Flatcar (TOFC) Evaluation

In cooperation with the Trailer Train Company and the Trailmobile Division of Pullman Standard, FRA initiated a program in the Rail

Dynamics Laboratory (RDL) designed to examine and improve the environment of typical goods (canned goods) currently shipped by rail in the TOFC configuration. The test began with a short series of over-the-road runs to determine the maximum vertical deflections experienced by lading in the trailers and how the lading responded. This data base was used to establish the level of input to be generated by the RDL single-ended vertical shaker, an analytical laboratory tool, and to validate mathematical models of the TOFC system being developed in conjunction with the test program.

Numerous variations of the baseline TOFC configuration were selected for testing. Configurations represented typical changes in loading freight car truck suspension components, trailer position and tire pressure, and trailer tandem axle location. The number of variations doubled when a second freight car truck of different manufacture was added to the test schedule. A test of this magnitude would be extremely cumbersome, costly, and time consuming if conducted on revenue track, but so far it has been accomplished with ease in the laboratory environment.

The ultimate goal of this initial program is to select from laboratory test results the TOFC configuration which imparts the best ride quality to the lading under examination and to validate these results with a series of over-the-road tests using only the optimized configuration. The impact of this program is threefold—it demonstrates that: (1) a laboratory tool is a viable method for investigating dynamic environment at reduced testing costs, within reasonable time frames, and with minimal over-the-road runs, (2) optimum configurations for different ladings can be selected in this manner, which may encourage the return to rail of manufactured commodities as improved suspension systems are developed under this or other FRA programs, and (3) direct comparison can be made of TOFC and COFC ride-quality charactertistics, thereby resolving some of the questions in the intermodal area with respect to the most efficient methods for transporting goods.

Track Train Dynamics Program

Perhaps one of the most significant programs to reach completion in 1975 was Phase I of the Track Train Dynamics (TTD) Program, a cooperative research effort being conducted by AAR, FRA, the Railway Progress Institute (RPI), and the Transportation Development Agency (TDA) of the Canadian Ministry of Transport. With the exception of two programs which require extensive field testing for validation purposes, all established goals of Phase I have been attained. Nine computer programs for the simulation of vehicle and/or train behavior have been developed. The major emphasis of these computer programs is on long train dynamics, particularly on predicting coupler loads, train action, and coupler-induced lateral loads on track. The Train Operations Simulator (TOS), which is a model and not a test facility, has been accepted widely throughout the industry and, through educational seminars conducted by AAR, has paved the way for the use of more sophisticated analytical tools developed under this program.

The TOS requires such inputs as grades, curvatures, milepost locations, station names, speed restrictions, train length, remote placement number and type, initial brake pipe pressure, and throttle and brake manipulations. The outputs derived are the speed-distance-time relationship for the train, coupler forces, and a rough calculation of the lateral/vertical force ratio. The TOS is being utilized extensively in the TTD research program to develop guidelines for train handling and make-up and has been used by the railroads in investigating the operation of new types of trains, in the placement of remote units, in accident investigations, and in braking performance studies. Railroads can use these computer simulations to draw their own conclusions concerning train handling techniques in a wide variety of situations.

Department of Defense Railcars

Another program in the dynamic analysis and evaluation area involved the first interdepartmental (Department of Defense and Department of Transportation) project to be conducted at the Transportation Test Center. FRA provided the support necessary to test 12 railcars used to transport spent nuclear fuel elements. It is imperative that these railcars exhibit minimal dynamic response to even the most severe track conditions. Tests were conducted in accordance with AAR specifications and in cooperation with a firm of technical consultants. This joint effort resulted in the stabilization of the vehicles through track suspension modifications to within the required limits for car body roll and wheel lift.

In FY 76 FRA will continue efforts to complete the programs initiated in FY 75 and to prepare a plan to develop a functional set of models and test capabilities that address freight car and track dynamic design criteria.

2.2 RAIL DYNAMICS LABORATORY

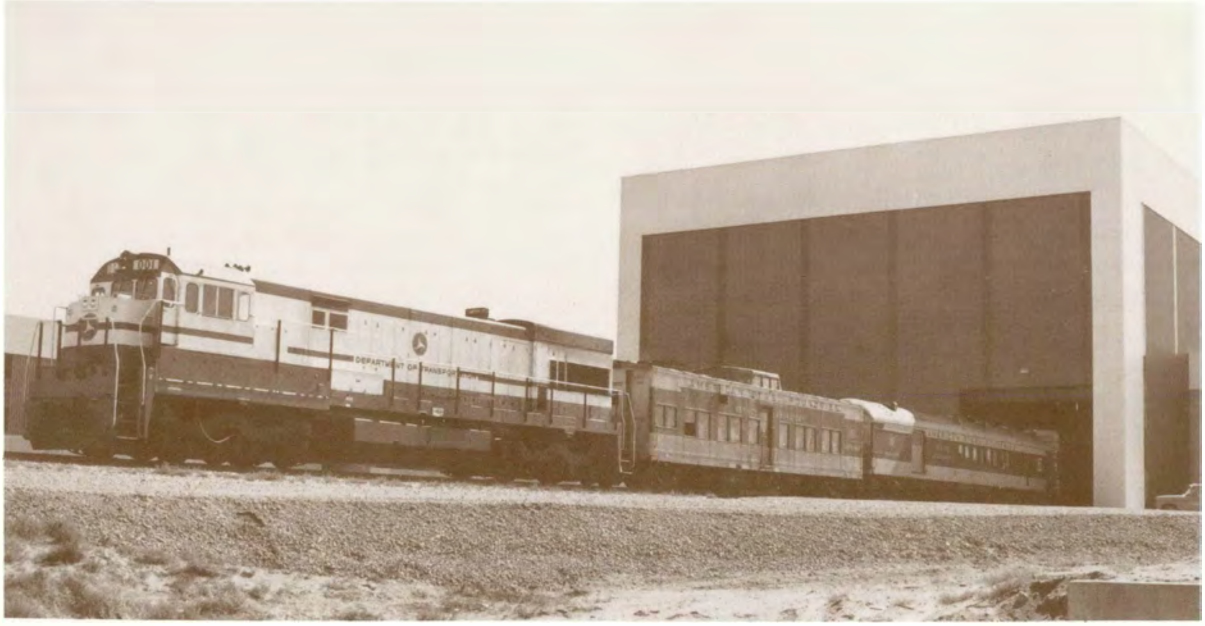
The railroad and transit industries have encountered dynamic operating problems with most, if not all, of their vehicles. These problems have, in many cases, led to accidents and derailments, damage to rail equipment and to goods being carried, increased vehicle and component maintenance cost due to excessive dynamic loads, and rough train rides for passengers.

Prior to the development of DOT's Transportation Test Center (TTC), no test facility was available in the United States to extensively evaluate and determine the solutions to dynamic operating problems. The Rail Dynamics Laboratory (RDL), a jointly funded (FRA and Urban Mass Transportation Administration) facility being completed at the test center, will provide the capability for subjecting a rail or transit vehicle to controlled conditions representative of actual in-service conditions. Using data obtained from these RDL investigations, the operational response of a vehicle in an actual situation can be predicted and, if unsatisfactory, corrective measures can be investigated and implemented. Through study of vehicle dynamics in the RDL, the number of dynamics-related accidents and derailments and their attendant costs should be reduced significantly.

Upon completion, the RDL will be used to support nearly all of FRA's hardware development programs and particularly the Dynamic Analysis and Evaluation, Improved Passenger Service, and Rolling Stock programs. Ultimate users of the RDL facility will be: FRA's Office of Safety for regulation; operating railroads; the National Transportation Safety Board; FRA's Office of Northeast Corridor Development for testing and evaluation; Amtrak; the railroad supply industry; AAR/RPI; and foreign transportation agencies.

The RDL building (figure), accepted in April 1974, is a modern steel and reinforced-concrete structure approximately 350 feet (107 m) long and 150 feet (46 m) wide. A building floor plan is shown in figure . Plans called for all support equipment and serv-

Figure 10. RDL Building.



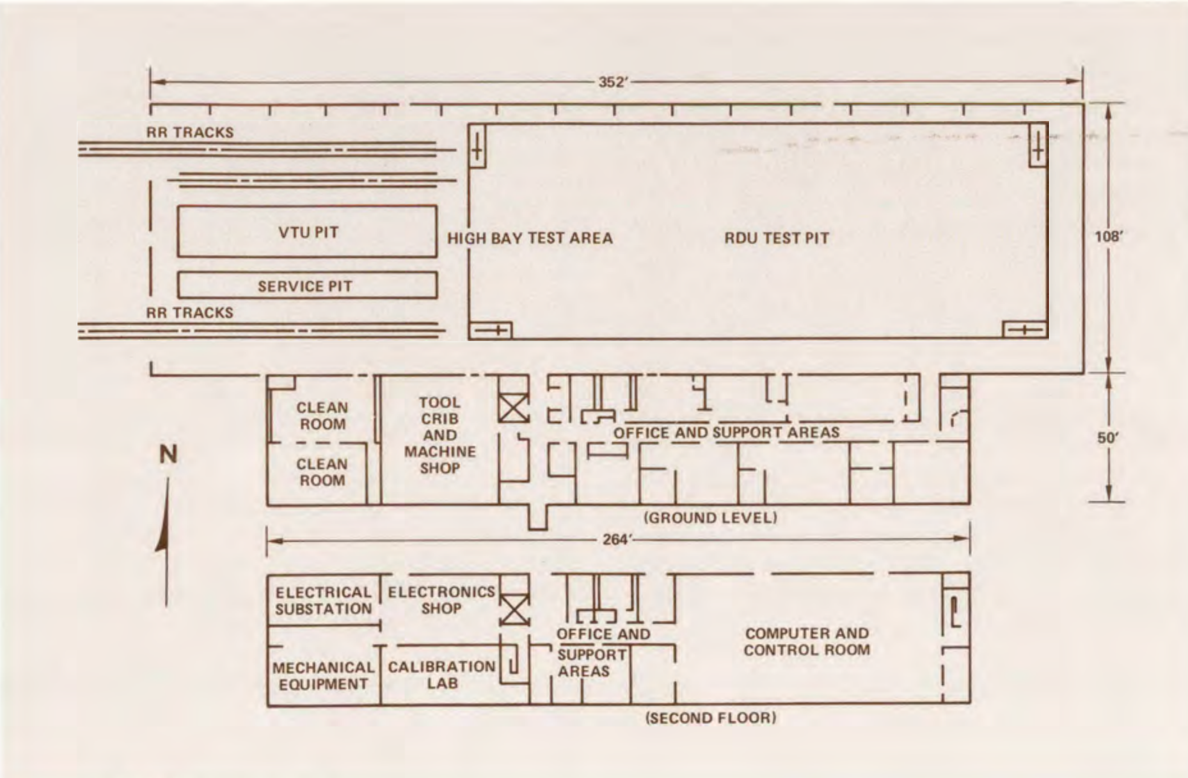


Figure 11. RDL Building Floor Plan.

ice areas, including the one-ended vertical shaker, to be housed in the high bay portion of the building and for the primary testing area to be located within the low bay portion containing the Rail Dynamics Simulator (RDS). The RDS was to be comprised of the following subsystems:

• Drive train, which provides rotation to the track module rollers;

• Track module, which simulates the tracks on which the test vehicle rests and has the capability to simulate vertical and lateral irregularities;

• Carriage assembly, which acts as the support and reaction structure for the track module;

• Instrumentation and control subsystem (ADAČS)

• Computer subsystem (ICSN)

• Communication system

A separate contractor was involved with each subsystem. During the development of some of the RDS subsystems, unforeseen technical problems arose which resulted in severe schedule delays of great concern to DOT.

In mid-1975, after the RDL program had continued to encounter R&D development and management problems, a DOT task force review resulted in the redirection of the RDL program so that it could be completed in a timely manner, relatively free of technical risk, and with minimum cost. The redirected program now has one prime contractor, instead of several major contractors. The RDS has been replaced by the Vibration Test Unit (VTU), which provides vertical and lateral vehicle excitation representative of the inservice environment, and the Roll Dynamics Unit (RDU), which simulates continuous "perfect" track for truck hunting, braking, and acceleration tests. The RDS formerly combined both vibration and roll in one simulator.

A vertical shaker (figure) located in the high bay test area of the VTU pit is essen-

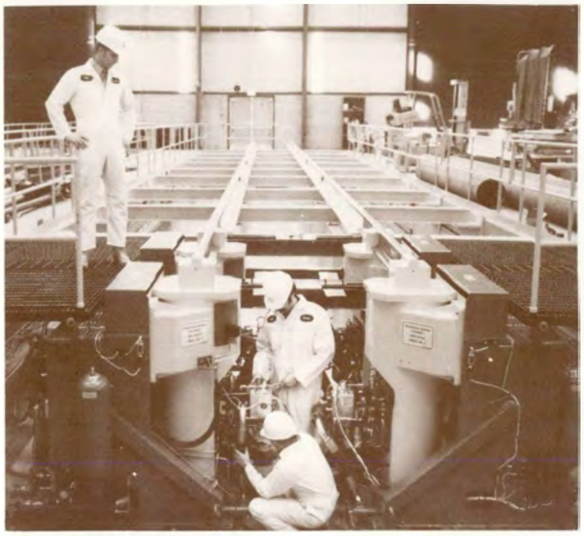


Figure 12. Vertical Shaker.

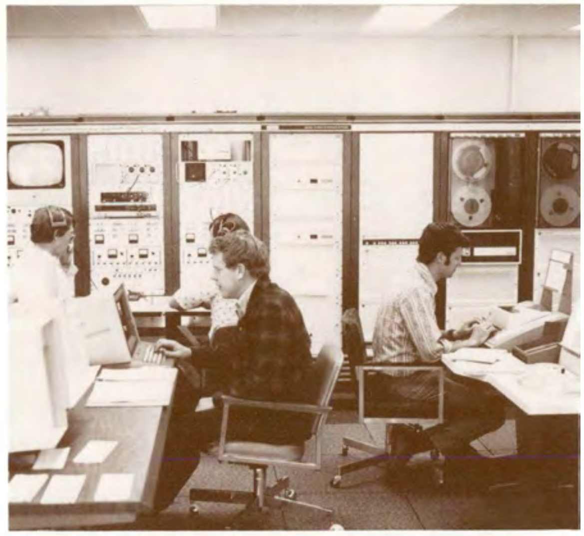
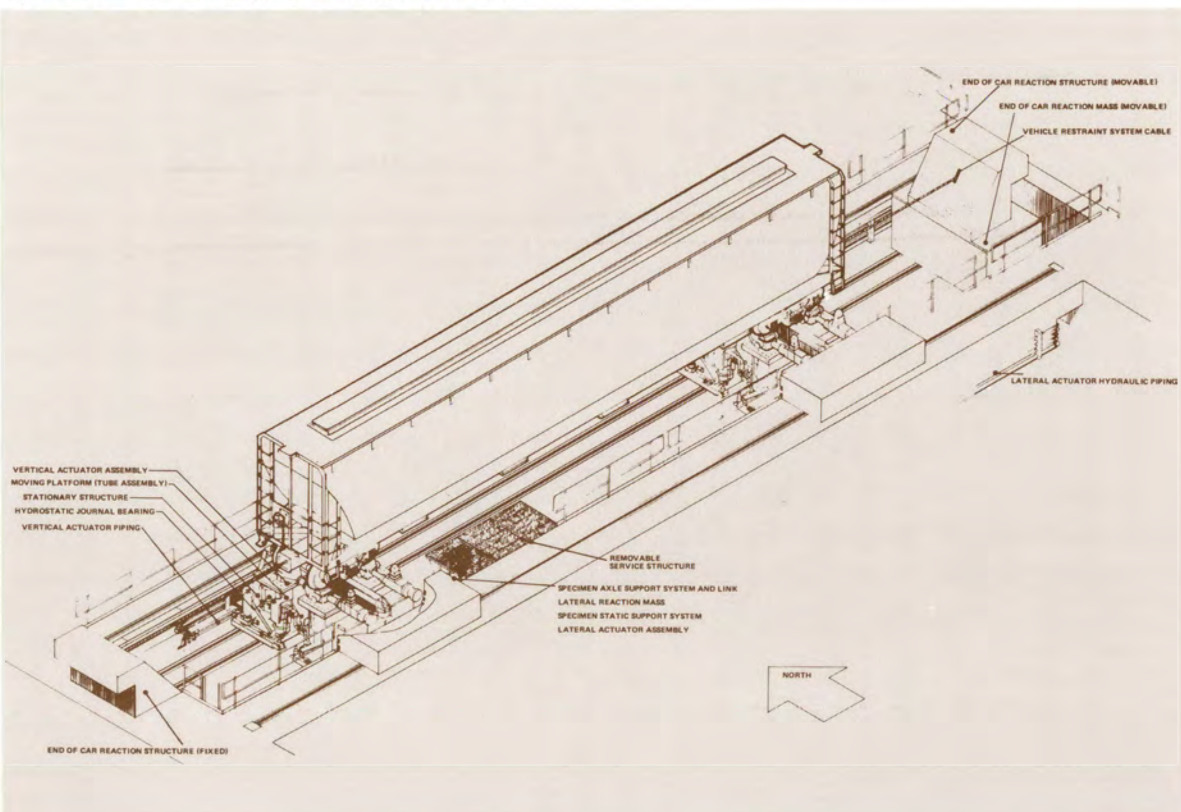


Figure 13. Vertical Shaker Computer and Test Controls.

tially operational for studying the responses of truck assemblies and total vehicles to vertically applied periodic and random excitation. The vertical shaker consists of four independently operated vertical actuators which can be placed under four wheels at one end of a test vehicle. Each actuator can accommodate wheel loads of up to 40,000 pounds (18,144 kg). The acceleration, frequency, and displacement of these actuators can be varied over a wide operating range to simulate operating environments of most

Figure 14. Artist Concept of Vibration Test Unit.



test specimens. Computer and test controls (figure) for the vertical shaker are located in the RDL control room.

The VTU consists of an upgraded vertical shaker. Schematically shown in figure , the VTU will be capable of subjecting both ends of a 320,000-pound (145,152 kg) rail vehicle with two two-axle trucks or one truck of a vehicle with a three- or four-axle truck to vertical and lateral vibrations which the vehicle would experience in traveling over track with representative profile and alignment variations.

The RDU, shown schematically in figure , will be capable of driving or absorbing power from both unpowered and powered rail vehicles weighing up to 200 tons. The rotation of the RDU rollers will simulate vehicle velocities on "perfect" tangent track. The RDU will also simulate conditions associated with steady-state curve negotiations of "perfect" track. ("Perfect" track is defined as track with no lateral or vertical irregularities.)

The subsystems which formerly supported the RDS will be modified for VTU and/or RDU operation. The status of these subsystems is as follows:

• The drive train will be connected to the roller module on the RDU. It consists of 600 hp (447.6 kw) D.C. motors, flywheels, power supplies, controls, and other components. This subsystem has been stored for more than a year in the RDU test pit at the TTC (figure) after successful in-plant tests.

• The hydraulic subsystem will be used to energize the lateral and vertical servo-hydraulic actuators on the VTU. Part of this subsystem has been delivered to the RDL building. This subsystem includes the RDL facility hydraulic power module (figure) which has been accepted by FRA and is currently being utilized in the vertical shaker system.

• The Integrated Computer Subsystem Network (ICSN) has been acquired by DOT and will be reconfigured to support the VTU and RDU configuration. The ICSN (figure) currently consists of five minicomputers and associated peripheral devices and is designed

Figure 15. Artist Concept of Roll Dynamics Unit.

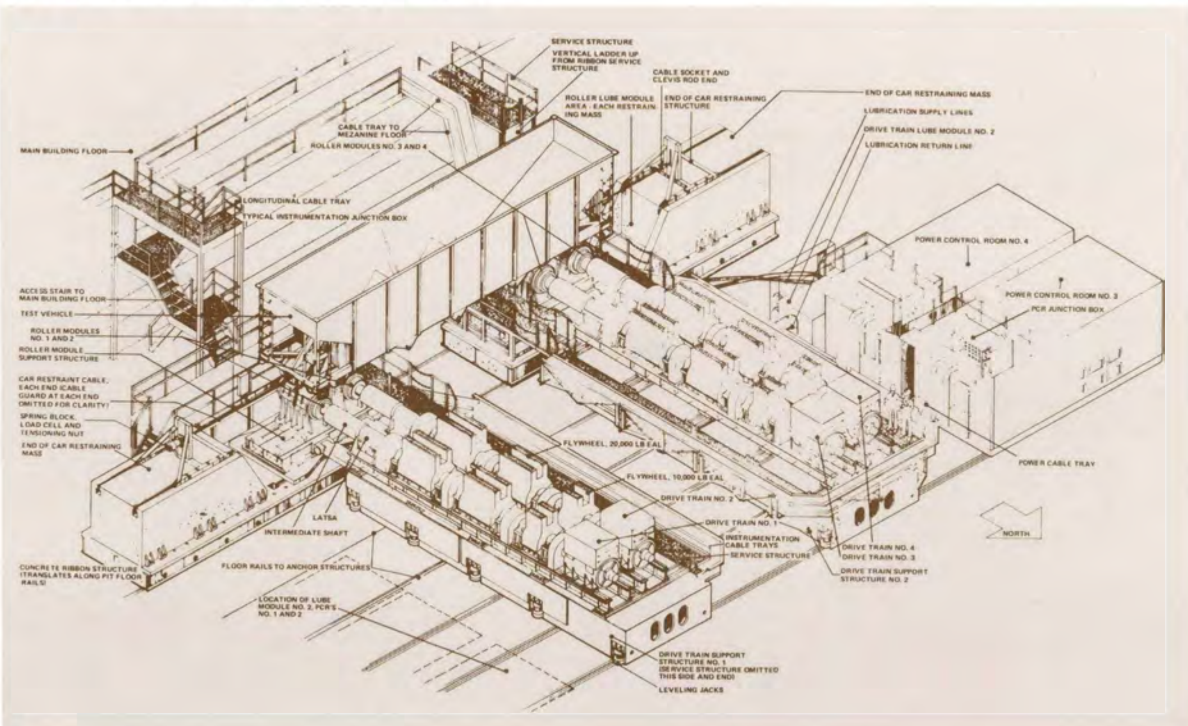


Figure 16. Drive Train Subsystem.

to excite, control, monitor, and acquire data from other parts of the RDU and VTU.

- The Analog Data Acquisition and Control Subsystem (ADACS) (figure) was accepted by DOT at TTC in April 1975 and will be reconfigured to support the VTU and RDU configuration. The ADACS provides analog data from laboratory equipment, including the vertical shaker.

The communication system has been procured and accepted by DOT. This subsystem is currently being utilized for vertical shaker operation and will also be used in VTU and RDU operations. The RDL test director communicates with the crew in the high bay test

Figure 17. RDL Facility Hydraulic Power Module.

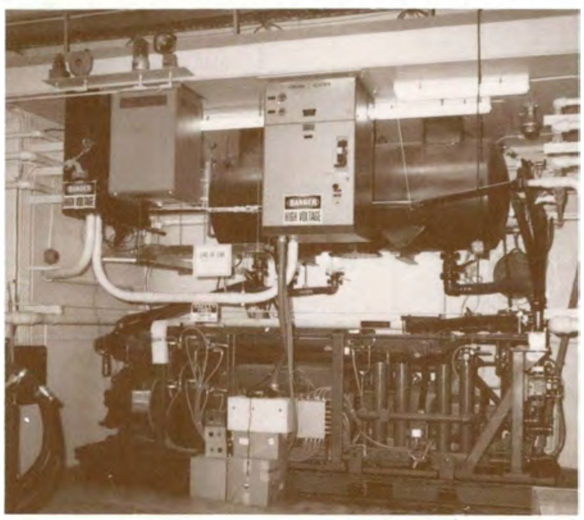
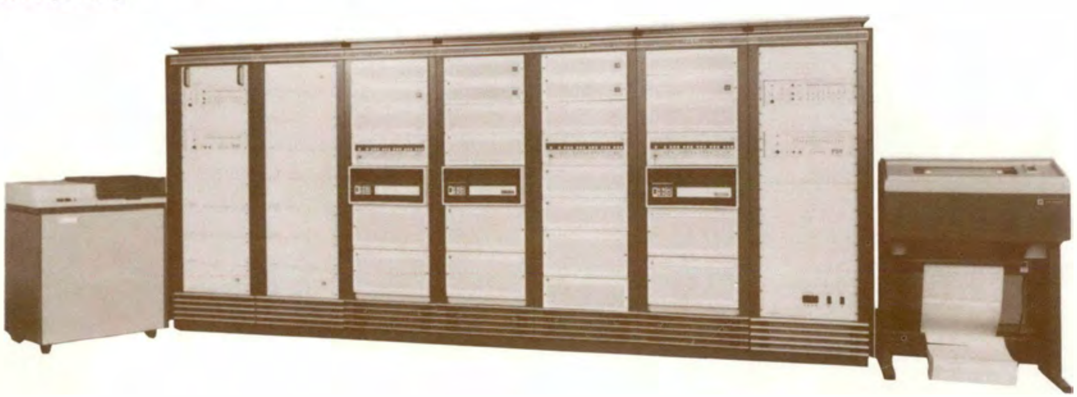


Figure 19. Analog Data Acquisition and Control Subsystem.

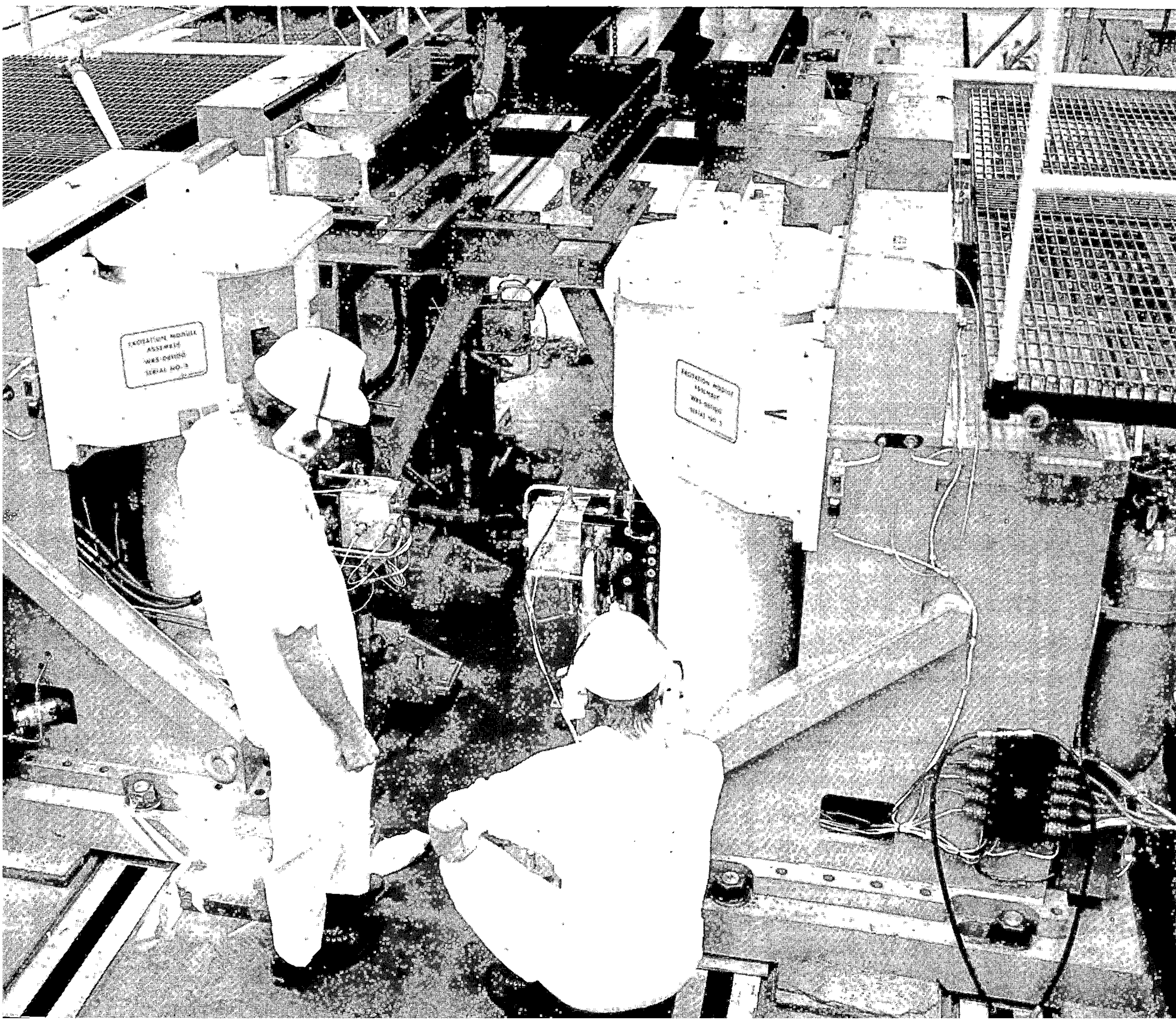
Figure 18. The Integrated Computer Subsystem Network (ICSN).

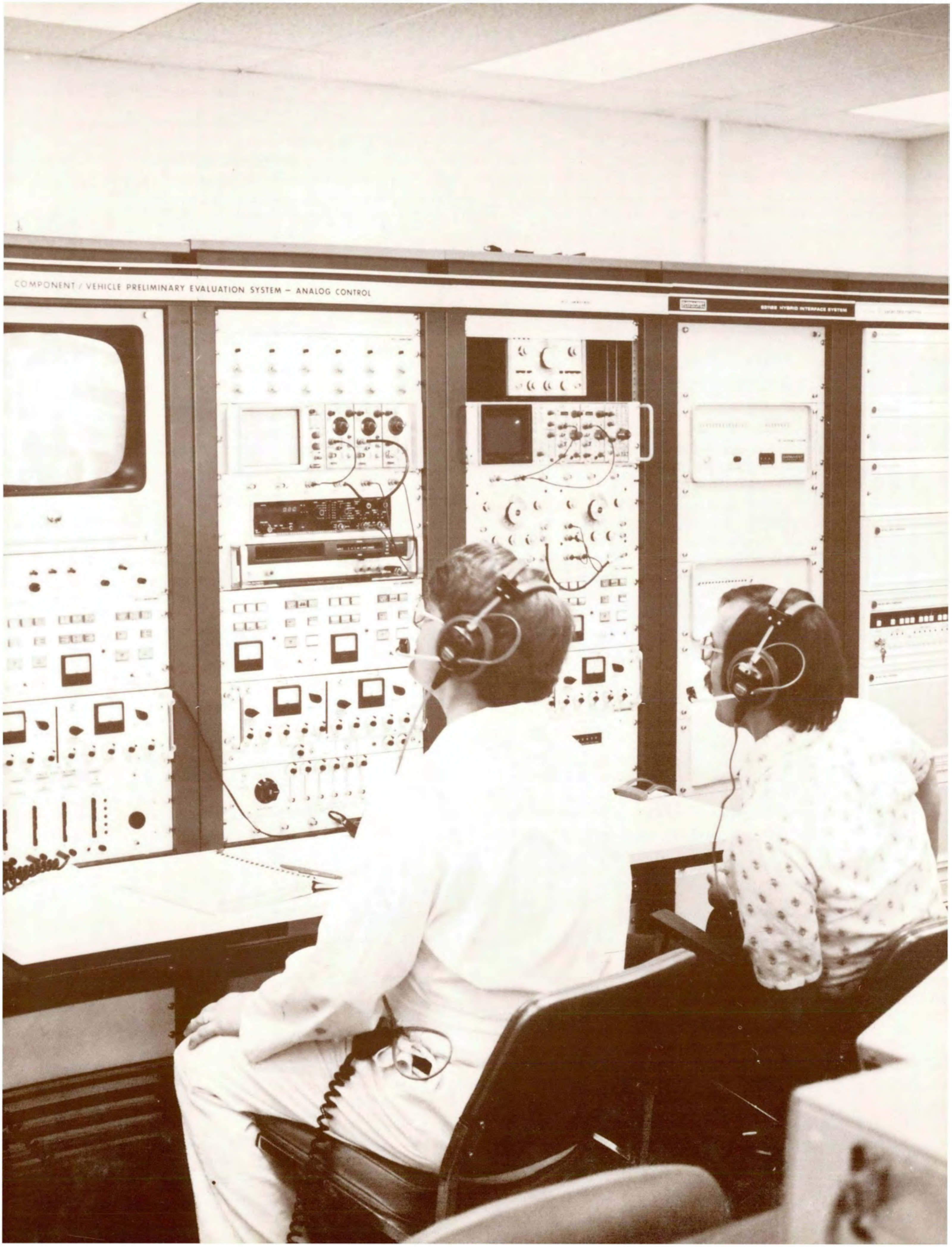


area and/or RDU test pit through a fixed communication station (figure). Crew members communicate with one another or with the test director through portable communication units installed in their hard hats (figure). These communication units are voice activated, require no hand operation, and are very efficient in a noisy environment. A skull bone-conduction microphone installed inside the helmet avoids safety hazards associated with an external unit suspended in front of the face. Earphone batteries are recharged when the hard hats are not in use.

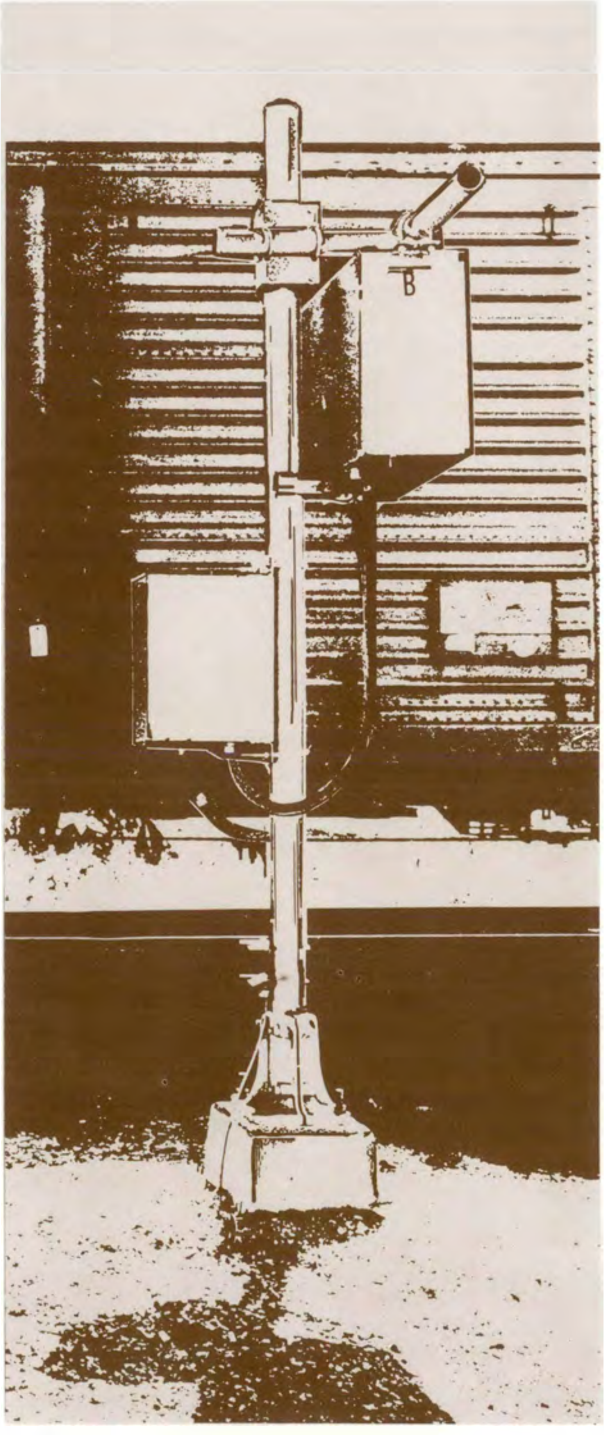
The first experiment on the vertical shaker will soon be completed on a TOFC integrated with various piggy-back trailers. The RDL (VTU and RDU) facility should be fully operational in FY 1977 once the engineering design, fabrication, installation, check-out, and acceptance tests are completed.

Figure 20. RDL Portable Communication Units Installed in Hard Hats.




COMPONENT / VEHICLE PRELIMINARY EVALUATION SYSTEM – ANALOG CONTROL
HYBRID INTERFACE SYSTEM

3.0 RAIL SAFETY R&D



3.1 SAFETY RESEARCH

FRA's Safety Research Program is concerned with making significant improvements in the following areas:

- Transport of hazardous material in tank cars;
- Rail vehicle occupant protection;
- Component failure prevention;
- Human factors in railroad operations;
- Grade crossing safety.

Improvements in these areas are expected to reduce the hazards associated with railroad operations and to result in more effective safety standards.

Hazardous Material Tank Cars

From 1971 through 1974, an average of 113 railroad accidents occurred each year which involved one or more tank cars carrying hazardous materials. Although this number is small compared with the total number of railroad accidents, a hazardous material tank car accident generally causes considerably more damage than does the usual railroad accident. On the average, there were 320 injuries, 3 deaths, and 12,217 persons evacuated annually during the period 1971–1974. Property damage from several of these tank car accidents has run as high as $10 million. R&D efforts are aimed at reducing the injuries, deaths, and property damage associated with hazardous material tank car accidents.

Extensive analytical and laboratory work was conducted prior to the reporting period to determine the effectiveness of thermal shields in reducing the severity of hazardous material tank car accidents. FRA, AAR, and RPI conducted field fire tests (both one-fifth scale and full scale) to verify the analytical and laboratory work. These tests demonstrated that thermal shields not only significantly extend the time to rupture (e.g., from 24 minutes to 94 minutes) but also reduce the violence of the rupture. A torch facility was constructed at TTC to test thermal shields by subjecting them to high-velocity, high-temperature jet flames. Tests conducted in the reporting period showed that there are a number of commercially available thermal coatings that can provide fire protection to tank cars even under torch-fire conditions.

Concern for protecting tank cars engulfed in flames prompted FRA to sponsor an analytical study prior to the reporting period which revealed that specifications for pressure relief systems were inadequate. FRA, with support from RPI/AAR, constructed a unique full-scale valve facility and used it to determine the flow capacities of pressure relief systems under conditions simulating flame engulfment. Preliminary results from the valve facility testing program confirm analytical flow predictions.

FRA has also sponsored prior work to reduce tank car head punctures. A conceptual study indicated that covering the lower half of the tank head with a shield would be an effective method of reducing punctures, and a cost-benefit analysis indicated that such a head shield would be cost-effective. Studies conducted by the Illinois Institute of Technology Research Institute (IITRI) showed that head shields could be safely attached to tank cars.

In order to reduce the likelihood of tank car puncture by couplers of adjacent cars, Washington University of St. Louis, under FRA's sponsorship, developed an analytical model to predict the performance of couplers in switchyard accident situations. In April 1975, FRA and RPI/AAR initiated a joint testing program to study the effectiveness of head shields and new coupler concepts in reducing tank car head punctures. Completion of the program is set for September 1976.

Structural stress and metallurgical analyses of tank cars were completed this year. The National Bureau of Standards completed a metallurgical analysis of steel plate samples taken from tank cars involved in accidents. Tests included full chemical analyses, ambient temperature tensile tests on longitudinal and transverse specimens, quantitative metallography, hardness tests, bend tests on longitudinal and transverse specimens, and impact tests. The Bureau reports recommend several modifications to present tank car steel specifications. Louisiana Tech University completed a tank car structural stress analysis which indicates that there are some ambiguities in existing structural specifications.

Future R&D efforts in the hazardous material tank car area will focus on (1) completing the switchyard impact tests, (2) conducting mainline impact tests, (3) developing performance specifications for thermal shields and tank car structures, and (4) conducting hazard assessment studies of rail transport of hazardous materials. This research will assist the FRA Office of Safety and the AAR in formulating regulations and specifications to reduce the deaths, injuries, and property damage caused by hazardous material tank car accidents. Other transportation modes and private industry are also expected to benefit from this research. The U.S. Coast Guard has already made use of a portion of the valve facility, and the National Fire Protection Association is monitoring FRA's thermal shield work for use in formulating codes for the protection of stationary tanks.

Rail Vehicle Occupant Protection

In 1974 train accidents resulted in 25 fatalities and 560 injuries to occupants of rail vehicles. R&D efforts are aimed at reducing the frequency and severity of such accidents. Preliminary work was begun in the last quarter of FY 74 to develop design specifications for crashworthy railcar interiors. From October 1, 1974, to September 30, 1975, FRA sponsored a three-task program to develop improved designs for rail vehicles and rail vehicle components.

The first task was to analyze the collision environment. FRA and National Transportation Safety Board (NTSB) accident reports for the period 1967 through 1973 and the "T" forms for accidents involving injuries or at least $5,000 damage for the period 1972 through 1973 were reviewed. Data from this review were used to develop a locomotive-caboose collision mathematical model.

The second task involved the formulation of occupant protection guidelines. Guidelines have been formulated, and work is under way to develop performance specifications for interior design to satisfy these guidelines. Interior features being studied include glazing materials, luggage storage facilities, seating,

Figure 21 and 22. Train-to-Train Impact Tests.

lighting fixtures, interior surfaces, emergency equipment and procedures, and flammability. Test data on human tolerance to shock are also being incorporated into this study.

The third task was to examine the mechanism of coupler override. When a moving locomotive impacts the caboose end of a standing train, several types of coupler override are possible. The caboose may override at the end opposite the impact; it may override at the locomotive end; it may buckle in the center; its center sill may buckle near the ends; or the caboose may jackknife. Several computer models were developed to predict and simulate the various types of coupler override. These models enable engineers to study the effectiveness of equipment changes and protective devices under various hypothetical impact conditions. Full-scale tests were conducted at the Transportation Test Center (TTC) to validate and verify the models. Contributors to the train impact test program were FRA, AAR, RPI, the Brotherhood of Locomotive Engineers, and the United Transportation Union. The tests were conducted by TTC with technical support from TSC and Washington University.

The TTC test involved six low-speed rear-end collisions between a locomotive and a caboose. These low-speed impacts, however, were not sufficient to validate the computer models; therefore, two higher speed tests were conducted to clarify the override mechanisms. The impact tests revealed a great deal about the conditions that lead to destruction of a locomotive cab and to resultant injuries and fatalities. This information has proved valuable in validating the mathematical models and in discovering the mechanism of coupler override.

Future plans call for completing the development of performance specifications for occupant protection.

Human Factors

Approximately 20 percent of all railroad accidents and virtually all railroad collisions are attributable to human errors. Human errors include negligence, operator error, failure to heed warnings, and errors due to fatigue. R&D efforts are directed toward developing a solid technological and data base for establishing standards of performance safety as required by the Federal Railroad Safety Act of 1970. The frequency and severity of human factor-related accidents emphasize the need to develop these standards as quickly as possible. Work completed prior to the reporting period in the human factors area has included (1) conducting detailed task analyses of the railroad engineer's and train dispatcher's jobs; (2) evaluating industry-built cab mockups for demonstrating innovative safety features, and (3) developing guidelines for new locomotive cab seating arrangements.

It is essential to railway safety that personnel in safety-critical jobs possess the minimum knowledge and skills required for the safe performance of their jobs. Therefore, FRA has sponsored research aimed at acquiring an understanding of the requirements of each safety-critical railroad job. During the past year the Naval Ammunition Depot, Crane, Indiana, completed a study to identify and describe the principal tasks performed by conductors, rear brakemen, and head brakemen in over-the-road freight operations of diesel-electric locomotive equipment. The study included a determination of task difficulty, potential hazards, and the critical nature of each task. Based on these task analyses, (and the previous railroad engineer and train dispatcher task analyses), a study was completed for the minimum safety-related knowledge, performance, and training requirements for railroad engineers, conductors, brakemen, and train dispatchers. The study included recommendations for conducting job training and developing techniques to measure and evaluate job knowledge and performance.

The interface between the train and the engineer on real freight operations has been the subject of extensive study at the Transportation Systems Center (TSC) during the past year. A package of instruments was developed and installed in several locomotive cabs, and in-cab events, such as cab motion, readings of principal instruments, and operation of principal controls, were recorded. This information, along with observations of the engineer's behavior and supervisor's ratings of the engineer's skill, was collected on runs on a number of different railroads. The data base thus established is now being analyzed to derive an empirical model in three modes of operation: starting, stopping, and maintaining a steady speed of changing grade. This model will be of considerable value in improving training and evaluation techniques and in guiding future research on cab instrumentation and train handling methods.

TSC has continued its work on developing and evaluating train handling aids. One of the most promising train handling aids is a Draft Buff Indicator (DBI), a device which will sense and display to the engineer the stretching (draft) and compressing (buff) forces being exerted throughout the train. With a DBI the engineer can see the distribution of draft and buff forces, can see when and where the forces change direction, can see slack pulses running through the train, and can compensate for the adverse forces by either braking or applying more power. The DBI was evaluated in the Track-Train Dynamics (TTD) program under joint sponsorship of FRA, AAR, and RPI. TSC is now developing an improved DBI which will display the magnitude as well as the direction of the coupling forces. TSC also evaluated an AAR-developed train handling aid called the Power Force Indicator (PFI). This device integrates the power output from all of the locomotives connected together to power the train (power consist) to give the engineer an indication of the total pulling force of the consist. The PFI is of greater value to the engineer in controlling the train and in diagnosing power losses than is the current load meter, which shows only the output of the lead locomotive. Another device which TSC evaluated is the L/V Hazard Detector, which senses and displays to the engineer the magnitude of the ratio of lateral to vertical forces (L/V) exerted by the train's wheels on the rails. A high L/V ratio can cause a derailment. This detector gives the engineer advance warning that the L/V ratio is reaching a dangerous level and allows him more reaction time to avoid a derailment.

Many train accidents have been attributed to inattention on the part of the crew in the locomotive cab. One possible explanation for this inattentiveness is that the crew members were adversely affected or distracted by intolerable levels of noxious gases, vibration, noise, and temperature. To investigate this hypothesis, TSC conducted a systematic evaluation of the train crew's physical environment. Information was obtained from a review of relevant literature, from crew members via their unions, and from field trips undertaken to observe working conditions in the locomotive cab and caboose. This initial exploration led to a definition of the problem of air quality, including the potential contaminants in the environment, their sources, the likelihood of their being critical for operational safety and crew well-being, and recommended procedures for their evaluation and control. A survey is now under way to collect standardized data on concentrations of the principal contaminants (carbon monoxide, nitrogen oxides, hydrocarbons, and particulates) in a variety of operational conditions, and a similar approach is being planned to examine the problems of noise, vibration, and temperature.

During the first 130 years of railroad history, the human operator was given, at best, secondary consideration in the design of locomotive cabs. Recently, however, there has been a dramatic increase in the consideration given to the design of the cab as a work space for train crewmen. FRA, through TSC, has evaluated several new cab designs. Boeing Vertol has developed displays, controls, and work space based on the functions performed in the cab and the needs of the people who perform these functions. A functional analysis has been completed, and several new alternative cab configurations were evaluated in full-scale mockups.

Future plans in the human factors area include (1) completing the cab design project by selecting one design for extensive operational tests, (2) continuing the development and evaluation of train handling devices, (3) completing the development of the locomotive engineer response model, and (4) fabricating and operating the Research Locomotive and Train Handling Evaluation Facility. FRA is in the process of conceptually defining functional capabilities and developing design specifications for such a facility before moving ahead with actual fabrication. When operational, this research facility will be FRA's primary experimental tool for evaluating train accidents caused by human errors. The knowledge gained from these experiments will assist in developing ways of reducing accidents. The facility will be used to conduct experiments simulating in-service conditions. These experiments will evaluate the performance of the locomotive engineman (1) in different locomotive cab environments, (2) with varying real-time train performance inputs, (3) in applying train handling controls and techniques, and (4) in varying accident situations. Conducting these experiments under actual field test conditions is precluded by the lack of control over variables, the dangers inherent in reenacting accident situations, and the money and time required to subject a statistically significant sample of enginemen to experimentation under over-the-road situations.

R&D efforts in the human factors area are expected to help FRA, the railroad industry, and railroad labor reach their common goal of reducing human factor-related accidents and improve the working environment of engine crews. This work should also prove beneficial to other transportation modes and other industries in reducing these types of accidents in their respective areas.

Grade Crossing Safety

Grade crossing accidents are the major cause of fatalities in railroad operations, accounting for approximately 65 percent of all fatalities resulting from railroad accidents. It is estimated that 3,650 locomotive/vehicle collisions occur annually, resulting in 1,453 deaths and 3,579 injuries. The objective of the grade crossing safety program is to reduce both the frequency and severity of grade crossing accidents. Work prior to the current reporting period in this area has included (1) developing a computer model to assist states in determining the best complement of grade crossing equipment for different classes of crossings, (2) improving locomotive visibility with high-intensity strobe lights, and (3) conducting impact tests involving a collision between a locomotive and a stationary automobile.

Figure 23. Strobe Light Installed on Locomotive.

During the past year there were a number of significant accomplishments in the grade crossing safety program. AAR completed a project under FRA sponsorship for numbering and inventorying all public highway railroad grade crossings in the United States. This project, in conjunction with the grade crossing computer model described in the "Eighth Report," will enable state highway departments and the railroads to evaluate their current grade crossing protection policies and to select protection equipment more efficiently. Research continued into decreasing the overall cost of wayside grade crossing equipment through design standardization and modularization. Modularization of grade crossing equipment involves the standardization of external shape, dimensions, mounting, and electrical connection as well as compatibility of electrical and mechanical input/output characteristics. A systems analysis of modularized grade crossing equipment completed in FY 75 included studies of train detection, signal transmission, associated logic, and motorist warning devices. In addition, various motion detection devices were subjected to detailed study and analysis of failure modes, functional requirements, and assessment of improvement potential.

Two studies completed this past year focused on concepts for new materials and mechanisms for grade crossing barriers. The lower initial costs of the new materials and mechanisms are expected to encourage their widespread implementation. Another project involved field tests of Whelan strobe lights. Developed under FRA direction, the strobe lights act as visual alerting devices to improve the visibility of locomotives. The field tests (carried out on three railroads in cooperation with the Illinois Department of Transportation) were designed to evaluate the maintenance requirements, durability and effectiveness of the lights. Test results indicated that the strobe light is an effective safety device.

Future research in the grade crossing safety program will concentrate on (1) fabricating and testing prototype grade crossing equipment, (2) formulating guidelines for establishing standardized designs for grade crossing protection equipment, (3) developing and testing several low-cost barrier concepts, and (4) evaluating the Whelan strobe lights on at least two additional railroads with different traffic and terrain problems. If successful, this research will benefit the many organizations concerned with grade crossing safety—e.g., FRA, Federal Highway Administration (FHWA), National Highway Traffic Safety Administration (NHTSA), Association of American Railroads (AAR), Railway Progress Institute (RPI), American Association of State Highway Officials (AASHO), state departments of transportation, state public utility commissions, highway departments and local governments. It should also result in more grade crossings being protected per resource dollar and in increased protection by grade crossing equipment.

Component Failure Prevention

In 1974, 2,175 train accidents were caused by the failure of vehicle components. To reduce the number of accidents due to component failure, researchers are working to develop design criteria which will make vehicles and vehicle components less prone to failure and techniques and mechanisms for predicting, detecting, and reacting to failures which do occur. Prior work in the component failure prevention area includes (1) studying the ways in which fatigue and thermal cracking begin, (2) conducting field tests to obtain representative dynamic loading cycles to which railroad tracks are exposed in normal operations, (3) developing a prototype ultrasonic wheel inspection unit that detects cracks in wheel rims and plates, (4) conducting a survey of freight car roller bearing requirements and failure modes, and (5) developing concepts for detecting hot boxes and local derailments.

Among the projects begun this past year was a study of the effects of both mechanical and thermal loading on the stress distribution in wheels. A finite element analysis in parametric studies was developed and used to assess the effects of mechanical and thermal loading induced by brake action. In another study two research firms examined the service life of railroad roller bearings. One firm reviewed bearing shop data from the Penn Central and Santa Fe railroads and studied European certification practices. Another firm reviewed the shop records of 11,589 bearings which were repaired by the Brenco Bearing Company. These reviews indicated that the expected bearing life was much shorter than had been assumed previously.

FRA is currently developing two mechanisms designed to detect component failures —hot journal sensors and local derailment detectors. These devices will automatically stop the train upon detection of a hot journal or a wheel on the ground. To establish a design base for both devices, the Naval Surface Weapons Center (NSWC) conducted 14 full-car derailment tests and 4 hot box temperature tests and obtained and analyzed basic shock signature data. Based on these data, laboratory devices were designed and tested and prototype devices were installed on four freight cars.

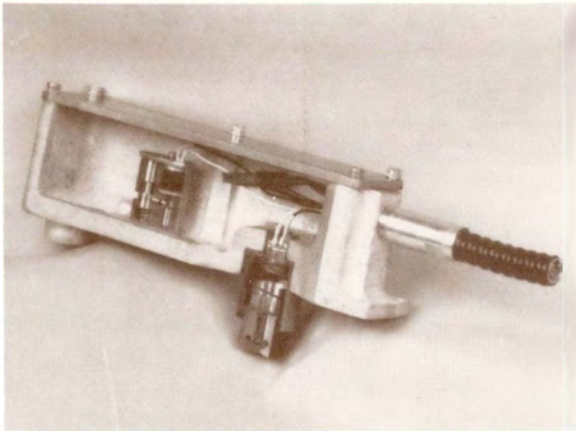


Figure 24. Hot Box and Derailment Detector.

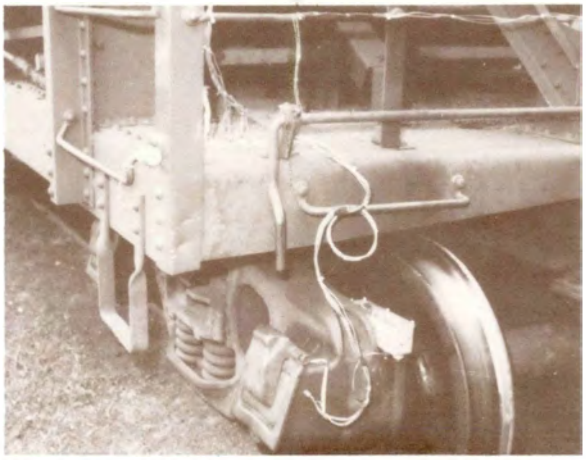


Figure 25. Installation of Hot Box and Derailment Detector.

In addition to developing the hot journal sensors and local derailment detectors, FRA has sponsored investigations into the effectiveness of existing inspection equipment and procedures. TSC completed an in-house study for FRA which demonstrated that several commercially available portable inspection systems are suitable for detecting cracks and flaws in wheel rims. Another study indicated that ultrasonic methods can be used to detect wheel plate cracks. The University of Houston completed its investigation of an acoustic technique for detecting a wheel-impact excitor, along with associated audio spectral analysis.

Future research in the component failure prevention area will include (1) installing hot journal sensors and local derailment detectors on 124 freight cars in service and collecting data for a 12-month period, (2) conducting field tests on the Union Pacific Railroad to validate the finite element mechanical/thermal loading analysis, (3) determining the most dangerous service conditions for all major wheel designs currently in use, (4) characterizing the failure toughness and fatigue fracture growth behavior of wheel steels used in domestic practice, and (5) developing improved certification procedures and performance specifications for in-service diagnosis of roller bearings.

The equipment and operational procedure improvements attained in the component failure prevention program will be used by the FRA Office of Safety in formulating and enforcing revised freight car safety standards.

3.2 IMPROVED TRACK STRUCTURES

In FY 1975, as in recent years, the Track Structures Research Program focused on attainment of two major goals: (1) fewer track-caused railroad accidents and (2) more cost-effective track construction and maintenance techniques and materials. The following statistics indicate the magnitude of track safety and performance problems:

- In 1974, 4,264 train accidents were caused by defective track, an increase of 20 percent over the 1973 total. These accidents cost $70 million in damage to track and rolling stock alone. This figure does not include human casualty costs, lading loss, cleanup costs, or damage to communities adjacent to accident locations.

- During the same year the railroad industry spent approximately $1.9 billion for track construction and maintenance and yet failed to markedly reduce the large backlog of deferred maintenance.

Improving track safety is the primary goal of the Track Structures Research Program, not only because of the unacceptably high level of track-caused accidents but also because of the alarming rate of increase. Additionally, very high returns can be gained from the investment of research and development resources in projects which lead to even small percentage reductions in the enormous costs of track construction and maintenance.

Attainment of these two goals is being pursued through the implementation of distinctly different strategies. In the case of track safety, the objective is identification of the limits to which the track system and its constituent components can be exercised safely. This includes specification of maximum track deflection under load, track geometry characteristics adversely affecting rolling stock, stress and fatigue limits of system components, and other boundary conditions that cannot be exceeded without jeopardizing safe train operations.

The research approach to reducing track construction and maintenance costs is to first determine how the system breaks down (mechanics of degradation) and then work with typical materials to discover how to reconfigure or repair the system in order to achieve greatest durability at least cost then set priorities among these as to most efficient method. There are intensive traffic situations involving freight, or high-speed passenger services where use of traditional designs, materials, and techniques to optimize track performance is so expensive as to place a damaging burden on railroads in serious financial trouble.

Track research work completed prior to the reporting period included a theoretical analysis of track buckling; an analysis of track-induced vibration within a standard 50-foot (15.3 m) freight car; successful application of a statistical technique to the analysis of sources and importance of diesel engine vibrations; and development of extensive model simulation techniques to avoid high-cost, full-scale experimentation.

The program was restructured in FY 1974 to place greater emphasis on track safety while dealing with track performance problems more effectively. Research results will be made available to the FRA Office of Safety for use in formulating new track safety standards and to the railroad industry to improve safety and cost-effectiveness. The project summaries which follow indicate the manner in which program goals were pursued during the reporting period.

Track Safety Research

A parametric analysis of residual and service-induced rail stresses was begun to determine relationships between these stresses and the creation of the most dangerous rail flaws. A computer simulation model will be used to analyze stresses and flaws in both continuous welded and jointed rails. A study was initiated to identify major factors affecting rail failure, including a definition of the relationship between the types of defects and rail failure. The contractor will apply discriminant analysis methods to data on rail failures provided by cooperating railroads. Another project which was initiated will provide preliminary information on rail material failure behavior and appropriate failure-prediction methodologies. In conjunction with the studies on load determination (described below) and rail stress, the project will provide the basis for making engineering estimates of (1) the expected life of rails containing known defects, (2) the anticipated rail failure rate of specific sections of track having known performance characteristics, and (3) the preventive and corrective action needed to minimize specific types of rail failure in both new and existing track.

The research effort described in the "Eighth Report" to determine the feasibility of applying sleeve expansion techniques to decrease the occurrence of railroad bolt hole fractures was con-

Figure 26. Maximum Distortion of the Concrete Tie Panel in the Chessie Tests at Sabot. Note Curved Alignments of Rail Indicating Superior Resistance of Concrete Ties to Lateral Displacement.

Figure 27. Maximum Distortion of the Timber Tie Panel in the Chessie Tests at Sabot. Note Straight Alignments of the Rail (each side of loading point). Indicating Decreased Resistance of Timber Ties to Lateral Displacement.

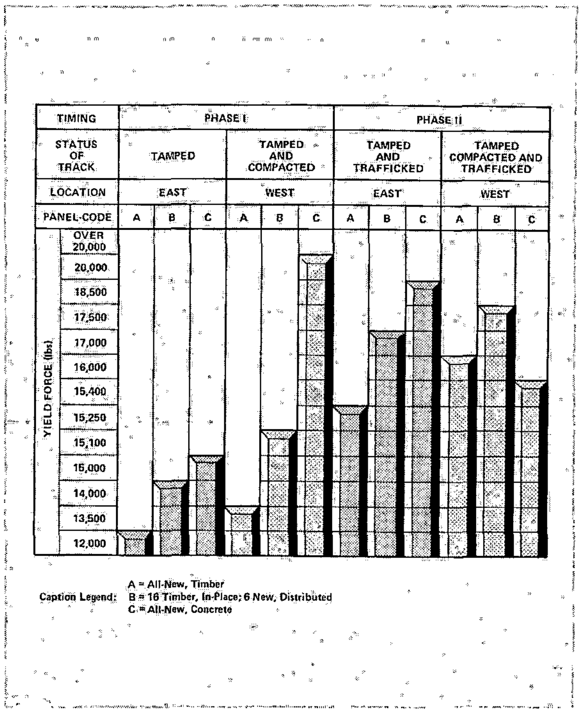


Figure 28. Relative Lateral Stiffness of Concrete Vs. Timber Crosstie Track.

tinued in the reporting period. Efforts will be directed in the investigation of the crack initiation and growth behavior, assessment of technique advantages and limitations, and the design of a field experiment.

Tests were completed on the main track of the Chessie System at Sabot, Virginia, to determine the relative lateral resistance to displacement of stressed concrete crosstie track compared with conventional timber-tie track. Analysis of test data is not complete at this time, but preliminary review suggests that concrete-tie track is substantially more resistant to displacement in the lateral plane than is timber-tie track. This investigation was conducted chiefly by the Chessie System, with assistance from a subcontractor.

Work being performed under contract to Princeton University will provide information on how to improve the safety and stability of railroad track by minimizing the probability of horizontal track buckling. Researchers will utilize a frame analysis of track in the horizontal plane to predict critical temperatures for buckling and will develop a frame analysis for determining the appropriate lateral track rigidity to be utilized in track stress and stability analyses.

An effort was undertaken to compile a digest of current literature pertaining to stresses in rails, rail failure behavior, manufacturing practices, rail flaw detection capabilities, and track loads. The digest will provide an updated data base upon which new work can be based without unnecessary duplication of effort.

Track Productivity Research

A study to identify the range and statistical distribution of loads experienced by track is the most important project begun during the reporting period. Up to now there has not been a comprehensive attempt in the United States to define this matrix of values. Yet, it is necessary to know the magnitude and frequency of loads that track is expected to sustain if its performance is to be improved. The contractor will develop and test analytical methods to characterize wheel/rail (W/R) loads. The resultant prediction tools will be used to define the range of loads experienced on U.S. railroads and to evaluate W/R load reduction strategies. The output of this project will be applied across the board in the balance of the track structures program.

FRA commissioned a study to determine the effect of crosstie/fastener characteristics on track performance and to evaluate contemporary wood and nontimber crosstie/fastener assemblies. The study will include the determination of the cost-effectiveness of nontimber crossties and the identification of optimal crosstie performance characteristics. A NASA Technology Utilization contract will survey the available technology for the refurbishment of deteriorated timber crossties. Research efforts will include an assessment of the technical and economic feasibility of applying certain promising techniques to existing crossties in-situ, on-site, or in batch-plant operations.

AAR's Technical Center, working under contract to FRA, completed the formulation and debugging of a family of track simulation models and the generation of a comprehensive test design for laboratory verification of these models. A Rolling Load Laboratory being funded and constructed by AAR will be used to verify the models. This full-scale, enclosed track simulation facility will be unique in the United States and will provide industry and government users with the opportunity to measure track specimen response to realistic loads under carefully controlled conditions while avoiding the high cost of field testing.

The same contract with AAR also produced a preliminary concept for a facility for accelerated service testing, which would permit the accumulation of years of over-the-road experience in a compressed time period through virtually continuous operation of a test train over a closed loop track. During the reporting period, FRA, working in cooperation with the railroad industry, began in-house efforts to assess the benefits and feasibility of constructing such a facility and to determine the level of industry support.

The demonstration test series begun in 1973 with the FRA ballast consolidator concluded with a test conducted on the Southern Railway to determine the effectiveness of this type of track maintenance equipment in improving the stability of jointed track involved in a general (out-of-face) re-smoothing operation. Test data have not yet been analyzed completely, but a preliminary review indicates that the technique retards the progressive increase in joint deflection under load typically experienced following return of the repaired track to revenue service. Upon completion of the test series, the consolidator was returned to the Transportation Test Center for use in track construction or modification activities. A final report on the complete test series will be issued early in 1976.

Current Track Tests

The Alaska Railroad installed two cold-region track test sections in its main track prior to the onset of hard-freeze conditions in October 1973. These test sections were installed in order to:

- Determine the durability of a more commonly used concrete tie when used where the roadbed heaves substantially due to freezing;

- Evaluate the cost-effectiveness of using concrete ties with adjustable rail-tie fasteners compared with timber ties in situations where roadbed heaving requires frequent repositioning of rail spikes in rail-tie shimming operations to reestablish track profile, resulting in rapid deterioration of the timber ties;

- Evaluate the use of compounds to bind particles of ballast together in order to make granular ballast cohesive in regions where the foundation soil is weak.

The crosstie and stabilized ballast test sections, located north of Anchorage at Montana and Houston sidings, have been under evaluation for two years. In the case of the 190 concrete ties (26-inch spacing [66 cm]), frost heaving has required repeated seasonal shimming of more than 2 inches (5.1 cm). No cracking of the Gerwick RT7S concrete ties has been noted. Railroad personnel, using air-driven impact tools to loosen tie

Figure 29. Ballast Shoulder Slump in the Houston Test of the Alaska Railroad.

Figure 30. Pandrol Fasteners attached to Adjustable Base Plates in the Montana Test of the Alaska Railroad. (railends have now been welded).

plate hold-down bolts (Pandrol fasteners having been attached to the plates), have determined that profile and alignment in heaved regions can be corrected much more easily with adjustable rail-tie fasteners than with timber ties and conventional fasteners. There is, of course, no degradation of concrete ties from continual fastener readjustment as would occur with repetitive respiking of timber ties.

The concrete tie-threadless fastener service test continues on the main track of the Chessie System at Lorraine, Virginia. Following 14 months of testing and the passage of 31 million gross tons (28.2 tonnes), performance of the test specimens can be summarized as follows:

Figure 31. Summary of Concrete Crosstie Performance in Lorraine, Virginia Test.

COMPONENTS

100 GERWICK RT7S TIES, TREC CS–5 FASTENERS

18 GERWICK RT7S TIES, PANDROL 607A FASTENERS

106 COSTAIN 223 TIES, PANDROL 607A FASTENERS

OVERALL STATUS

GENERAL TRACK CONDITION .... VERY GOOD

BALLAST CONDITION.................... GOOD

TIE CONDITION .... GOOD

FASTENER-INSULATOR CONDITION......... GOOD

PAD CONDITION.......................... FAIR

Figure 33. Pad Displacement and Skewed Rail Fastener, Chessie Test at Lorraine.

None of the defects are serious, but data from the two inspections appear to establish trends. Clearly, the tie pad movement continues to be a major consideration in optimizing performance of the concrete tie-rail fastener system.

The entire nine-section Kansas Test Track on the Atchison, Topeka, and Santa Fe Railroad was opened to mainline traffic in December 1974. The track was subjected to 20 million gross tons (18.1 tonnes) of traffic prior to being removed from service in June 1975 due to what is thought to be an embankment failure. The Waterways Experiment Station (WES) of the U.S. Army Corps of Engineers is conducting an extensive investigation of the mechanics of the test track degradation.

Figure 32. Concrete Crosstie Defects in Lorraine, Virginia Test.

NUMBER OF VARIOUS DEFECTS

	NO. OF TIES WITH CRACKS	NO. OF BROKEN INSULATORS	NO. OF SKEWED CS–5 FASTENERS	NO. OF DISLOCATED PADS
FIRST INSPECTION DECEMBER 10, 1974	7		31	106
SECOND INSPECTION JUNE 10, 1975	13	4	86	152

Useful results of the Kansas Test Track program can be summarized as follows:

- It was concluded that when clay soil embankments are overloaded, rigidly supported track systems deteriorate rapidly. When the embankment contained too much moisture, a pumping action was created by the motion of the concrete structure during train passage. The finer clay particles were pumped up into the ballast, leaving voids in the embankment and greatly reducing track resistance to both vertical and lateral displacement. As was recently confirmed through research by British Rail, utilization of cohesive soils in rigidly supported track systems should be avoided.

- The use of cast-in-place fasteners in concrete beam or slab track was found not to be cost-effective due to the lack of straightness of rails produced in the United States. When a rail is placed on a beam or slab, gaps exist between the concrete support and the rail due to deviations in both components. When these gaps occur at fastener locations, the rail is insufficiently supported to withstand loads. The use of shims at the fastener location to fill the gap was found to be impractical because of limitations on shim thickness and the fact that additional shimming would be required by uneven settling of the supports. Until roller-straightened rail is readily available in the United States, designers will probably have to rely on so-called second-pour techniques. These techniques involve the introduction of a grant beneath rail fastenings suspended from a positioned rail or the combination of precisely dimensioned concrete ties suspended from carefully positioned rail with a second-pour integration of the ties with a base slab.

- The problem of research demands versus operational requirements seriously compromises effective investigative efforts attempted via in-service tests on trackage of operating railroads. This problem gives support to the argument that facilities capable of simulating in-service conditions and dedicated to track, rolling stock, and ancillary test purposes are essential to improving the performance of the U.S. railroad network.

The Kansas test track has produced technical data which is applicable to present-day railroad operations and which may ultimately be useful in future years if conventional crosstie track is shown not to be cost-beneficial in specific situations and must be replaced by more durable designs. Moreover, a considerably expanded understanding of soil and ballast mechanics can be expected from the WES investigation.

Future program development will be geared toward exploiting the products of ongoing and new research discussed herein. Expected new starts will include:

- Rail Residual Stress Analysis—An examination of the contribution of residual stress following manufacture, shakedown, and continued use to the retardation or promotion of flaw growth.

- Rail Reliability Prediction—Using the input of the residual stress analysis project and other rail behavior studies, a model will be assembled that will estimate the remaining service life of rails containing known minor flaws. This estimating capability would permit more informed decisions as to when defective rail should be removed from service, thereby reducing costs.

- Relation of Vehicle-Track Response to Wheel-Rail Interface Forces—Present FRA Track Safety Standards specify neither the maximum magnitude or duration of wheel loads which track systems can withstand safely nor the contribution of combinations of track defects to vehicle perturbations. Both of these topics are scheduled for examination in 1976.

- Ballast Material Selection Factors—Industry sources have expressed great interest in having a set of practical field tests which can be used in ballast quarries to predict future performance of materials drawn from the same location. Long-term material characteristics vary considerably from one area to another, and a technique to select or reject materials at the quarry on the basis of performance is not available today. A project leading to development of appropriate evaluation techniques will begin in 1976.

3.3 AUTOMATED TRACK INSPECTION

Track Measuring Car Developments and Operations

Improvements in automated track inspection technology can be used to help solve both safety and productivity problems. Safety inspections of the national railroad network (326,000 miles (525,000 km) of railroad track) are conducted by railroad employees. FRA safety inspectors currently make spot checks by visual and manual methods to insure compliance with Track Safety Standards. The number of safety defects found on the small percentage of track checked by FRA inspectors and the 400 percent increase in track-caused accidents since 1960 indicate that larger samples of track should be inspected by FRA. Automated track inspection vehicles developed by FRA can provide the larger data base by performing accurate measurements of track geometry at high speeds (up to 80 mph (130 km/h)). These vehicles can also be used to monitor track construction and for maintenance-of-way planning (discussed in the following section).

FRA has a single track-geometry measurement vehicle that has served as both a research tool and an operational system for checking compliance with FRA's Track Safety Standards. As part of the same program FRA has developed and employed another system used to provide computerized data acquisition and processing support

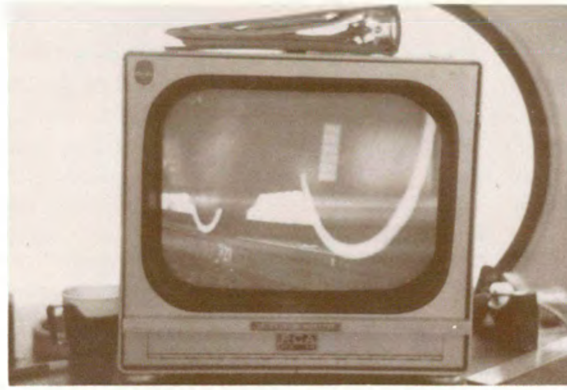


Figure 35. Special Testing—TV monitoring wheel rail activity for DODX test vehicle.

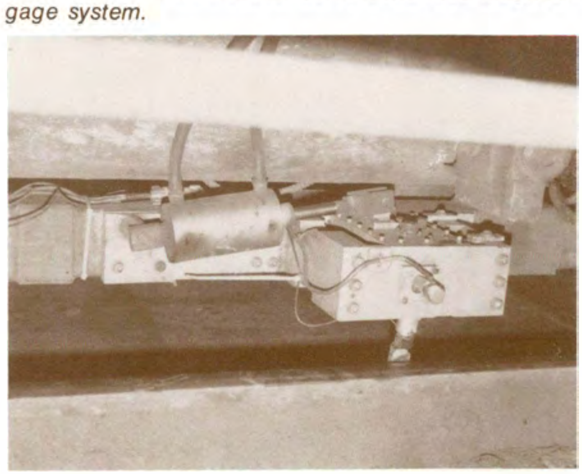
to field testing operations of track and vehicle research projects.

The FRA track geometry measurement system has been used extensively to develop and test improvements in automated track inspection technology. The research efforts have produced the only system in existence which is capable of conducting track inspections as required by the Track Safety Standards and providing track condition data in the proper format to promote efficient track maintenance management. The system can measure gage (distance between rails), crosslevel (elevation of one rail above the other), wrap (rate of change of crosslevel), profile (rail smoothness), alignment (rail straightness, and curvature (angular change of track direction per given distance(chord)).

New instrumentation developed during the reporting period includes the prototype servomagnetic gage and the compensated ac-

Figure 34. Conducting Automated Track Inspection for AMTRAC and the FRA Office of Safety.

Figure 36. New all-weather servo-controlled magnetic gage system.

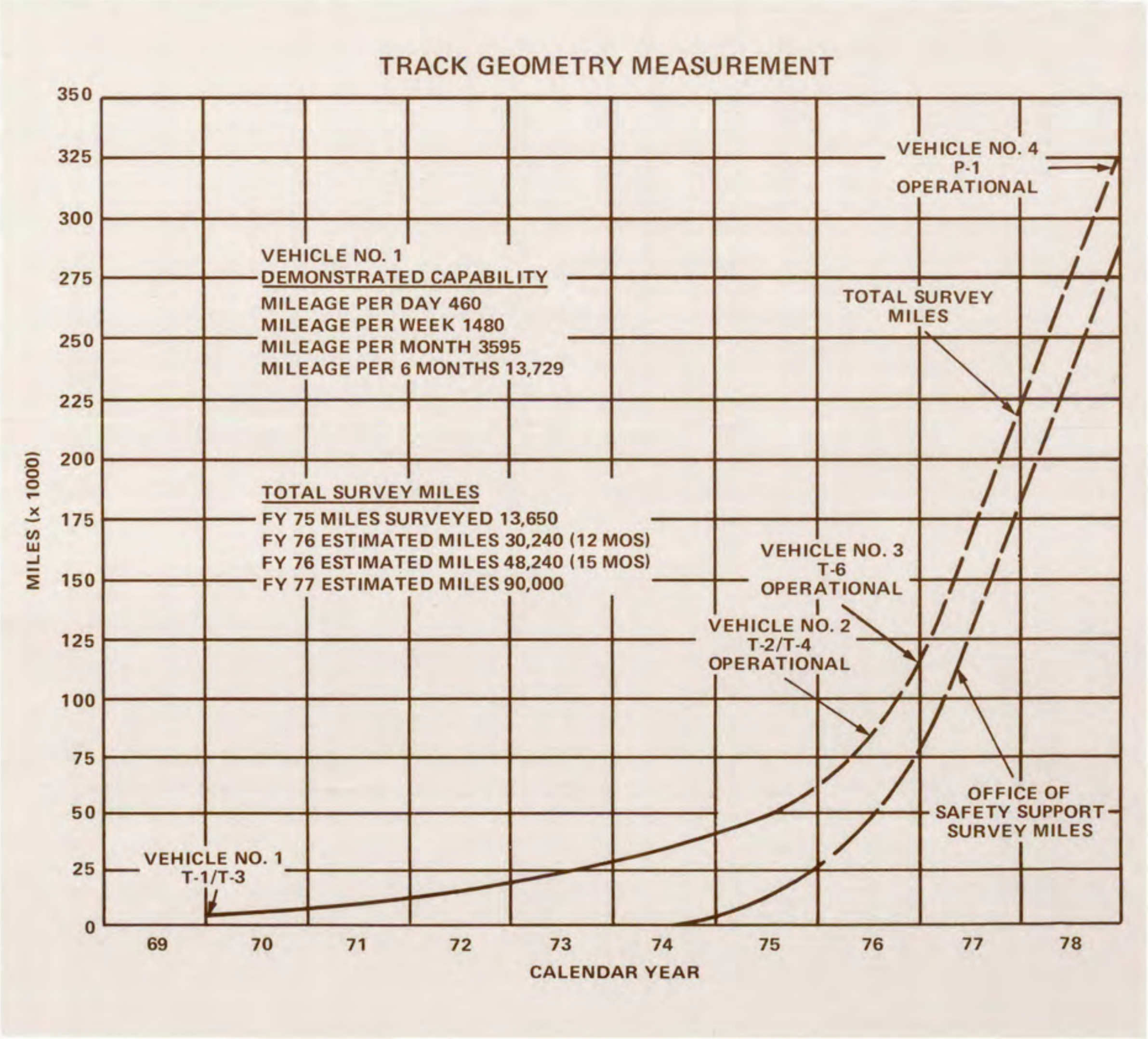


celerometer crosslevel measurement systems. The new servomagnetic gage measurement system has proved superior in field tests to the older capacitive system in that it is operable during inclement weather. This system, which uses magnetic sensors to measure gage, was chosen over seven alternative gage-measuring systems using contact, optical, and magnetic sensors. The new compensated accelerometer crosslevel measurement computes crosslevel by mixing the output of a rate gyroscope with that from an accelerometer system and produces more accurate measurements in long curves than the older system, which used a vertical gyroscope to sense crosslevel changes.

Improvements were also achieved in computerized data processing. New computer programs were developed for more efficient utilization of onboard computers in processing track geometry data and generating track inspection reports. These improvements will permit more rapid data processing at lower costs.

Improved profilometer sensors were subjected to operational testing on seven railroads during the reporting period. The new sensors are smaller, lighter, easier to calibrate, and less sensitive to the environment. They can be used to accurately measure profile variations in wave lengths from a few feet up to 200 feet (61 m). The basic mea-

Figure 37. FRA Track Geometry Measurement.



surement can be converted to 62-foot (19m) mid-chord offset deviations to comply with Track Safety Standards.

By FY 1975, the track inspection system had advanced to the point where the technology could be implemented in the development of an automated track inspection capability for the Office of Safety. Accordingly, FRA began the Automated Track Inspection Program directed toward providing the Office of Safety with this capability. Three additional track inspection vehicles will be fabricated, the last of which will serve as the prototype for future cars to be used by FRA and the railroads. The first step in the program was the acquisition and refurbishment of two used railroad cars, which began in FY 1975. After installation of track inspection systems, the two additional vehicles will go into service as safety enforcement tools in FY 1976. Fabrication of the prototype vehicle will begin in FY 1977 and be completed in FY 1978.

Use of Track Geometry Measurement Cars for Maintenance of Way (MOW) Planning

The railroad industry currently does not have a systematic and scientific method to determine the optimal allocation of scarce maintenance resources. In response to this problem, FRA is developing MOW planning techniques which use statistical interpretations of track geometry data to determine (a) which sections of track are in the worst condition and (b) which sections are likely to degrade substantially in the future. This information will enable MOW planners to make more rational decisions in applying maintenance resources. As stated in the last report, data analysis and presentation techniques were developed and tested on two railroads. Additional surveys on the two railroads were made during the reporting period, and the comparison reports are being utilized by both companies. Beginning in FY 1977, the track condition of the Facility for Accelerated Service Testing (FAST) at the test center will be surveyed periodically, and the comparison techniques will be applied to document the track condition and to provide a controlled evaluation of the planning methods.

Improved Rail Flaw Detection

As discussed in earlier reports, FRA acquired a best-state-of-the-art rail flaw detection system mounted in a rail-highway vehicle. TSC constructed a slow-speed calibration track containing carefully measured rail defects in Cambridge, Massachusetts, adjacent to the TSC laboratory facilities. In Winchendon, Massachusetts, a higher-speed track has been leased by TSC from the Boston and Maine Corporation. This out-of-revenue-service track contains specimens of all important types of rail defects. Both tracks were used to delineate the technical limits of the operational flaw detection system. Certain system deficiencies were revealed and reported to the manufacturer. The manufacturer is not only modifying the FRA-owned system to improve operation but also is applying these design improvements to models being supplied to industry customers.

A major impediment to increasing the speed of flaw detection systems is reliance on operator interpretation of analogue data as it is produced, which causes errors and restricts data flow due to skill limitations and operator fatigue. To solve this problem, FRA has contracted for the development of an automatic data interpretation capability.

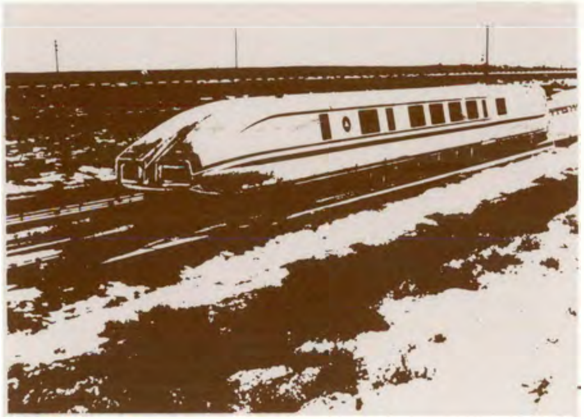
Rail Longitudinal Stress Measurement

Determination of the tensile or compressive states of rails is a difficult task. As a result, railroad maintenance engineers work at a serious disadvantage not knowing whether the compressive stress in a segment of track is about to induce potentially catastrophic track buckling or whether tensile stress is approaching the limit of the rail-end fastenings' capability to resist rupture or pull-apart. Work has been under way at the University of Oklahoma for a year to investigate the feasibility of measuring rail stress using a moving ultrasonic transducer. A serious problem was encountered when the transducer was positioned on the rail head in that wide variability in rail steels makes it almost impossible to calibrate the transducers. An investigation will be conducted in the coming year to determine the feasibility of overcoming this problem by positioning transducers on each side of the rail so that the ultrasonic energy is transmitted through the rail web (the thin vertical part of the rail), where material variability is at a minimum. Unfortunately, the transducer would have to be equipped with an automatic obstacle-avoidance system when in this position to avoid collision with rail joint assemblies, piles of ballast, switches, etc. This system would not be practical for use on jointed rail because the transducer would be moved at least every 39 feet (11.9 m) to avoid the joint assembly. However, the system may be applicable to continuous welded rail (on which the large majority of track buckling incidences occur) because joints would be encountered only at quarter-mile (.40 km) intervals.

Track Impedance

The "Eighth Report" described a three-phase project directed toward the development of a vehicle to measure track impedance (response to dynamic loading). A contractor has completed Phase I and most of Phase II. Phase I demonstrated the feasibility of making continuous measurement. Phase II demonstrated means of measuring track impedance and developed the production hardware design. The decision as to whether to proceed with Phase II (hardware fabrication and testing) will be made after analysis of the final Phase II report, which will be received in FY 1976.

4.0 PASSENGER SYSTEMS R&D



Initially, FRA's passenger rail R&D program emphasized improvements in conventional rail technology. This led to the development of the Metroliner and the Turbotrain, concepts which were frontrunners in rail technological developments. Subsequently, R&D efforts concentrated on the development of very high speed—300 mph (483 km/h)—tracked levitated vehicles. These vehicles require either radical changes in the existing right-of-way or procurement and construction of new right-of-way. There is serious opposition to the second alternative because of (1) the increased energy consumption required for increased speed, (2) the high cost of constructing new, innovative guideway on the conventional railroad right-of-way, and (3) the high cost of new intercity right-of-way.

The passenger rail R&D program is now reemphasizing developments which can utilize existing rights-of-way, with emphasis on near-term R&D payoffs and the selective application of existing rail technology. With this in mind, FRA is structuring a program to evaluate the latest advances in rail passenger improvements, including an evaluation of foreign train systems and how that technology might be applied to U.S. train systems.

The R&D program is seeking to develop technology to support Amtrak in providing intercity passenger service. Technology areas being investigated include traction and propulsion; suspension, support, and guidance; braking and adhesion; auxiliary and emergency equipment; signal, control, and communications; train performance evaluations; and passenger systems developments.

The goals of the passenger systems R&D program are as follows:

- To provide the technology that will permit maximum effective use of passenger systems in meeting the nation's transportation needs;
- To provide technology data and advice to the Secretary for use in meeting his responsibility in connection with Amtrak;
- To provide support to Amtrak in developing new passenger equipment;
- To provide direct R&D support to the Northeast Corridor Project.

4.1 SYSTEMS ANALYSIS AND TECHNICAL ASSESSMENT

Improved Passenger Service

The Improved Rail Passenger Service Program has been developed in response to particular needs of the railroad industry, its customers, and the nation as a whole. First, in order for Amtrak to attract travelers to the railroads and thus satisfy the objectives of the Rail Passenger Service Act of 1970, it must provide attractive, comfortable, reliable, and fast intercity service. Second, increasing rail ridership could help the nation to conserve energy. Third, the program provides a positive approach for applying advanced rail systems technology to existing train systems. And fourth, provide the technology for the development of an improved passenger train which will facilitate the development of improved passenger cars and equipment.

The primary objectives of the Improved Rail Passenger Service Program are (1) to advance rail systems technology, and (2) to develop methods for evaluating and specifying the requirements for advanced passenger train systems and system components.

Initially, the program will focus on basic methodology for evaluating train systems and components and developing specifications based on the interrelationship of technical, economic, and energy-related factors. The program will make considerable use of output from other ongoing FRA R&D programs concerned with improvement of train subsystems and components. This work will be coordinated with the continual surveillance and evaluation (for Amtrak and others) of existing advanced passenger train candidates, such as the Canadian LRC, the French RTG and TGV, the British APT and HST, tilt trains developed by the Swiss and Italians, and the German ET 403.

During the next two years efforts will be directed toward developing methodology for evaluating and/or developing specifications for train systems and components. It will also include the evaluation of advanced train systems, both foreign and domestic, for future applicability to Amtrak operations on and off the Northeast Corridor. While this is not a technology program in itself, it will make use of and rely heavily upon the results of R&D programs both within and outside of FRA. It will also utilize results of previous and ongoing socioeconomic and cost/benefit studies (e.g., Northeast Corridor, HSGT Alternatives Study) to develop models for determining the operational requirements for trains.

In addition to the candidate train evaluations, the program will involve a number of tasks dealing with train evaluation methodology, track-train dynamics modeling, operations analysis, signal, control, and communications, environmental factors, and service facility requirements. Important technical inputs to these tasks will consist of results from other programs such as those now under way in the areas of ride quality (LTV/SIG truck evaluation, Metroliner truck testing), train performance (TSC), and dynamics and modeling (TSC and contractors), plus those planned for braking/adhesion.

Status of Prior and Current Related Systems

The DOT Turbotrain program, completed in January 1972, provides an example of equipment demonstration of a self-powered (gas turbine), modern train system which could be of value in the consideration of an improved passenger train. Designed initially for 150 mph (240 km/h) service, the Turbotrain presently is geared for 125 mph (200 km/h) Boston to New York service. Amtrak purchased two five-car Turbotrains and one Canadian four-car Turbotrain for use in the program. It also leased two French-built (ANF-Frangeco) five-car Turbotrains, called the RTG, which are capable of 125 mph (200 km/h). ANF-Frangeco has claimed high reliability for its system. Amtrak has now purchased these French-built trainsets and two additional trainsets, and FRA will be monitoring Amtrak's experience with this equipment. Amtrak is also purchasing seven Rohr-built versions of the RTG. A more advanced and streamlined turbine-driven prototype, the TGV, is currently being evaluated by the French.

The British Advanced Passenger Train APT is in its developmental stage and will not be placed in revenue service until 1978 or 1979; however, the 125 mph (200 km/h) High Speed Train (HST) is now in service. The Canadian-built LRC train has completed limited tests at the Transportation Test Center and will be placed in revenue service for approximately one year. A two-coach train with powered body tilting for use on sharply curved lines has been delivered by Fiat to the Italian State Railway for trials with a four-coach train, and a similar broad-gauge set will be supplied to Spain in 1976. FRA is reviewing these and other foreign programs in an effort to keep abreast of foreign technological developments.

Metroliner Improvement Program

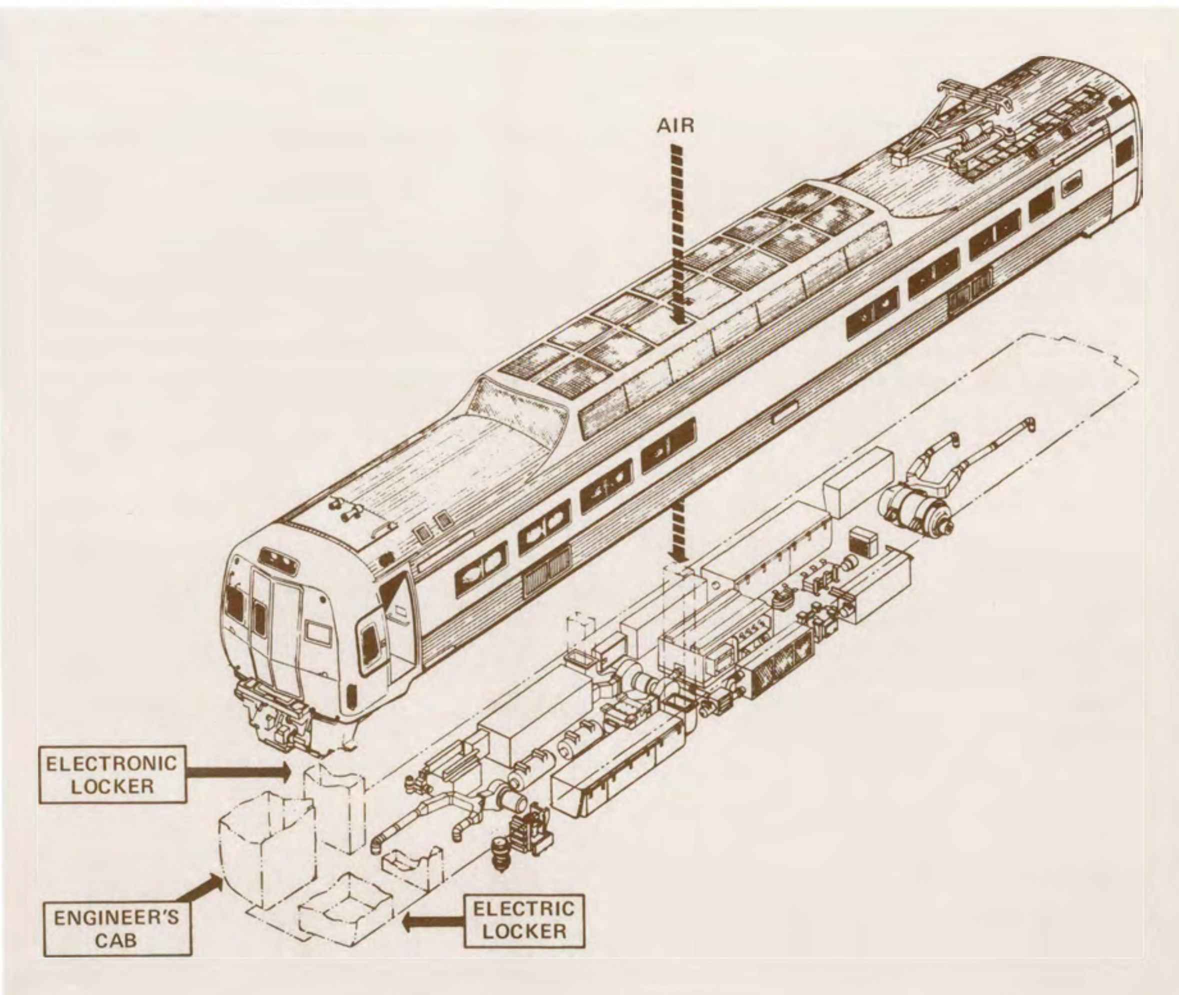
The Metroliner Improvement Program (detailed in the "Sixth Report" was completed during the past year. The objective of the program was to make improvements in those components of the self-propelled cars that had been responsible for a high failure rate and high maintenace costs. Specifically, these improvements included (1) increasing maximum scheduled speed from 100 mph

(161 km/h) to 120 mph (193 km/h), (2) increasing maximum acceleration from .66 to 1.0 mph per second (1.06 to 1.61 km/h per second), and (3) increasing reliability from 75 percent to 90 percent.

Four prototype cars, two equipped with General Electric Company (GE) electrical propulsion and control equipment and two with Westinghouse Electric Corporation equipment, completed road tests in June 1975 which verified that modifications are effective and reliable. Except for some minor corrections on the GE cars, the cars passed the test with ease. Modifications included provision of car-monitoring equipment to simplify detection of electrical component failure, a complete rewiring of propulsion circuits, relocation of dynamic grids to the roof, installation of roof-level inlets for equipment cooling, and redesign of the propulsion drive systems.

During the winter of 1974 and early spring of 1975, the four cars completed a 25,000-mile (40,200 km) reliability test. Availability for service of the two improved Westinghouse-equipped Metroliners was 97 percent compared with 70 percent for the present car, and the mean time between failure (MTBF) was 360 hours compared with 60 hours for the present car. Estimated maintenance cost of the updated car was 21 cents/car mile (13 cents/car km) compared with 82 cents/car

Figure 38. Improved Metroliner Car.



mile (51 cents/car km) for the present car. Amtrak is now assessing the feasibility and cost benefits of these modifications on its remaining fleet of 57 cars.

4.2 SUPPORTING TECHNOLOGY

Electrical Traction and Propulsion

The present FRA electrical traction program, now aimed exclusively at railroad applications, constitutes a natural exploitation of the power conditioning and linear motor projects which were developed under the Propulsion R&D Program for Advanced Technology. As now structured, the electrification and traction program is designed to support FRA/OR&D rail transportation requirements for both passenger and freight. FRA's efforts to stimulate R&D in this area have taken on particular importance in light of the energy situation and current reappraisal of railroad electrification in the United States.

The most important FRA development in the area of power conditioning has been the variable-voltage/variable-frequency power system now undergoing low-speed testing in the Tracked Levitated Research Vehicle (TLRV). If tests prove successful, this type of system will represent the most powerful and most advanced system for locomotives to date. Equally important, the TLRV power system, by permitting the use of rotary three-phase motors, can significantly extend the practical adhesion limits imposed on locomotives: this implies more powerful locomotives with the same weight of present units or, conversely, lighter locomotives with the same power of present units.

The linear electric motors (LEM) which FRA is developing offer a number of potential advantages for railroad applications, including:

- Better braking through avoidance of wheel/rail adhesion problems.
- Significant reduction in wheel flats, since the linear motor practically eliminates wheel slippage or sliding. (Traction and braking forces are not transmitted through the rails.)
- Reduced vehicle and track maintenance costs. Because it has no moving parts, the LEM is as simple and rugged as a transformer. The reduction of unsprung masses reduces track damage and, consequently, those costs associated with track repair.
- Extending safe operational speeds to 212-244 mph (350-400 km/h) on new passenger lines.
- Application as freight car accelerator retarder in yard car sorting operations, allowing fuller automation of the yards.
- Reduced wheel/rail noise.
- Improved train operation on steep rail grade.
- Construction of a more powerful and lighter locomotive, with or without onboard power generation. The present limit on maximum thrust that can be transmitted through the drive wheels at four to six points of contact would no longer be a constraint.
- Higher safe speeds on existing rights-of-way. The LEM is expected to inhibit derailment and truck hunting because of a stronger coupling of the vehicle to the track. (The LEM can develop large attraction forces.)

TLRV Propulsion System

The TLRV electrical propulsion system has now completed checkout and verification tests, including static tests to simulate starting mode, forward-run mode, braking, and reverse run. Linear Induction Motor (LIM) support and guidance cushions were installed and tested, and acceptance testing of wayside power rails was completed. Low-speed testing on 1,500 feet (457 m) of electrified guideway is scheduled for completion in April 1976, and a comprehensive report will follow. The low-speed tests will yield essential information on the practicality of the system and, in particular, will address its most critical feature—the transition from a starting mode to a running mode.

LIMRV Testing

The Linear Induction Motor Research Vehicle (LIMRV) was subjected to a series of tests over the vehicle's entire speed range to determine the electrical characteristics of the linear induction motor. The principal results have established a significant correlation with mathematical models developed in the United States, Japan, Switzerland, and Germany. The motor winding will now be reconnected to obtain, in effect, a shorter motor, the characteristics of which will be determined in 1976. The importance of testing a shorter motor is that power loss (a basic problem with all linear motors, stemming from the finite length of the motor) will be magnified for test purposes, resulting in a more complete understanding of these motors.

Other LIMRV tests which were completed dealt with braking, motor edge effect, electromagnetic wake verification, wheel/rail adhesion, and noise. Reports on these tests are now being prepared. Tests on a slotted reaction rail (representing the linear equivalent of the well-known squirrel-cage rotary motors) showed negligible effect of this type of rail on motor performance.

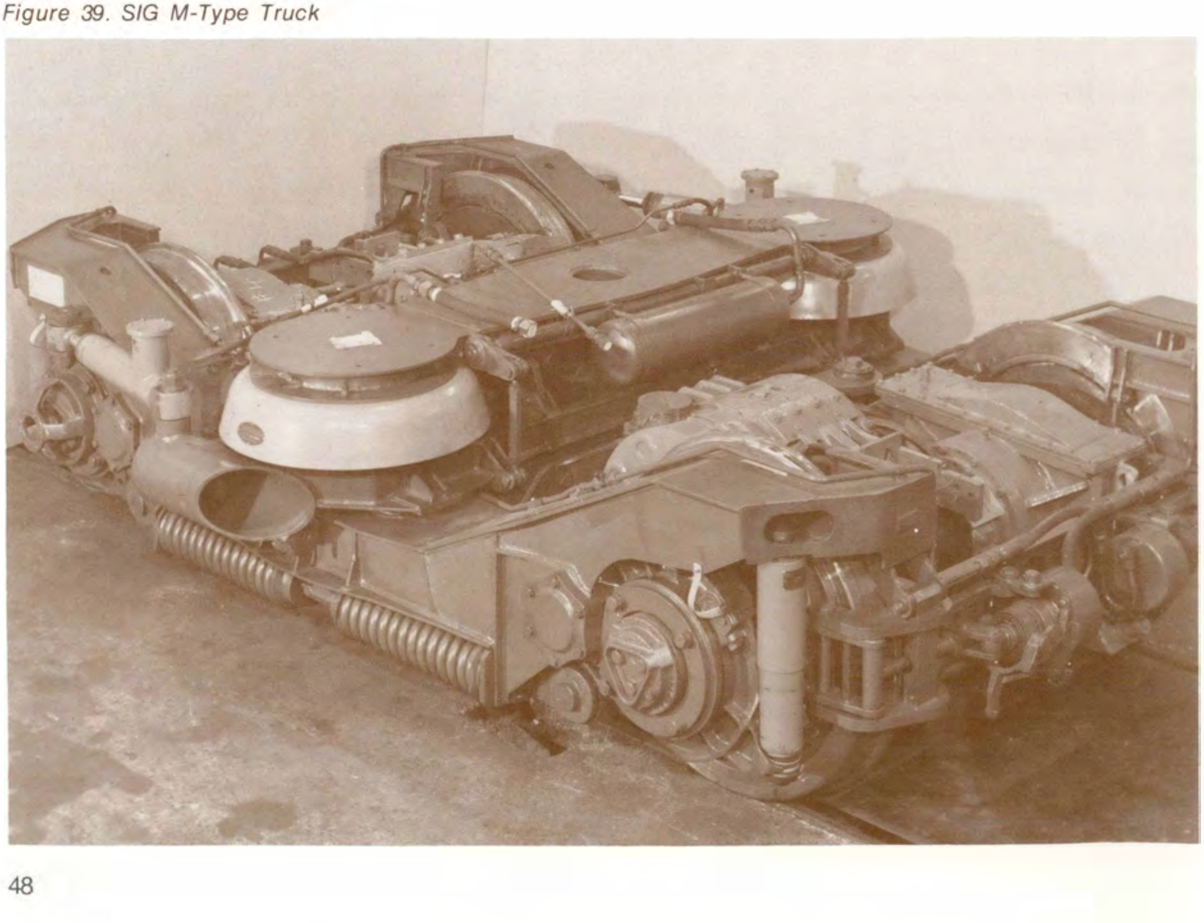
Design work began in the fall of 1975 to convert the motor to single-sided operation. Elimination of the vertical rail (required by double-sided motors) will simplify construction, maintenance, and vehicle switching.

Suspension, Support, and Guidance

The objective of the suspension, support, and guidance program is to facilitate the design of high-speed passenger trucks which will operate with improved ride quality at 125 mph (202 km/h) in regular passenger service.

In 1973 FRA awarded a contract to provide a truck with improved ride quality for testing on a Metroliner. A Swiss firm is the subcontractor for the design and fabrication of five new trucks of the latest Swiss design. This design, which is in use in other countries, will offer reduced noise and improved ride quality through its unique primary suspension and improved air-suspension secondary spring. The truck was fatigue tested, and, following minor modifications, the tests were completed successfully. Two trucks were installed on Metroliner Car No. 850 and have met the specification performance requirements in road tests conducted between Washington, D.C., and New York. A ride-quality comparison road test between Metro-

Figure 39. SIG M-Type Truck



liner Car No. 850, which had the new Swiss trucks, and Metroliner Car No. 855, which had the original trucks, revealed improved ride quality in Car No. 850. Metroliner Car No. 850 is scheduled to be put into revenue service so that further experience can be gained with this improved design.

In order to better understand the effects of wheel-rail contours on truck dynamic behavior, FRA has awarded a research contract to the University of Pennsylvania to develop a numerical method for determining contact stresses at the surface of conforming bodies. Researchers will utilize realistic models of worn or specially designed wheel-tread and track profiles, and results of the research will be used to explain the various forms of stress-induced rail and wheel failures. Tangential forces and coefficients of creep will be evaluated in relation to rail-wheel stress interactions that influence the dynamic behavior of the rail car trucks in terms of vibrations, hunting, and derailment.

4.3 ADVANCED SYSTEMS

Tracked Levitated Vehicle Technology

Following the passage of the High Speed Ground Transportation Act in 1965, FRA began an evaluation of all high-speed ground transportation systems being proposed for future implementation. Because infrastructures for ground transportation systems have very long lifetimes (50-100 years), it appeared essential to search for needs 25 or more years hence rather than merely to consider incremental improvements to present technologies.

A number of studies have shown that advanced high-speed ground transportation has the potential to add significantly to the nation's transportation capability, supplementing existing highway, air, and conventional rail transportation systems. These studies led to two conclusions—that tracked levitated vehicle (TLV) technology had the most potential for achieving the advanced performance and that the goal of the TLV R&D program should be to define the potential performance of a TLV system for intercity travel that is distinctly superior to extensions of existing systems and gain an understanding of the characteristics and principal cost factors of such a system over the speed range.

The principal advantage of TLV systems is that they can provide a safe, nonpolluting, and comfortable mode of travel and, because they do not come in contact with the guideway, can do so at high speeds with low maintenance costs.

Prototype Tracked Air Cushion Vehicle (PTACV)

For the past five years FRA, in cooperation with the Urban Mass Transportation Administration (UMTA), has been developing a prototype tracked levitated vehicle in order to demonstrate the present state of the technology. This system is the world's first nonpolluting, all-electric, 60-passenger, air cushion vehicle operating on an inverted-tee guideway. The vertical member of the inverted tee guides the vehicle and acts as the reaction rail for propelling the vehicle in conjunction with the linear induction motor. This feature, and the fact that the guideway is a simple slab of concrete similar to a concrete roadway, makes the inverted-tee guideway relatively inexpensive when compared with the channel guideway.

The goal of the PTACV project is to verify the technical feasibility and public acceptance of a TLV as a mode of transportation by designing, fabricating, and testing a prototype system. If regional planners can observe the system in operation, they will be better able to determine if a TLV system can satisfy their particular needs.

The prototype vehicle is powered by a linear induction motor, levitated and guided

Figure 40. Prototype Tracked Air Cushion Vehicle (PTACV) on Test Track at TTC, Pueblo, Colorado.

by air cushions fed by electrically driven air compressors, and controlled by an automatic vehicle control system with manual override. The vehicle is supplied with electrical power by a wayside distribution and power collection subsystem. All vehicle subsystems utilize present technology; however, integrating these subsystems into an operational system represents a technological advancement.

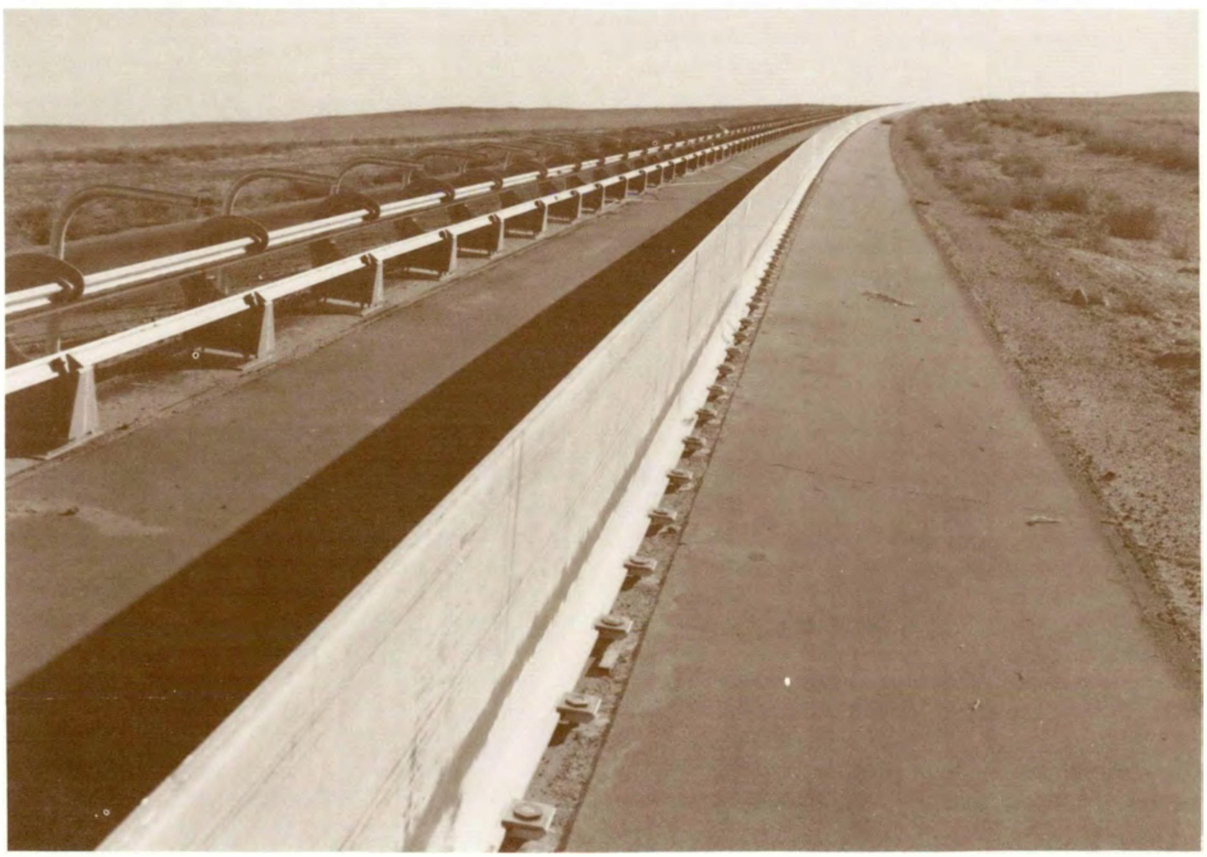
During the past two years, vehicle construction was completed, and following a subsystem checkout period the vehicle was shipped to the Transportation Test Center.

During the past year, the fully assembled vehicle has undergone a series of static and low-speed checkout and system operational tests on the TTC test track. These tests were designed to demonstrate vehicle operability and readiness for high-speed operations and to verify, to the extent possible, the degree of system conformance to performance specifications.

On May 9, 1975, the vehicle reached a speed of 102 mph (163 km/h), thus setting a new U.S. speed record for levitated vehicles. At that time the speed of the vehicle was limited by the length of finished test track that could be used safely. Construction of the total track (5.68 miles, 9.14 km) has been completed, which will permit testing at 150 mph (240 km/h) for approximately 20 seconds before bringing the vehicle to a safe stop.

During these tests, no problems were encountered in the operation of the vehicle which would appear to preclude testing the vehicle to its top speed. However, while the vehicle was in the maintenance building for a static checkout test of the propulsion control unit, an accidental overheating of the aluminum reaction rail caused by the LIM

Figure 41. PTACV Guideway During Construction of Power Rail Cover at TTC, Pueblo, Colorado.



operation charred a section of the fiberglass cover on the LIM and the insulation of some of the windings. As a result of the accident, which occurred in June, vehicle testing was interrupted for three months while repairs were being completed.

When testing is resumed, the system will be demonstrated at TTC to interested transportation planners. The test program will determine basic system performance characteristics (safety, speed, acceleration, environmental effects, and ride comfort) and will establish requirements and characteristics for operating and maintenance procedures and costs.

One of the most active regional transportation planning groups interested in TLV systems is the North Central Texas Council of Governments, which includes the cities of Dallas and Fort Worth. Working under an UMTA technical study grant, this group has performed a preliminary engineering study to determine the feasibility of operating a TLV system between Dallas and Fort Worth. FRA provided the group with technical assistance in analyzing TLV operating and performance characteristics. Preliminary findings indicate that a 40-mile (64 km) route for a TLV system running between the two cities and through the new airport is feasible and practical from an engineering standpoint.

Tracked Levitated Research Vehicle (TLRV)

Since 1968, when two preliminary design contracts were awarded, FRA has designed and fabricated a tracked air cushion vehicle for full-scale research in TLV technology. The vehicle was designed to test various subsystems under operation at speeds up to 300 mph (483 km/h). Such subsystems included linear motors, variable frequency and voltage power conditioning units, turbofans for cushion air supply, 8250VAC wayside electrical power distribution and collection, and an active or passive secondary suspension control. The TLRV is designed to operate in a U-channel guideway and to seat four occupants—a vehicle operator, an instrumentation observer, and two passengers. In addition, the vehicle has a number of braking subsystems—an aero brake, friction brakes, LIM braking, and an arresting capability for use in emergencies.

For the past three years, the TLRV has been undergoing tests at TTC utilizing the turbofan engines for propulsion. As more guideway was constructed, vehicle operations were conducted at successively higher speeds up to a maximum of 91 mph (146 km/h) on the full three miles (4.8 km) of test track. During the past year the LIM and power conditioning unit have been installed. The work on TLRV is now being used as a test bed to support the traction and propulsion systems project. This work is covered elsewhere in this report.

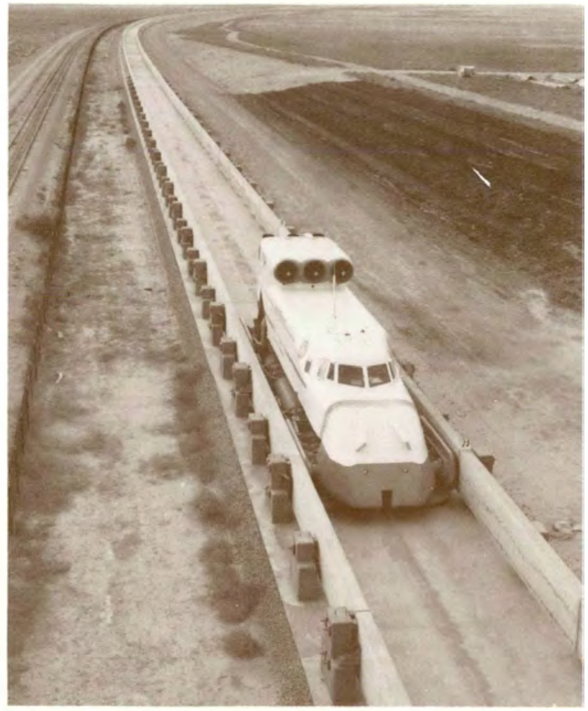
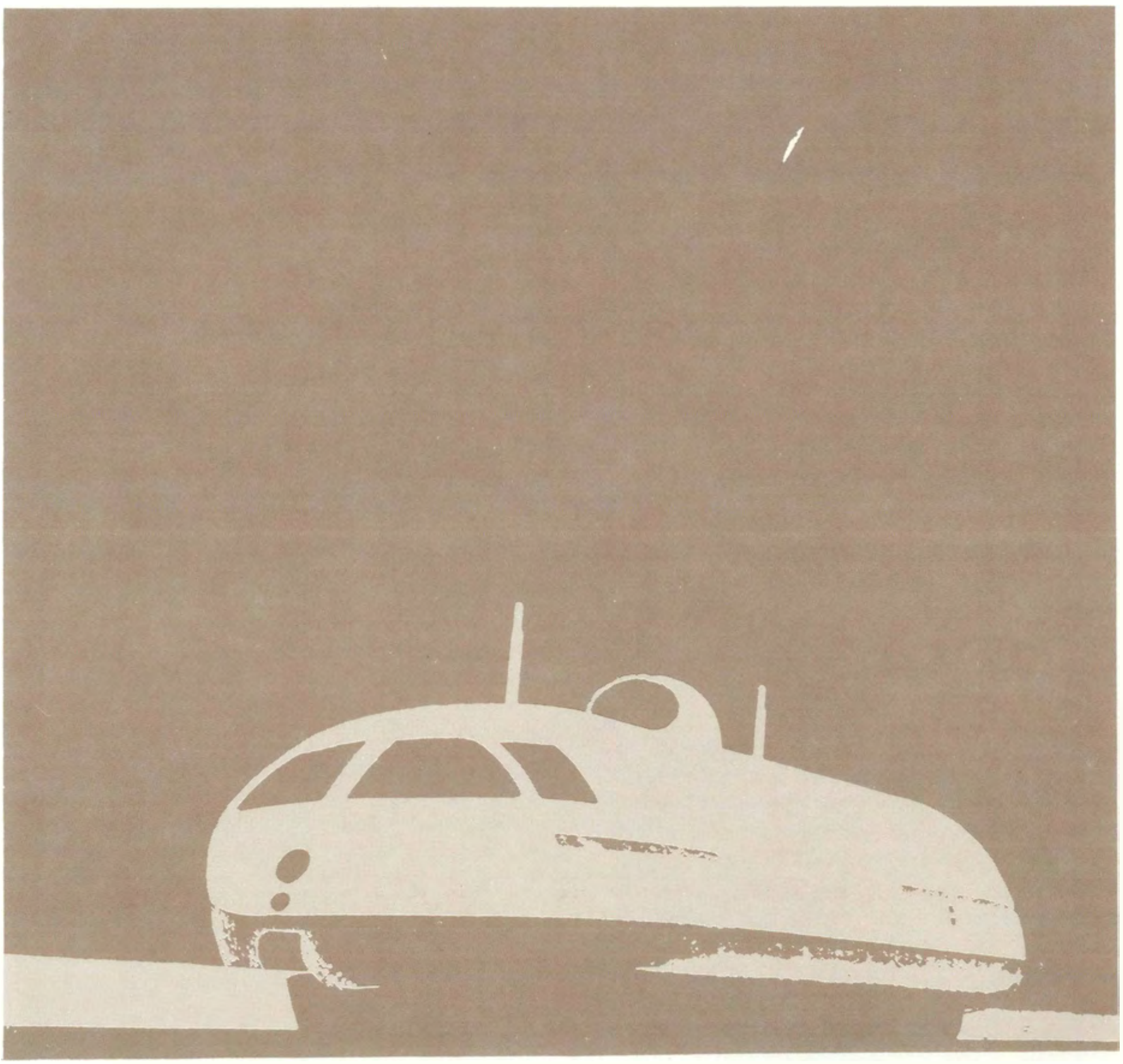


Figure 42. TLRV Undergoing Tests Under Turbogan Propulsion at the TTC.

Magnetic Levitation

The use of magnetic forces to support and guide high-speed ground vehicles appears very promising technically and economically, but it is yet in an early stage of development, particularly compared to air cushions. The feasibility of magnetic levitation, both the attraction and repulsion varieties, had been established by earlier FRA-sponsored work. But the problem of integrating this type of vehicle suspension into a complete vehicle/guideway/transportation system had not been adequately examined. Such questions as whether magnetic levitation would be compatible with various propulsion devices, guideway configurations, switching requirements and operation in trainsets had not been answered. Further work will be necessary to determine the feasibility of the magnetic levitation system as a future mode of transportation.

Accordingly, conceptual designs of revenue vehicle systems were developed during the past year for both the repulsion Maglev concept and the attraction Maglev concept. Both efforts relied on analytical and experimental data acquired in earlier DOT studies of magnetic levitation. The designs were to be used in a rocket sled demonstration to verify that the suspension subsystem of each Maglev concept would perform as predicted. Due to a reordering of DOT priorities, both programs were terminated prior to any test equipment construction. A final report on the conceptual design of the repulsion Maglev concept was produced, while the work on the attraction Maglev concept has not been documented.



5.0 TRANSPORTATION TEST CENTER

There were significant changes in all areas at the Transportation Test Center (TTC) during the past year. These included changing the name of the test center from the High Speed Ground Test Center (HSGTC) to the Transportation Test Center; changing the mission statement and table of organization; and shifting emphasis from advanced vehicle testing to more conventional railroad and transit equipment testing.

The volume of testing at the TTC has in creased to an average of two tests each workday; often, as many as six or seven tests are conducted in a day. Highlighting the year's testing was the completion of the TTC's first international test program, which involved the Canadian Light, Rapid, Comfortable (LRC) Train. The LRC Train ran more than 20,000 miles (32,180 km) in six weeks, exceeded distances of 1,000 miles (1,610 km) per day, and reached speeds up to 120 mph (193 km/h). Another TTC test program, completed in May 1975, involved a remarkable series of train-to-train collision tests with full-scale trains. In the final test of the series, a 1.5 million-pound (0.68 million kg) train with caboose was struck by two locomotives and a 1.7 million-pound (0.77 million kg) train moving at 30.4 mph (49 km/h). The tests, jointly sponsored by government and industry, are expected to aid in developing safer locomotive designs and in improving crashworthiness of locomotive cabs.

Major construction activities at the TTC during the past year included completion of a power distribution system that allows all buildings on the site, with the exception of the LIMRV building, to operate on commercial power; paving of the road from Pueblo Memorial Airport to the TTC; completion of two major buildings (Center Services Building and Operations Building), and completion of the Service Yard and Wye Lead, providing seven yard tracks and a rail connection to the Center Services Building.

A Facilities Master Plan was completed and copies of completed master plan were made available by September 1975. The status of planned and existing facilities at the test center is as follows:

- Approximately 13 miles (20.9 km) of conventional railroad test tracks are completed; about 33 miles (53.2 km) are planned. Eight miles of track are under construction and should be completed before June 1976.

- An electrified third rail transit test track loop 9.1 miles (14.6 km) in length has been constructed. Plans call for additional trackage within the loop, consisting of elevated structures, tunnel-entry simulation, screech loop, and perturbed track sections.

- A 3-mile (4.8 km) U-shaped guideway built for the Tracked Levitated Research Vehicle (TLRV) has been partially equipped with wayside power and reaction rail.

- A 5.7-mile (9.2 km) guideway, which includes a center reaction/guidance rail and a 4,160-volt wayside power system, has been completed. The Prototype Tracked Air Cushion Vehicle (PTACV) has operated over the entire length of track, reaching speeds of 102 mph (164 km/h) in May 1975.

- A 6.2-mile (10 km) precisely aligned conventional railroad track with a center aluminum reaction rail for the Linear Induction Motor Research Vehicle (LIMRV) is complete. The LIMRV has operated at speeds up to 255.4 mph (411 km/h) during testing.

- A Tank Car Torching Test Facility with a half-mile (0.8 km) radius safety zone is now in operation on a remote portion of the test center site to examine the characteristics of tank car insulations under propane torch conditions.

• The Rail Dynamics Laboratory (RDL) for vibratory and dynamic testing of full-scale rail and transit vehicles is in limited nontest use pending completion, installation, and acceptance of major items of sophisticated test equipment.

• The Center Services Building and the Operations Building have been completed.

• The electrical distribution systems for all buildings on site and the systems for the PTACV and the TLRV are complete. The electrical distribution system using commercial power for the Transit Test Track (TTT) is under construction.

• Two miles of temporary 600 VDC overhead wire power system catenary were installed over the west side of the TTT. The system will be used for testing the Standard Light Rail Vehicle (SLRV).

• Two 750 kw turbo-generators are operational for furnishing emergency power to the fire pump, Center Services Building, Rail Dynamics Laboratory, Project Management Building, and the Operations Building.

• A water well, standpipe, and emergency fire pump provide water and fire protection to buildings in the core area.

• A guard station has been constructed to control access to all areas at the TTC within the security fence (excluding the Operations Buildings, which is outside the fence).

• Street lighting design is near completion; construction and improvements will follow.

• Development of a fuel storage area was begun with the installation of two 30,000-gallon (113.550 litre) tanks.

• Maintenance buildings are in use for transit vehicles, the LIMRV, the TLRV, and the PTACV.

• Soil conservation, environmental protection, and security fencing programs are in progress.

5.1 TEST FACILITIES

Test center facilities for testing conventional rail equipment include (1) the Train Dynamics Track, with some 4.5 miles (7.2 km) of curves and grades that can be modified to incorporate perturbations which resemble deteriorated track conditions, (2) the Impact Facility Track, a 0.75-mile (1.21 km) tangent (straightaway) track where destructive and nondestructive impact test projects are conducted, and (3) the Transit Test Track, a 9.1-mile (14.6 km) loop with a 600-volt DC outside third rail for powering rapid transit cars. For most of the period covered by this report, the Transit Test Track was the only closed loop track at the TTC and therefore was in high demand for both transit and railroad testing that required continous running. This congestion was relieved by construction of 4.2 miles (6.8 km) of railroad track for the northern segment of the High Speed Track and a 1.5 mile (2.4 km) "Balloon Loop" track for reversing the running direction of trains. Construction was completed in August 1975 and accepted for use two months later. Two spring-loaded track switches are used to allow round-and-round operation of test trains which can depart from the "Balloon Loop," travel the length of the Train Dynamics Track, and then return to the "Balloon Loop" via the new northern segment of the High Speed Track.

In June 1975 work began on the construction of 8.3 miles (13.4 km) of railroad track to complete the High Speed Track, a 13.5-mile (21.8 km) oval designed for train speeds up to 160 mph (258 km/h). It should be completed and accepted early in 1976.

The Transit Test Track has been used extensively for the Urban Mass Transportation Administration test activities. The track consists of six different combinations of welded and jointed rail or wooden and concrete crossties. Each segment of track is representative of track found on various metropolitan transit systems throughout the country. A third rail system supplies the loop with 600 volt DC electric power. At present, power is supplied by the generator of the test center's 3,700 horsepower diesel locomotive and by trailer mounted auxiliary generator units. A power line and substation (transformer) are now being built to supply the loop with commercial power.

The 7,700-square-foot (715 m^2) Transit Maintenance Building, located near the eastern side of the Transit Test Track, contains a spur track and 100-foot service pit. The building has a 600 volt DC power source for repairs, servicing, and other work on transit cars. A track scale, installed adjacent to the

Transit Maintenance Building and accepted in December 1974, was adjusted electronically to measure within 10 pounds (4.5 kg) of the calibrated car weight, using a railroad scale car weighing 85,000 pounds (38,549 kg).

5.2 SUPPORT FACILITIES

Two major support buildings, the Center Services Building and the Operations Building, were completed this year and are now occupied by test center personnel. The 63,000-square-foot (5,880 m^2) Center Services Building houses maintenance and repair facilities for rail vehicles, research vehicles, and test center rolling stock. The Service Yard and Wye Lead, a rail access to the facility, were completed in March 1975. The Operations Building, a 28,000-square-foot (2,600 m^2) structure, contains 11,000 square feet (1022 m^2) of office space for the government staff and the operations and maintenance contractor's staff. The building also has a Central Control/Data Collection area, a cafeteria to feed 500 people, and a conference room capable of accommodating 200 people.

5.3 OPERATIONS

Rail Systems

FRA is cooperating with the railroads (through AAR), the railroad equipment suppliers (through RPI), and the Canadian government (through its Transportation Development Agency) in a joint government-industry program to learn more about the dynamic relationships between moving trains and the tracks they run on. The goal of this program, called the Track-Train Dynamics Program, is to develop improved railroad equipment and operating procedures.

The test center's contribution to Phase I consisted of two series of tests—lateral/vertical ratio tests and lateral stability tests. In both series of tests, freight car trucks (wheel and axle sets with supporting side frames, center bolster and springs, etc.) were instrumented to measure the trucks' dynamic reactions and the wheel-rail interaction forces. Test data will provide a better understanding of truck hunting (a highly unstable and sometimes destructive side-to-side pivoting vibration of the truck) and many derailment conditions.

Some of these tests resulted in the make-up of a train with an extremely unusual configuration—five locomotives, three buffer freight cars, the test freight car, three more buffer freight cars, five more locomotives, and (usually) a two-car set of instrumented FRA Track Geometry Cars to record actual track and equipment conditions at the time of the test. This consist was designed to create forces comparable to those encountered by a car near the front of a train of some 150 or so cars. When the train started or moved up a grade, the front locomotives pulled while the rear locomotives "dragged their feet" by braking to simulate the load imposed by a large number of following freight cars. When the train went down a grade, the front five locomotives braked while the rear five pushed hard on the rear of the train to simulate the force of a large number of cars rolling downhill. The resulting high compressive (buff) and tension (draft) forces gave an accurate picture of what happens to cars in long trains subjected to the same forces.

For another program, stability tests were run on the Train Dynamics Track's perturbed "rock-and-roll" section, where undulating lengths of track were placed alternately on opposite sides of the track to induce a rocking motion in the test train. Wheel lift of some two inches or more was observed in some especially severe tests (approximately 20 mph (12 km/h)). The test center also tested the stability of certain Department of Defense freight cars with heavy loads on the perturbed track portion of the Train Dynamics Track.

Other conventional rail projects completed at the test center during the past year included train-to-train impact tests and testing of a new passenger train and new passenger cars.

In the Train-to-Train Impact Test Program, a series of impacts simulating actual accidents was conducted in the spring of 1975 on the test center's Impact Facility Track. Early tests in the series were at low speeds—approximately 3 and 5 mph (4.8 and 8 km/h). Later tests at 9 mph (14 km/h) did some damage, but the last two tests, at 18 mph (29 km/h) and 30 mph (48 km/h) were the most spectacular. Test results are expected to aid in developing safer locomotive designs and in improving the crashworthiness of locomotive cabs.

In October 1974 a pre-production model of a new, 120 mph (193 km/h) Canadian Light, Rapid, Comfortable (LRC) passenger train arrived at the test center. The low, streamlined locomotive and coach ran 29 tests and more than 20,000 miles (32,180 km) before leaving the test center at the end of November. Constructed by a consortium of three Canadian firms, the LRC represents an evolutionary advance in passenger train design. A notable feature of the train's coach is a powered banking system which senses a curve and tilts the coach body just enough to keep passengers comfortable in their seats at speeds considerably higher than is possible with conventional coaches.

In the summer of 1975 four new 74-passenger Budd Company stainless steel railroad coaches were tested for Amtrak at speeds up to 120 mph (193 km/h) on test center tracks (primarily the 9.1-mile (14.6 km) Transit Test Track loop. The cars, which feature attractive decor and comfortable seats, were tested for ride quality, stability, and reliability. An Amtrak E-8 locomotive accompanied the new Budd coaches and was used for some of the testing. The four cars completed qualification tests and were accepted by Amtrak representatives. They are the first of 492 such coaches ordered.

Current FRA testing at the test center includes a multiphase program to study and reduce the probability of catastrophic failure of rail tank cars carrying liquified petroleum gas or other flammable ladings. FRA has contracted with the U.S. Army Ballistic Research Laboratories (BRL) to participate in this program. Major test objectives of the current phase are to predict tank car response to torching conditions and to evaluate the performance of two thermal insulating coatings, one or both of which will be applied to railway tank carriers.

Test equipment (remotely controlled torch, tank car for fuel storage, mobile office, and control room) was set up in 1974 and is now in operation at an isolated site near the geographic center of the test center.

Planning preparations were completed for a series of switchyard impact tests involving tank cars and hopper cars. Two 100-ton, (91 tonnes), 33,000 gallon (124,900 litres) tank cars for LP Gas were received during the period of this report, which will be used in the impact test series. Preparations were also made for two proprietary conventional rail test programs at the end of this reporting period. American Steel Foundries and Dresser Industries were both scheduled to test their freight car truck designs during the winter of 1975-1976. American Steel Foundries conducted similar tests during the summer of 1974.

UMTA Rail Transit Systems

Two Urban Mass Transportation Administration (UMTA) test programs were completed during the past year at the Transportation Test Center; a third program is still in progress.

Four Gas Turbine-Electric (GT-E) cars designed and built for the New York Metropolitan Transportation Authority completed a six-month test program at the test center in December 1974. Electric-powered commuter cars developed prior to those used in the test program could not be operated over non-electrified portions of the rail unless they were pulled by a conventional locomotive. This necessitated the transfer of passengers from one train to another (electric-powered to diesel locomotive-powered) in order to reach extremes of the line. The 100 mph (161 km/h) Gas Turbine-Electric commuter cars can be powered by the third rail on electrified track or, when necessary, can provide their own power over nonelectrified trackage. Except for two generator sets which occupy opposite corners of the roof area of each car, the Gas Turbine-Electric cars are visually identical to the conventional all-electric cars in use on the Long Island Railroad. The Gas Turbine-Electric cars are now in operation on that railroad.

The year-long test program involving two R-32 New York City transit cars (subway cars built in the early 1960s) was completed in February 1975. The conventional electric propulsion system normally used in these cars was replaced with an onboard energy storage system. This system stores the energy normally dissipated as heat during braking in a rotating flywheel and then extracts it when needed for the next start and acceleration. This reduces both the car's consumption of electrical energy and the braking heat radiated to the air in the subway tunnel. (Heat from braking is so intense that the subway tunnels in New York have to be force-cooled even in winter.) In addition, the rotating flywheel provides an onboard supply of energy sufficient to move the car to the nearest station in the event of a wayside electrical power failure.

Subway cars normally use a system called dynamic braking to retard speed. This consists of converting the propulsion motors at the wheels to generators which create a drag to slow the rotation of the wheels. Current from the motors-turned-generators is routed through a large resistor grid that glows red-hot and dissipates the energy in the form of heat to the surrounding atmosphere. With the onboard energy storage system, this current is routed instead to another electric motor-generator and is used to increase the rotational speed of a flywheel connected to the motor. When the car is ready to start up, the motor at the flywheel functions as a generator and, using the energy in the flywheel, generates electricity to drive the propulsion motors at the car's wheels. In actual operation, the flywheel runs at a maximum speed of 14,000 rpm and "runs down" only to around 9,400 rpm. At the low rpm enough current is fed to the flywheel motor to keep it at that speed. Current comes from the wayside power system. If braking results in the generation of too much current (which would cause the flywheel to overspeed), the excess is routed through a dynamic brake grid.

Each subway car contains two flywheel units which rotate in opposite directions to cancel out the gyroscopic forces of the rapidly rotating masses. Each flywheel is enclosed in a cylindrical housing with a tapered end which is located near the middle of the car's underbody and provides the only visual indication that the car is equipped with the energy storage system.

The two R-32 cars with energy storage system equipment installed are now back in service in New York City where they are being used to collect comparative data on the cost of operating both types of propulsion systems.

Two other New York City Transit Authority transit cars (R-42 model) are undergoing testing at the Transportation Test Center in a continuing project to develop various kinds of special instrumentation, including a track geometry measuring system. This system will differ from that used in the FRA Track Geometry Cars in certain respects that will make the UMTA system more effective in adverse weather conditions. The R-42 design, built in the late 1960s, is the first New York subway car design to incorporate air conditioning.

Advanced Systems

During the reporting period for this report, test operations were conducted with the following advanced technology vehicles, which are discussed earlier in this report in Section 4.0:

- Linear Induction Motor Research Vehicle (LIMRV)
- Tracked Levitated Research Vehicle (LTRV)
- Prototype Tracked Air Cushion Vehicle (PTACV)

5.4 PUBLIC AFFAIRS

Industry, government, and individuals, both foreign and domestic, continued to exhibit a high level of interest in testing and construction activities at the Transportation Test Center during 1975.

In October 1974 Paul Cunningham of NBC visited the TTC to film an eight-minute television segment for the NBC *Today Show*. During the same month, some 200 attendees of the FRA-sponsored Eleventh Annual Railroad Engineering Conference toured the test center.

In May 1975 the test center hosted numerous representatives of government, industry, and news media who observed the final Train-to-Train Impact Test at 30.4 mph (49 km/h). A guided tour of test center facilities was provided in conjunction with this event. FRA and test contractor representatives provided briefing for the visitors.

In September 1975 a test center open house was held in conjunction with the official dedication of the newly paved access road from the Pueblo Memorial Airport. John W. Barnum, Deputy Secretary of Transportation, hosted the open house, which was attended by approximately 400 people.

During FY 75 the United States Information Agency contracted with a film crew to prepare a film for the agency to use in foreign countries.

More than 6,500 people visited the center during 1975, among them the following groups and individuals:

Congressional

U.S. Senator Vance Hartke, Indiana
U.S. Senator Gary Hart, Colorado
U.S. Representative Joe Skubitz, Kansas
California State Senator James Mills, President Protem
California State Senator Al Alquist

Government

Secretary of Transportation Claude S. Brinegar
Deputy Secretary of Transportation John W. Barnum
Robert Hemphill, Assistant Administrator for Transportation Programs, Federal Energy Administration
Asaph Hall, Administrator, Federal Railroad Administration
Bruce Flohr, Deputy Administrator, Federal Railroad Administration
The Department of Transportation Field Coordinating Group: Robert Kessler, Merv Martin, Tad Weigle, Charles Rumpf, Robert O'Connell, and Herb Peets
The FRA-sponsored Eleventh Annual Railroad Engineering Conference
Mike Norton, Regional Administrator, General Services Administration
Don Berry, Regional Commissioner, Federal Supply Services
Tom Reinhard, Congressional Relations Officer, Amtrak
Maj. General William Palmer, Commanding Officer, Ft. Carson
Mr. Paul Hartmann, Director of Railroad Division, Iowa Department of Transportation
Dr. Clifford Seitz, National Transportation Safety Board
John Hirten, Deputy Administrator, Urban Mass Transportation Administration
David Stevens, Staff Assistant to Governor Evans, State of Washington
W. Bond, Secretary of Transportation, Illinois
Donald Gardner, Commissioner, Department of Transportation, Iowa
Rear Admiral Henry Arnold, Director of Tactical Air, Surface & Electronic Warfare Development Division, Office of Chief of Naval Operations
Lester Lamm, Executive Director, Office of Federal Highway Administration, Washington, D.C.
Dick Gallagher, Chief Engineer, Southern California Rapid Transportation District
Don Garder, Chief Electrical Engineer, Southern California Rapid Transportation District

Foreign

Marcel Cavaille, Minister of Transportation France
Claude Abraham, Director of Air Transport, France
Martin Guarino, President, Uruguayan National Railroads
D. J. Lyons, Director General of Research, Department of Environment (DOE) Great Britain
Wolfgang Goehwiler, President, Swiss Industrial Group, Switzerland
Viscount Garnack (Lord), Vice Chairman, North American Advisory Group, British Overseas Trade Board
Jeant Bertin, President, Societe De L'Aerotrain, France
Deutsche Bundestag (West German Legislature), Transportation Committee (11)
Robert Lambert, Industrial Attaché, French Government Economic Mission
Jesus Torres-Moncayo, Director of Research, Mexico City Metro
Nicolae Pasca, Romanian Ministry of Transportation
Leonid Nailesca, Romanian Ministry of Transportation
Demag Transportation Systems, Federal Republic of Germany (6)
B. Bernieri, President, Italian Railroad
Graham Jones, Representative of Minister of Transportation, Canada
Hans Isliker, Director of Research, Transportation, Federal, Switzerland
Taag Karlsson, Executive Vice-President, Volvo Bus Division, Sweden
Ted Rudback, Canadian Transportation Development Agency

Industrial

Richard Duchossois, Chairman, Rail Progress Institute, President, Thrall Car Manufacturing Company
Malcolm Richards, Vice-President, Penn Central Railroad
Elwood Ahnquist, President, Pullman Standard

Gregory Gagarin, President, Knorr Brake Corporation
Jim Crawford, Senior Executive Vice-President, Garrett Corporation

Associations, Committees

Locomotive Maintenance Officers Association, Diesel-Electrical Committee (10)
Association of American Railroads
Open Top Loading Rules Committee (33)
Railway Planning Group (26)
Arbitration Committee (46)
Brake Equipment Committee (45)
Hazardous Materials Committee (15)
National Association of Accountants
Institute of Rapid Transit, Transit Track Construction Subcommittee (16)
Denver Chamber of Commerce, Transportation Committee (28)

6.0 INTERNATIONAL COOPERATION

FRA is a participant in formal agreements and memoranda of understanding which the Department of Transportation (DOT) has with 10 foreign countries. These agreements are designed to benefit the U.S. railroad community by providing useful technological information and eliminating duplicative research. Primary activities over the past year were with the Soviet Union. In the past, cooperation with the German Federal Republic was pursued more aggressively; but with curtailment of the Advanced Systems Technology program, the pace has been slowed. However, with the signing of a memorandum of understanding on September 3, 1975, between Secretary Coleman and German Minister of Transport Gscheidle for cooperation in conventional rail and for research in near-term payoff areas, activities between the two countries are being reevaluated. Following is a summary of FRA's international cooperation activities during the past year.

Cooperation with Soviet Union

FRA's cooperative activities with the Soviet Union were formalized with the signing of an agreement entitled "Cooperation in the Field of Transportation" on June 19, 1973, between the U.S. Secretary of State and the Soviet Foreign Minister. This agreement provides, in part, a mechanism for the mutual transfer of multimodal information on transportation and for the exchange of delegations for the purpose of familiarizing each country with the other's state of technology. Previous visits to the Soviet Union have indicated that, in general, Soviet railroad technology efforts are considerably greater than those of the United States and the United States can derive substantial benefits from Soviet technology. The USSR is the most rail-intensive country in the world, carrying 50 percent of world ton-mile freight on 10 percent of available trackage. The Soviet Union also has the most extensive electrified railroad system in the world, with 24,000 route miles (38,600 km) (27 percent of the total rail network) carrying 51.2 percent of the railroad freight tonnage on electrified lines. The Soviet railroads have several thousand technical staffers conducting railroad research at various institutions. Soviet railroad personnel training is conducted at 13 training institutions. One such institution which an FRA delegation visited recently is the Leningrad Railway Institute. It has an enrollment of 13,000 students who receive instruction from more than 1,000 faculty members.

During the past year FRA pursued an active program of cooperation with the Soviet Union. From November 11–14, 1974, the Second Meeting of the US-USSR Joint Committee on Cooperation in the Field of Transportation was held in Washington, D.C. The purpose of the meeting was to review the progress of the joint cooperative activities in implementing the programs agreed upon at the committee's first meeting and to hear reports from working groups in the various transportations modes. Committee members agreed to create a working group for cooperation in the field of transport of the future. During November 11–13, 1974, the Third Meeting of the Joint US-USSR Working Group on Railroad Transportation was also held in Washington. The working group reviewed progress to date and discussed plans for future cooperative programs and familiarization trips by delegations from both countries.

The Third Meeting of the US-USSR Joint Committee on Cooperation in the Field of Transportation was held in Moscow from September 2–4, 1975. The committee reviewed cooperative activities which had taken place since its second meeting and heard reports from the working groups. In accordance with a Joint US-USSR Communique signed by President Nixon and L. I. Brezhnev, General Secretary of the Soviet Communist Party, at Moscow on June 3, 1974, the First Joint Meeting of the Soviet-American Working Group on "Transport of the Future" was held at Moscow from August 27 to September 1, 1975. At this meeting, information was exchanged on the present state of technology to lay out future plans and courses of action for cooperation in the field of transport of the future. Cooperation in this field initially will be directed towards magnetic suspension and linear traction motors designed for speeds up to 805 mph (500 km/h). The Fourth Meeting of the Joint US-USSR Working Group on Railroad Transportation was held September 1–3, 1975, in Moscow. Working group members summarized cooperative activities since its third meeting, established a cooperative plan for 1976, and set the date and place for the fifth meeting. It was agreed that FRA would receive the USSR Ministry of Railroads delegation in October 1975 to familiarize delegation members with maintenance of rolling stock, refrigerated cars, Metroliner trains, and the Transportation Test Center. The working group agreed to exchange information on the following areas:

- Construction and operation of railroads in cold climates;
- Automated system for freight traffic control;
- Methods of electromagnetic/acoustic rail flaw detection;
- Railroad electrification.

Agreement was also reached to send a Soviet delegation to the United States in the third quarter of 1976 to study the effects of heavy axle loads on the reliability of service and the service life of track, and to familiarize the Soviets with modern methods and means of inspecting track structures on the U.S. railroads. A similar U.S. delegation is to visit the Soviet Union in the third quarter of 1976 to discuss matters relating to Soviet technology in the field of track construction, maintenance, and inspection. A hardware exchange agreement was concluded at the Fourth Railroad Working Group meeting whereby the United States was to receive from the Soviets 10 concrete cross ties for testing and evaluating in the United States and the United States was to supply the Soviets with a draft gear for freight cars for tests and evaluation in the Soviet Union.

Cooperation with the German Federal Republic

FRA's cooperation with the German Federal Republic is based on two documents—a memorandum of understanding signed June 12, 1973, by the U.S. Secretary of Transportation and the German Federal Minister for Research and Technology and a second memorandum dated September 3, 1975, between the Secretary of Transportation and the German Federal Minister of Transport. The former agreement was designed to promote cooperation in research and development for advanced transportation technologies, particularly tracked levitated high-speed transportation systems. The latter agreement was designed to promote cooperation in research and development for conventional rail technologies.

The agreement of June 12, 1973, is being reexamined jointly in order to direct cooperative efforts more toward programs which have short-term payoffs. In June 1975 FRA representatives visited with officials of the German Ministry of Transport and German Federal Railways to examine the state of German railroad electrification and to prepare groundwork for future joint meetings to develop cooperative programs. It was agreed that FRA would meet separately with members of the German Ministry of Research and Technology and members of the German Ministry of Transport and German Federal Railways at Washington in October 1975. Indications are that visits, correspondence, and cooperation with the German Federal Republic will prove beneficial. Present plans call for more active cooperative efforts with the German Federal Republic during the next year.

Cooperation with Other Countries

The U.S. Embassy in Mexico sponsored a technical seminar on railroading from June 3 to June 5, 1975, at the U.S. Trade Center, Mexico City. The theme of the seminar was

"Advances in Railroading". FRA took an active part in this seminar by arranging speakers from the U.S. rail industry, AAR, and FRA, with the FRA Administrator being the keynote speaker.

Other DOT/FRA agreements with foreign countries, including Canada, France, Iran, Italy, Japan, Poland, Romania, and Spain, have been in somewhat of an inactive state since they cover areas in which one or both sides have low priorities or have terminated their R&D programs.

International Reference Exchange

FRA continues to be a member of the International Union of Railways (UIC), the Office for Research and Experiments (ORE), and the Organization for Economic Development and Cooperation (OECD). Through these memberships FRA receives all technical literature disseminated by these organizations, which has proven to be a valuable tool in FRA's R&D efforts.

7.0 TECHNOLOGY SHARING

Railroad Research Information Service

The Railroad Research Information Service (RRIS), sponsored by FRA, has completed its third year of operation at the Transportation Research Board (TRB) of the National Research Council. RRIS now has on file more than 9,500 references to railroad-related technical literature, representing an addition of 2,500 items in the past year. A general model of RRIS as it is now functioning is shown on the next page.

The "Railroad Research Bulletin," a semiannual publication of RRIS, contained nearly 1,555 items in its Autumn 1975 edition, including 100 computer programs, most of which were obtained through a cooperative arrangement between RRIS and the American Railway Engineering Association. The Spring 1975 edition, which contained 1,413 items, carried the first entries of technical reports available from the exchange of information with the International Union of Railways (UIC).

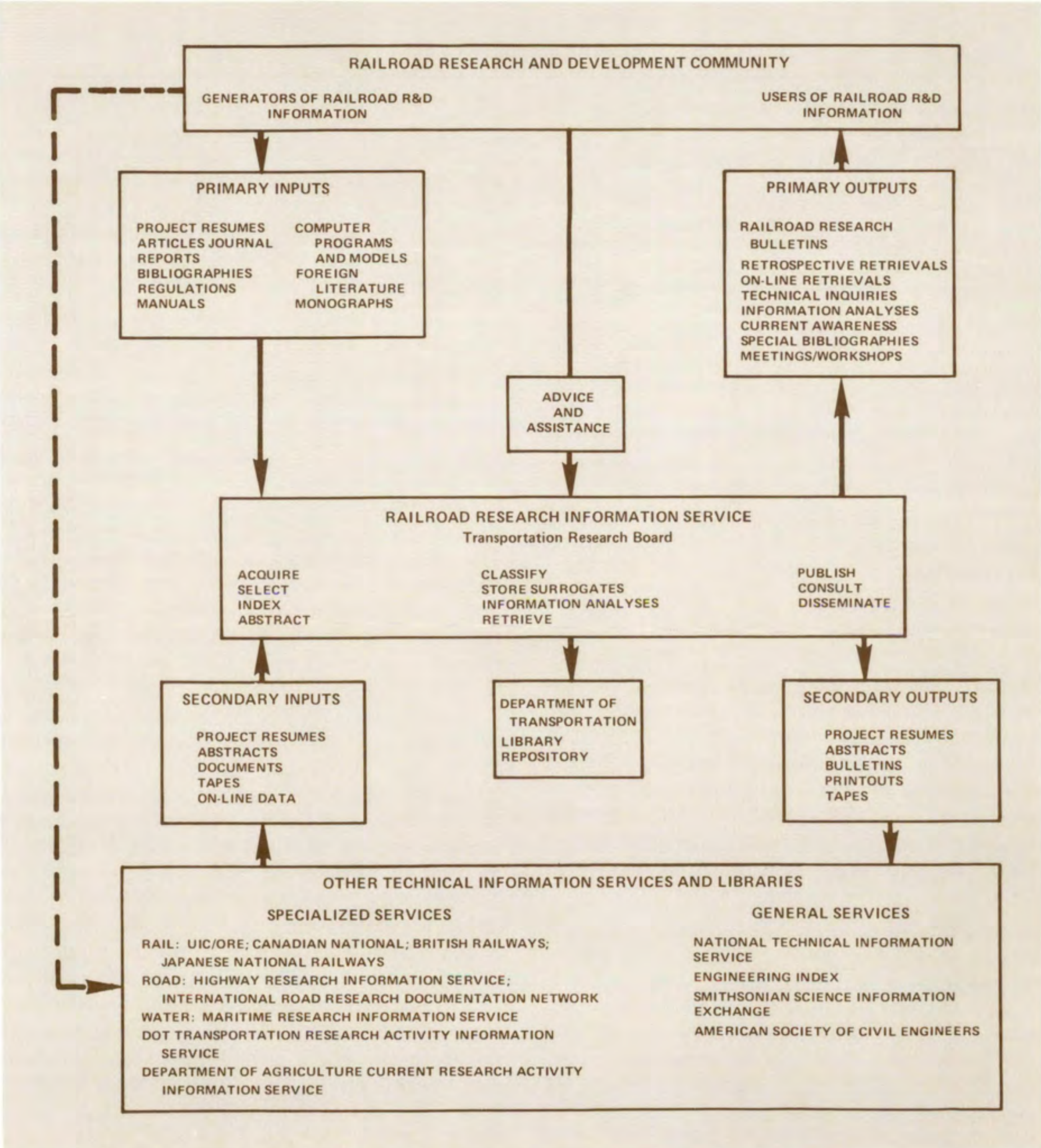
The RRIS was established to make the results of worldwide railroad research available to railroad companies and associations, equipment manufacturers, research organizations, colleges and universities, state and local transportation organizations and agencies. Reports of railroad-related research by these same organizations are furnished to TRB in return for inclusion in the RRIS and for future editions of the "Bulletin."

Through RRIS, the technical community can make specific subject-matter information retrievals on a batch-mode basis known as a file search. Use of this retrieval service, which is available to all interested parties appropriate to its cost, increased greatly during 1975.

A seven-member U.S. delegation visited the Soviet Union from May 26 to June 5, 1975, to learn about Soviet railroad electrification and to bring back information on Soviet technology. The U.S. delegation included three members from FRA, one from the Southern Railway Company, one from General Motors Electromotive Division, one from the General Electric Company, and an FRA consultant. The delegation visited facilities at Moscow, Kiev, Mineral Waters, Rostov, and Georii Dezh and returned highly impressed with the Soviets' sophisticated electrification technology.

During the past year emphasis was placed on improving the quality of the ongoing research section of the "Bulletin." This section is highly dependent upon the voluntary input of information from the research community. Completion of a research project report is all that is necessary in order to have a research effort recognized by RRIS. Since all data requested may not be appropriate for public consumption, the contributor may omit that information which may be considered proprietary or otherwise restricted. Summaries of 400 ongoing R&D projects appeared in the Autumn 1975 edition. As the technical community gains a better understanding of RRIS, the subject matter in the ongoing research section of the "Bulletin" is expected to increase and to improve in quality.

Potential users or contributors may obtain additional information concerning "Bulletin" subscriptions and other RRIS services from: Manager, Railroad Research Information Service, Transportation Research Board, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418, phone (202)389-6611.



TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

RESEARCH PROJECT REPORT

For Publication and Dissemination by the Railroad Research Information Service

Subject Area (s) ____________
(Selected from list on reverse side)

Title of Project ____________

Performing Organization Name and Address ____________

City ______ State ______ Zip ______ Project No. ______

Investigator (s) ____________ Telephone No. ______
(List Principal Investigator first)

Funding Agency (s) ____________ Contract or Grant No. ______
(Name)

____
(Address)

Co-sponsor (s) ____________

Responsible Individual ____________ Telephone No. ______

Date Started ______ Status: Proposed Active Completed as of ______
(Month and Year) (Month and Year)
Programmed Inactive Terminated Estimated Completion Date ______
(Underline or circle appropriate term) (Month and Year)

Estimated Cost: Current Fiscal Year $ ______ Total $ ______ Planned
(Include contributed personnel and equipment)

Previous Fiscal Year $ ______ Next Fiscal Year $ ______

Objectives, Scope and Method ____________

Title, Author, and Date of Reports Issued ____________

Information Furnished by ____________ Date ______

Title ______ Affiliation ______ (over)

HINTS ON HOW TO FILL OUT THIS FORM

Performing Organization Name and Address. Enter the full name and postal address of the organization which is performing the work. Also enter any code the performing agency has assigned to the work.

Principal Investigator. Enter name of investigator for the activity. More than one investigator may be entered if the responsibility is shared. Telephone No. Enter office telephone number of Principal Investigator.

Funding Organization Name and Address. Enter the full name and postal address of the organization and unit that provides financial support for the work. Also enter any code the sponsoring organization has assigned to the work.

Responsible Individual. Enter name of the sponsoring agency's individual who is responsible for the monitoring of the work. Telephone No. Enter office telephone number of Responsible Individual.

Enter report titles, authors, and dates that may have been published in the course of the work or at the end of a recently completed activity. Also enter the place where the report may be acquired.

SUBJECT AREAS

00 Right of Way	10 Environmental Protection	20 Freight Transport Demand Analysis
01 Track	11 Advanced Systems	21 Freight Operations
02 Train/Track Dynamics	12 Safety	22 Logistics and Physical Distribution
03 Vehicle Design	13 Electrification	23 Passenger Operations
04 Propulsion Systems	15 Socioeconomic Factors	24 Industry Structure and Company Management
05 Braking Systems	16 Energy	25 Government Policy, Planning, Regulation
06 Signals, Control and Communications	17 Information Systems	26 Bibliography and Documentation
07 Human Factors	18 Economics	
08 Rail/Highway Grade Crossings	19 History	
09 Materials Science		

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APPENDIX A

OFFICE OF RESEARCH AND DEVELOPMENT
And The Transportation Test Center
FY 1975 CONTRACT OBLIGATIONS

(Dollars in Thousands)

	Scope of Work	***Contract Amount***	***Contractor***	***Location***
2.0	RAIL FREIGHT SYSTEMS			
2.1	Improved Rail Freight Service			
	Track-Train Dynamics Program, Phase I	$ 171	Association of American Railroads	Washington, D.C.
	Membership	26	International Union of Railways	Paris, France
	Technical Information Acquisition	550	National Academy of Sciences	Washington, D.C.
	Freight Car Truck Tests	158	National Aeronautical and Space Administration	Washington, D.C.
	Systems Engineering	165	Transportation Systems Center	Cambridge, Mass.
	Freight Car Dynamics	58	Clemson University	Clemson, S.C.
	Truck Design Optimization Project	411	Southern Pacific Transportation Co.	San Francisco, Ca.
	AAR Track Train Dynamics LTV Model	148	Ensco, Inc.	Springfield, Va.
	Truck Design Optimization Project	88	Ensco, Inc.	Springfield, Va.
	Rail Vehicle Systems Dynamics	54	Mitre Corp.	McLean, Và.
	Operations & Maintenance Support Services	35	Kentron Hawaii, Ltd.	Dallas, Texas
	Locomotive Transfer	90	U.S. Army Transportation	Washington, D.C.
	Rail Systems Dynamics	397	Transportation Systems Center	Cambridge, Mass.

	Scope of Work	Contract Amount	Contractor	Location
	DOD Rail Car Stability Tests	46	Kentron Hawaii, Ltd.	Dallas, Texas
	Data Acquisition Processing & Evaluation	289	Ensco, Inc.	Springfield, Va.
	Miscellaneous	8		
	Subtotal	$ 2,694		
2.2	Rail Dynamics Laboratory			
	Drive Train System	19	General Electric Co.	Schenectady, N.Y.
	RDL Track Module	590	Gulf & Western Industries, Inc.	Swarthmore, Pa.
	RDL Systems Engineering and Vertical Shaker	1,810	Wyle Laboratories	Colorado Springs, Co.
	Data Acquisition and Control System	23	Edmac Assoc., Inc.	Rochester, N.Y.
	RDL Support	299	Transportation Systems Center	Cambridge, Mass.
	Miscellaneous	5		
	Subtotal	$ 2,746		
	FREIGHT SYSTEMS TOTAL	$ 5,440		
3.0	RAIL SAFETY R&D			
3.1	Safety Research			
	Hot Box and Derailment Detector	590	Naval Surface Weapons Center	Silver Spring, Md.
	Component Failure Prevention	1,540	Transportation Systems Center	Cambridge, Mass.
	Tank Car Coupler Impact Test Support	140	Ensco, Inc.	Springfield, Va.
	Tank Car Structural Study	9	Louisiana Technical University	Ruston, La.
	Operations & Maintenance Support	32	Kentron Hawaii, Ltd.	Dallas, Te.
	Tank Car Shelf Coupler Analysis	100	Washington University	St. Louis, Mo.
	Tank Car Metallurgical Tests and Analysis	$ 60	National Bureau of Standards	Gaithersburg, Md.
	Tank Car Thermal Shield Tests	450	Ballistics Research Laboratory	Aberdeen, Md.
	Hazardous Material Tank Car Research	341	Transportation Systems Center	Cambridge, Mass.
	Human Factors Research	653	Transportation Systems Center	Cambridge, Mass.
	Rail Vehicle Systems Dynamics	54	Mitre Corp.	McLean, Va.

	Scope of Work	Contract Amount	Contractor	Location
	Grade Crossing Protection Research	885	Transportation Systems Center	Cambridge, Mass.
	Subtotal	$ 4,854		
3.2	Improved Track Structures			
	Inspection, Operations and Maintenance of Kansas Test Track	203	Atchison, Topeka and Santa Fe Railway Co.	Chicago, Ill.
	Track Inspection & Test Support Services	40	Ensco, Inc.	Springfield, Va.
	Kansas Test Track Data Analysis	99	Shanon & Wilson, Inc.	San Francisco, Ca.
	Track Mechanics	20	Princeton University	Princeton, N.J.
	Nondestructive Measurement of Longitudinal Rail Stress	50	University of Oklahoma	Norman, Ok.
	Lading Damage Study	30	Illinois Institute of Technology	Chicago, Ill.
	Track Subsoil Stabilization	79	University of Arkansas	Little Rock, Ark.
	Data Processing	276	Control Data Corp.	Rockville, Md.
	Improved Track Structures Research	2,598	Transportation Systems Center	Cambridge, Mass.
	Test Track Construction at the Transportation Test Center	3,796	Federal Highway Administration	Washington, D.C.
	Miscellaneous	13		
	Subtotal	$ 7,204		
3.3	Automated Track Inspection			
	Track Inspection & Data Acquisition Support	1,995	Ensco, Inc.	Springfield, Va.
	Operation & Maintenance of Test Cars	277	Penn Central Transportation Co.	Philadelphia, Pa.
	Instrument Government Furnished Cars with Track Geometry Measurement System	1,300	Ensco, Inc.	Springfield, Va.
	Data Processing	145	Control Data Corp.	Rockville, Md.
	Miscellaneous	1		
	Subtotal	$ 3,718		
	SAFETY RESEARCH TOTAL	$15,776		
4.0	PASSENGER SYSTEMS R&D			
4.1	Systems Analysis and Technical Assessment			

	Scope of Work	Contract Amount	Contractor	Location
	Test Track Construction at the Transportation Test Center	1,000	Federal Highway Administration	Washington, D.C.
	Modification to Metroliner Cars	80	Westinghouse Electric Corp.	Pittsburgh, Pa.
		93	General Electric Corp.	Erie, Pa.
	Testing of Metroliner Cars	79	Penn Central Transportation Co.	Philadelphia, Pa.
	Metroliner Improvement Program	99	J. W. Marchetti, Inc.	Wilmington, Del.
	Engineering Support for Metroliner Trucks	22	Budd Co.	Philadelphia, Pa.
	Data Acquisition & Processing	175	Ensco, Inc.	Springfield, Va.
	Metroliner Truck Improvement Program	186	LTV Aerospace Corp.	Dallas, Texas
	Rail Vehicle Dynamic Analysis	45	Battelle Columbus Laboratories	Columbus, Ohio
	Metroliner Inspection Program	36	L. T. Klander & Assoc.	Philadelphia, Pa.
	Rail Vehicle Systems Dynamics	54	Mitre Corp.	McLean, Va.
	Assistance in Evaluation of Locomotive	18	Budd Co.	Philadelphia, Pa.
		10	Batelle Columbus Laboratories	Columbus, Ohio
	Rail Systems Dynamics	63	Transportation Systems Center	Cambridge, Mass.
	Miscellaneous	15		
	Subtotal	$ 1,975		
4.2	Supporting Technology			
	Technical Support	33	Mitre Corp.	McLean, Va.
	Synchronous Linear Motors	46	Polytechnic Institute of N. Y.	New York, N.Y.
	Linear Motor Field Testing	321	Aerospace Manufacturing Co.	Torrance, Ca.
	Rail Vehicle System Dynamics	242	Mitre Corp.	McLean, Va.
	Operation & Maintenance Test Support	50	Kentron-Hawaii, Ltd.	Dallas, Texas
	Numerical Analysis Method for Linear Induction Motor	55	Jet Propulsion Laboratory	Pasadena, Ca.

Scope of Work	Contract Amount	Contractor	Location
Propulsion Research	330	Transportation Systems Center	Cambridge, Mass.
Communications and Control	60	Transportation Systems Center	Cambridge, Mass.
Development & Testing of New Tunnel Supports	400	University of Illinois	Urbana, Ill.
Miscellaneous	3		
Subtotal	$ 1,540		
4.3 Advanced Systems			
Power Rail for Tracked Levitated Research Vehicle (TLRV)	247	Advanced Machine Corp.	Los Angeles, Ca.
	168	Dow Engineering Co.	Houston, Texas
TLRV Test Support	219	Mitre Corp.	McLean, Va.
TLRV Test Operations	111	Grumman Aerospace Corp.	Bethpage, N.Y.
Linear Motor Field Testing	1,070	Airesearch Manufacuring Co.	Torrance, Ca.
Adjustment to TLRV Power Distribution System	17	Airesearch Manufacuring Co.	Torrance, Ca.
Guideway Construction	143	Federal Highway Administration	Washington, D.C.
Rail Vehicle System Dynamics	215	Mitre Corp.	McLean, Va.
TLRV Operations and Maintenance	50	Kentron-Hawaii, Ltd.	Dallas, Texas
TLRV Research	50	Transportation Systems Center	Cambridge, Mass.
Tracked Magnetic Levitated Vehicle (TMLV) Research	250	Ford Motor Co.	Dearborn, Mich.
	16	Mitre Corp.	McLean, Va.
	122	Rohr Industries, Inc.	Chula Vista, Ca.
Prototype Tracked Air Cushion Vehicle (PTACV) Guideway Construction	307	Rohr Industries, Inc.	Chula Vista, Ca.
PTACV Testing	520	Rohr Industries, Inc.	Chula Vista, Ca.
PTACV Operations and Maintenance	50	Kentron-Hawaii, Ltd.	Dallas, Texas

Scope of Work	Contract Amount	Contractor	Location
Miscellaneous	27		
Subtotal	$ 3,582		
Passenger Systems Total	7,097		
TOTAL OFFICE OF RESEARCH AND DEVELOPMENT	$28,313		
5.0 TRANSPORTATION TEST CENTER			
Electrical Services	95	Southern Colorado Power Company	Pueblo, Co.
Architect/Engineering Design Services	27	Laramore, Douglas & Popham, Inc.	Chicago, Ill.
Construction of Technical Services Buildings	18	H. H. Houston Construction Co.	Denver, Co.
PTACV Guideway Construction	145	Rohr Industries, Inc.	Chula Vista, Ca.
Construction of Administration Building	40	Lueder Construction Co.	Omaha, Neb.
Installation of Permanent Electrical Power Distribution	45	Gardner-Zemke Co.	Albuquerque, N.M.
Operations & Maintenance Support Services	4,717	Kentron-Hawaii, Ltd.	Dallas, Texas
Electric Forklift	40	General Services Admin.	Auburn, Wash.
Fire Truck	44	Western Fire Equipment Company, Inc.	Pueblo, Co.
Pueblo Army Depot Support	$ 50	Pueblo Army Depot	Pueblo, Co.
Construction of Road to Pueblo Airport	2,125	Federal Highway Administration	Washington, D.C.
Miscellaneous	208		
Transportation Test Center Total	$ 7,554		
GRAND TOTAL	$35,867		

GLOSSARY OF ABBREVIATED TERMS

AAR—Association of American Railroads
ACI—Automatic Car Identification
ADACS—Analog Data Acquisition and Control Subsystem
COFC—Container-on-flatcar
DBI—Draft-Buff Indicator
DOT—Department of Transportation
FAST—Facility for Accelerated Service Testing
FRA—Federal Railroad Administration
ICSN—Integrated Computer Subsystem Network
IITRI—Illinois Institute of Technology Research Institute
LEM—Linear Electric Motor
LIM—Linear Induction Motor
LIMRV—Linear Induction Motor Research Vehicle
LRC—Light, Rapid, Comfortable Train
MOW—Maintenance-of-way
OR&D—Office of Research and Development
PFI—Power Force Indicator
PTACV—Prototype Tracked Air Cushion Vehicle
R&D—Research and Development
RDL—Rail Dynamics Laboratory
RDS—Rail Dynamics Simulator
RDU—Roll Dynamics Unit
RPI—Railway Progress Institute
RRIS—Railroad Research Information Service
SLRV—Standard Light Rail Vehicle
TDA—Transportation Development Agency (Canadian)
TDOP—Truck Design Optimization Project
TLRV—Tracked Levitated Research Vehicle
TLV—Tracked Levitated Vehicle
TOFC—Trailer-on-flatcar
TOS—Train Operations Simulator
TSC—Transportation Systems Center
TTC—Transportation Test Center
TTD—Track Train Dynamics
TTT—Transit Test Track
UIC—International Union of Railways
UMTA—Urban Mass Transportation Administration
USRA—United States Railway Association
VTU—Vibration Test Unit

DEPARTMENT OF TRANSPORTATION
UNITED STATES OF AMERICA