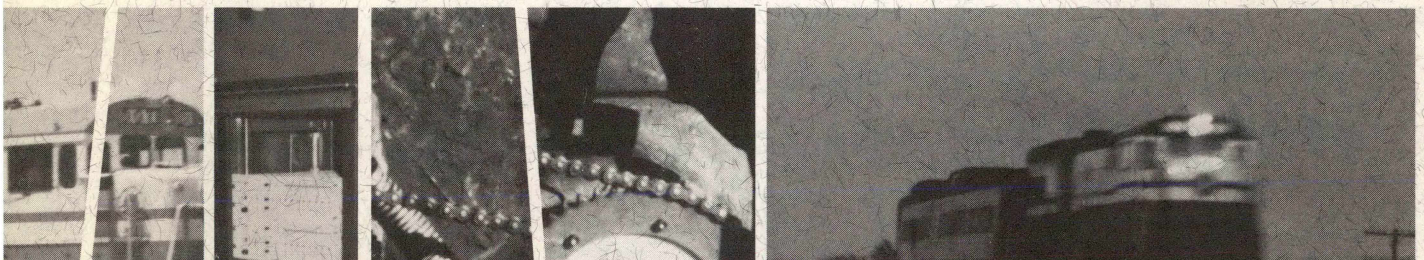
EIGHTH REPORT ON THE RAILROAD TECHNOLOGY PROGRAM

Federal Railroad Administration

1974

By the Secretary of Transportation to the President, the Senate, and the House of Representatives



PREFACE

The Secretary of Transportation is required to report at least 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 Eighth Report covers not only HSGT-fund research, development and demonstrations programs administered by the Office of Research, Development and Demonstrations (ORD&D) of the Federal Railroad Administration (FRA) in accordance with section 10(a) of the Act, but also encompasses related work performed under appropriations for advancing railroad technology and safety.

The 1965 Act and several public laws amending it have been published in the previous annual reports. Because no changes have been made since the Act became continuous, publication will henceforth be omitted. The earlier reports have also contained a full bibliography of reports published in conjunction with research, development and demonstrations efforts. The Railroad Research Information Service, operated by the National Research Council and sponsored by FRA, has picked up 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 3.8 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 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 SUMMARY AND HIGHLIGHTS

This Eighth 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, Development and Demonstrations (ORD&D) in carrying out the mandates of the High Speed Ground Transportation Act of 1965 (as amended) during the year ending September 30, 1974. The report also covers corresponding and interrelated work carried out under the annual appropriation for railroad research. Both types of funded activities involve the facilities of the Department's High Speed Ground Test Center (HSGTC) operated by FRA at Pueblo, Colorado.

In accordance with Department of Transportation (DOT) policy, FRA has identified goals for its research, development and demonstration programs which have been set forth in the report and expand upon the goal expressed in the 1965 legislation: the ". . . promotion of a safe, adequate, economical and efficient national transportation system." A listing of the "Highlights" of accomplishment during the year indicates the contribution of the RD&D programs in providing the technology for meeting the national commitment.

The Congress has expressed interest in the economic impact of Government expenditures. Accordingly, this report includes as:

Appendix A, a listing of contract obligations incurred in FY 1974 together with the names of the contractors and their places of business.

1.1 Research, Development and Demonstrations Program Highlights for the Year Ending September 30, 1974

Improved Rail Freight Service

- Beginning of multi-phase, multi-year Truck Design Optimization Project (TDOP) for the development of performance and testing specifications to use in assessing freight car truck modifications and new truck designs.
- Initiation of an analysis of classification yard technology, an effort designed to establish existing and anticipated needs for hardware development to meet future operational demands.
- Demonstration of computer-automated freight-car management and control with the Rail Terminal Management System (RTMS) beginning partial operation at the Kansas City Southern Yard in Shreveport, La.
- Initiation of a joint project with the FRA Office of Economics to demonstrate the feasibility of an intermodal network system with recommendations for management and control and development of facilities and equipment to reduce operating costs and improve service performance.
- Development of a computer model for assessment of the fuel (energy) implications of traffic diversion between modes.

Safety Research

- Joint Government/industry analytical and experimental study to determine performance of modified couplers under derailment conditions. The AAR/RPI has conducted field tests of this coupling. Washington University has developed a mathematical model to simulate the performance of these couplers under adverse conditions.
- Design study for the development and installation of head shields to decrease the likelihood of tank-car puncture under accident conditions.
- Fire testing of tank cars at White Sands, New Mexico, to test insulation for retarding heat penetration, improvements in valves for relief of pressure from boiling lading, and modifications in construction materials to make cars more resistant to heat failure.
- Establishment of a site at the High Speed Ground Test Center (HSGTC) for testing the most promising thermal insulations under "torching" conditions to determine their ability to withstand high-velocity, high-temperature, jet-like flame impingement.
- Completion of a sophisticated facility to test and qualify full-sized hazardous-material tank car relief valves at the Edwards Air Force Base in California.

- Tank car structural stress analyses and metallurgical investigations at Louisiana Technical University and at the National Bureau of Standards (NBS) to develop guidelines for mechanical design and material properties to increase the margin of safety against rupture and "rocketing fragments."
- Initiation of joint study with AAR Cab Committee to improve crashworthiness of rail vehicles through development of a locomotive cab design that gives consideration to occupant protection and structural integrity for safety, to environmental considerations, and to allowances for future technological improvements in train monitoring and control.
- Establishment, through controlled crash tests at the Test Center, of a base line for comparing energy-managing devices to decrease the lethality of train/auto collisions.
- Evaluation of locomotive and rear-end markers to determine the degree to which high intensity strobe lights are effective in attracting attention to train movement.
- Initiation of research into methods of decreasing the overall cost of wayside grade-crossing equipment.
- Development of a computer model to assist the states in determining the best complement of grade-crossing protection equipment for different classes of crossings located within a state.
- Determined that, if the shoes are badly worn, drag braking followed by emergency braking can initiate fatigue cracks in the rims of low-carbon steel wheels.

Improved Track Structures

- Development of an integrated family of track simulation models to evaluate versatility and use.
- Investigation of the basic material properties of ballast substances at the University of Illinois.
- Installation of concrete ties and threadless rail-tie fasteners on track at Lorraine, Virginia, to compare heavy-service performance with reduced fastener maintenance costs.
- Visit of DOT/FRA-sponsored track delegation to the Soviet Union to evaluate USSR track research and maintenance under cooperation agreement.
- Participation in an international symposium on high-speed propulsion in France.
- Installation of two cold-region sections of test track on the Alaska Railroad to: (1) determine survivability of concrete ties under frost heaving, (2) to evaluate cost-effectiveness of such ties in comparison with timber ties and (3) to evaluate effectiveness of ballast binding compounds to distribute train loads more favorably to already-weak soil foundation under track.
- Demonstration indicating that, with five-second applications of the FRA Ballast Consolidator, track develops a resistance to lateral and longitudinal tie displacement 30% greater than without application.
- Development and installation of a new fastener anchorage for the Kansas Test Track.
- Studies of track-degradation and maintenance-planning using data-analysis and presentation techniques for use by various levels of maintenance-of-way personnel.

Automated Test Inspection and Test Support Services

- Track geometry tests with the DOT track measuring cars over 9,357 miles of trackage on nine different railroads, including tests to determine compliance with FRA Track Safety Standards.
- Acquisition of an advanced state-of-the-art ultrasonic rail-defect detection system housed in a hi-rail truck.

Passenger Service

- Completion of electrical and mechanical modifications on four prototype Metroliners.
- Award of contract for design and fabrication of new M-type truck for the Metroliners to obtain noise reduction, low-maintenance wheel profiles and improved ride quality. Five test trucks have been completed.
- Collection and processing of ride-quality, acoustic and track-roughness data. FRA is to provide to AMTRAK qualitative information to aid in the specification of new passenger rolling stock.
- Consultation to the Northeast Corridor Improvement Program on appropriate track designs for joint use by high speed passenger trains and slower moving freight trains.
- Use of the Test Cars to study the dynamic behavior of the pantograph-catenary power collection system on the Penn Central.
- Measurement of wheel-rail forces, suspension-system behavior and ride quality in the cab of a new locomotive developed for AMTRAK.

Supporting Technology and Facilities

- Occupancy of Rail Dynamics Laboratory (RDL) building in April 1974.
- Fabrication begun on Vertical Shaker at RDL.
- Contracts awarded for all subsystems of the Rail Dynamics Simulator (RDS).
- Delivery of Drive Trains for the RDS.

- Participation in ten-year Government/industry Track-Train Dynamics Research Program with Association of American Railroads (AAR), Railroad Progress Institute (RPI), and Canadian Transportation Development Agency (CTDA), including joint development of a "Train Mass Distribution (TDM) Graph" displaying the weight of each car in a train in bar-graph form to assist the engineer in anticipating train handling problems associated with load distribution.
- Collection of train-consist dynamic data in a joint effort with the AAR Cab Committee to validate computer simulation models for studying track/train interactions and developing safety guidelines for train make-up and train handling.

Railroad Research Information Service

- Semi-annual publication of Railroad Research Bulletin by the Transportation Research Board under FRA sponsorship, listing 3400 additional items of railroad-related technical literature.
- Agreement through the Transportation Research Board (TRB) with International Union of Railways for exchange of railroad research references.

Advanced Technology

- Satisfactory performance of air cushions on the TLRV at various hover heights at forward speeds up to 91 mph (147 km/h).
- Promise shown in the ram air cushion concept of providing a low-cost system by reducing guideway costs.
- Completion by the Stanford Research Institute of a series of repulsive Maglev sled tests and computer simulations. The repulsive Maglev suspension is now understood and its behavior can be predicted at low speeds.
- Installation and static check-out of the Linear Induction Motor (LIM) in the TLRV.
- Extension of the University of Illinois program to explore new tunnel liner materials and test unconventional steel rib design, bolted concrete segments and monolithic liners using new fibre-reinforced reg-set concrete.
- Successful demonstration that the water cannon, manufactured by Terraspace, Inc., can break gneissic granite and dolometic limestone using pressures up to 540,000 psi (160 kgf/m²).
- Use of a computer program for tunneling research by the U.S. Corps of Engineers to compute costs on a new water supply system being planned for Hartford, Conn.
- At 255.4 mph (411 km/h), the Linear Induction Motor Research Vehicle (LIMRV) became the world's fastest wheel-on-rail vehicle. The vehicle's dynamic response was well below allowable limits and no degradation of track alignment was observed.

High Speed Ground Test Center

- Completion and activation of the Storage and Maintenance Building.
- Completion and occupancy of the building for the Rail Dynamics Laboratory.
- Construction on schedule of the Technical Service Building.
- Award of contract for Operations Building.
- HSGTC tied in with commercial high-voltage electric power.
- Extensive testing of transit equipment by the Urban Mass Transportation Administration (UMTA) with Transportation Systems Center (TSC) support.
- Continuing technical assistance from the Soil Conservation Service on the development and management of a long-range conservation plan for the HSGTC.
- First industry-financed proprietary testing of rail equipment at the HSGTC.
- Award of contract for a master plan to provide orderly development of the HSGTC, to provide a management tool for planning and budgeting at the Test Center and to establish a workable document for users of the Test Center, describing all facilities, test tracks and utilities.
- Over 4000 visitors to the HSGTC in 1974.

2.0 GOALS

The goal of the High Speed Ground Transportation (HSGT) Program is set forth in the 1965 legislation as the "promotion of a safe, adequate, economical and efficient national transportation system." By inference, the program calls for a multi-modal approach to the movement of goods and people throughout the country. The Federal Railroad Administration, in carrying out this program and the related railroad research program, seeks to provide the systems and technological basis for making maximum effective use of intercity rail and guided ground transportation in meeting the Nation's transportation needs and the Government's transportation goals and objectives.

More specifically, the goals of the FRA Research, Development and Demonstrations Programs are to:

- Provide transportation of goods and people that is safe, reliable, convenient, rapid, and low in cost.
- Reduce highway and airport congestion.
- Utilize resources more effectively.
- Conserve increasingly scarce fossil fuel resources.
- Provide a quiet and clean transportation system.

In working towards these goals, FRA:

- Analyzes engineering systems alternatives for meeting current and projected transportation needs.
- Undertakes and stimulates research and development (R&D) in intercity systems and the critical elements of such systems in the framework of both conventional railroad operations and advanced systems.
- Demonstrates effectiveness of selected transportation improvements.

Through its research, development and demonstration programs FRA contributes to the fulfillment of its stated missions to:

- Consolidate Government support of rail transportation activities.
- Provide a unified and unifying national policy for rail transportation.
- Support improved intercity ground transportation and the future requirements for rail transportation.
- Administer and enforce railroad safety laws and regulations.
- Provide assistance to the Secretary of Transportation on matters relating to rail transportation and safety.

3.0 RAIL TECHNOLOGY

3.1 General

The objective of the Federal Railroad Administration's R&D efforts in rail freight transport continues to be "improvement" in the capability of the railroad system to meet accelerating National demands for the movement of goods. There is a compelling urgency to achieve a contemporary rail system which has the capacity to handle substantial increases in volume on a cost-competitive basis. Faster and more efficient operations and maintenance are key elements but are no substitute for reliable schedules and delivery of lading in an undamaged state. And even though trains consume less energy and emit less pollutants per unit of work than most other modes of transportation, increased utilization of the rail system is largely dependent upon significant improvements in the degree of safety and reliability of operations.

While laying the foundation for more optimal systems in the future, the FRA research program is specially structured to insure that technical advances, which are prerequisites for satisfying the requirements of an acceptable rail system, are realized at the earliest possible time. By design, the integrated R&D program developed by FRA relies on collaborative projects and funding from both the Federal Government and private industry. The intent is to provide a comprehensive framework encompassing the known spectrum of research needs while minimizing duplication and encouraging greater interest, participation and investments by industry.

The Rail R&D has been segmented into five program areas: IMPROVED RAIL FREIGHT SERVICE, SAFETY RESEARCH, IMPROVED TRACK STRUCTURES, AUTOMATED TRACK INSPECTION AND TEST SUPPORT SERVICES, and IMPROVED PASSENGER SERVICE. Although these programs are mutually supportive, each will be described separately in the succeeding sections of this report.

3.2 Improved Rail Freight Service

The railroad system in the United States has two unique capabilities—the ability to transport extremely heavy loads over land and the ability to move large volumes of cargo traffic with efficient use of energy and land sources. These capabilities are largely attributable to the inherent mechanical efficiency of a steel wheel moving over a fixed steel rail or guideway, a structure capable of distributing high loadings to its foundation in a relatively confined space.

It is most unfortunate that the health of the railroad industry, a key link in the Nation's economy and a vastly under-utilized national resource, has been deteriorating at a time when its inherent economies are sorely needed for an efficiently-balanced national transportation system. "During 1973, the National Commission on Productivity (NCOP) examined the causes of this decline and offered some possible solutions. Jointly with the Office of Science and Technology and the Council of Economic Advisors, the Commission undertook an extensive analysis of productivity in American railroads. A task force of leading government, academic and industry experts spent 18 months diagnosing the ailing industry. Their findings and prescriptions were published in *Improving Railroad Productivity*, (NCOP, 1973).

The NCOP study indicated that research and development should be directed to innovations that help the industry adapt to the evolving freight market and changing customer needs while, at the same time, emphasizing innovations that reduce costs directly. Clearly, quality of service and cost avoidance would be the determinants in turning around the present trend of declining viability, according to the study. The study points out a potential for a technological lag as a condition that could arise should institutional constraints such as out-moded regulations, certain labor practices and industry balkanization be removed. Five areas are suggested where research and development leading to innovations can and should be undertaken to avoid that lag. Some are in the Improved Rail Freight Service Program in the Office of Research, Development and Demonstrations (ORD&D) which is oriented toward hardware, others fall into the purview of economics and operations research being undertaken by the FRA's Office of Economics.

To accomplish the research recommended in the Productivity Study, the Improved Rail Freight Service Program of ORD&D has been divided into four functional subprograms—

- Systems Analysis/Technology Assessment
- Classification Yard Technology
- Component Development, and
- Intermodal Systems

The Systems Analysis/Technology Assessment subprogram is broadly based and covers subjects dealing with railroad productivity in general. Analyses of railroad operations are intended to identify problems in which technological innovation shows promise of increasing productivity. By advancing the state of the art in areas where private capital investment is not likely to occur, Government research serves as a stimulus or catalyst as the case may be. In this program the Federal Government is providing one-third sponsorship of a ten-year joint Government-industry Track-Train Dynamics Research Program and has developed and continues to sponsor the Railroad Research Information Service (RRIS) referred to elsewhere in this report. To enhance the RRIS capability, arrangements for the exchange of railroad technical information on an international basis have been initiated and maintained through membership in the International Union of Railways (UIC), its Office of Research and Experimentation, and the International Railway Congress Association (IRCA).

The Classification Yard Technology subprogram seeks through research to increase the productivity and decrease the cost of operating classification yards which have been shown to be the principal contributor to unreliable service and a significant cost element in the transportation of goods by rail. Car management and utilization improvements to increase the yard through-put are being sought in this program area through a cost-sharing arrangement with a railroad for the development of a Rail Terminal Management System (RTMS).

The Component Development subprogram includes investigations into the feasibility of improving the present standard railroad car coupling and braking systems to a point where such improvements and the removal of present physical constraints will increase operational efficiency and automation potential and will also reduce maintenance costs. Research to encourage the development of improved rail car suspension systems through a Truck Design Optimization Project began in June 1974.

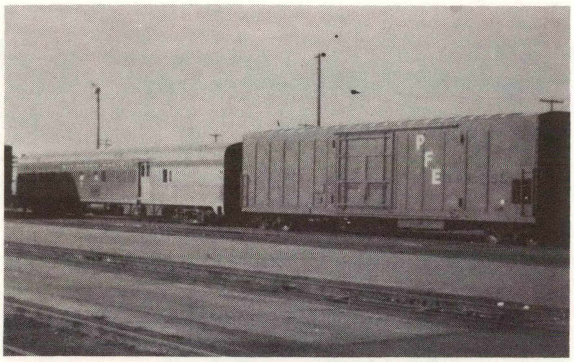
The Intermodal Systems subprogram initiated in 1974 in response to the Railroad Productivity Commission's recommendations pertaining to containerization provides follow-on technological support to the Intermodal Network Feasibility Study conducted by FRA's Office of Economics. The study, when its final report is published in 1975, is expected to show that significant innovation in rail intermodal operations will increase the share of freight traffic carried by the railroads in the years ahead. Based on early findings of the intermodal study effort, ORD&D initiated several research projects in 1974, among which were: (1) a study of the effects of aerodynamic drag on TOFC/COFC (trailer-on-flat-car/container-on-flat-car) operations; (2) an investigation into fuel consumption in TOFC/COFC rail service as compared to highway movements; and (3) an evaluation of the performance of lightweight TOFC/COFC rail cars, including the use of several different trucks (suspension system) in high-speed, high-mileage service. A systems engineering effort by ORD&D is scheduled to follow the economics research of the Intermodal Network Feasibility Study.

Major accomplishments of the Improved Rail Freight Service Program in 1974 are indicated below in further discussion of specific projects.

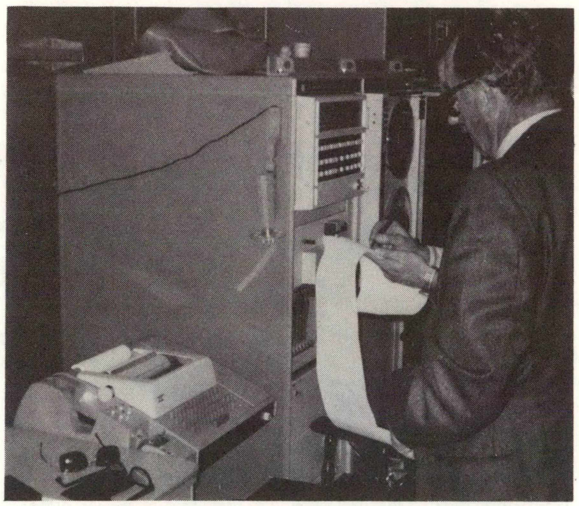
Freight Car Truck Design Optimization Project

In June 1974, the Southern Pacific Transportation Company began the multi-phase, multi-year Truck Design Optimization Project (TDOP) described under Freight Car Truck Development in the Seventh Report. Test track sections have been selected using the track geometry measurement capability of the FRA Test Cars. Test trucks, instrumentation, and data-acquisition equipment have been procured and are being assembled. Initial field testing, scheduled for February 1975, will use the equipment shown in Figure 1 (a & b). Examples of the instrumentation to be used in collection of physical force data experienced by trucks while moving over the test tracks are shown in Figure 2 (a–d).

To insure the widest possible understanding of the objectives and goal of TDOP, FRA sponsored an industry orientation briefing in August 1974. This briefing was attended by 85 officials representing various railroads, truck designers and suppliers; academic institutions and research organizations. In the future, open "in-progress reviews" will be held as significant milestones in the project schedule are reached. Project status and research findings will be reported to the technical community at these reviews. These in-progress reviews are to provide a forum for industry participation that will contribute to ultimate acceptance



a. Southern Pacific Railroad Instrumentation Data Collection Car and Test Car.



b. Mini-computer Data Collection Package.

Figure 1. Truck Design Optimization Testing Equipment.

of the research findings by the industry. These findings will result in conclusions in the form of performance and testing specifications for use in assessing truck modifications of new truck designs.

Classification Yard Technology

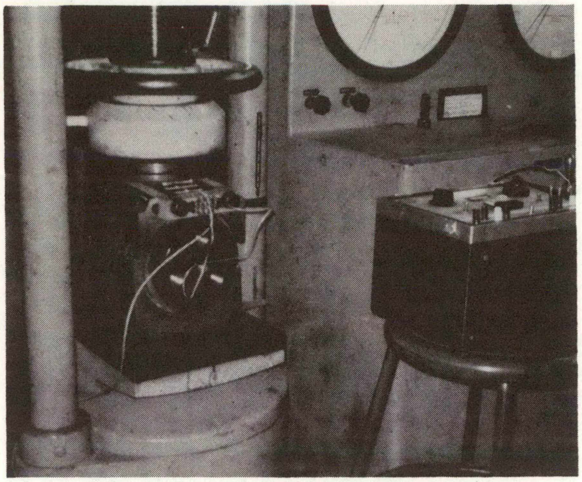
FRA has initiated state-of-the-art assessment of classification yard technology to establish existing or anticipated needs for hardware development required to meet future operational demands. The contractor is to prepare a technical development plan for guiding future research on classification yards. An earlier functional analysis of railroad freight car classification yards, made in 1974 by the Transportation Systems Center to determine the operational variances that exist among different yards according to the purposes they serve, will aid in the ongoing technology assessment effort.

The focus of the classification yard assessment is on improved terminal or "thru-port" (a term depicting an enroute sorting facility) operations. Specific tasks for the contractor include: (a) preparing a detailed description of the hardware involved, its true cost of ownership, its performance characteristics, and the operating practices in existing yards; (b) summarizing available estimates of the rail freight traffic and service demands likely to be placed upon the Nation's railroad network of classification yards for the periods 1980 through 1990 and 1990 through 2000; (c) formulating optimum yard-network interaction concepts, such as long-train versus short-train, to meet these traffic and service demands; and (d) delineating by priority those areas of classification yard technology to which Federal research and development will offer the greatest potential for benefits in terms of improved rail freight service. The results of this analyical study are exepected to be available and summarized in time for the next annual report. Following the assessment, a systems engineering effort will be undertaken to determine what research and development activities will provide potential for high pay-off.

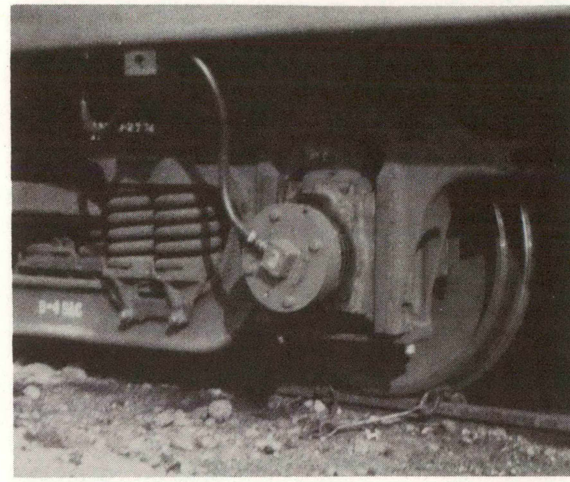
Freight Car Management and Control in Yards

Two years ago, in a joint Government-industry effort, FRA and the Kansas City Southern (KCS) Railway Company entered into a pioneering project to develop and demonstrate a sophisticated system of computer-automated management and control of freight cars in yards. In 1974, that Rail Terminal Management System (RTMS) began partial operation at the KCS Deramus Yard in Shreveport, Lousiana. Deramus is a flat switching yard (as opposed to a hump-retarder yard) with 31 classification tracks and eight receiving/departure tracks and serves as the principal classification yard at the hub of the KCS and the Louisiana and Arkansas (L&A) Railway Company, with a daily throughput of approximately 2,000 cars.

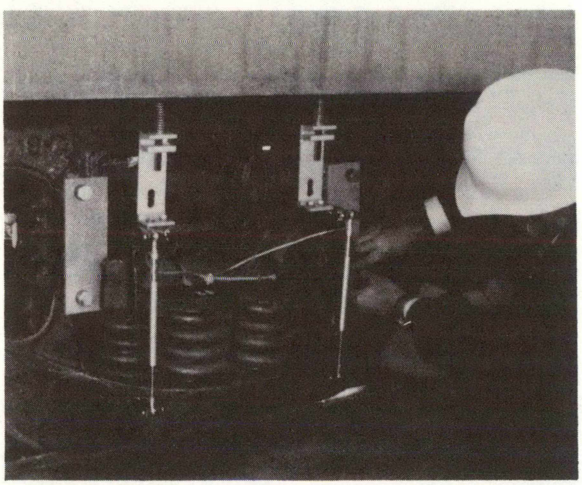
Recent FRA and industry studies have identified delays and handling expenses associated with classification yards as major impediments to high-quality performance in rail freight service. While an average freight car spends less than 8% of its time in a train moving with load, over 60% is spent waiting in classification yards. The poor reliability in transit time from shipper to consignee, often associated with rail freight service, results more from yard delays than from any other cause. The RTMS project attempts to solve this problem through reduced paperwork processing and near "real-time" availability of yard inventory information.



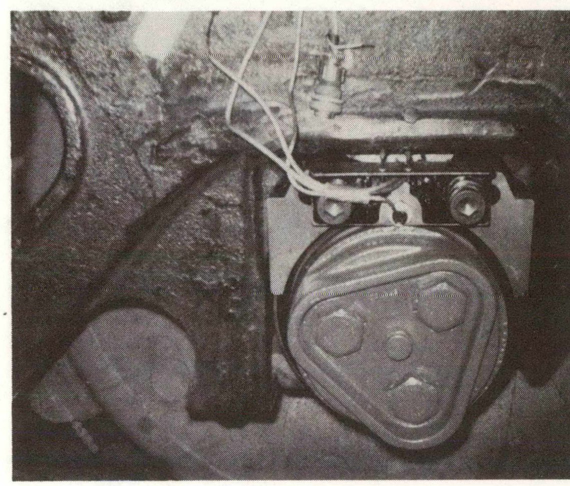
a. Laboratory Calibration of Truck Bearing Adaptor Sensors.



b. Speed Indicator on Instrumentation Car Truck.



c. Instrumented Truck (Left to Right) Lateral Travel Gage to Measure Relative Motion between Side Frame and Bolster, Bolts and Shims to Vary Gib Clearance, Vertical Travel Gage to Measure Bolster Travel Relative to Carbody and Vertical Travel of Springs.



d. Lateral Force Sensor on Bearing Adaptor.

Figure 2. Equipment for Collection of Physical Force Data.

RTMS is designed to monitor, schedule, and otherwise aid in the supervision of the progress of all KCS/L&A-carried rail freight passing through Shreveport, both within yard limits and on KCS/L&A industrial sidings extending throughout northern Louisiana as well. By May of 1974, the KCS had gained enough confidence in RTMS minicomputers to discontinue its perpetual inventory card system and to depend entirely upon the partially implemented RTMS as its most complete and reliable source of yard-management information. The complete RTMS at Deramus will encompass nine automatic-car-identification (ACI) label scanners; three label-decoding computers; 252 bi-directional wheel sensors; a main processing computer plus a back-up computer; facilities for automatically transmitting and receiving data directly from other computers within the KCS system; and input/output teletypes, printers, and cathode ray tube (TV) displays located at various operating positions in the yard. An additional description of RTMS appeared in the Seventh Report.

Operation of RTMS begins when an "advance consist" car listing, corresponding to the make-up of a train due to arrive at Deramus, is received by RTMS computers. As an inbound train passes one of the five ACI scanners which surround Deramus, RTMS verifies the "advance consist" or automatically generates a corrected listing. As the cars are being inspected by yard personnel, RTMS automatically prepares a switch list, routing loaded cars to their final destination and empty cars to other system locations with the greatest need for empties. When all the wheel-sensors become operational, RTMS is expected, during the switching process, to monitor the movement of all cars within the 31–track classification area, detect automatically mis-switched cars (placed in wrong block or track by engine crews) and alert railroad supervisory personnel to the need for corrective action. After outbound cars are assembled on a departure track, RTMS is to verify the listing of departing cars, transmit an "advance consist" to the next terminal enroute, and transmit information to the KC's accounting computer in Kansas City for automatic customer or interchanging billing.

RTMS also has 28 separate computer programs which can be used to generate reports or to perform other necessary yard functions. For example, one program generates a list of all the loaded freight cars within the yard that have not been moved within the past 24 hours or any other desired time span selected by management for special attention. RTMS is somewhat open-minded to the extent that the system can be modified to perform additional management information functions.

FRA's interest in the RTMS project is in determining, through analysis and evaluation, the merits of employing these forms of yard control and data automation for general improvement of freight service. FRA continues to observe RTMS to determine its possible contributions to: (a) increasing the utilization of the physical plant and equipment and the terminal throughput and operating flexibility, (b) reducing the costs of handling cars and yard switching, (c) postponing or eliminating the need for capital investment in new yards, (d) controlling car distribution and repair, and (e) reducing costs and errors in car accounting. FRA will also consolidate and disseminate to the industry data on installation and start-up problems, before-and-after performance results, and relevant costs. An RTMS approach might prove practicable in as many as 1,000 flat yards throughout the country.

Possible improvements of the technology employed in RTMS will also be considered for opportunities in other yards to reduce terminal operating costs and to improve the reliability and mainainability of RTMS system components.

Railroad Signaling Systems

During the past year, the Transportation Systems Center (TSC) has conducted a study of the technology of existing railroad signal systems to assess to what extent state-of-the-art technology in signaling and control systems is suitable for use in the simultaneous control of high-speed passenger trains and lower-speed heavy freight trains operating over the same trackage. An optimum rail signaling system, coupled with sufficient trackage, should permit the operation of trains at varying train speeds with a minimum of delay or congestion and a maximum of efficiency in physical plant utillization and safe operations.

In signaling analysis, TSC assessed the equipment available from suppliers rather than that actually in use by railroads in route situations with mixed traffic. TSC study investigated the extent to which existing signaling installations approach filling the need for minimizing service impairment while maintaining a safe separation between passenger and freight trains. This overview study also found that the technical alternatives available for upgrading existing technology for line-haul operations are adequate and available, basically "off the shelf," from the supply industry. The report, "Operation of High Speed Passenger Trains in Rail Freight Corridors", will indicate that the decision factors involved in operating mixed traffic are essentially operational and service-standard dependent rather than constrained by signal-system limitations.

Intermodal System Technology

In May 1974, the Office of Research, Development and Demonstrations and the Office of Economics began planning for a joint project to demonstrate the feasibility of an Intermodal Network System for the Nation's railroads. This project, as a follow-up on the findings of an economic feasibility study (Intermodal Network Feasibility Study) which recommended such a network, envisions an FRA/industry evaluation of the study's operational and management control recommendations along with the development of facilities and equipment to reduce costs and improve service performance. Initial planning of an operational demonstration involves a line-haul segment between a city pair of the proposed network which will permit an assessment of the potential for improvement in a complete network. Supporting projects have been initiated to provide the systems engineering of terminal configurations, transfer equipment and rolling stock. Results of the systems engineering are expected to be: (a) optimum terminal designs for high-capacity gateway (connecting point for two or more railroad systems) terminals and low-capacity feeder or intermediate point terminals; (b) performance requirements for transfer (truck-to-rail and vice versa) equipment and TOFC/COFC (Trailer-on-flat-car/Container-on-flat-car) rail cars and their propulsion; and (c) the management and control systems required to maintain service quality and maximum utilization of equipment.

Fuel Consumption of Rail Transportation

In addition to environmental considerations, an increasingly relevant aspect of fuel consumption is the relative energy efficiency of various modes of transportation and their respective impacts on the overall use of transportaion fuel. Interest by railroad management and governmental agencies in fuel usage by railroads has been heightened by the energy crisis and the rapidly rising cost of fuel in an industry beset with cash-flow problems. Although rail has a fuel-efficiency advantage over highway in line-haul intercity movements, the special circumstances regarding the fuel efficiency of branch line or feeder movements (engine with one to five cars) are not as clear due to a lack of data. Prospective branch line abandonment situations raise questions of whether there is an energy-advantage to abandonment. For example, a locomotive hauling two or three cars burns more fuel than would trucks to move the same cargo.

Assessment of the fuel implications of the diversion of rail traffic to motor carriers, or vice versa, in overland movement requires consideration of numerous factors such as terrain, load size and distance moved. TSC has developed a computer model for FRA to aid in the assessment of these factors. Parameters used in the analysis include:

(a) physical description of the train (car and locomotive weights, horsepower, capacity),
(b) route topography (distance, grade, curvature)
(c) operating conditions (speed, idle time, switching time, number of stops) and
(d) the load carried.

Use of the computer model developed for analysis of branch lines has been extended to include other railroad operations such as intercity freight and passenger service.

Actual measurments of fuel usage by operating trains of various consists, including unit trains and dedicated trailer-on-flat-car (TOFC) and container-on-flat-car (COFC) trains, are planned. These measurements of quantities consumed will be used to calibrate and verify the analytical model predictions. In case-by-case evaluations of energy efficiency between truck-rail modal choices, the model is expected to furnish the fuel consumption data of rail as compared to highway.

Intended primarily to provide the basis for economic consideration of fuel costs and for assessing energy efficiency performance, the analytical model in simulating operations can, when based upon known emission levels and power requirements, also provide insight into air pollution factors.

3.3 Safety Research

Safety Research is not limited to this FRA R&D program. The other three program areas also contribute to improving the safety of railroad operations. However, the Safety Research Program is specifically aimed at producing significant improvements in five areas:

(a) Transport of hazardous materials in tank cars
(b) Rail vehicle crashworthiness
(c) Grade crossing safety
(d) Human factors as the cause of railroad accidents
(e) Specialized equipment for rail safety.

The resulting improvements are expected to provide positive responses to hazards revealed by the Office of Safety inspection programs and assure the establishment of more effective safety standards. Accomplishments of the Safety Research Program also influence planning in the other three railroad research program areas.

Hazardous Material Tank Cars

In one major element of the safety R&D program, FRA seeks to improve the ability of cars transporting flammable and toxic materials to survive derailments without catastrophic consequence due to tank rupture. Many serious accidents have been caused by couplers, trucks, displaced rails, and other objects puncturing the tank. The FRA work has been undertaken in cooperation with Railway Progress Institute/Association of American Railroads (RPI/AAR) Tank Car Safety Project. The industry group has provided test facilities, test specimens and consultation in the search for means to reduce the propensity for initial penetration of the car tanks by couplers of adjacent cars. The search has entered the stage of RPI/AAR industry field trials of shelf "E" couplers (Figure 3) with which no serious operational problems have been encountered to date. A shelf E coupler is a standard E coupler with the addition of upper and lower shelves. At Washington University in St. Louis, FRA has initiated an analytical and experimental study to determine the performance of these couplers under derailment conditions. Further derailment tests with RPI/AAR support are planned at the HSGTC to verify the accuracy of an analytical model and to optimize the design of new couplers and draft gears under yard impact.

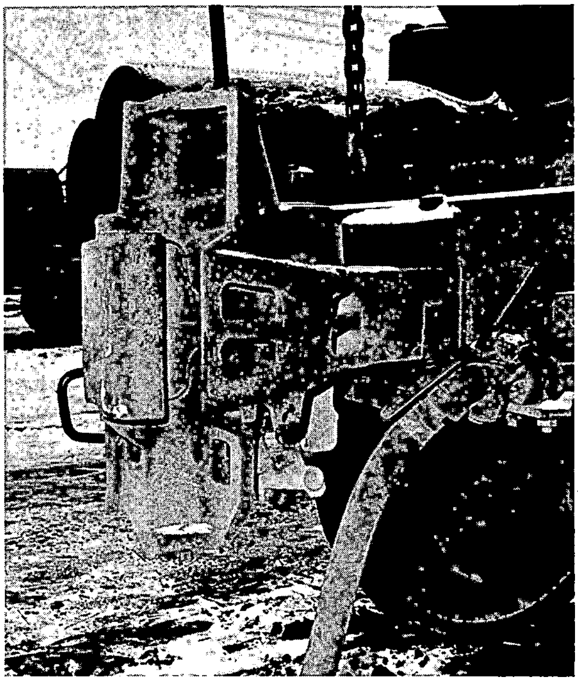


Figure 3. "E" Coupler with shelves.

Another method proposed for decreasing the likelihood of punctures is to cover the lower half of the tank head with a shield. Several types of head shields will be designed by Louisiana Technical University and thoroughly tested and analyzed by the Illinois Institute of Technology Research Institute (IITRI), both statically and dynamically, to insure that a shield will remain in place during normal operation of a tank car.

In addition to puncture prevention, work is underway to reduce the propagation of any fire consequent to derailment. Feasible means under consideration for avoiding the rupture of tank shells after they have been enveloped in fires from leaking fuel encompass:

(a) The addition of insulation to retard heat penetration,
(b) Improvements in the relief valve to bleed off boiling lading fast enough to stabilize the internal pressure at a level below design limits, and
(c) Possible modification in the construction materials of the vessels so as to better resist sudden failure of the steel at high temperatures.

Development of an effective and durable insulation coating which can be applied to existing tank cars has progressed in four areas: (1) computerized heat-transfer analyses, (2) one-fifth-scale model experiments, (3) full-scale testing and (4) insulation-material investigations. The RPI/AAR group has cooperated in all these areas.

The heat-transfer computer model developed by Calspan, Inc., was validated on one-fifth-scale model tank car replicas (contributed by the RPI/AAR) subjected to controlled "burning" in pits at the White Sands Missile Range in New Mexico. As reported in the Seventh Annual Report, these experiments were carried out by the staff of the Army's Ballistics Research Laboratory, Aberdeen Proving Grounds, Maryland. Significant potential for improvements was revealed; for example, a coating of ½″ (13 mm) of thermal insulation to a bare tank extended the time to imminent failure from eight minutes to fifty-five minutes.

Full-scale fire testing at a separate facility at White Sands began in July 1973. In the first test, an uninsulated test tank ruptured violently in approximately 25 minutes, propelling 128 fragments as far as 1,400 feet (430 m) from the center of the test pit. The next test, utilizing an identical tank but with a ⅛″ (3 mm) coating of thermal insulation on the shell, confirmed the one-fifth-scale predictions. The time to rupture was extended to one hour and thirty minutes, and the severity of the explosion was considerably reduced. Two of the four major tank-car fragments remained in the test pit. Instrumentation in the tank car during the test produced data in agreement with the parameters of the analytical computer model.

The demonstrated potential benefits of the application of thermal coatings to tank cars are dependent upon identification of a material which will not only have suitable thermal properties and withstand the long-term tank-car environment, but will also be cost justifiable. Accordingly, typical tank-car plate sections, coated with the most promising candidate materials for thermal insulation, are being subjected to high-velocity, high-temperature, jet flames at the Test Center (Figure 4).

Figure 4. Coating Sample under Test in Flame Test Facility at the Test Center.

Long-term environmental performance of selected coating materials will be evaluated by the Ballastics Research Laboratory by exposure of coating samples to weathering and other accelerated aging tests.

A sophisticated facility to test and qualify full-sized hazardous-material tank-car relief valves (provided by RPI/AAR) has been completed at the Edwards Air Force Base, California. The testing of valves is conducted with propane, vaporized by steam lines built into the test tank car. Data have been obtained in the course of the testing sequence which show that relief valves in use today perform in accordance with design requirements. However, certain valves are not adequate in the midst of a fire. Relief valves have been redesigned by the manufacturer to provide more reliable performance. These redesigned valves will be tested under actual flow conditions and functional tests will be made under controlled heat to determine their vagaries in a fire condition.

Tank-car structural-stress analyses and metallurgical investigations are continuing at Louisiana Technical University and at the National Bureau of Standards to develop guidelines for mechanical design and material properties which will increase the margin of safety against rupture and "rocketing fragments." Also, Louisiana Tech is reviewing the specifications for tank car construction in order to strengthen the requirements for those structural members which are the weakest.

Rail Vehicle Crashworthiness

In the broadcast sense, the objective of the Rail Vehicle Crashworthiness sub-program is to improve rail vehicle occupant survival under conditions which include train collisions, derailments, and other accidents. While the optimum strategy for improving rail safety is through accident avoidance, reality dictates designing into rail vehicles a reasonable degree of occupant protection and crashworthiness for those occasions when accidents do occur. The work presently underway will provide the necessary technical and cost information to support modifications in rail vehicle structures and attachments to reduce loss of life and the extent of injuries suffered in train accidents.

A general analysis of the collision environment requires an examination of prior collision data to determine injuries sustained and other collision costs to estimate benefits that could occur through improved structural designs for major classes of rail vehicles such as passenger cars and locomotives. A contract has been awarded to Boeing Vertol to conduct such an examination.

A second task will be to seek existing data on human tolerance to smoke, vibration, temperature, noise, and accelerations. Occupational Safety and Health Act (OSHA) regulations will be reviewed and acceptable tolerance-level guidelines will be established. Measurements of the temperatures, vibrations, accelerations, and noise which exist in contemporary rail vehicles will be made.

Preliminary work, begun in the last quarter of FY 74, consists of the development of design specifications for crashworthy rail-car interiors. This work includes a study of the interior construction of rail-car vehicles—seating materials, design and placement of seats, door and window opening devices, and other safety devices.

A third task to improve rail vehicle crashworthiness will be the development of a new locomotive cab design. This task includes consideration of occupant protection, the maintenance of structural integrity, and the cab environment, and an allowance for future technological improvements in train monitoring and control. The work is being coordinated with labor and industry.

Human Factors in Railroad Operations

The overriding objective of the Human Factors effort is to develop a solid technological and data base for the establishment of standards under the Federal Railway Safety Act of 1970. At the present time, approximately 40% of railway accidents and virtually all collisions in the last twenty years were caused by human errors.

From continuing research on the influence of human behavior in railroad safety, criteria of job knowledge, job skills, and training have been developed for the jobs of train crews and dispatchers. A detailed analysis of the train dispatcher's job has been published by TSC. Minimum job knowledge and proficiency standards necessary for operational safety can be determined from the description of any job which is detailed enough to identify job responsibilities, the tasks that job performance entails and the relationship of task performance to safety. It was recognized that assurance of compliance with standards would require the development of standardized job-knowledge tests and job-proficiency checks.

Many train accidents have been attributed to loss of attention on the part of the crew in the locomotive cab. Reasons proposed have included both undesirable characteristics of the cab environment and more subtle factors related to the complexities of human behavior. Based on a review of the literature on vigilance, an experimental attack on the problem of maintaining alertness in locomotive crews has been initiated at TSC. Under this sub-task, the cab environment is being surveyed and evaluated, with particular emphasis on identifying intolerable levels of noxious gases, vibration, noise, and temperature. There are, however, additional countermeasures against the loss of crew vigilance that can be better approached by studying the crewman himself, in particular, the identification of physiological and behavioral indices of vigilance loss and the development and evaluation of devices for maintaining alertness. Under that cab environment sub-task, investigations started in the middle of FY 74 are continuing through controlled experiments on human behavior in a situation devised to induce boredom and fatigue.

Technical assistance was provided by TSC in the evaluation of industry-built cab mockups for demonstrating innovative safety features. Human factors guidelines for the design of a new locomotive cab seating arrangement were prepared by TSC for the joint labor/industry effort.

Preparation of performance specifications for a locomotive research simulator is continuing. The prime function of the simulator will be to serve as a test bed for experiments on man-machine interactions in the locomotive cab. On-the-road testing is not feasible because of danger, cost or lack of precise control of variables under study. Innumerable studies will require the use of a simulator. Five study areas have been identified as initial candidates:

(a) Evaluation of new train handling concepts,
(b) Development and evaluation of train handling aids and safety devices,
(c) Evaluation of proposed changes in cab design and equipment,
(d) Evaluation of an engineer's role in advanced train concepts, and
(e) Analysis of accident causation by duplication of accident conditions.

Grade Crossing Safety

This program has the objective of achieving significant reductions in the 1200 deaths and 3500 injuries which occur in grade crossing accidents each year. There are two alternatives to reach this goal; (a) improve protection at grade crossings to prevent accidents and (b) equip locomotives with energy absorbing devices to improve the chance of survival of anyone involved in grade crossing collisions. Both approaches are being pursued in grade crossing protection R&D underway, and FRA is working with the Federal Highway Administration to assist the states in improving protection. Because there are around 250,000 grade crossings and only 26,000 locomotives, it is possible that installing energy-absorbing devices on locomotives could be more cost effective than grade crossing improvements. There are railroad operating problems, however, which complicate the situation and could change the cost effectiveness ratio from positive to negative.

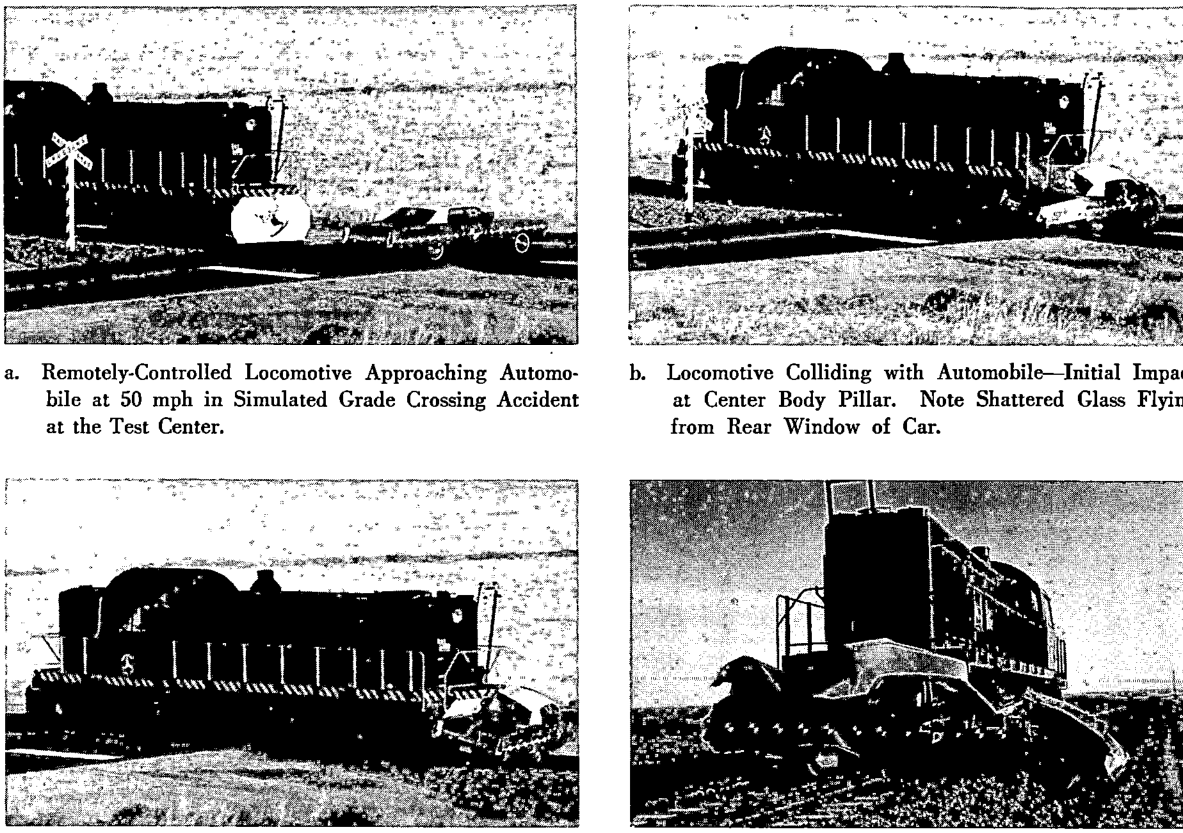
Impact tests involving a collision between a locomotive and a stationary automobile Figure 5 (a–d) were completed in FY 74 and have established a reference base for possible development of energy-absorbing devices. Such devices to decrease the severity of collisions will be investigated in systems analyses. If any promising concepts are discovered, test devices will be designed, fabricated, and then evaluated through instrumented model crash tests.

Locomotive visibility improvements, utilizing new high-intensity strobe lights (Figure 6), are being evaluated in cooperation with the Santa Fe, Bangor and Aroostock, and the Boston and Maine Railroads. Train-crew acceptance, maintenance, durability, and conspicuity are being studied by the railroads. High-intensity strobe lights, mounted in pairs on locomotives, have been shown to be very effective in the enhancement of train visibilty at grade crossings. Crew acceptance of these high intensity lights has been very good and maintenance appears to be low.

Research into methods of decreasing the overall cost of wayside grade crossing equipment has been initiated. Standardization and modularization design techniques will be applied to a wide range of wayside equipment to determine concepts which could lower the initial and recurring costs of the safety equipment. The grade crossing barrier has been isolated in an on-going study to investigate materials and mechanisms which would lower its overall costs and, thereby, encourage its widespread implementation.

Innovative ideas for active crossing protection will be evaluated with the objective to develop and test various grade crossing protection systems which demonstrate sound potential of application, increased effectiveness, and competitive overall cost (Figure 7).

A computer model was developed at TSC to assist the states in determining the best complement of grade crossing protection equipment for different classes of crossings within each state. This model has the capability of evaluating, in terms of the different types of protection equipment available, various factors that affect grade crossing safety to provide guidance as to the most effective course of safety policy with a given amount of funds.



a. Remotely-Controlled Locomotive Approaching Automobile at 50 mph in Simulated Grade Crossing Accident at the Test Center.

b. Locomotive Colliding with Automobile—Initial Impact at Center Body Pillar. Note Shattered Glass Flying from Rear Window of Car.

c. Locomotive Pushing Automoble Impaled on Coupler Down Track.

d. Locomotiye and Demolished Automobile at Rest 1500 Feet from Point of Impact.

Figure 5. Locomotive Automobile Impact Testing.

Component Failure Prevention

Approximately $18 milion in damage costs were suffered by the railroad industry in 1973 through accidents caused by defects in wheels, axles and journal/roller bearings. At the present time, FRA's Vehicle Materials and Inspection Equipment (VMIE) project is primarily concerned with reducing the number of in-service failures due to defects in these components. Successful achievement of the project goals, however, will provide a basis for more comprehensive application of the knowledge gained to other structural members of the vehicle.

The VMIE project, the results of which should contribute significantly to reducing railroad accidents and time delays due to in-service failures consists essentially of work in two major categories:

(a) the characterization of the material properties of wheels, axles and journal/roller bearings to assess their capability to perform satisfactorily in the railroad environment and

(b) the development of nondestructive inspection equipment and methods that will permit early detection of incipient failure of components before catastrophic failure and subsequent derailment can occur in service.

One of the best ways to reduce failure in equipment components is to prevent the development of fatigue and thermal cracking in the component material. Before this can be accomplished, the causes of such cracking must be understood. Under contract to FRA, United States Steel Corporation Engineers and Consultants are studying ways in which cracking begins. Fatigue cracks in the rims of low-carbon steel wheels have been initiated by subjecting railroad car wheels to cycles of drag-braking followed by emergency brake applications under controlled laboratory conditions. Follow-on work will attempt to formulate feasible corrective actions.

Another approach to reducing fatigue-type failures is to determine a methodology to establish the service life of truck components and recommend certification procedures. This determination

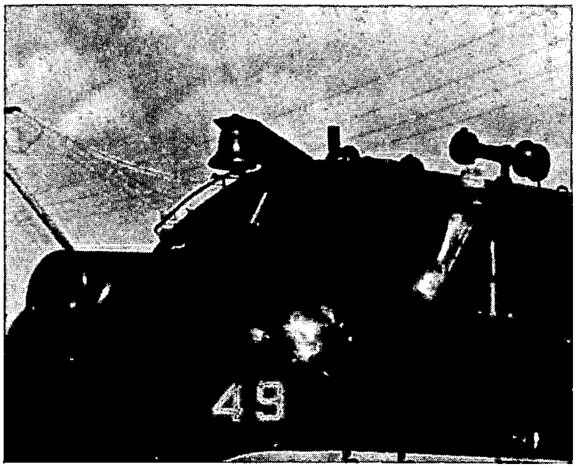


Figure 6. Front-end Strobe Lights for Increasing Locomotive Conspicuity.

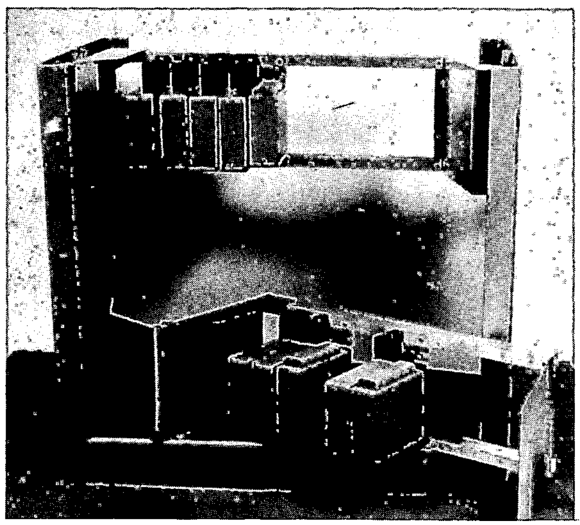


Figure 7. Proposed Standard Modular Relays for Grade Crossing Warning Device Circuitry. Standard Relays and Other Components Should Lower Investment Costs Below Those of Present Custom Built Equipment.

is important because truck components have a finite service life and are not designed to be "fail-safe." Illinois Institute of Technology Research Institute (IITRI) has completed field testing to obtain representative dynamic loading cycles to which railroad trucks are exposed in normal operations. These data will allow laboratory verification and a more accurate prediction of the useful life of railroad cars. Fatigue testing of wheels and studies of typical truck component failures were also undertaken in the contract with IITRI.

An immediate problem is the continuing occurrence of defects in many existing railroad vehicles. At some point of growth, a defect in a component material, whether it be a flaw or a fatigue crack, can cause abrupt component failure. Repeatable methods for measurement of such defects—with a coincident determination of how "close" they are to being critical—are essential to insure removal of defective components before failure. In support of this requirement, the Boeing Commercial Airplane Company is currently investigating crack growth characteristics and critical crack sizes in railroad vehicle wheels.

New methods for inspecting truck components are needed because current methods are inaccurate, slow and costly. Ideally, such components should be inspected in routine movement by unattended automatic monitoring and diagnostic units. Development of new techniques, procedures and equipment is required to facilitate existing inspection methods.

Several projects are underway to develop, test and evaluate various automatic-inspection methodologies. The University of Houston is investigating an acoustic technique for detecting cracks in rolling railroad car wheels, utilizing a wheel-impact excitor, along with associated audio spectral analysis. Simple and reliable portable inspection units, suitable for use by Federal inspectors as well as railroad shop personnel, are needed to determine whether components meet equipment safety standards. Here, FRA R&D efforts are meant to serve as catalysts to promote availability of requisite inspection equipment and to foster development of measurement technology in areas where it is lacking. A prototype ultrasonic wheel inspection unit, designed to detect cracks in wheel rims and plates (Figure 8), was developed under contract by Scanning Systems, Inc., during FY 74. Using this unit, which weighs only three pounds, inspection of the complete wheel rim for surface defects can be accomplished in about one minute.

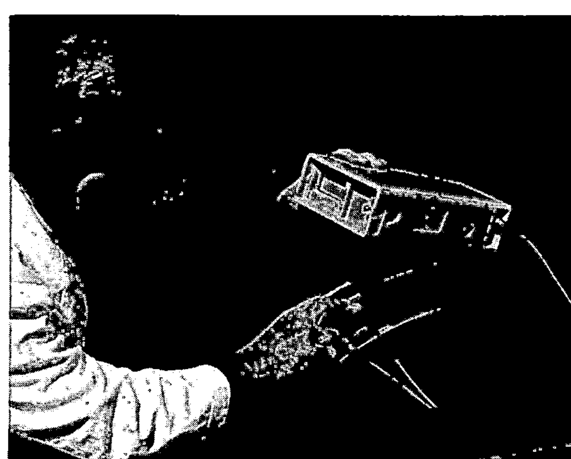


Figure 8. Prototype Ultra-sonic Wheel-Rim Flaw-Detection Unit.

In the development of inspection capabilities, FRA has the following related work under contract:

(a) Battelle Northwest, Inc., investigated an ultrasonic technique to detect cracks in railroad wheel rim and hub fillet surfaces.

(b) NASA-Huntsville and Southwest Research Institute, in conjunction with the United States Steel dynamometer braking tests, are investigating methods to detect changes in the test wheel rims due to heat generated during tread braking.

(c) NASA and Southwest Research Institute respectively are evaluating an ultrasonic birefringence method and magnetic technique (Barkhausen) for detecting undesirable changes in the rims of wheels.

3.4 Improved Track

The Improved Track Research program contributes directly to fulfillment of two major missions of the Department of Transportation—fostering transportation technological development and improving transportation safety. It became clear during the last year, however, that emphasis on the safety issue, as it relates to railroad track, is of paramount importance. The number of train accidents attributable to track causes has continued to increase. Those causes include rough track, broken rails, defective turnouts, cracked rail-joint bars and inadequate longitudinal rail restraint leading to buckled track. In general, these failures in track systems or components are assignable to excessive material wear, fatigue or displacement. ORD&D has assigned added importance to safety-related research. Meanwhile, momentum has been maintained in research for more efficient track-system performance.

Analytical Research

Analytical research activities can often be classified as pure rather than applied research. While pure research is an essential ingredient of growing technology in general, ORD&D carefully selects for support only those types of advanced research necessary to provide otherwise-lacking data to goal-oriented projects.

Progress has been made on track analytical projects commenced prior to the period covered by this report and which include:

(a) Development of an integrated family of track simulation models—models were identified and ranked in accordance with versatility and limitations.

(b) A comprehensive test plan for validation of the simulation models has been completed;

(c) Investigation of the basic material properties of ballast substances commenced at the University of Illinois and now one-quarter complete.

Current Track Tests

Concrete ties and threadless rail-tie fasteners were installed in the spring of 1974 on the main line of C&O-B&O Railroad at Lorraine, Virginia (Figure 9). These track system components are being tested to determine the performance characteristics of best-state-of-the-art concrete ties when subjected to severe service and the cost-effectiveness of relatively maintenance-free rail-to-tie fastening systems. First quarter-year observations suggest that one fastener component (elastomeric pad) is likely to prove greatly superior to a second in its ability to resist displacement from beneath the rail. Should this be borne out by the test, useful tie-pad design data will be revealed. The first six months' experience showed good performance of the concrete ties, but at least two years' experience is needed before conclusions can be drawn on their ability to carry the traffic loads.

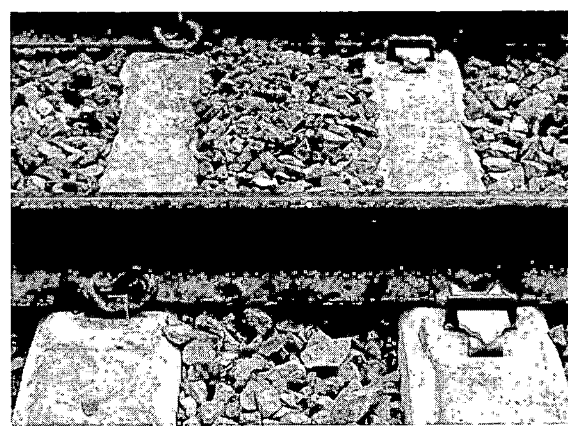


Figure 9. Two Types of "Threadless" Rail Fasteners Used in the Concrete Tie Test at Lorraine, Va.—Pandral Clips to the Left and Tempered Spring Model CS-5 on the Right. Fasteners Avoid Recurring Tightening Costs.

The Alaska Railroad installed two cold-region track test sections in their main track before the onset of hard-freeze conditions in October 1973. These test sections were installed to attain three objectives:

(a) To determine the survivability of a widely-accepted type of concrete tie when used where roadbed heaves substantially due to frost action;

(b) To evaluate the cost-effectiveness of using concrete ties with adjustable rail-tie fasteners as compared with timber ties subject to "spike-kill" (Figure 10)—and foreshortened life—in situations where roadbed heaving requires frequent rail-tie shimming to re-establish track profile;

(c) To evaluate the use of compounds to bind (or "glue") particles of ballast together in order to confer cohesiveness to granular ballast in regions where the foundation soil is weak.

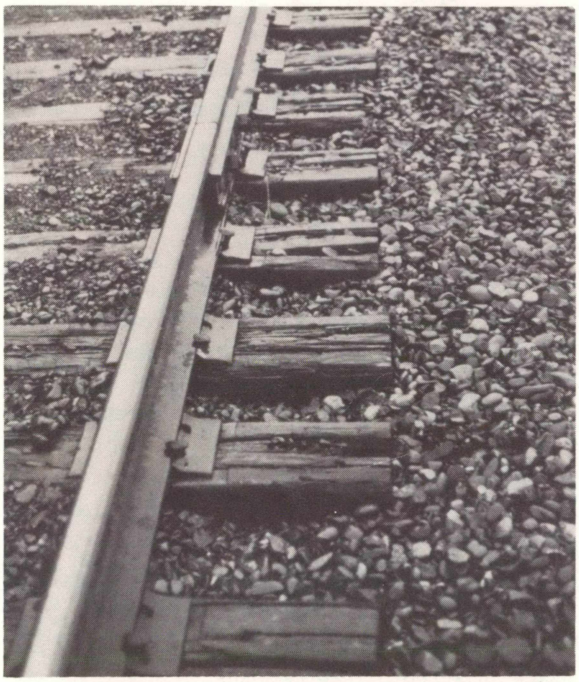


Figure 10. Alaska Railroad Ties "Spike-killed" by Frequent Realignment.

Data at the end of nine months indicate no structural problems with the ties and no track settlement where the ballast had been treated, this latter experience being a distinct improvement over past history at the location.

The Seventh Report described the purchase of a ballast consolidator and plans for effectiveness tests. Throughout the fall of 1973, the FRA consolidator participated in a series of tests on five railroads—The Southern, Boston and Maine, Penn Central, Missouri Pacific, and Cotton Belt. In the following spring, the equipment returned again to a new location on the Southern for a similar test, directly designed and administered by the staff of the Railroad's test department. The purpose of all of these tests was to measure the effectiveness of the consolidator in immediately restoring track ballast disturbed through routine maintenance work to the ballast's original or undisturbed state of compaction. Conventional track maintenance procedures rely on traffic vibration to re-consolidate disturbed ballast. Track is notoriously vulnerable to lateral buckling during this "natural" ballast consolidation period, especially if there is substantial compressive stress in the rails. Therefore, during the re-consolidation period, traffic must move at speeds lower than normal.

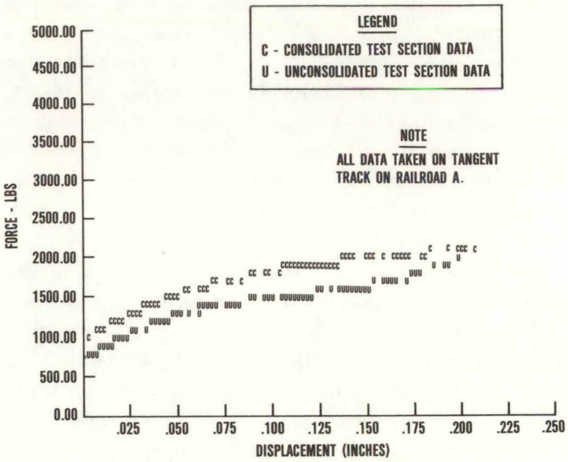
Test procedures were designed to determine the force levels required to drive individual ties a fixed distance, 0.237″ (6 mm), in the transverse and longitudinal planes of the track. Tie motion in these planes will occur as a consequence of track buckling and longitudinal rail creep, a precedent effect strongly contributing to the onset of buckling. The value, 0.237″ (6 mm), defines the range of displacement beyond which a tie will continue to move under an application of sustained constant force. In other words, no additional resistance to tie motion can be provided by ballast material once tie displacement has occurred to this extent, a conclusion generally confirmed by similar experiments in Europe based on different track configurations and axle loadings than prevail in the U.S.

Tests were conducted in conjunction with general or out-of-face track smoothing operations on four 660-foot (200 m) zones—two each on tangent and curved track—on each of the five railroads. One of each pair of test zones had the operation of the ballast consolidator integrated into the work plan. The second zone of each pair did not have this effect applied and served as a control section.

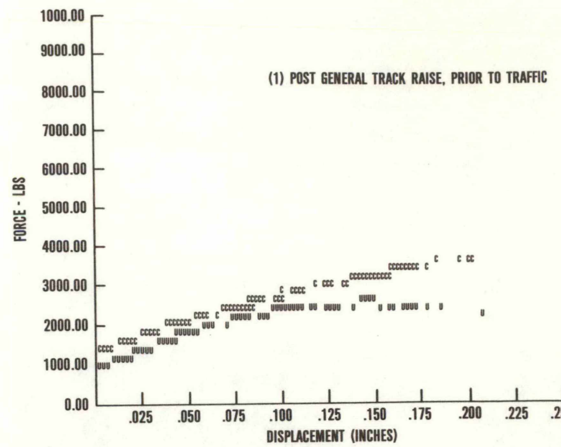
Test data unmistakably indicate that a five-second-per-crib (space between two ties) application of the consolidator to a re-worked section of track in which the upper region of the ballast layer has been completely disturbed immediately develops a resistance to lateral and longitudinal tie displacement 30% greater than was evident in similar track sections where the equipment was not operated. Figure 11 (a&b).

Kansas Test Track

When the Kansas Test Track in the main line of the Atchison, Topeka and Santa Fe Railroad Company at Aikman, Kansas, was initially placed in service in May 1973, a number of rail-to-base fastener failures occurred in the three test track segments utilizing reinforced concrete beams or a slab as support. As was reported in detail in the last report, the failures were due to pull-out of certain fastener anchors from the concrete because of uplift forces far in excess of the commonly accepted values that had been used in design calculations.



a. Tie Resistance to Lateral Displacement Summary Data (1).



b. Tie Resistance to Longitudinal Displacement Summary Data (1).

Figure 11. Results of Ballast Consolidator Application to Disturbed Track.

A redesign of the fastener anchorage was carried out by the Cement and Concrete Research Institute. Extensive analyses and testing led to a specification incorporating the following modifications to the original fastener anchorage system:

(a) In-place, vertical steel studs were removed;

(b) New vertical holes, 8 inches (203 mm) deep by 1¼ inches (32 mm) diameter, were drilled down through the cast-in-place anchors;

(c) Fully-threaded steel rod stock, 7½ inches (190 mm) long, was placed into these openings as studs; and

(d) These new studs were secured in place by the addition of an epoxy compound that included finely-divided cast-iron particles for greater strength.

In the course of drilling the enlarged vertical holes, an additional procedure followed was the installation of a ¼-inch (6 mm) circumferential groove beyond the nominal periphery of each hole, some 2¼" (57 mm) above the floor of each hole. This step provided a keyway for the shear-resistant epoxy and, by mechanically interlocking the epoxy to the hole-wall, essentially eliminated creep under vertical load. The track repair work was completed in accordance with the specifications by September 1974. Remaining effort fell to the Railroad to re-install the long lengths of welded rail on the three affected test sections. Re-opening the entire test track was scheduled for December 1974.

Rail Behavior and Performance

Considering the causes of train accidents assignable to track defects, it is evident that rail failure is the most common. This conclusion is not surprising in view of the mix of rail sizes and service ages that comprise the industry's plant. Even though heavier and newer rail tends to predominate in mainline trackage, this condition is by no means universal.

More important, however, than the size and age of rail is the service environment to which rail is exposed. Intensively utilized main tracks are subjected to repetitive heavy loads. Fatigue damage develops which is directly related to the magnitude of flexural stresses experienced by these rails. In turn, the magnitude of rail stress resulting from rolling loads is affected by the quality of track maintenance applied by a given carrier. There is extensive intuitive agreement in industry with this viewpoint, but quantitative data describing the limits of vertical rail flexural strain that can be sustained without incurring fatigue damage is lacking. Moreover, once a defect is initiated in a rail, the criticality of defect size and the rate of crack propagation, as a function of traffic tonnage, are only dimly understood. An opportunity for intensive application of the techniques of advanced metallurgical analysis and fracture mechanics has been recognized in this situation. A research plan has been developed, the results of which will lead to an ability to predict rail performance if track support values and expected tonnage are known.

With respect to prolonging rail life, FRA entered into technical discussions with a large airframe manufacturer who has developed a technique for inducing circumferential compressive stress around holes of up to three inches (7.6 cm) in diameter drilled in structural members. The goal is to transfer this technology, one which prevents the initiation of radial cracks or the further growth of small cracks already present, to application in older bolted rail. The predominant failure mode of bolted rail is radial or "star" cracking in the end-region emanating from the bolt-hole. While there are presently some 40,000 miles (64,300 km) of continuously welded (unbolted) rail in the heavy-density trackage, there are also more than 60,000 miles (96,600 km) of 39′ (11.9 m) long bolted rails. These end-bolted rails tend to be the older rail components of the maintrack mileage and, as such, are prime candidates for proven measures that can economically extend safe life pending eventual replacement by welded rail. The current rate of installation of continuously welded rail suggests that there will continue to be significant quantities of failure-prone bolted rail in track for the next fifteen to twenty years.

3.5 Automated Track Inspection

Improved Rail Flaw Detection

Directly dependent upon the studies aimed at determining critical defect size and rates of growth associated with each defect type is the capability, in terms of transducer sensitivity, of locating these flaws before they result in catastrophic, in-service failures. There are several types of dangerous rail defects. The bolt-hole cracking, discussed above, is one. Other types include rail transverse and longitudinal defects.

Currently, the rail industry and an associated proprietary service use three techniques for detecting flaws in rail. These techniques are exemplified in systems that are continuously transported along the track and may be briefly categorized as: (1) residual magnetism, (2) inductive field and (3) ultra-sonic. One common characteristic of these flaw-detection systems as presently used is relatively slow transport speed, seldom exceeding fifteen miles per hour. Another is variability in sensitivity to the presence of a flaw. What are not known, lacking understanding as to critical flaw size, are how sensitive a system response need be and how this sensitivity could be affected by forward transport speed of the system.

During FY 74, FRA acquired a best-state-of-the-art, ultra-sonic, rail-defect detection system, housed in a hi-rail truck capable of rail-highway operation (Figure 12). At the same time, negotiations were undertaken with the Boston and Maine to obtain two sections of unused trackage in which rails having known defects will be installed. One of these sections, in Cambridge, Mass., is several hundred feet long and will be used for system calibration purposes in that many milled-in defects of accurately known size will be present. The second section, which is in the Cheshire Branch of the railroad near Winchendon, Mass., and is several thousand feet long, will contain rails exhibiting a complete spectrum of service-induced defects. These rails have been selected from the group of defective rails removed from track following routine testing carried out in the spring of 1974 by the Railroad. Once these rails are installed, the location and size of the individual defects will be defined by manual search with appropriate instrumentation.

With best-state-of-the-art, well-calibrated equipment and the longer test track, it will soon be possible to define the limitations of the system in terms of sensitivity and forward transport speed. Once these limits have been identified and when some understanding of critical flaw size from the Rail Behavior project has been gained, tests will be attempted to determine what system modifications are necessary to detect rail defects while the equipment is moving at reasonable speed. Further, investigation must determine at what repetitive interval a specific type of track requires inspection. While these studies are in progress, means of automatically evaluating defect search data will be developed under FRA direction.

Surprisingly, no such data-processing methodology is employed today in any quarter, at home or abroad. Reliance is placed solely in the human interpretation of defect signal indications (aided in some cases by warning alarms). Application of the results of both the Rail Behavior and Improved Rail Flaw Detection projects should strongly contribute to alleviating the financial and social burdens imposed on the industry and the community by the present-day rail-failure accident experience by enabling reduction in the frequency of occurrence.

Rail Longitudinal Stress Measurement

Historically, one of the more dramatic track behavioral phenomena, that of buckling, has continued to be a major concern of track design and maintenance engineers. Track buckling, often involving several feet (meters) of lateral track displacement, occurs most frequently with little or no warning—sometimes under, sometimes in advance of, traffic—and, when evident, presents virtually an insuperable obstacle to safe passage of trains.

Figure 12. Rail Flaw Detection Vehicle—with Ultrasonic Sensor Transport Carriage Deployed at Rear.

Many factors can and do contribute to the onset of track buckling. While the problem has plagued the industry for well over 100 years, it has been aggravated in the last two decades by the introduction of continuous welded rail (CWR). Usually lengths of uninterrupted CWR will be one-quarter mile (0.4 km) long. Industry practice encourages installation of even longer rail-string lengths of up to several miles (multi-kilometer). This procedure is not desirable of itself, but the installation of long lengths of rail, lacking the fractional-inch (several millimeters) space every thirty-nine feet (11.9 m) that accommodates axial stress relief in bolted track, demands continued extra care in the design and maintenance of procedures intended to contain CWR stresses.

In general, track, including CWR, experiences variations in longitudinal or axial stress in the parallel rails directly related to temperature fluctuation. As temperature rises, increasing compressive stress in the rails must be contained by being distributed incrementally and locally through the support base on which rails rest, or buckling of the rail-tie frame will occur.

Controversy prevents agreement as to the mechanics of track failure in this instance—does the track first lift off the ballast bed, does it suddenly shift laterally, or is there a combination of these events? There is no lack of agreement, however, on the point of excessive axial stress as a trigger of buckling.

The need for a technique permitting rapid, continuous measurement of absolute axial stress in rails has long been recognized by FRA, the National Transportation Safety Board and the rail industry. Only within the last year has it been possible to develop sufficient confidence in one method to justify a serious look. A team of specialists at the University of Oklahoma is now working on the application of a promising ultrasonic technique (acoustic birefringence) built on the hypothesis that a small, but detectable, stress-conditioned time delay in the echo-return of intermittent pulses directed progressively into rail along its top surface can provide a direct measure of absolute axial stress. This project, begun in the spring of 1974, has a two-year life and is expected to produce performance specifications for an axial rail-stress measurement system that can be mounted in a rail vehicle. Operation of such a system by track maintenance personnel will enable the pinpointing of not only dangerous compressive stresses in rails but the only slightly less unwanted tensile stresses that lead to rail pull-aparts at welds or joints.

Track Measuring Car Developments and Operations

Utilization of the FRA track-measuring cars increased substantially during the year ending September 30, 1974. Track geometry tests covered a total of 9,357 miles (15,055 km) of trackage on nine railroads.

Newly developed track geometry measuring instruments, including inertial profilometers and curvature-measuring devices, have been integrated into the operating system. Other instruments were modified to provide better reliability. Additional improvements such as an inertial alignometer and crosslevel-measuring device are underway. An integrated exception report, which lists track geometry defects as they are detected, can now be generated by the onboard computer within two or three hours after the end of a day's run. A curve-evaluation program was developed and added to the off-line data processing programs. This program identifies previously undetected defects in curved track by comparing curvature and cross-level data. Statistical-comparison programs were developed to analyze the variation of track quality from location to location and from one year to the next. These comparative studies allow railroad management personnel to evaluate and plan their maintenance activities more effectively.

The increased use of the track-measuring cars was, in part, due to the interest of FRA in investigating whether the railroads of this country are in compliance with the FRA Track Safety Standards. Exceptions to the minimum FRA Standards are listed on a digital printout onboard the cars when they are measuring track. This information is immediately available to the FRA inspector on board and is used by him and the railroad to take immediate action if necessary. The track data are further processed after the inspection run for more detailed information regarding compliance of the track to the Standards for the speed classification as defined by the railroad.

The Test Cars have also been used for purposes other than measuring track geometry. One example was the test conducted for the Penn Central between Washington and New Haven to study the dynamic behavior of the pantograph-catenary power-collection system. As a result, the railroad was able to identify major causes of equipment malfunctions and make repairs to the wire of the power-distribution system that significantly improved operations.

Precision Track Geometry Measuring Device

The Track Survey Device (TSD), originally built for surveying the Linear Motor Research Vehicle track at the Test Center, was adapted to operate on conventional railroad track for collecting precise track geometry measurements. Data on fourteen track segments, representing various quality levels, were selected to form the basis of a catalog of representative track geometry measurements. The catalog includes both an actual geometric representation of the rails and a statistical representation (power spectral densities, etc.) of the geometric parameters. These data are required as guideway inputs to the wheels, both in the Rail Dynamics Laboratory Simulator and in specially-designed vehicle computer models. The TSD is also being used on the Kansas Test Track in order to establish an accurate settlement history.

Use of Track Geometry Measurement for Maintenance-of-Way Planning

Track-degradation and maintenance-planning studies have been performed in cooperation with the Bessemer and Lake Erie Railroad and the Denver and Rio Grande Western Railroad. Track geometry data, collected periodically on the two railroads during the past three years, were used as the basis for the studies performed. Data analysis and presentation techniques were developed for use by various levels of maintenance-of-way personnel to evaluate year-to-year changes in track conditions and the maintenance operations of the railroad. The results were presented to a special committee of interested railroad engineers of the American Railway Engineering Association by the two participating railroads and the extremely favorable response indicated potential for future safety and cost/benefit improvements. The presentation was given again at Washington, D.C., to representatives from DOT and several eastern railroads with a similar enthusiastic reception.

Track Impedance

Track deforms vertically and laterally under the loads of a moving train. The dynamic properties of the track have an important effect on ride quality as well as the operating safety of the train. In order to analyze the train and track as an interactive system, it is essential that the behavior of the track under dynamic load—commonly called track impedance—be understood. FRA contracted with Battelle Columbus Laboratories to develop a mobile track-impedance measuring vehicle for obtaining data on the impedance of track. Phase I of the vehicle-development program is in process and includes conducting a literature survey and evaluating several design concepts. Phase II will include experimental evaluation of some concepts for load application and for motion measurement and the completion of a detailed design. Phase III will cover the fabrication, demonstration and delivery of the measuring vehicle.

Northeast Corridor Improvement Program

The Regional Reorganization Act of 1973 brought about the establishment in FRA of a implementation group called the Northeast Corridor Improvement Office. It is the mission of this organization to undertake the system analyses that will fulfill the legislative mandate to establish an improved high speed passenger service in the Corridor.

Development of cost-effective track designs for high-speed train movement is necessary for success of the project. This is not a simple task even though the Japanese National Railroad passed through this phase some years ago, because it is not yet clear as to what extent heavy, slower-moving freight traffic must use the same tracks. In the Japanese situation the high speed tracks are totally dedicated to the support of new, lightweight passenger equipment.

Consultation on the evaluation of appropriate track designs has been and will continue to be provided to the Northeast Corridor Improvement Program as it unfolds.

3.6 Improved Passenger Service

Passenger Research

A number of studies performed by the Department of Transportation have indicated the benefits to be derived from the improvement of existing rail passenger service. The Northeast Corridor Report, released September 1971, found that, for the near and intermediate-term, high-speed rail was the most cost-effective means of expanding and improving the intercity passenger transportation capacity of the densely populated region between Washington, D.C., and Boston, Massachusetts. The High Speed Ground Alternatives Study made by the Office of the Assistant Secretary for Policy, Plans and International Affairs in 1973 reaffirmed the general conclusion for the Northeast and found potential in other corridors.

The Metroliner demonstration proved conclusively that an increase in the quality of service (measured in time, comfort, and convenience) at reasonable cost can result in a substantial increase in rail ridership. The Metroliners, in fact, reversed the declining trend in New York-Washington rail patronage. The impact of the energy shortage, the predicted increase in leisure time, and the propensity to travel provide an opportunity for future growth in intercity rail passenger service, if passenger service developments are planned properly. The Rail Passenger Research program seeks to aid in that orderly development by providing:

(a) Technology that will permit maximum effective use of rail passenger systems in meeting the Nation's transportation needs;

(b) Technological data and advice to the Secretary for use in meeting his responsibility in connection with AMTRAK; and

(c) Support to AMTRAK in conducting mutually agreed-upon passenger train research and development.

Metroliner Improvement Program

The Metroliner Improvement Program (detailed in the Sixth Report) has continued during the past year with efforts to make improvements in those components of the self-propelled cars that had been responsible for a high failure rate, high maintenance cost, and less-than-satisfactory ride quality. Four prototype cars are now undergoing road testing to verify that modifications are effective and reliable.

Electrical and mechanical modifications have been completed on four prototype Metroliners, two of which are equipped with General Electric Company electrical propulsion and control equipment and two with Westinghouse Electric Corporation equipment. The modifications included provision of car-monitoring equipment to simplify detection of failure in electrical components, a complete rewiring of propulsion circuits, a relocation of dynamic-braking grids to the roof, installation of roof-level air inlets for equipment cooling, and redesign of propulsion drive systems. Many of these improvements have since been incorporated in other passenger cars used in intercity suburban service, such as New York-New Haven and Philadelphia-Harrisburg. The testing completed to date indicates that the prototype cars have adequate capacity to operate at an acceleration rate of 1.0 mph (1.6 km/h) per second and can be run without difficulty at the design speed of 130 mph (210 km/h). In the fall of 1974 the four cars will operate as a train during a 25,000 mile (40,200 km) reliability test to determine if any of the new components are subject to an unpredicted failure rate. Whether or not the remaining 57 fleet cars are modified to conform to the upgrading is a decision to be made by AMTRAK.

Due to truck design characteristics, the Metroliner cars have never provided ride quality as good as some conventional passenger equipment. In FY 73, in an effort to provide an improved truck, a contract was awarded to LTV Aerospace Corporation to fabricate five new Metroliner trucks for test purposes. Swiss Industrial Company (SIG) of Neuhausen Rhine Falls, Switzerland, is LTV's subcontractor for the design and fabrication of the new equipment. The trucks will be the latest model

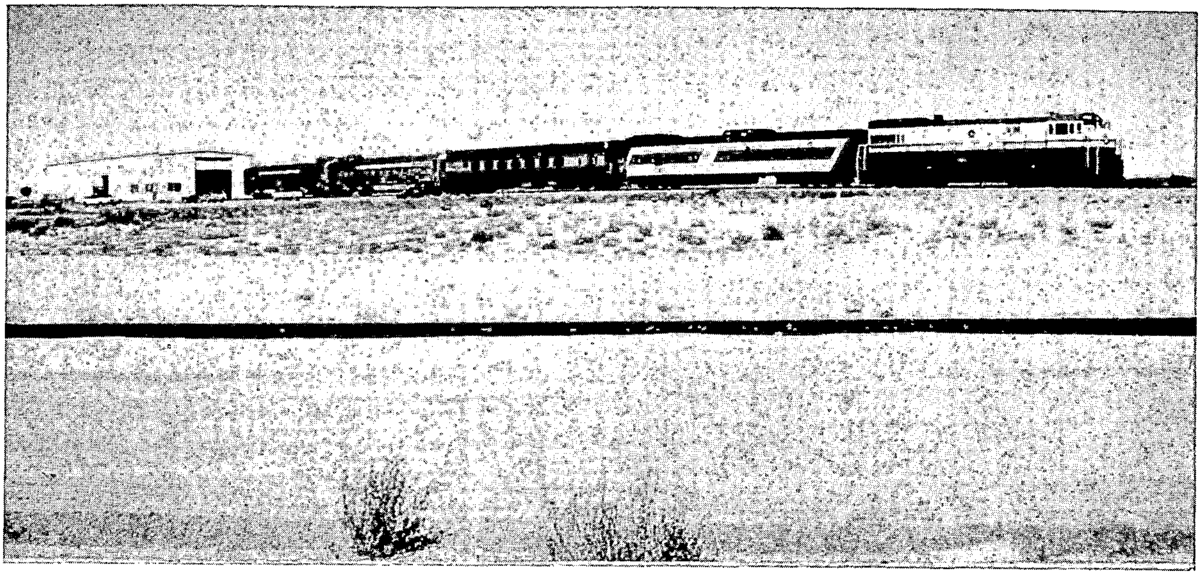


Figure 13a. FRA, AAR and General Electric Company Test Car Consist—AMTRAK High Speed Passenger Locomotive Truck Tests at HSGTC.

of the SIG M-type design, which has been successfully tested in Switzerland and France, and are currently on order for Finnish, Dutch, and Swiss railroads. The M-type truck will offer reduced noise, low-maintenance wheel profiles and improved ride quality due to a unique primary suspension and an improved air-suspension secondary spring.

The five test trucks have been completed and fatigue tests have been run. The first test produced cracks in the H-frame of the truck and, although there is evidence that faulty test equipment inflicted overloads on the truck, steps have been taken to strengthen the design. After relatively minor modifications of the frames were completed, the fatigue tests were successfully completed. Road tests will be made to verify load distribution and determine ride quality provided by the new trucks. The load distribution data will serve to validate the sufficiency of loads applied during fatigue testing. The decision remains to be made as to whether all or part of the Metroliner fleet will be retrofitted with the new trucks.

Other Equipment Improvements

In a joint effort by FRA, General Electric and AMTRAK, a GE locomotive equipped with a new high-speed, up to 130 mph (209 km/m), gearbox of the type intended for future AMTRAK use was tested at the High Speed Ground Test Center (Figure 13a) and on the tracks of the Atchison, Topeka and Santa Fe Railway (Figure 13b). Wheel-rail forces, suspension-system behavior and ride quality in the cab were measured. Using these data, the truck design will be modified in order to achieve better truck stability and less fatiguing ride and to verify that wheel forces on the track will not create an unsafe condition or significant rail wear.

A portable ride-quality and acceleration measuring device, the size of a suit case, was built for FRA by Ensco, Inc. (Figure 14). This battery-powered data-acquisition system measures and records linear and angular accelerations in the vertical, lateral, and longitudinal directions. The frequency and amplitude range of the system were designed for application inside passenger cars. The system has been used in several types of passenger cars, collecting ride-quality data for evaluation by FRA and AMTRAK. A special analyzer has been acquired by FRA and will be used to study passenger-car as well as freight-car vibration data.

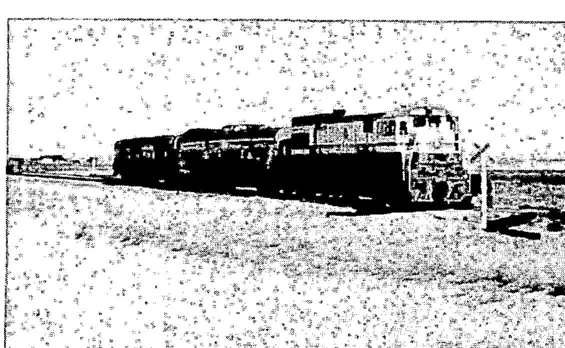
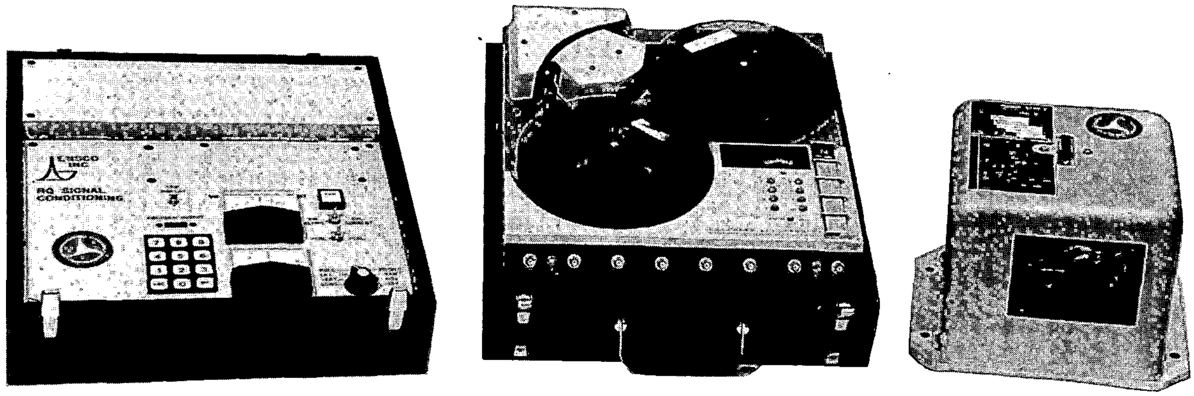


Figure 13b. High Speed Locomotive Truck Test Run on ATSF RR at 122.4 mph.



Conditioning & Coding Unit **Tape Recorder** **Accelerometers**

Figure 14. FRA Portable Ride-Quality Data Acquisition System, Used in Support of AMTRAK.

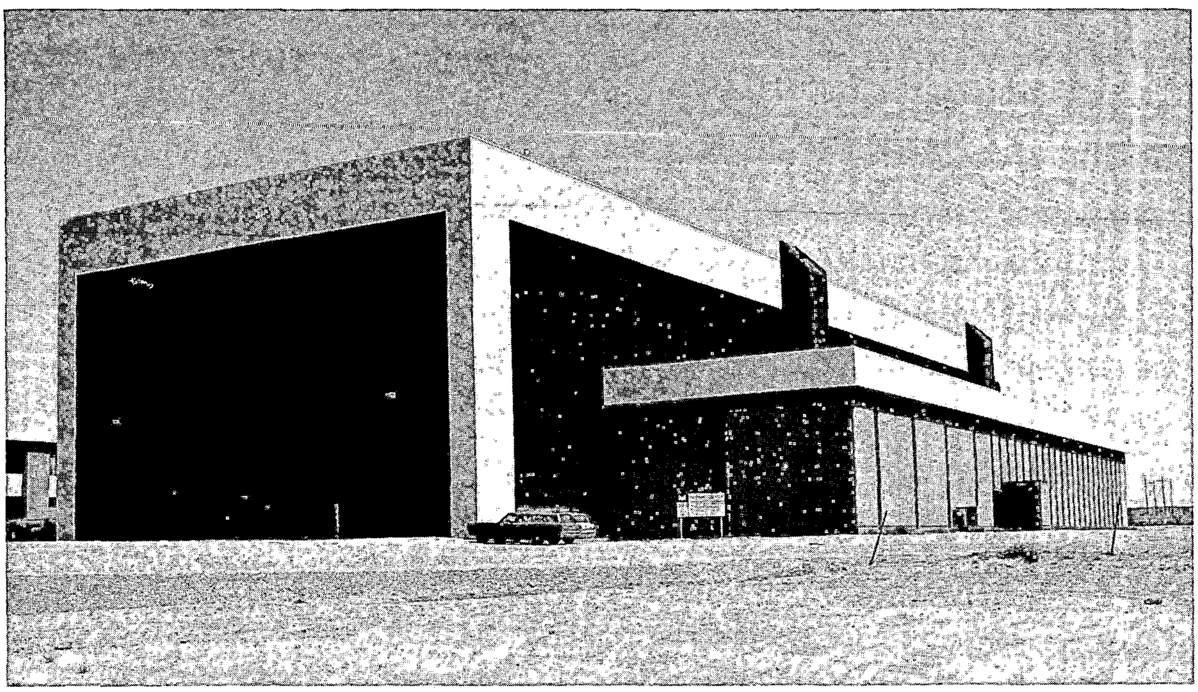


Figure 15. Rail Dynamics Laboratory Building.

3.7 Supporting Technology and Facilities

Rail Dynamics Laboratory

Occupancy of the Rail Dynamics Laboratory (RDL) building (Figure 15) at the HSGTC took place in April 1974. The laboratory is currently providing support services for test cars utilizing the Center test tracks. The completed RDL building will house—along with the associated control, monitoring, data-acquisition and data-processing systems—a Rail Dynamics Simulator (RDS) and a vertical shaker. The HSGTC Operation and Maintenance contractor operates and maintains the RDL. An area in the RDL high bay is set aside for test vehicle preparation activities (Figure 16) such as installation and calibration of instrumentation, vehicle modification and component or subsystem retrofit. In addition, general Test Center support service capabilities—such as machine shop, clean room, instrumentation calibration and repair, and computer maintenance—are included in the RDL. The Seventh Report contains a detailed description of the RDL facility. A major part of RDL activity has been concentrated on the fabrication and installation of test-support tooling required for the operation of the vertical shaker.

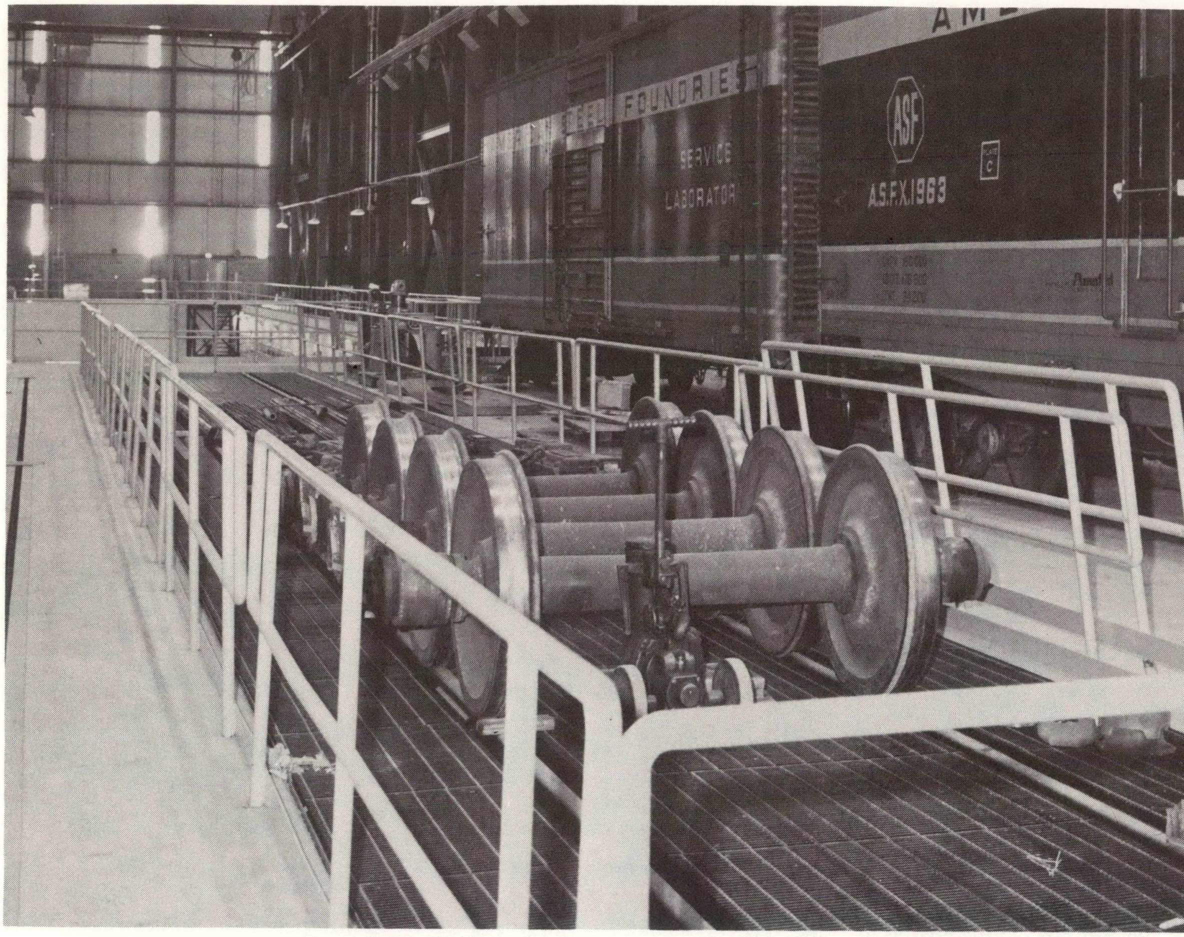


Figure 16. View of the Rail Dynamics Laboratory Test-Specimen Preparation Area.

Some of the major laboratory items ready for service or recently delivered to RDL include:

(a) *The Simulator Test Pit* (Figure 17)—which, due to its design, provides for the safe operation of the simulator—is essentially complete. A fire extinguishing system has been installed along the side of the test pit and successfully tested.

(b) *The RDL Facility Hydraulic Module* (Figure 18) has a 3,000 psi (20,684 kN/m^2), and 360 gpm (.023 m^3/s) variable-volume power supply capability that will be used for the operation of the vertical shaker actuators. The module has been installed by the contractor and is in the final check-out phase prior to being integrated with the laboratory's high and low pressure distribution manifolds that connect to the RDS and vertical shaker.

(c) *The RDL Machine Shop* is in operation and has the capacity for the fabrication of fixtures which are required by Test Center projects (i.e., for RDL test system set-ups and test vehicle modifications). The shop is currently being used to fabricate test-support tooling for the vertical shaker. Many of the machines in the shop were obtained from the facilities of other Government agencies.

(d) *The vertical shaker* will be located in the RDL high bay and is designed to study the response characteristics of truck assemblies and total vehicles subjected to vertically-applied periodic and random excitation. Both tracked and rubber-tired vehicles can be accommodated with wheel loads of up to 40,000 lbs. (18,144 kg). The vertical shaker has the capability of studying the following test vehicle characteristics: (1) fatigue susceptibility of vehicle bodies and components, (2) natural frequencies and (3) response modes of vehicles and their cargo. Methods of attenuating shock and vibration in a test vehicle to protect cargo and improve ride quality will also be explored.

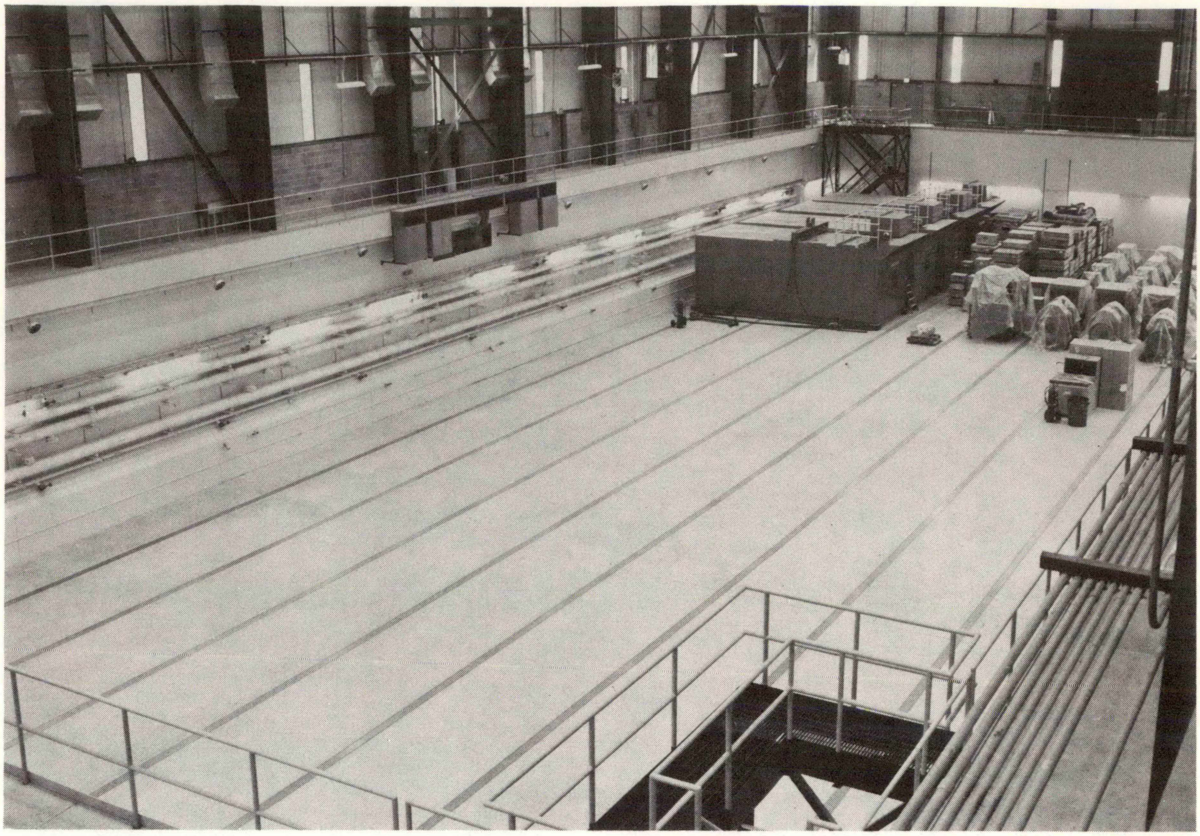


Figure 17. Rail Dynamics Simulator Test Pit.

The initial configuration of the vertical shaker consists of four excitation modules. These modules can produce vertical accelerations on a railroad truck or one end of a rail car. Figure 19 illustrates two of the four as well as the associated displacement-versus-frequencies capabilities. The modules are controlled by a stand-alone hybrid computer control system. This system has the data-acquisition capability to handle up to 128 channels of control and response data. The RDL instrumentation system (which includes transducers, signal conditioning, closed-circuit television and pulse cameras) will be used during test operations of the vertical shaker.

The vertical shaker is being manufactured, with installation in the RDL scheduled for January 1975 and acceptance tests starting February 1975. The first experimental program scheduled for the shaker will be the evaluation of a trailer on a flat car (TOFC), an 89-foot (27.1 m) flatcar with various combinations of piggy-back trailers. Data from the vertical shaker will provide the fundamental vehicle characteristics (normal modes and natural frequencies) that will contribute to a better understanding of dynamic behavior when these same test-specimens (vehicle and/or components) undergo the more complex dynamic inputs (vertical and lateral vibrations and rolling motion) provided by the RDS.

Rail Dynamics Simulator (RDS) Subsystems

The general arrangement of the RDS and test vehicle will be as illustrated in Figure 20. Table 1 below presents some of the RDS system capabilities.

The RDS consists of six subsystems—each of which is in various stages of design, development and/or delivery as described below:

(a) *The Drive Train* (Figure 21)—consisting of 600-hp (447.6 kw) D.C. motors, flywheels, power supplies, controls, etc.—have been delivered by the contractor (General Electric) and are currently in storage in the RDL. In-plant testing of this system has been successfully completed and the drive trains will be installed on the RDS equipment sections. The drive train system will subsequently be connected to the track module system.

(b) *The Track Modules* (Figure 22), simulate railroad tracks. This subsystem was originally planned to achieve a more "real world" irregular track simulation having: (1) yaw in addition to independent vertical, lateral, and roll rail displacements; (2) variable track-structure impedance and; (3) curve negotiation. This simulation capability proved to be neither technically feasible nor cost effective and was, therefore, deferred indefinitely in 1973.

During the past year the track module subsystem has had significant design changes which have not only delayed the ultimate operational date of the RDS but have had a significant design impact on the carriage assemblies, reaction structures and service structures system which mechanically interface with the track module system.

The track module subsystem will be connected to the drive train subsystem through constant velocity couplings (CVC). A quarter-scale CVC module test (Figure 23) was conducted to evaluate the dynamics and operation of this CVC unit. Preliminary results of this test showed the CVC to have high efficiencies at severe misalignment angles and excellent torsional stiffness characteristics.

(c) *Equipment Section* which houses hydraulic excitation modules to energize the track module system's servo-hydraulic actuators and ancillary systems such as fire protection equipment and electrical switchgear and supports drive trains and reacts against track module lateral forces.

This past year the Boeing Company was directed by DOT to make appropriate design changes to satisfy new track module requirements. Included in these changes were modifications resulting from the aforementioned track-module design improvements as well as the addition of a self-contained fire extinguishing system. Approval of the final design is expected early in 1975. Some hardware fabrication is currently underway. Figure 24 displays the start of fabrication of the steel-shell equipment section which is to be completed in mid–1975.

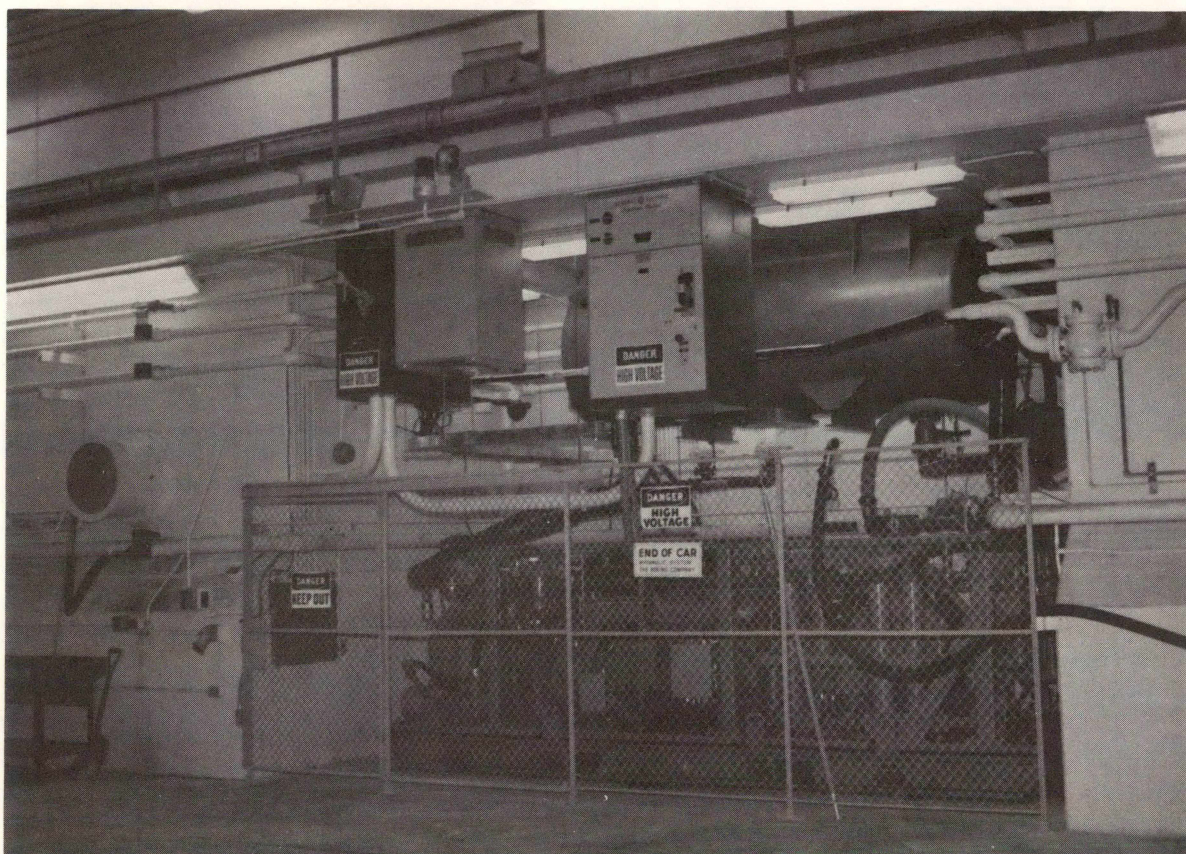


Figure 18. RDL Facility Hydraulic Power Module.

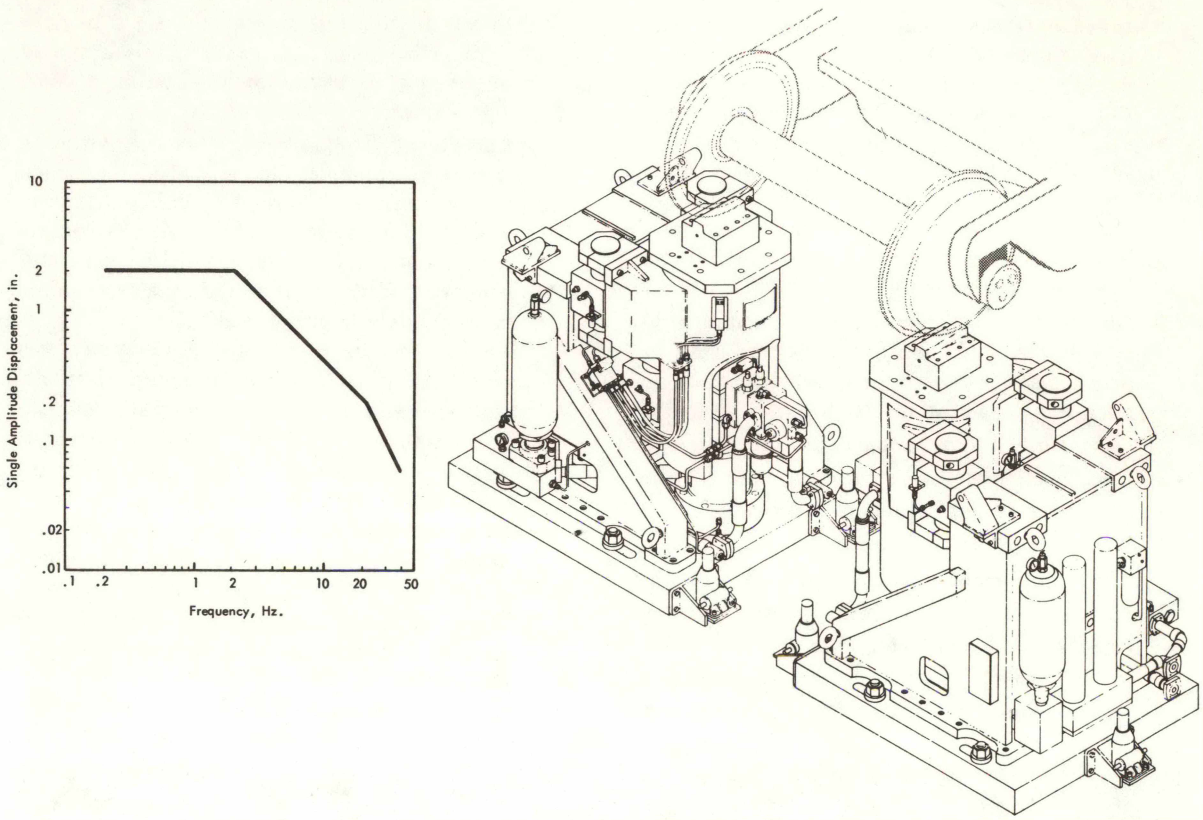


Figure 19. Typical Configuration of Vertical Shaker Excitation Modules and Projected Displacement Capabilities vs Frequency.

TABLE 1.—RDS Design Capabilities.

• **RAILCAR PARAMETERS:**	
— Overall Length	180 ft (54.9m)
— Width	20 ft (6.1m)
— Height	26 ft (7.9m)
— Weight	320,000 lb (145,150 kg)
— Number of Axles	4
— Truck Center Distance	19 ft–2 in (5.84m)—157 ft–2 in (47.9 m)
— Gage	4 ft–8½ in (1.44m)—5 ft–6 in (1.68m)
— Truck Wheel Base	54 in (1.4m)—108 in (2.7m)
— Axle Load	80,000 lb 36,287 kg) max (60-in (1.5m) rollers); 50,000 lb (22,680 kg) max (42-in (1.1m) rollers)
— Speed	144 mph (232 km/h) (60 in 1.5m) dia. rollers); 288 mph (464 km/h) (42 in (1.1m) dia. rollers)
— Overhang	14 ft–0 in (4.3m) max
— Height from Top of Rail Centerline of Coupler	17½ in (.4m)—34½ in (.9m)
• **TRACK PARAMETERS:**	
— Super Elevation	2.88 deg (.05 radians) dynamic
— Steady State Curve	100 ft (30.5m) min radius
• **COUPLER:**	Static Link (Dynamic Capability Deferred)

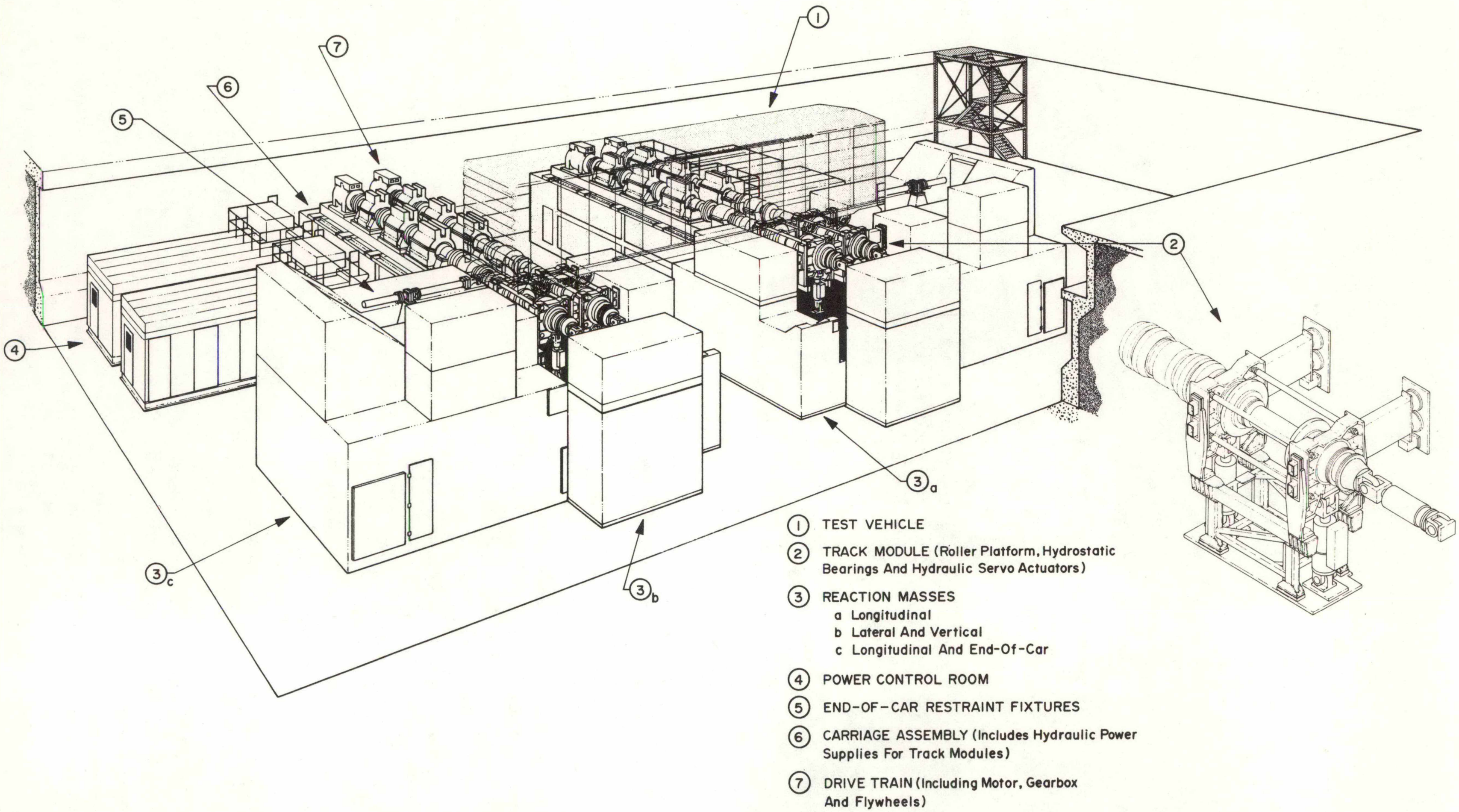


Figure 20. General Arrangement of the Rail Dynamics Simulator and Test Vehicle.

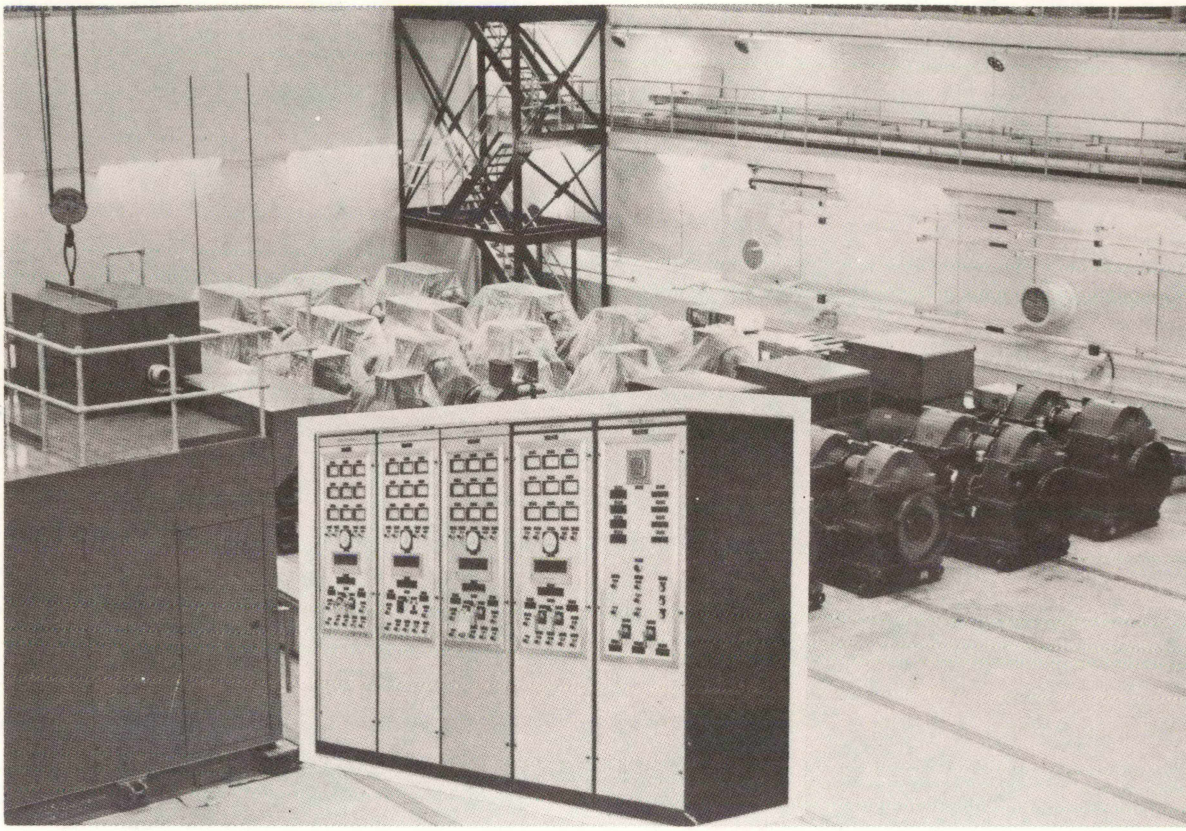


Figure 21. RDS Drive Train and Associated Control Consoles.

At the end of 1973, after the weight had increased substantially, DOT directed the contractor to perform loading tests on the air bearings. Airfloat Corporation, the air bearings subcontractor successfully tested 80 inch (2m) diameter and 35 inch by 43 inch (.9m by 1.1m) air bearings (Figure 25) at 105,000 pounds (47,627 kg) and 22,125 pounds (10,036 kg), respectively.

(d) *The Integrated Computer Subsystem Network (ICSN)* is designed to excite, control, monitor and acquire data from other parts of the RDS. In March 1974, a contract was awarded to Datacom, Inc., to design and build an ICSN consisting of five minicomputers and associated peripheral devices. The ICSN design is essentially complete and fabrication is underway on these computer systems:

(1) Profile generator computer system (Figure 26) presents the vertical and lateral track irregularity profiles to the analog control system (see section below on analog Data Acquisition and Control Subsystem), and presents a speed profile to the drive train, and

(2) Data acquisition computer system (Figure 27) acquires, digitizes and stores response data from the vehicle under test and the test machine, as well as the control system, for a specified test duration.

A sixth computer is at Wyle Laboratories (RDS System Engineer) to be used for preliminary RDS software development. The contractor has completed acceptance tests of the Initial Software Development System. ICSN hardware delivery to RDL, including installation and checkout, is scheduled for early 1975.

(e) *The Communication Subsystem* contract, which was awarded to Reaction Instruments, Inc., in January 1974 provides short-range voice communications among RDL operations personnel. This subsystem consists of a fixed communication station in the RDL control room combined with portable communication units installed within hard hats worn by personnel in the test area (Figure 28). These communication units are voice-

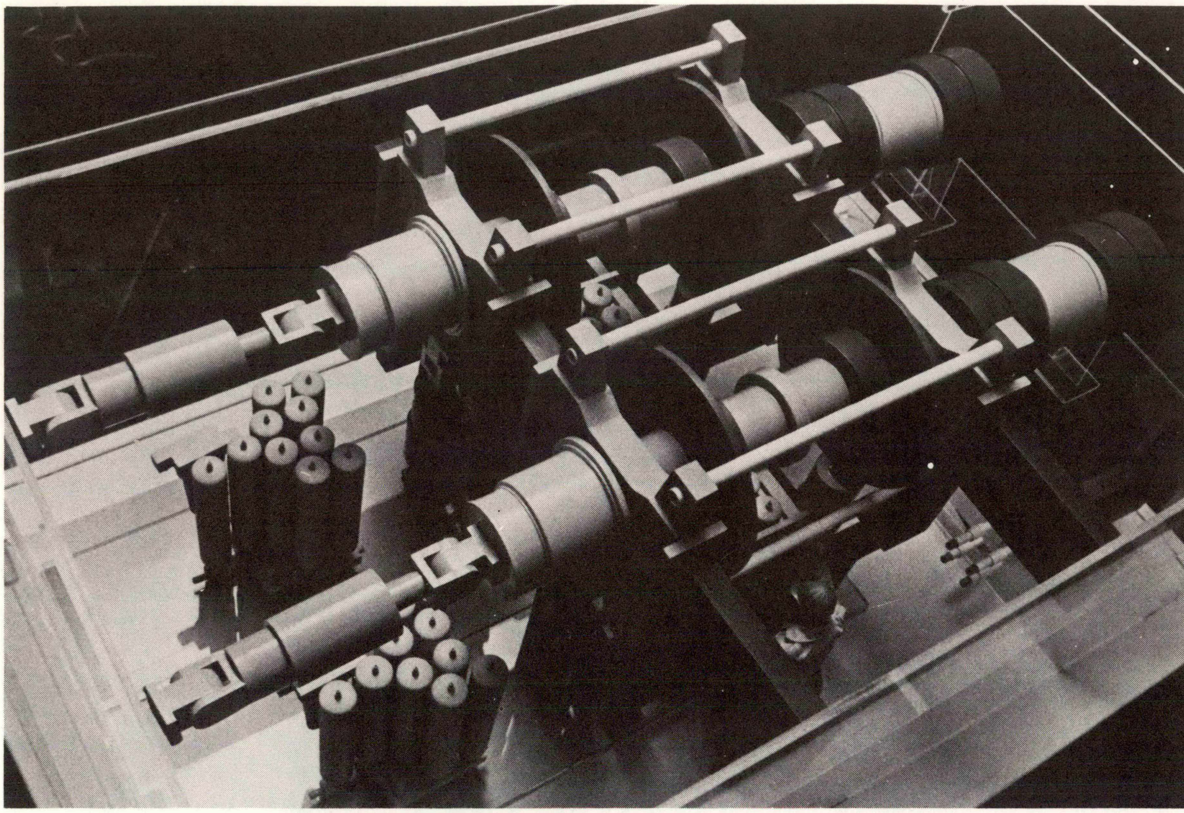


Figure 22. Model of RDS Track Module—Two-Axle Configuration.

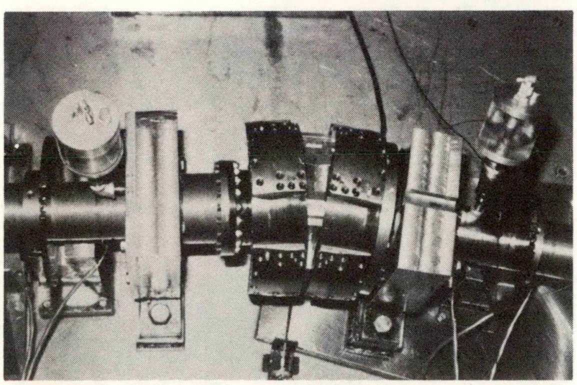


Figure 23. Quarter Scale Constant Velocity Coupling Model Test Set-up.

activated, require no hand operation and are very efficient in a noisy environment. Each hard hat is equipped with ear protectors which house the battery, communication electronics, and earphones. A top-of-the-skull bone-conduction microphone inside the helmet is used to avoid safety hazards associated with an external unit suspended in front of the face.

The overall communication subsystem design is essentially complete and in-plant testing has begun. Delivery, installation and checkout of incremental portions of the communication system for use with the vertical shaker operation are expected in early 1975.

(f) *The Analog Data Acquisition and Control Subsystem (ADACS)* is utilized to obtain vehicle test data and to provide analog control of the RDS as well as the vertical shaker. In January 1974, a contract was awarded to Edmac Associates, Inc., to design and build the ADACS. This system provides analog data from the following RDS and test vehicle sensors: rate gyros, tachometers, temperature sensors, accelerometers, linear displacement sensors, and sound pressure sensors. In addition, ADACS provides analog control to drive the track module and future dynamic end-of-car module servo-actuators. Overall subsystem design is essentially complete and in-plant testing is in progress at the contractor's facility. This subsystem is expected to be operational in early 1975 and will support test programs scheduled in 1975 for the vertical shaker.

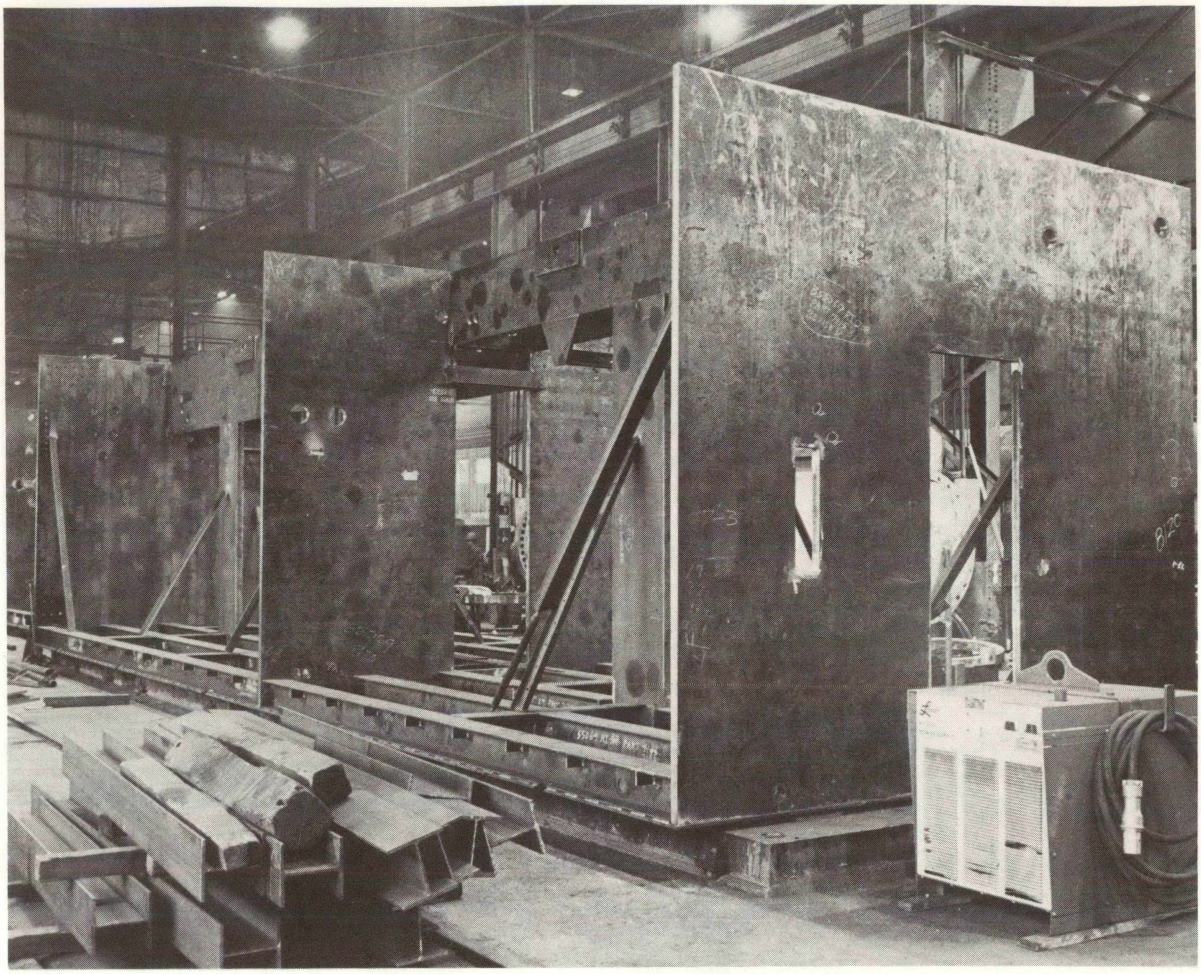


Figure 24. Initial Fabrication of Steel Shell—Equipment Section.

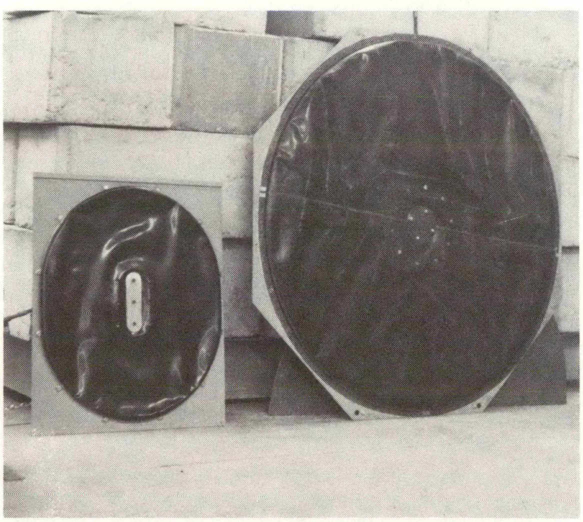


Figure 25. 35-inch x 43-inch and 80-inch Diameter Air Bearings with Test Load.

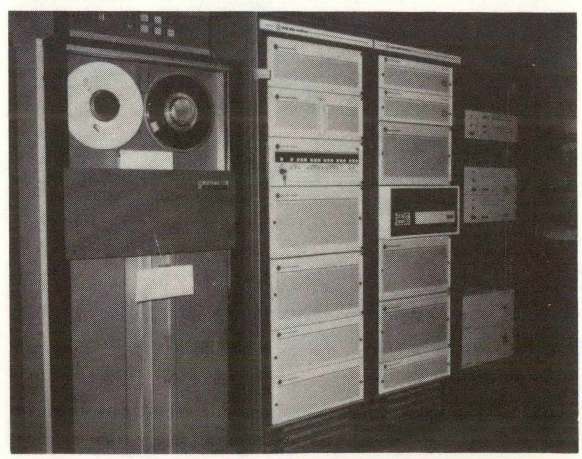


Figure 26. Profile Generator System Computer with Analog Conversion Equipment on the Right and Magnetic Tape Unit on the Left.

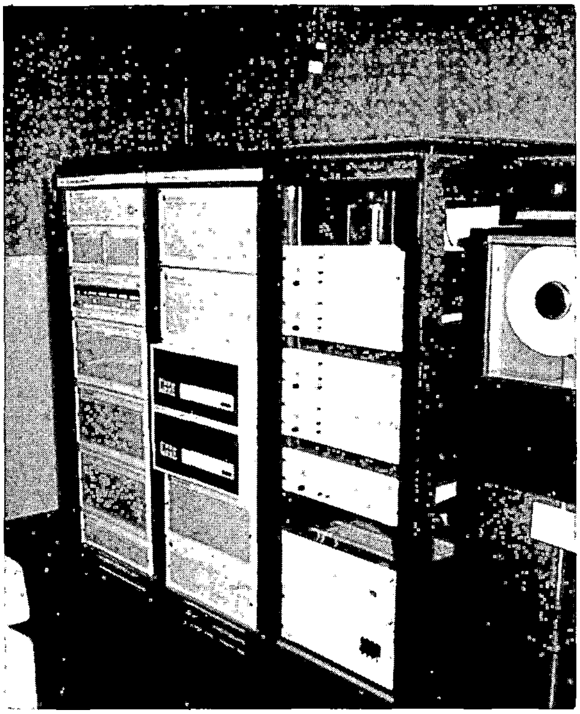


Figure 27. Data Acquisition System Computer with Analog Conversion Equipment and Magnetic Tape Unit on the Right.

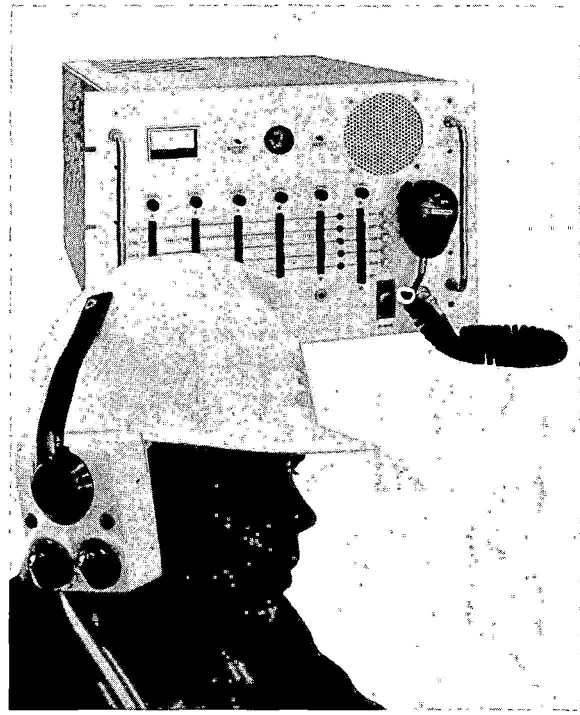


Figure 28. Fixed Station and Hard Hat of RDL Prototype Communication System.

Track-Train Dynamics (TTD) Research Program

In a joint Government-industry program, the FRA in cooperation with the Association of American Railroads, the Railway Progress Institute, and the Transportation Development Agency of the Canadian Government has undertaken a ten-year comprehensive track-train dynamics (TTD) research program to develop better understanding of the kinematics of railroad performance. This research effort is divided into three phases, the first of which has entailed the collection and analysis of data that are necessary to define quantitatively the characteristics of the present railroad system in North America. In the second phase of the track-train dynamics (TTD) research program, these data are to be applied to the development of improved equipment.

Under project management by the AAR staff, the joint program effort has thus far produced:

(a) A three-volume comprehensive bibliography of subjects on Track-Train Dynamics which was incorporated in the RRIS System (see Section 3.8 below);

(b) A two-volume manual containing recommended interim guidelines for improved freight train handling;

(c) The first volume of a Harmonic Roll Series includes Problem Definition, Historical Background, Current Industry Practices, Recommended Guidelines, and Bibliography.

(d) The second volume of a Harmonic Roll Series includes 70-Ton Truck Component Data, Physical Restraints, Mechanical Properties and Damping Characteristics; and

(e) An Accident Investigation Manual containing procedures to be followed in investigation of derailment incidents in order to establish a cause or combination of causes.

In late 1973 and early 1974, FRA participation in TTD furnished: (a) direct funding for research projects involving vertical train stability, box car rocking, longitudinal track-train dynamics modeling, processing of dynamic models, factors contributing to wide gage and rail rollover, model validation and the measurement of vertical and lateral wheel displacement data, (b) instrumentation and data collection/processing provided from experienced FRA contractors, and (c) human factors analysis of enginemen's sensitivity to operational situations.

A major test conducted under the Track-Train Dynamics Research Program was the Steel Coil Unit Train Test (Figure 29a). Ensco, Inc., under contract with FRA, provided the instrumentation

Figure 29a. Partial View of 52-Car Steel-Coil Unit Train, Showing the Cabling Connecting the Instrumentation Located throughout the Train to the FRA Digital Data Acquisition System.

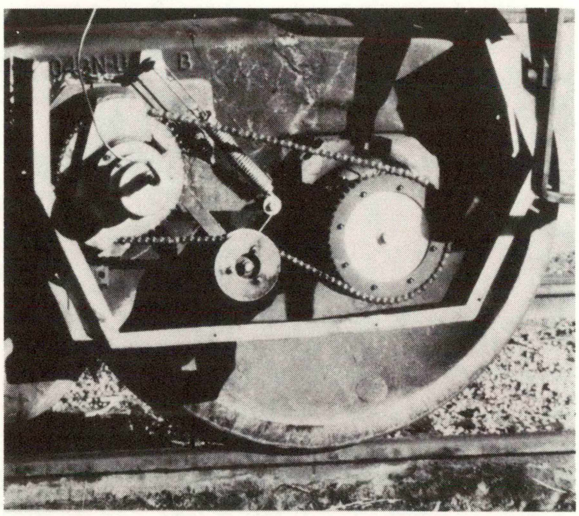


Figure 29b. Example of Specially-Designed Instrumentation and Transducers Used on the Steel Coil Unit Train to Measure Dynamic Characteristics during a 1,100-Mile Test.

(Figure 29b), data-acquisition, and test-coordination support for this project. The purpose of the test was to collect train-consist displacements and brake cylinder pressures under revenue operating conditions. More than forty channels of data collected from instrumentation locations distributed throughout the train consist were recorded by both digital and analog recorders over 1100 miles (1770 km) of track. The test data were used by AAR to validate several computer simulation models. Validated models are used to study track/train interactions and to develop safety guidelines for train make-up and for train handling.

As a part of the joint industry-Government track-train dynamics program, two train handling aids were developed and are undergoing evaluation on operating trains. One, the "Slack Draft Indicator", (SDI) shows the engineer whether selected couplings in his train are in draft (under tension) or in buff (compression). The sensing and transmitting devices are attached at the selected couplings in a matter of minutes (Figure 30) and a portable display is easily installed in the locomotive cab. By giving the engineer additional information on the occurrance and propagation of dynamic events within his train, the SDI is expected to contribute to improved safety and a reduction in lading damage through proper train handling.

The second aid, the "Train Mass Distribution Graph", is a chart displaying the weight of each car in a train in bar-graph form, thus permitting the engineer to anticipate train handling problems associated with the load distribution. Data were collected on board operating trains (Figure 31) on five railroads, and TSC is correlating train dynamics data with locomotive control settings and instrument readings.

Figure 30. Attachment of Slack Draft Indicator Sensing/Transmitting Devices.

Figure 31. Data Recording System on an Operating Train.

Two other tests under the TTD Program were initiated in 1974, the Lateral/Vertical (L/V) Ratio Test and the Lateral Stability Test. Freight trucks were instrumented in both tests at the High Speed Ground Test Center in order to measure their dynamic motion and the wheel-rail interaction forces. Speed, draft and buff forces were controlled to induce potential derailment (high wheel-rail lateral forces) conditions. Data collected will be used to validate vehicle dynamic models which will increase understanding of the phenomena of truck hunting and many derailment conditions and eventually lead to their prevention.

Noise

FRA's ORD&D was requested to comment on the Environmental Protection Agency's (EPA's) Proposed Railroad Noise Emission Standards. Specifically, the proposed standards would require, effective within 270 days of final adoption, that:

— A stationary locomotive's noise be held to 93 dB(A) at any throttle setting and 73 dB(A) at idle when measured from a distance of 100 feet (30.5 m). Effective within four years, those locomotive ceilings would drop to 87 dB(A) and 67 dB(A), respectively.

— Locomotive noise be held to a maximum of 96 dB(A) when moving "under any condition of grade, load, acceleration or deceleration", and 90 dB(A) after four years.

— All rail cars meet a noise ceiling of 88 dB(A) at speeds up to 45 mph (72 km/h) and 93 dB(A) at higher speeds.

FRA has made an assessment of the technical feasibility of the proposed standards, costs of implementation, and scheduled effective dates and has concluded that the feasibility appears questionable with respect to the scheduled dates.

3.8 Railroad Research Information Service

The Railroad Research Information Service (RRIS), under FRA sponsorship, has completed its second year of operation at the Transportation Research Board (TRB) of the National Research Council. RRIS now has on file over 7,000 references to railroad-related technical literature, representing a gain of 3,400 items in the past year. The Railroad Research Bulletin, issued first for Autumn 1973 and again for Spring 1974 and Autumn 1974, will continue to be published at six-month intervals. Each issue contains the new references acquired since the previous issue, e.g., the Autumn 1974 Bulletin contains over 1,800 new items.

The RRIS was established to make the results of world-wide railroad research available to railroad companies and associations, equipment manufacturers, research organizations, colleges and universities, state and local transportation agencies, Federal agencies, and international transportation organizations and agencies. The reports of railroad-related research by these same organizations are furnished in return to the TRB for inclusion in RRIS file and future Bulletins.

The RRIS has completed a working arrangement with the International Union of Railways (UIC) for the exchange of railroad research references. This agreement calls for cooperation between the two bodies in a regular exchange of information. The Documentation Bureau of UIC will send RRIS:

- Abstracts from the Documentary "Pool" (USSR literature included) mostly in English (in a few exceptional cases, only French versions will be available) indexed according to the UIC Subject Term List.
- English summaries of reports from the Office for Research and Experiments of the UIC (ORE Reports).
- The semi-annual bibliography, "Reports and Studies of UIC."
- Detailed analysis of important documents relating to transport economy and politics, railroad management, reconversions and new technology, major projects, etc.
- Special bibliographies and documentary studies that are prepared by the Documentation Bureau with the help of the documentary pool.
- A quarterly list of acquisitions of the Documentation Bureau library.
- Abstracts of on-going research and projected studies of ORE and other UIC bodies.

In return RRIS will give UIC information on all documents in its files relevant to European operations as well as furnish the Railroad Research Bulletin twice yearly.

RRIS also offers to the technical community the capability of making specific subject-matter information retrievals on a batch mode basis known as a File Search. This service is available to all interested parties at rates appropriate to its cost.

The RRIS is a part of the larger Transportation Research Information System which includes the Highway Research Information Service, Maritime Research Information Service, Highway Safety Information Service, and Transportation Research Activity Information Service. Information in these other services having application to railroading can be accessed through RRIS. The RRIS file now includes all research reports submitted to the National Technical Information Service (NTIS) by the FRA. All of the research reports (previously referenced in Appendix B of the FRA Annual Reports on the High Speed Ground Transportation Act of 1965) on advanced systems of ground transportation, as well as those specifically concerned with railroading, will henceforth be found in the RRIS files and, when new, will be published in the Bulletin.

Potential users of RRIS may obtain additional information concerning Bulletin subscriptions and other services directly from: Manager, Railroad Research Information Service; Transportation Research Board; National Research Council; 2101 Constitution Avenue, N.W.; Washington, D.C. 20418.

4.0 ADVANCED TECHNOLOGY

During the past year, the advanced systems program was redirected to emphasize technology development as part of a long-range research effort in support of the evolution of ground transportation improvements. The work reported here is identified by its relationship to engineering disciplines rather than as part of any preconceived fully-developed transportation system. Through accumulation of data from a wide range of research projects, a technology base is being established that should find application in both improvements of the existing rail system and development of prospective new systems over speed ranges appropriate to market requirements in freight and passenger services.

Full-scale research vehicles have permitted component testing in a realistic environment at the Department's High Speed Ground Transportation Center at Pueblo, Colorado. In addition, studies and experimentation have continued at other facilities of Government, universities, and private industry.

FRA's R&D budget for FY 76 contains no funds for continuing Tracked Levitated Vehicle work, and initiatives have already been taken to phase out projects where FY 75 funds can be recaptured for expenditure in designated rail research programs having higher priority.

4.1 Air Levitation and Guidance

Previous annual reports have described the design and construction of the Tracked Levitated Research Vehicle (TLRV) which was intended to provide information on many aspects of advanced technology as well as air cushion levitation and guidance.

During aeropropelled tests conducted by Grumman Aerospace Corporation, the TLRV's air cushions were tested at various hover heights under static conditions and at forward speeds up to 91 mph (146 km/h). Throughout the range of operating conditions tested, the air cushions performed satisfactorily; however, Grumman experienced chronic difficulties in attempting to calibrate the sensors used to measure the operating gap (i.e., hover height) of the air cushions. The sensors, which employ a photo-optical technique for measuring the cushion gap height, gave inconsistent readings during calibration tests and could not be used. Without accurate gap-height data, it was not possible to determine accurately air-cushion operating characteristics.

The aeropropelled phase of TLRV test operations at HSGTC ended in December 1973 when installation of the electric propulsion system in the vehicle was begun.

Basic studies in air cushion levitation technology have continued at Massachusetts Institute of Technology (MIT) and the Transportation Systems Center (TSC) to aid FRA in the analysis and design optimization of fluid, non-contacting and frictionless suspensions which can be either air cushion or magnetic forces.

In the past year, MIT has concentrated on developing analytical models of suspension performance and verifying them through scale-model experiments for three basic classes of plenum-type air-cushion suspensions, including: (1) simple plenum with a mechanical secondary suspension, (2) flexible bag, and (3) hinged plate (Figure 32). The influence of air-supply duct-compressor interactions on suspension performance has been studied in detail and recommendations have been made to eliminate potential cushion-to-air supply system interaction problems. The air-cushion performance models provide a reference for the comparative evaluation of the generic types of fluid suspensions on the basis of passenger comfort, power consumption and vehicle-to-guideway contact.

MIT studies have also shown that significant improvement in suspension performance can be obtained with the use of actively-controlled suspensions. Some of the affected performance parameters are ride quality, suspension oscillation, vehicle-suspension coupled resonance, and vehicle-to-guideway contact. MIT built and tested an experimental scale-model suspension, which employs low-pressure pneumatic actuators, as a demonstration of the potential for improved performance, using actively-controlled air-cushion suspensions.

TSC has continued studies on a concept known as ram air, which differs from a conventional air cushion in using the vehicle's forward motion to supply air for levitation and guidance. A system definition study, conducted jointly by TSC and MITRE during 1973, showed that a ducted-fan propulsion system at the front end of the vehicle would be very attractive for the ram air cushion because the fan wake can be directed underneath the vehicle for levitation and would attenuate the noise level of the combined propulsion-suspension system. Lift, guidance, and propulsion would all be produced from the single ducted fan. The fan could be powered by either a low-pollution gas-turbine engine or a lightweight rotary electric motor. This approach is not only technically simple but also shows potential for significant reductions in guideway costs because large vertical clearances of approximately 12 inches (.3m) are possible and there is no need for a linear induction motor's reaction rail when utilizing fluid propulsion. Furthermore, a subsequent study by TSC has shown that the ram air-cushion concept has the potential for lower energy consumption than other air cushion and repulsion Magnetic Levitation Vehicle concepts.

In order to test a combined levitation and propulsion concept developed in the ram air cushion definition study, Princeton University, under contract to TSC, has constructed a small self-propelled ram-air cushion-vehicle model to conduct flight demonstrations. The model, which uses a battery to supply power to a ducted fan, is shown in its 300-foot (91m) test track at Princeton. It levitates without any forward velocity and then accelerates to cruise speed. Throughout the demonstrated range of speeds, the model is stable in all degrees of freedom and shows no evidence of contact with the channel guideway configuration.

Aerodynamic tests were also conducted in a wind tunnel at Princeton on a simplified ram air cushion configuration which has longitudinal flaps or winglets running lengthwise on each side (Figure 33). These winglets restrict the air flow from the fan escaping between the side of the model and the channel guideway, thereby containing the high pressure necessary [approximately 50 psf (244 kg/m^2) for a full scale vehicle] for lift underneath the vehicle with minimum power expenditure. In accordance with the ram air cushion concept, these appendages would be mounted on hinges in such a way that the outer tips can follow any local irregularities of the guideway while the vehicle proceeds in an essentially straight path. The concept is very similar to that of the motion of a flexible lip (outer edge) on a conventional air cushion as it traverses a guideway. The wind tunnel tests provided information on the dynamic motions of the winglets as a function of forward speed.

In another set of tests, the same wind tunnel model was mounted on a special carriage which can move the model at 30 ft/sec (9.1 m/s) through the above-mentioned 300-foot (91m) guideway. The purpose of this second series was to obtain a direct comparison of results from the wind tunnel with those from moving-model experiments. In this manner, testing techniques can be determined for studying the aerodynamics and dynamic motions of tracked high-speed ground vehicles.

4.2 Magnetic Levitation and Guidance

Studies of magnetic levitation (Maglev) were designed to determine whether magnetic fields can be used in lieu of wheels to support and guide high-speed passenger vehicles. Two schemes show particular promise. One, a repulsion concept, uses superconducting magnets in the vehicle which act against an aluminum clad guideway. Since superconductivity is a low-temperature phenomenon, the magnets must be cooled to near absolute zero. The eddy currents generated in the guideway by the motion of the vehicle produce a stable repulsive force which tends to lift and center the vehicle in its channel-shaped guideway. The other concept, attraction, uses ordinary electromagnets in the vehicle attracted toward steel rails installed on the guideway. Because the attractive force which tends

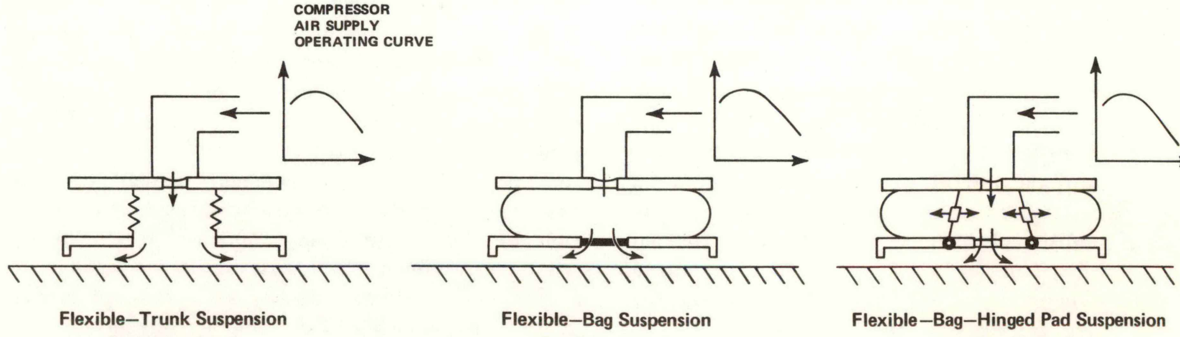


Figure 32. Specific Suspension Configurations Included in General Suspension Models.

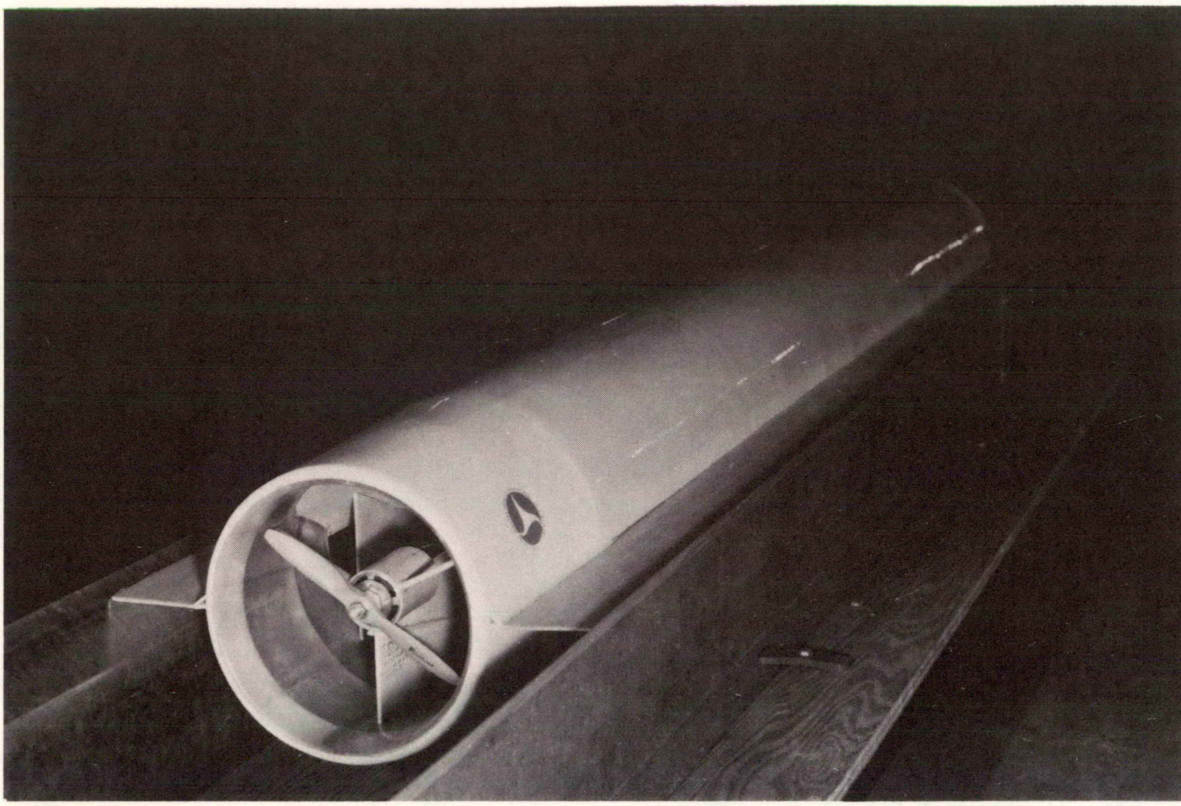


Figure 33. Ram Air Cushion Model in Guideway at Princeton University for Wind Tunnel Tests.

to reduce the gap between the magnets and rails is unstable, the current to the magnets must be servo-controlled to oppose variations in the gap. Both Maglev techniques free the vehicle of mechanical contact with its guideway, thus eliminating associated noise and wear. Whereas the repulsion suspension floats 6 to 10 inches (150 to 250 mm) above the conducting surface of its guideway, the attraction vehicle hangs about 1″ (25 mm) below.

The technical characteristics of repulsion Maglev were summarized in the 7th Report. During the present reporting period, FRA sought to obtain similar knowledge on attraction Maglev, the feasibility of which has been established at low speeds—less than 100 mph (160 km!h)—with vehicles built by the Rohr Corporation (California) and MBB and Krauss-Maffei (Munich, West Germany). Important questions about the behavior of such systems at speeds of interest to FRA—200 to 300 mph (320 to 480 km/h)—remain unanswered. Consequently, it has become necessary to develop an analytical model which can be validated with small-scale tests and which can predict full-scale performance. Ford Motor Company has developed a model of the magnet/rail system which, while still approximate, represents an advance over previously published work in three respects: (a) peaking of the magnetization near the magnet poles gives the fields and forces more correctly, (b) magnetic saturation of the steel rail is accounted for and (c) the results are related to the actual current fed into the electromagnets. The predictions of this model for the drag as a function of speed are shown in Figure 34.

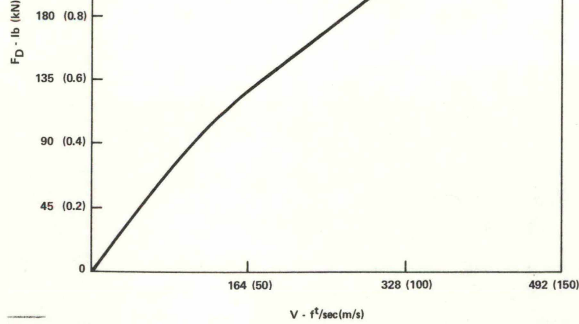


Figure 34. Drag Force (FD) Speed (v) for 10 kN of Lift.

In late 1973 Stanford Research Institute completed a series of repulsion Maglev sled tests in California for FRA. The sled and track were described in the 6th and 7th Reports.

The severe heave and pitch of the sled caused by passage over the superficial welds between the 20-foot (6.1m) long aluminum guideway plates were virtually eliminated by rewelding. To provide needed damping of sled oscillations servo-controlled coils were fastened to the underside of each magnet enclosure.

The sled was fully instrumented to record its dynamic behavior as it traversed the 400-foot (122m) guideway. Various guideway offsets such as vertical and lateral steps were introduced into the guideway to stimulate strongly the heave, roll and yaw motions of the sled and to trigger vehicle instabilities, if any. These offsets, that amounted to 25% of the normal clearance, induced oscillatory motions that were analyzed to evaluate both passive and active damping. In more than thirty tests of the vehicle no instabilities were observed in any degree of freedom (even with zero control current) despite the severe perturbations. However, active control resulted in greatly attenuated vehicle disturbances as compared to passive damping (Figure 35). The dynamics tests were simulated on a computer and provided good approximations to the experimental data. The dynamics of repulsion Maglev vehicles are now understood well enough that their motion can be accurately predicted for a variety of disturbances at low speeds.

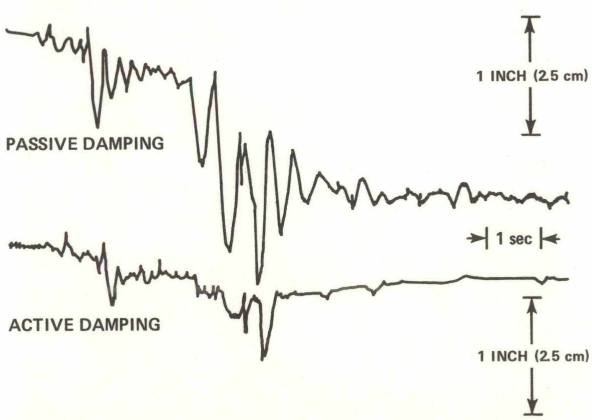


Figure 35. Comparison of Heave Motions—Active vs Passive Damping Test.

4.3 Propulsion

The FRA propulsion R&D program is aimed at developing the hardware required for safe, convenient, rapid and economical transportation of goods and people. Efforts are concentrated on linear motors, power conditioning, and power collection/distribution for high-speed vehicles. Some of the propulsion hardware developed under FRA sponsorship has evolved to the point where it is already possible to design and fabricate prototypes—notably, powerful motor controls (power conditioning units). Moreover, excellent test beds are now available at the Pueblo Test Center for the evaluation of propulsion hardware applicable to ground transportation. This new technology of linear motors and power conditioning units is applicable to railroads as well as tracked levitated vehicles over a broad range of operational requirements.

Hardware for propulsion R&D is undergoing tests on the Linear Induction Motor Research Vehicle (LIMRV) and Tracked Levitated Research Vehicle (TLRV). In addition, the PTACV is expected to yield data of interest to propulsion R&D. Laboratory and analytical research at TSC, PINY (Polytechnic Institute of New York, formerly Polytechnic Institute of Brooklyn) and JPL (Jet Propulsion Laboratories) is continuing.

Principal accomplishments during the past year include:

(a) More accurate evaluation of LIMRV propulsion due to the upgrading of the instrumentation system.

(b) Mounting of propulsion hardware into the TLRV.

(c) Updating of performance analyses for the LIM and PCU (power conditioning unit) of the TLRV.

(d) Completion of a research phase on single-sided linear electric motors (SLEM).

(e) Development of computerized mathematical models of prominent LIM theories.

Linear Induction Motor for the LIMRV

After reaching a speed of 255.4 mph (411 km/h) the LIMRV instrumentation was expanded and improved to gather data on additional electrical characteristics of the LIM. Obtaining these characteristics will be of prime significance to the world-wide investigation of linear induction motors for modern transportaton systems. The electronic data-acquisition system has been expanded to include additional real-time displays in the ground telemetry station, on-board analog instrumentation, and a new simple and ingenious measurement system which will obtain slip (a fundamental motor parameter) with a high degree of accuracy. With the new instrumentation checked-out and the vehicle speed upgrading tests completed (See Section 4.11), a comprehensive electrical test program was started in September 1974 to cover the full speed range of the vehicle.

TLRV Propulsion System

The TLRV LIM and power conditioning unit were completed and factory-tested last year. The results of the testing have been analyzed and, on the basis thereof, it has been predicted that the propulsion system will accomplish the transition from a "start" to a "run" mode in approximately 1000 ft. (305 m).

Following the completion of the factory tests, the module was shipped to the Test Center, where all components were assembled into the vehicle (Figure 36). Support equipment was procured and checked out. The electrical power system in the TLRV shelter was sufficiently completed in August for checkout purposes (after a 2½ month delay due to industrywide electrical equipment shortages). Using surplus LIMRV reaction rail and the power rails from the China Lake tests, described in the Sixth and Seventh Reports, 1500 feet (457 m) of the three-mile (4.8 km) guideway was electrified and checked out (Figure 37).

Single-Sided Linear Electric Motors (SLEM)

A research phase on single-sided linear electric motors (SLEM) has been successfully completed. Because of the positive results of analytical and laboratory work at Polytechnic Institute of New York (PINY) and TSC, as well as in Europe and Japan, FRA is now planning a development program for SLEMs. This program contemplates laboratory wheel testing, as well as tests utilizing the LIMRV. Like all linear electric motors, SLEMs do not make mechanical contact with the vehicle guideway or track, thus allowing higher speeds and safer braking. Other advantages, common to all linear motors, are that they are quiet, inherently reliable due to the absence of moving parts, emit no pollution along the route, and are free of mechanical and vibration problems. The most important potential advantage offered by SLEMs over the present double-sided linear motors is that they eliminate the protruding vertical reaction rail (about two feet, i.e., 610 mm, tall) and use instead a horizontal reaction rail structure that is flush or nearly flush with the track. Elimination of the vertical rail represents a major simplification of construction and maintenance, as well as vehicle switching from one track to another. Moreover, the SLEM can extend attainable speeds on new or existing railroads, not only by eliminating the limitations of wheel-rail adhesion, but also by in-

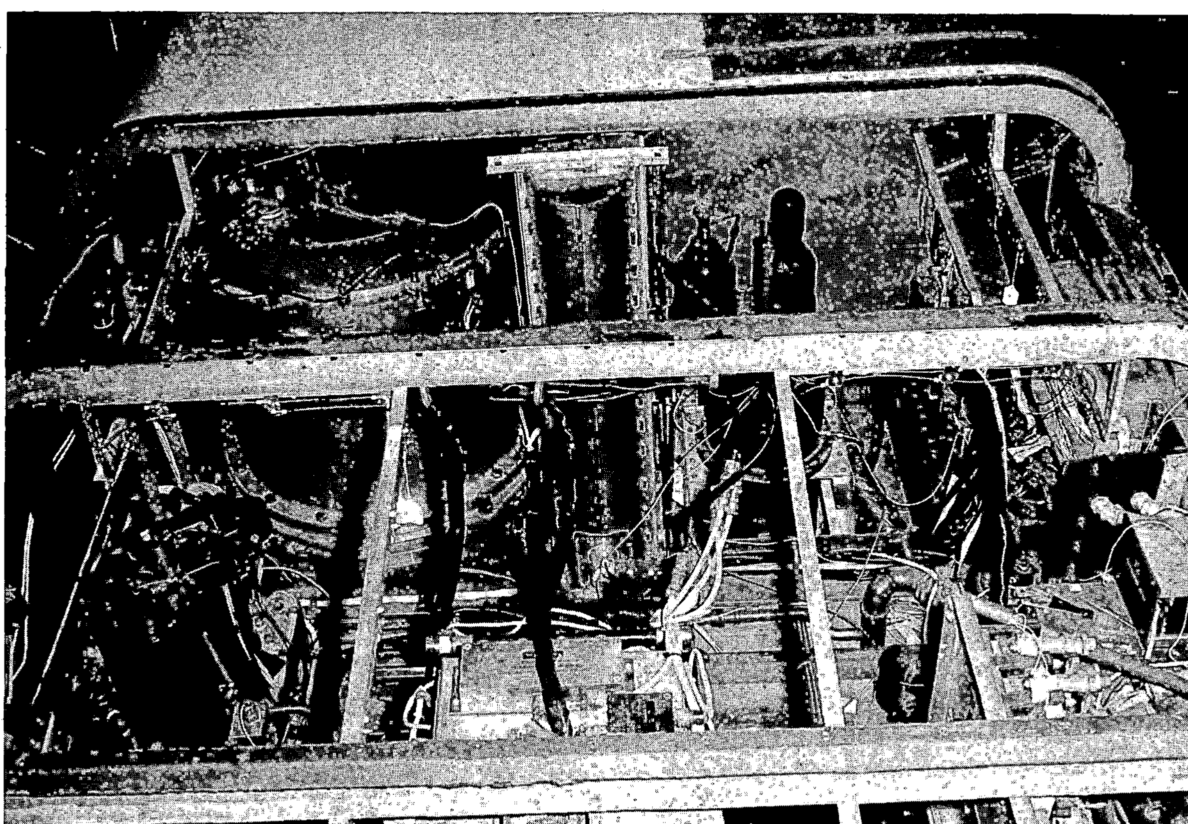


Figure 36. Assembly of Propulsion Components in the TLRV.

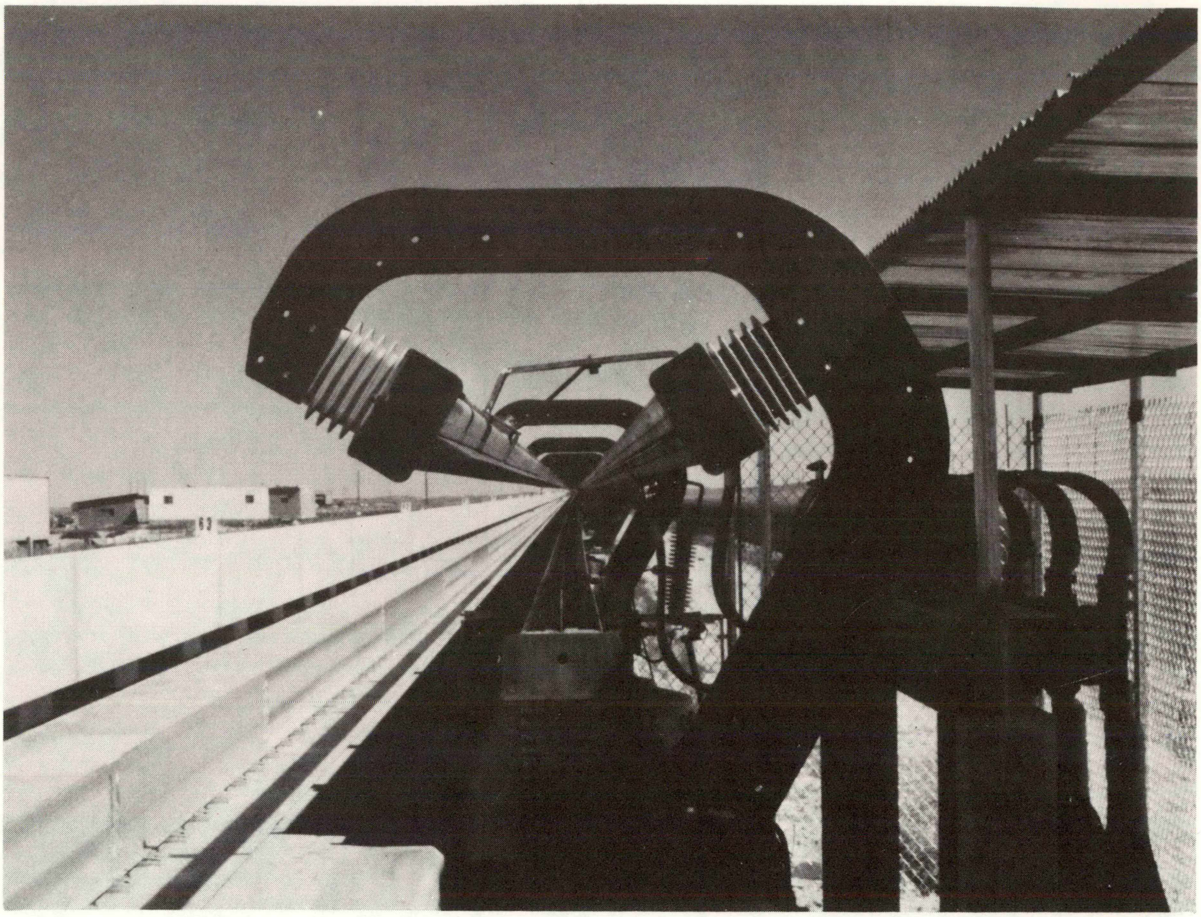


Figure 37. Three-Rail High-Speed Wayside Power System (Center) and Reaction Rail (Lower Left) Being Installed in the Guideway for the TLRV.

hibiting truck hunting because of attraction forces between the vehicle and the track.

An important analytical result of the PINY work is a preliminary evaluation of the potential advantages of SLEMs of the synchronous type over those of the induction type. The major advantages are:

- Larger clearances with the track.
- Unity power factor, implying major overall improvements (cost, weight, dimensions) for the entire electrical system, including fixed wayside installations.
- Higher efficiency, implying significant energy savings.
- Useful guidance and attraction forces that can be exploited to avoid derailment.

LIM Mathematical Models

The past year has seen two major accomplishments of FRA-sponsored work in LIM mathematical models:

- The completion of a mathematical model by JPL (Elliott's theory). This computerized model is expected to be the most general and accurate model available.
- The build-up of a computer library of LIM models at TSC. To date, this work has involved translating into computer language three other leading LIM theories (Oberretl of Switzerland, Yamamura of Japan, and Mosebach of Germany).

These efforts make available to contractors, investigators, manufacturers, DOT, and other agencies a practical means of designing LIMs, predicting their performance, and identifying areas of uncertainty. An application of the above models is given in Figure 38, which shows curves of LIMRV thrust as predicted by the four leading theories mentioned above. These curves clearly illustrate one specific use of test hardware. The LIMRV comprehensive electrical test results (which will be available in the spring of 1975) will yield the actual performance curve of the motor, allowing the verification of four theories developed in four different countries in the last three years.

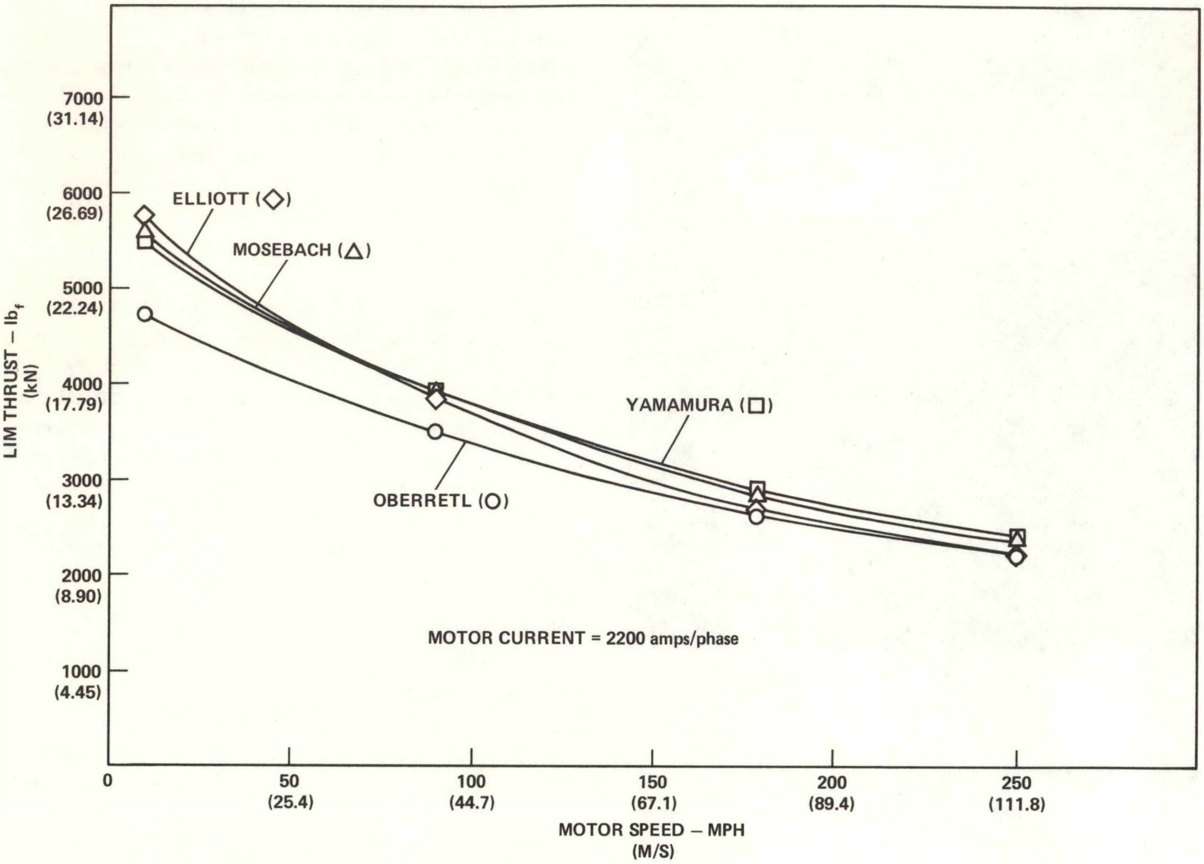


Figure 38. Maximum LIMRV Thrust That Can Be Developed at Various Speeds as Predicted by Four Leading Theories.

Work has started to utilize and extend LIM mathematical models as required for single-sided linear induction motors. Some important preliminary results obtained by JPL show that:

(a) Attraction and repulsion forces of these motors depend heavily on the thickness of the reaction rail's aluminum layer, i.e., lift/propulsion ratios can be varied over a wide range.

(b) A fairly wide range of thrust control for constant lift force can be obtained by simultaneously varying the motor voltage and frequency.

4.4 Power Conditioning, Collection, and Distribution

Evaluation of power conditioning units (PCU) has continued at TSC with effort in the past year concentrated on experiments with scale models of two types: the natural commutated PCU and the forced commutated PCU. Tests to date have only been run on static loads; dynamic tests will be run using a dynamometer when delivered in 1975. The dynamometer is programmable and able to simulate acceleration, cruising, and braking conditions of traction motors. It will allow testing of PCU performance for a wide range of motors, from conventional rotary to high-speed linear.

TSC completed screening tests on 10 different brush materials for power collection; three proved unsatisfactory and seven candidates remain for the dynamic tests in 1975. Wear rates were less than anticipated; this result is ascribed to the "clean" laboratory environment, i.e., the absence of rain, sand, and oxidation. Assembly of the special apparatus for dynamic testing of the TLRV collector was completed (Figure 39).

A cost study of various electrical distribution systems was begun at TSC in September 1974 and some preliminary data were obtained. The studies will proceed to include the range of power factors (a fundamental electrical parameter) that can be expected in electrical transportation systems. As an aid in designing operational systems, the interaction of the PCU with commercial power distribution systems was investigated to clarify the effects of different load configurations on power factor and harmonic distortion.

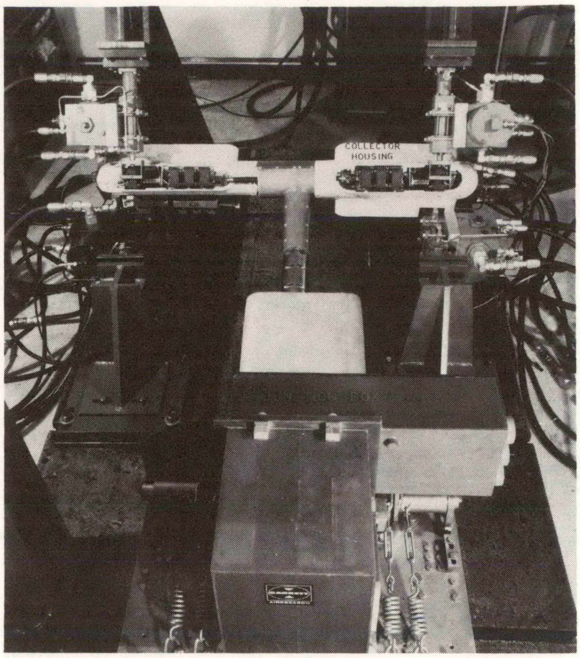


Figure 39. Apparatus for Dynamic Testing of TLRV Power Collector.

4.5 Communications and Control

The communications requirements for high speed ground transportation, identified seven years ago specify a frequency bandwidth of 50 MHz to handle all communications needs. The results of research and studies based on these requirements indicate the leaky waveguides or narrow-beam microwave systems can meet the stated goals. However, considerable R&D would be required and the studies suggest that the systems will be expensive to build and maintain.

During the past year, MITRE Corporation made an effort to restate the communications requirements, using the knowledge gained by previous research and reducing requirements wherever possible. As a result, the following modified set of guidelines was formulated:

(a) The reliability and safety specifications for command and control information must be more stringent than for passenger telephone.

(b) Some passenger amenities, such as television and music, can be met by pre-recorded programs (e.g., tape cassettes).

(c) The route-continuous (all information available along entire route) system requirement can be modified to allow for a segmented system. Such a design would use less bandwidth and would provide greater flexibility in the choice of carrier frequencies.

Based on the study, the original specification for communications can be reduced to a telephone system and a back-up command and control system. The restrictions on radiated power remain the same, the system must not interfere with other communications and must be free from outside interferences. The requirements for bandwidth are significantly reduced—the original specification was for 50 MHz, the new requirement is for less than 2 MHz.

A field test site for wayside vehicle communications systems has been completed at Ft. Devens, Massachusetts. The first test specimen, 600 ft (183 m) of leaky coaxial cable from Sumitomo, Ltd. of Japan, has been installed and is being tested. Figure 40 shows the site at Ft. Devens with the test specimen on the mounting poles. A tension support pole is required at intervals to reduce the catenary effect and the lateral force on the smaller support poles (Figure 41).

Obstacle Detection

An experimental, infrared, obstacle-detection system, installed at the HSGTC on the TLRV guideway, performed satisfactorily for a period of two months, i.e., it was able to detect obstacles while maintaining an acceptable false-alarm rate. After that initial period, two types of failure occurred: (1) several receivers developed a high false-alarm rate due to ambient sunlight and (2) the optical filters on the face of the units became pock-marked. The filters are clear plastic with a light-polarized film. Apparently, the thin film expands with heat and separates from the plastic.

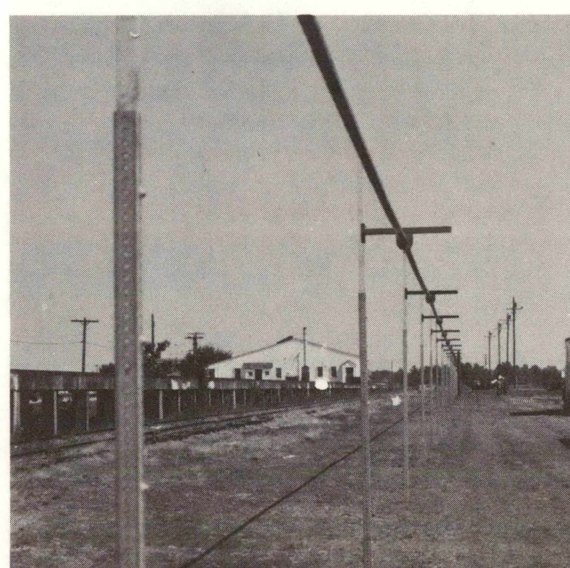


Figure 40. Communication Cable Mounted on Metal Poles and Supported with Wooden Clamps at Ft. Devens, Mass.

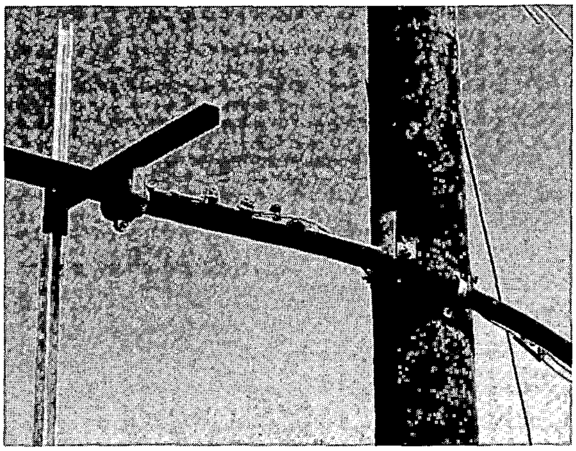


Figure 41. Communication Cable End Support Provides Tension to Minimize Bow in Line.

Both of these problems have been referred to the manufacturer, Applied Metro Technology, for solution.

4.6 Guideways

Research and development in high speed ground transportation guideways for TLV systems has proceeded with both analytical studies and actual field-guideway construction aimed primarily at cost reduction, because fixed-structure costs comprise about 60 percent of a total system investment. Guideway construction, guideway tolerances and cost data have been obtained for air cushion systems—the Tracked Levitated Research Vehicle (TLV) and the Prototype Tracked Air Cushion Vehicle (PTACV). Analytical research studies by MITRE, Duke University, a team of TRW, Inc. and ABAM Engineers and the Massachusetts Institute of Technology (MIT) have provided computer simulations, conceptual designs and cost guidelines. An experimental model guideway study is under way to determine if analytical and experimental results are in agreement. This research has been aimed at obtaining a better understanding of such factors as ride comfort and construction methods, which contribute in varying amounts to guideway costs.

During this reporting period the initial 3.13 miles (5.04 km) of PTACV concrete slab guideway was completed at the HSGTC at a contract cost of $206,000 per mile ($128,000 per km). An additional 2.6 mile (4.18 km) segment is about to be completed at a cost of $352,000 per mile ($219,000 per km).. The large increase in cost is due to inflation.

On the first segment an asphalt layer, one inch thick (2.5 cm), was applied over a concrete slab. The asphalt was eliminated on the second segment. There was little cost savings in these changes, because the savings without asphalt were cancelled by the additional concrete grinding necessary to meet the smoothness requirement.

Two methods of specifying guideway smoothness have been used on concrete guideways at the HSGTC. One is a deviation from a straight line of given length and the other, a measured profile index (PI) expressed as inches per mile of guideway length. The PI is the summation of the measured mid-chord excursions (inches) outside of a given bandwidth per unit length of guideway. A 25-foot (7.6 m) long California Profilometer, a common instrument in the highway industry, is used to measure the surface roughness. The first PTACV segment had a smoothness specification of $\frac{1}{8}$ inch in 10 feet (0.32 cm in 3.05 m) for the concrete and asphalt surfaces. The roughness was measured with the profilometer and the PI was 16 and 3 inches per mile (25 and 4.7 cm per km) for the concrete and asphalt surfaces, respectively. The concrete surface did not fully meet the straight line specification and the low spots were later filled with asphalt. The second segment specification had a PI of 7 inches per mile (11 cm per km), which is the same requirement for normal highway construction. Because the roughness specification for the second TLRV guideway segment was achieved with a PI of 4 inches per mile (6.3 cm per km), it was known, therefore, that the PTACV guideway smoothness and superelevation could be achieved with normal construction methods.

Guideway electrification, which included installation of an aluminum reaction rail and the three wayside power rails, of the initial PTACV segment has been completed. Proposed anchors for the TLRV and PTACV reaction rails were field tested to determine if they met strength requirements or if modifications could be made to obtain cost savings. Variables tested included the type of grout, size (diameter and depth) of holes in the concrete and the size and surface roughness of the anchor bolt. The test results indicated that the proposed TLRV anchor did not meet the strength requirements, but other anchors of different configuration with other grouts were acceptable. The PTACV anchor was adequate for the initial segment; however, a cost savings was possible for the second segment by modifying the anchor shape.

While no new TLRV guideway was constructed in the last year, the existing 3 mile (4.8 km) guideway was surveyed for true elevations and a 1500 ft (457 m) segment was electrified. Brass plugs were inserted in the guideway on 25-foot

(7.6 m) centers for precise location of the reaction and power rails. These brass plugs create a true line on the guideway and were surveyed for elevation for possible use in computer simulations for vehicle/guideway interaction analysis and monitoring of guideway movements. The TLRV electrification consisted of a temporary installation of reaction rail from the LIMRV track and the power rails from the previous power tests at China Lake. Accurate alignment of this hardware was achieved without difficulty.

A change in the gage (width between guidance panels) of the TLRV guideway has indicated that neoprene pads may have experienced creep under load. In the original guideway design, the pads were necessary to reduce temperature loads on the support posts.

Conceptual guideway designs and costs by TRW Inc., and ABAM Engineers, Inc., were reported in the Seventh Report. Their reports are now available from NTIS. TRW/ABAM have completed final designs for a lower cost TLRV at-grade guideway. The cost, estimated at $870,000 per mile ($540,000 per km) in mid-1973 dollars, is a 25 per cent reduction from the previous construction cost.

A report was completed by MIT, under contract to the Transportation Systems Center, which summarizes MIT's analytical techniques and findings for elevated guideways for 150 and 300 mph (241 and 483 km/h) TLV systems. The analysis methods incorporate both static and dynamic loads, various pier spacings and design constraints, multispan and/or cambered spans and ride-comfort constraints. The report presented the effects of these variables on the design and material requirements (costs). Pier stiffness was found to have little effect on guideway design.

Duke University has completed its analytical investigations of the interactions between the guideway slab and guidance wall and is now under contract to build and test a scale-model elevated guideway. Results from this new research will be compared with analytical results from both Duke and MITRE computer simulations. This study is intended to add to the understanding and validity of analytical methods.

During this reporting period, MITRE has expanded its computer simulation used for a Maglev guideway to accept many other types of guideway configurations and loading criteria. Fairly simple models of the TLRV and PTACV were developed and incorporated in the program. Variations in construction tolerances were used in a study on ride quality. The program has been run with a semi-continuous guideway of up to 10-spans. Results have shown that deflection differences between the 10-span guideway and a 6-span guideway are very small. Guideway camber was included in the program and was demonstrated as a means of reducing cabin accelerations. For the guideway stiffnesses and span lengths studied, the maximum increase in the vehicle force to the guideway for the TLRV and PTACV models were 8 and 6 percent, respectively. This force increase is the difference between the static vehicle weight and the effective force when traveling at maximum speed over elevated guideways. Because these load increases are small, it would appear for the cases studied that, for guideway design only (no ride comfort data), the analysis could be made with static forces.

4.7 Tunneling

In view of the potential for large cost benefits from improved technology for construction of underground systems, FRA has continued its emphasis on tunneling research programs. In conjunction therewith, FRA has been increasingly active in the affairs of the U.S. National Committee on Tunneling Technology and in organizing an International Tunneling Association. An FRA staff member is currently chairman of the former and vice president of the latter.

The project to extend the computer program for estimating the costs of hard-rock tunneling to include soft-ground conditions was completed during the last year. The program was described during the Rapid Excavation and Tunneling Conference in San Francisco and is now in use by the U.S. Army Corps of Engineers to compute costs on a new water supply system being planned for Hartford, Conn.

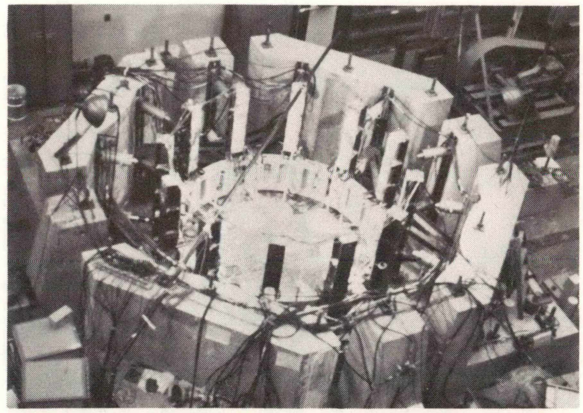
The University of Illinois has expanded its program to explore new tunnel liner materials, designs and construction techniques. A number of structural tests have been performed, using the large-scale test frame mounted in the high-bay laboratory of the Civil Engineering Building at the University. Steel ribs of unconventional design for supporting tunnel openings have been devised and tested as have new designs for bolted concrete segments and monolithic liners, using the new fiber-reinforced reg-set concrete.

During the past year, two monolithic concrete liners, cast with fibre reinforcement, were tested and evaluated at the University. The tests simulated the conditions which would exist with a slip-formed liner, using the design for an extruded liner system as developed in 1973 by the University. In order to determine the liner thickness and concrete properties required under various loading situations, tunnel designers must have an understanding of the structural behavior of this type of liner, both after the slipform has passed and, at a later time, when the concrete has gained full strength. The structural tests showed that the liners exhibit quite ductile behavior. Figure 42 (a–c) shows three views of a liner under test. Classical plastic analyses predict this type of behavior for ideal plastic structures, but fibre-reinforced concrete is far from an ideal plastic. Prediction of ultimate load is not possible without a non-linear analysis. A computer program for a non-linear analysis is being used by the University to provide a rational basis for the design of continuous steel-fiber-reinforced concrete liners.

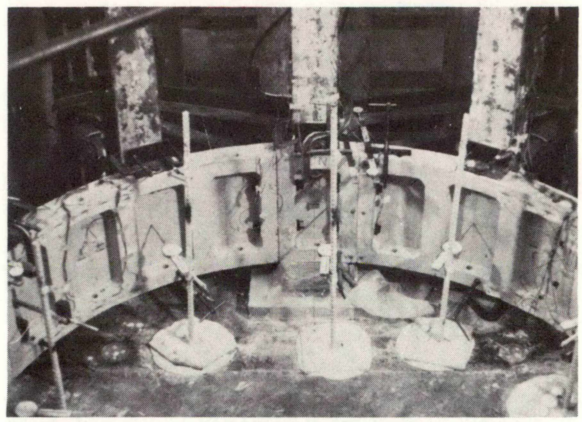
Several more fiber-reinforced as well as conventionally-reinforced liners will be tested to determine differences in their behavior and their ultimate capacities. The analysis techniques will be further refined so that the entire behavior can be predicted from zero to maximum load. The objective of this testing is to develop a means for designing the most economical liner for adequately meeting established serviceability and safety requirements.

In transportation tunnels, steel ribs or sets provide important, but only temporary, support until a durable and watertight liner is in place. The final liner is generally of continuous reinforced concrete, and the temporary supports may or may not be removed. In most cases, the resistance of steel ribs cannot be considered in the long-term design of a tunnel support because of the possibility of rust and corrosion of the steel. The short-term usefulness is, nevertheless, an important consideration.

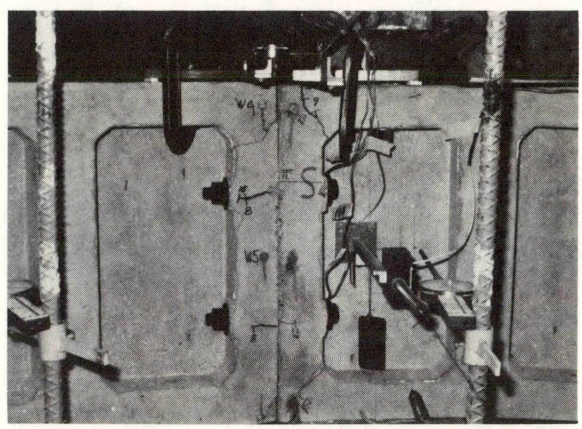
Rock tunneling requires support of the opening as close behind the face as possible. Therefore, steel sets should be inserted as excavation takes place. It is not possible to bore the opening of a tunnel to the exact dimensions of the sets; there is often considerable overbreak of the rock. Therefore, wood blocking is placed between the set and the rock and held in place by wood wedges which are driven between the blocking and the ribs. Because the wedges are driven from one side and the geological forces are not necessarily perpendicular to the ribs, the forces on the ribs are inclined. These forces can produce torsional loads with the possibility of lateral buckling. Unfortunately, conventional rolled-steel beams used for steel ribs do not handle torsional loads very well. Circular and square tubular sections are much stronger under torsional loads; therefore, larger-scale tests have been conducted on tubular sections, both empty and filled with concrete, under various loading conditions. The data obtained have been analyzed and compared with those obtained from tests on conventional steel-beam sections.



a. Overview of Tunnel Liner Test Area.



b. A Closer View of a Test Specimen with Instrumentation.



c. Cracks Developed in Test Specimen Provide Information for Improvement in Liner Design.

Figure 42. University of Illinois Tunnel Liner Tests.

Fiber-reinforced, regulated-set concrete also has interesting potential for use in shotcrete. Shotcrete is usually a mixture of cement, sand and small-sized aggregate which is sprayed on tunnel walls to provide early support after excavation to prevent movement of the surrounding ground and conse-

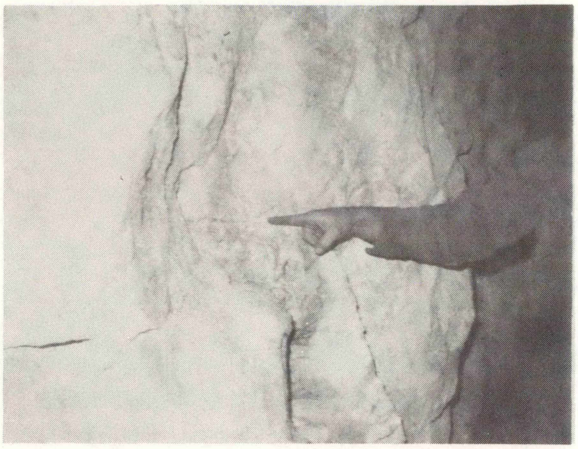


Figure 43a .Dolomitic Limestone Rock Face after 18 Water Jet Pulses at Jet Pressures Near 450,000 Pounds per Square Inch.

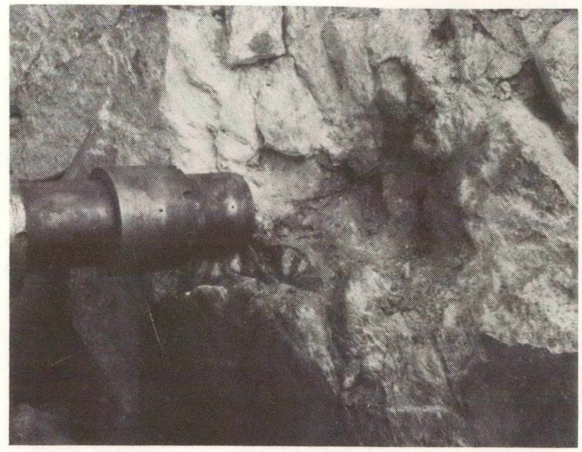


Figure 43b. Granite Gneiss Rock Face after 22 Water Jet Pulses at Jet Pressures Near 450,000 Pounds per Square Inch.

quent disentegration of the opening. The addition of wire fibers and use of regulated-set cement in shotcrete improves its characteristics by giving it tensile strength, ductility and an early set. Experimental mixes having various quantities of wire fibers and regulated-set cements, are being tested to compare their characteristics with that of conventional mixes.

Terraspace, Inc., has continued work on its water cannon which was reported in the Seventh Report. During the past year, the cannon was tested in an underground dolomitic limestone quarry in Cockeysville, Maryland, where 40 test shots were made (Figure 43a). Subsequently, 27 test shots were made against gneissic granite in an open quarry at Fort Belvoir, Va. Figure (43b). Both series of tests showed that rock can be successfully broken with high-pressure water (shots were made at pressures up to 540,000 psi (3700 MH/M^2), but that further research is required to reduce the noise level of the unit and that some redesign of the nozzle might result in elimination of need to evacuate air from the nozzle in order to achieve high water pressures. Such projects are in progress.

4.8 Aerodynamics

As part of an FRA effort to develop a coordinated ground-vehicle aerodynamics research program plan, including conventional rail and high-speed TLV concepts, A.G. Hammitt, Assoc. prepared a report for ORD&D, assessing aerodynamic problem areas pertinent to HSGT. The report discusses such topics as aerodynamic drag, lift, and rolling moments; static and dynamic air cushions; fluid propulsion; tunnel wall effects on aerodynamic forces; wayside environment (effects on structures, people, and other vehicles; noise; and pressures and wakes caused by HSGT vehicles. An attempt has been made to assess priorities, determine costs for experimental testing, and identify problem areas that are applicable to more than one type of HSGT system as well as those that are unique to a particular concept or class of vehicle.

MITRE's Tunnel-Vehicle System computer program has been utilized this past year to study the flow phenomena associated with entry, venting, multiple-vehicle operation, and single-vehicle travel in an open-ended tunnel. Given the initial geometries of the vehicle and tunnel, the initial vehicle position and speed, and the acceleration (or deceleration) profile, the program then computes the complete travel path of the vehicle in time. Included in the calculations are the vehicle drag and power requirements and time histories of all thermodynamic data in the tunnel/vehicle annulus. The entry problems that were studied included those of varying entrance geometries and vehicle speeds. The venting analysis included consideration of the venting of entrances and exits and venting along the length of the tunnel. One-way operation of several vehicles operating in the same tunnel was investigated for the effects of an earlier vehicle's motion on the pressure peak associated with a second vehicle's entering the tunnel.

During high-speed testing of the PTACV at the HSGTC in 1975, an investigation will also be made of vehicle side-force loadings due to aerodynamic distrubances such as crosswinds and gusts. Results will be correlated with a study completed for TSC by Kaman Avidyne last year that compared theoretical side-force and yawing-moment predictions on the PTACV configuration with data available from wind-tunnel tests. This verification is necessary in order to improve current wind-tunnel testing techniques for the simulation of side-wind effects on high-speed ground vehicles in semi-enclosed guideways.

4.9 Noise Impact on Environment

Stationary noise measurements were conducted on the PTACV at Rohr's Chula Vista plant during 1974. The results indicated that the vehicle failed to meet interior and exterior noise criteria under hovering conditions. In order to identify the mechanisms associated with the generation of noise about the vehicle, an acoustic test plan has been generated. Vehicle noise, external and internal, will be measured as part of the PTACV test program.

In a research effort conducted for TSC this year, Bolt, Beranek, and Newman analyzed the various sources of noise on the PTACV qualitatively and compared some of the theoretical predictions with small-scale experimental measurements. The results of this analysis will be correlated with the acoustical data taken on the PTACV at HSGTC during the test program.

As part of the LIMRV Program at the HSGTC discussed in Section 4.11, a series of running and stationary tests were conducted during the summer of 1974 to acquire noise data and ground vibration-level measurements. The test objective was to quantify noise and ground vibration of high-speed steel-wheel-on-rail vehicles as source data for use in the following areas:

(a) Determination of train car-body skin-design requirements of future high-speed revenue vehicles to insure acceptable internal vehicle noise level.

(b) Determination of noise impact on existing or planned wayside communities and the requirements for insuring acceptable background noise levels.

(c) Evaluation of community response to train-induced ground vibration.

Noise analysis conducted for FRA by MITRE during 1974 centered on TLV noise impact and TACV noise evaluation. Noise level requirements, aerodynamic noise, air cushion tests, and measurements on the Krauss-Maffei Maglev vehicle provided by K-M were evaluated for their possible

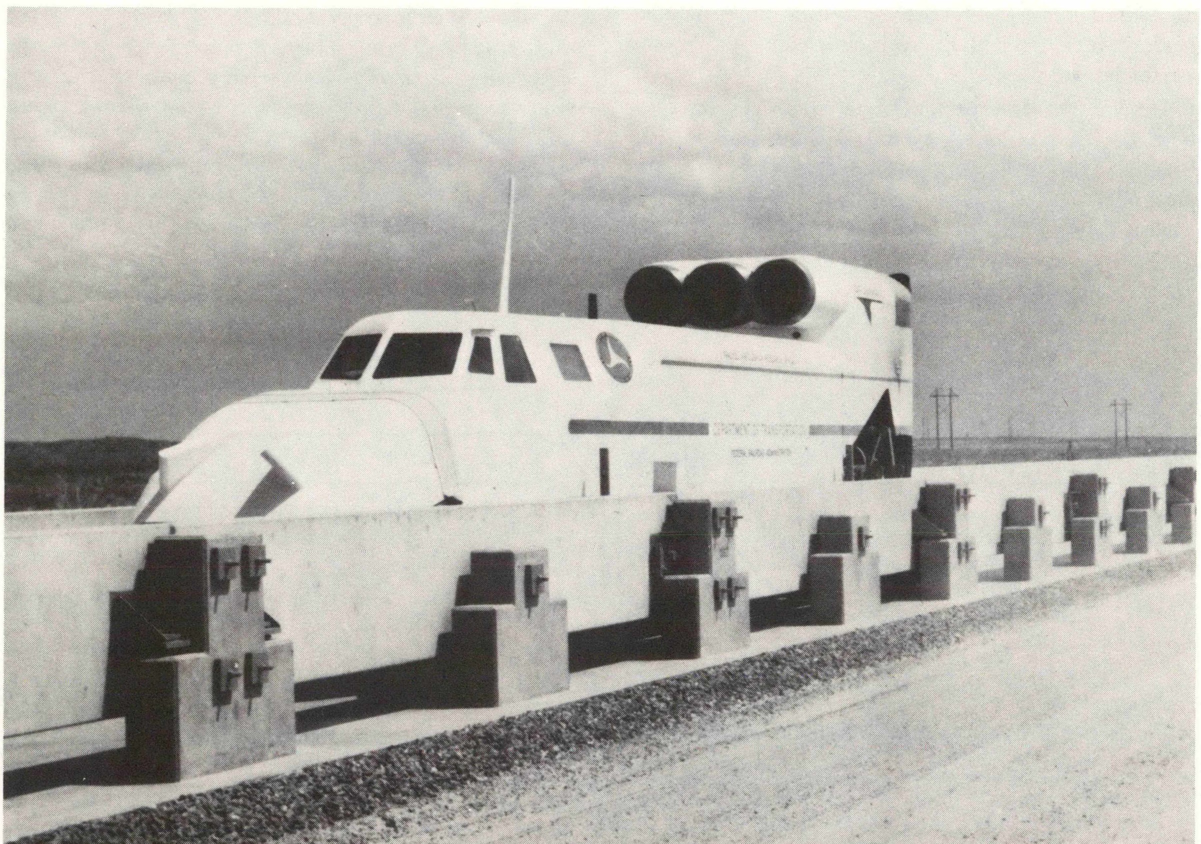


Figure 44. TLRV Test Operation

impact on the Advanced Systems TLV programs. TLV noise impact on an adjacent community, based on the available research, appears to be a compound function of the noise level of each passing vehicle, the duration of the noise and the number of passes per day.

The development of a noise specification for any high-speed/150 mph ($\geq$240 km/h) ground system should consider the effect of exposure to high peak-noise levels for short periods of time and the contribution of aerodynamic noise to the total noise level.

TSC played an active role in FRA's noise-abatement research during 1974 by furnishing technical support for the LIMRV tests at HSGTC and the previously discussed PTACV stationary noise measurements at Rohr's Chula Vista plant.

4.10 Tracked Levitated Research Vehicle (TLRV)

During testing of the TLRV in its aeropropulsion mode (Figure 44) thrust was derived from the exhaust of the vehicle's three turbofan engines used for cushion air supply. As more guideway became available, vehicle operations were conducted at successively higher speeds and included performance tests of the vehicle's ride quality and performance.

During the test period, data were obtained for both the Body/Chassis (B/C) and the Independent Cushion (I/C) suspension modes. The B/C suspension forms the mounting for the body on the chassis and provides isolation from heave, pitch and roll motion. It also allows for banking of the body with respect to the chassis ($\pm$13 degrees) to enable coordinated turns at speeds up to 300 mph (480 km/h) on superelevated sections of the guideway. In this mode, the levitation cushions are locked to the chassis, and isolation from yaw and lateral motion is provided by a system of two airsprings plus a servoactuator mounted between each guidance cushion and the TLRV chassis. The servoactuator may be used as a passive damper or as an actively controlling element, depending on whether the passive or active suspension system mode is employed.

In the I/C mode, the body is locked to the chassis, and every air cushion (i.e., guidance or levitation) is connected to the chassis by means of two airsprings and a servoactuator element. Again, either a passive or active suspension system mode may be employed.

Because analysis of the B/C data has progressed farther at this time, discussion is limited to this mode.

With the B/C suspension, the vehicle body is supported at each end by an "A"-frame connected to the chassis through a pair of airsprings. Figure 45 is a sketch representative of both the front and rear systems. The average pressure in the supporting airsprings is passively controlled to provide a preset height by means of load-leveling valves which meter air from the vehicle's pneumatic supply into the springs or dump air from the springs. The load-leveling valves correct spring pressure to maintain the preset height in the pres-

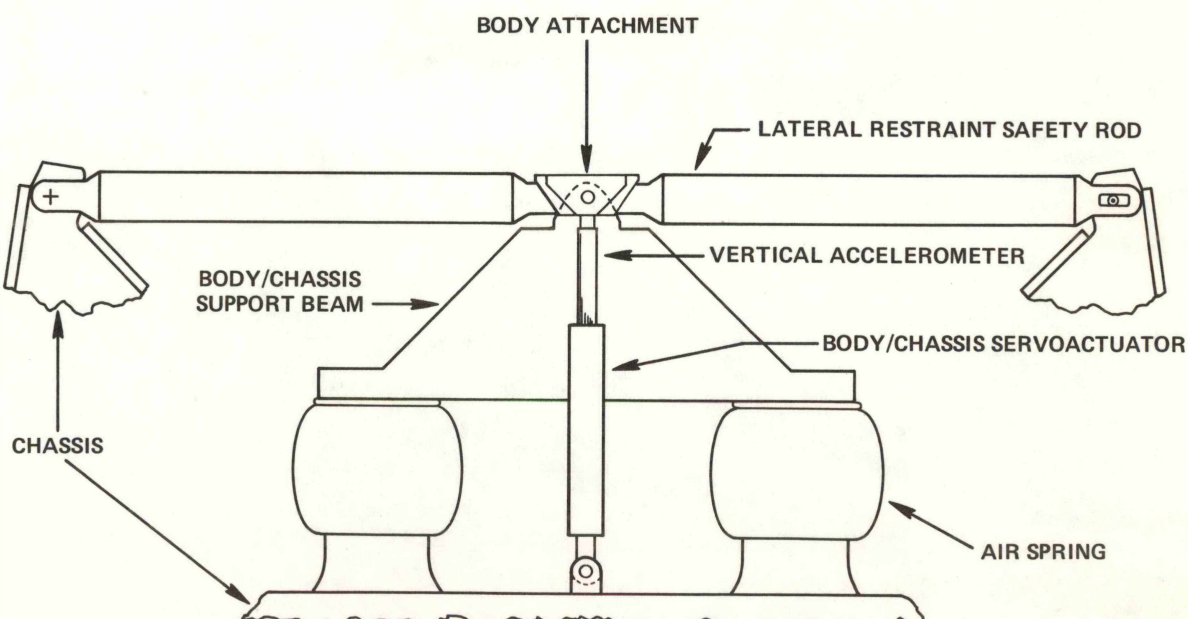


Figure 45. TLRV Body/Chassis Support System (Front or Rear).

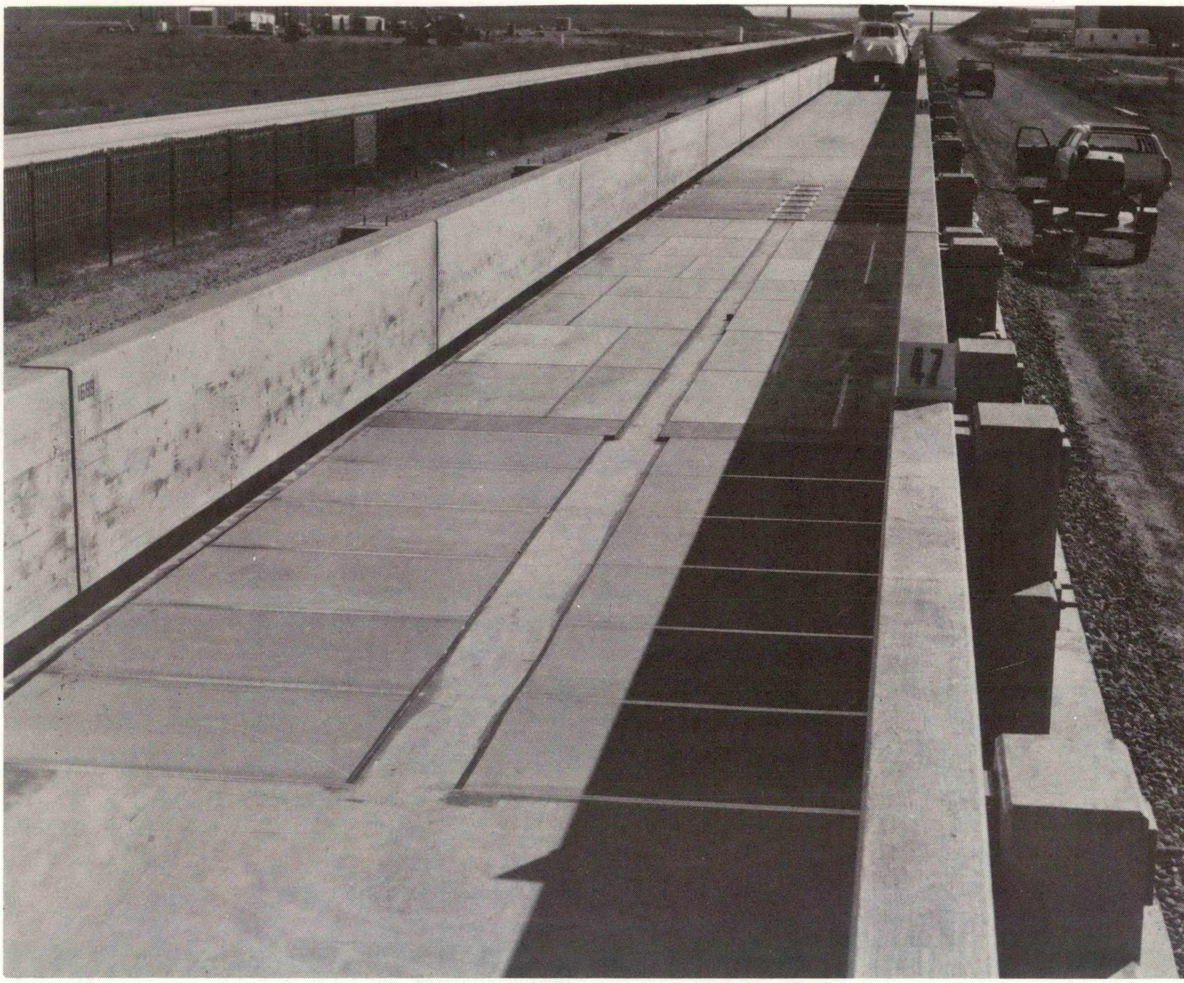


Figure 46. Long-Wave Perturbation Installed in TLRV Guideway.

ence of air-supply-engine power changes, aerodynamic-lift effects, or centrifugal forces occurring while operating in the curved sections of the guideway; however, they do not respond to short-term dynamic responses. The servoactuators are located adjacent to the main-support "A"-frames and respond only to the relative vertical motions between body and chassis.

To determine the tolerance of the TLRV to irregularities in the guideway and to apply known excitations to the suspension system, perturbation surfaces were fabricated and bonded to the guideway slab. Two types of surfaces were used, a ramp/step and a long wave. The ramp/step was made up of a combination of aluminum sheet, wood filler and fiber glass bonded together to provide ramps 25 feet (7.6 m) long and varying from 1/4 inch (6 mm) to one inch (25 mm) high at the far end. Long-wave-type perturbations were similarly constructed to approximate a theoretical parabolic pulse with a 100 foot (30.5 m) chord and a 1 1/2 inch (38 mm) height at the center. The long-wave perturbation is shown installed in the guideway in Figure 46. For some tests, installation was made on only one side of the guideway levitation surface so as to introduce a roll excitation to the TLRV. The design of the perturbations permitted easy installation and removal without delaying the test program or altering the guideway's concrete surfaces.

Typical measured body-accelerations at the aft B/C suspension are shown in Figure 47 for a one-inch (25 mm) high ramp/step and in Figure 48 for the parabolic wave. The ramp/step initially causes a sharp reduction in cushion pressure with the resulting negative (downward) acceleration, followed by a rebound (i.e., positive acceleration). The sharp drop-off and rebound occur because of the abrupt nature of the ramp/step and, even at low speeds, the perturbation excites all the natural response frequencies of the vehicle systems.

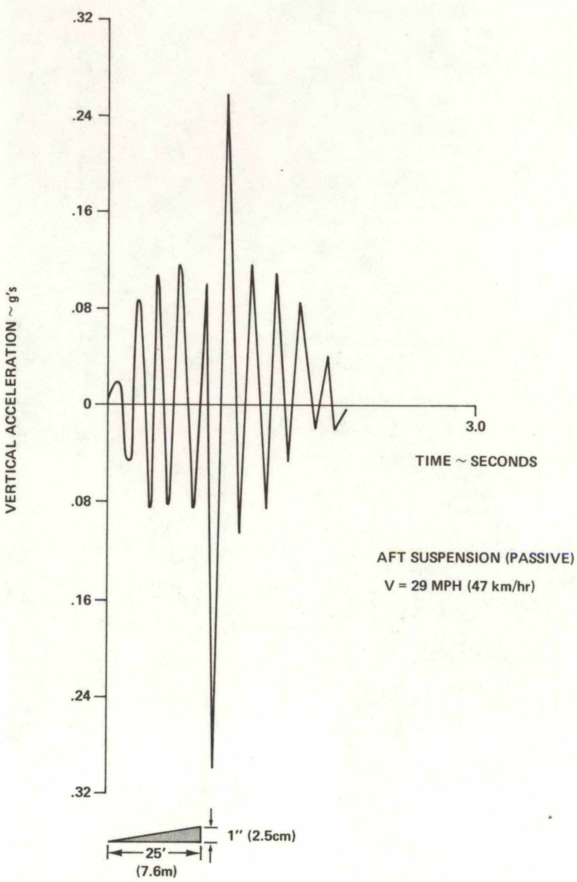


Figure 47. Typical Measured TLRV Body Accelerations for Ramp/Step.

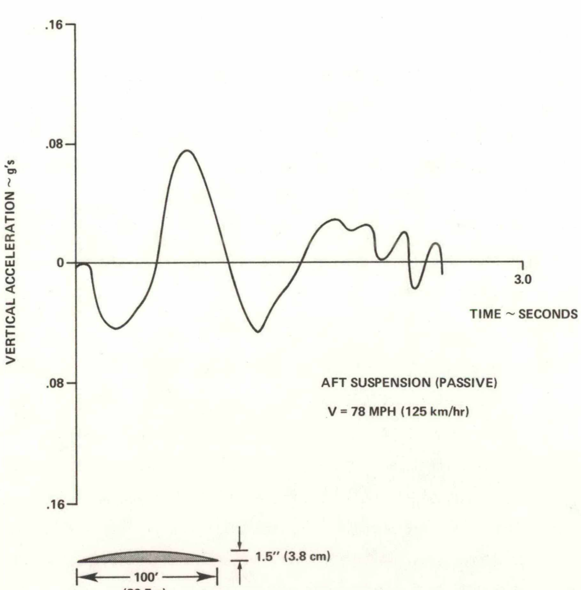


Figure 48. Typical Measured TLRV Body Accelerations for Long Wave.

The long wave excites vehicle responses with periods equivalent to the time required to pass over the perturbation. In this instance, the pressure change is more gentle and does not excite the higher-frequency body responses. Thus the responses show higher acceleration for the one-inch (25 mm) ramp/step than for the 1.5-inch (38 mm) long wave, even though the vehicle test speed over the wave is, in this case, 2.5 times higher. The measured acceleration levels were moderate, even for the ramp/step. The perturbations have proved to be valuable tools in evaluating the suspension systems because they provide a known input which can also be mathematically described and used in an analytical model of the system to facilitate correlation of theoretical and experimental results.

Three miles (4.8 km) of guideway became available for TLRV testing in November 1973 with the completion of the second 1½ miles (2.4 km). As construction progressed and more guideway sections became available for TLRV operation, vehicle test speeds with aeropropulsion gradually increased to a maximum of 91 mph (146 km/h) on the full three miles (4.8 km).

4.11 Linear Induction Motor Research Vehicle (LIMRV)

In the fall of 1973, two surplus Air Force J52–P3 jet engines were installed on the LIMRV which can now be accelerated by the combination of LIM and the jet engines to speeds slightly above the design speed of 250 mph (409 km/h). The vehicle is decelerated by the LIM dynamic braking and disc brakes before reaching the end of the 6.2 miles (10 km) of track.

The LIMRV is the world's fastest steel-wheel-on-steel-rail vehicle as well as the fastest LIM-propelled vehicle. On August 14, 1974, in the last run in a series of speed-upgrading tests, it attained a speed of 255.4 mph (411 km/h). More than a dozen earlier runs exceeded speeds of 200 mph (322 km/h). Vehicle dynamic response was well below allowable limits and no degradation of track alignment was observed. Because wear on the disc brake pads was excessive, mechanical braking effort has been reduced at speeds above 200 mph (322 km/h) to lengthen pad life.

An aircraft ring slot parachute was added to the LIMRV, primarily for use if its dynamic brakes failed at high speed. The previously reported chain arresting system also remains ready to stop the LIMRV safely in the event of a braking system failure.

Several auxiliary systems of the LIMRV failed in tests during the first half of 1974. The auxiliary power unit (APU), a 175 hp (130 kw) gas turbine in the tail of the vehicle, was damaged by sand ingestion and required a complete overhaul. One of the external plug-in J52 starters burst, causing minor damage to the vehicle. The starter was allowed to run unloaded for several minutes, causing the starter gearbox to overheat and freeze mechanically. Recurrence has been prevented by changes in operating procedures.

After study of the safety aspects, the previous 110 mph (117 km/h) limit on manned operation of the LIMRV was raised to 150 mph (240 km/h). The result is increased operating efficiency because manned runs are more flexible and require less preparation time than do those that are remotely controlled. Operation above 150 mph (240 km/h) continue to be radio-controlled from the data van.

Electrical performance tests which were in progress at the end of the reporting period will determine thrust, efficiency, and electrical characteristics of the LIM during propulsion and braking. The LIMRV will also be used for empirical determination of wheel/rail friction coefficients and for investigation of rail vehicle suspensions at very high speeds.

4.12 Prototype Tracked Air Cushion Vehicle

The Prototype Tracked Air Cushion Vehicle (PTACV) is the world's first passenger-carrying, all-electric, tracked levitated vehicle that is designed to provide safe, comfortable and non-polluting service at speeds of at least 150 mph (240 km/h). The vehicle is powered by a linear induction motor (LIM), levitated and guided by air cushions fed by electrically driven air compressors and controlled by an automatic vehicle control system with manual override. Electrical power to the vehicle is provided at 4160V by a wayside distribution system and a power collection subsystem. All of the vehicle's subsystems utilize state-of-the-art technology; however, the integration of these subsystems into an operational system represents a state-of-the-art advancement in TLV technology. One of these advancements is the use of a solid-state variable-voltage power control unit (VVPCU) for the propulsion system.

During the past year, the fully assembled PTACV has undergone a series of static and low-speed checkout and system operational tests on a 500 ft. (152m) test track at the Rohr Industries, Inc., plant in Chula Vista, California (Figure 49). This testing was aimed at demonstrating vehicle operability and readiness for high speed operations at the HSGTC and verifying, to the extent possible on the limited track, the degree of system conformance to performance specifications. Delivery of the vehicle to the HSGTC upon completion of testing at Chula Vista was delayed a few months until early September (Figure 50) to permit analysis and redesign of propulsion control-system components to rectify performance deficiencies detected during initial subsystem checkout.

Construction of the test facilities for the high-speed testing of the PTACV at the HSGTC was largely completed during the year ending September 30, 1974. Under the civil engineering cognizance of ABAM Engineers, Inc., Tacoma, Washington, the first 3.13 miles (5.04 km) of concrete guideway were constructed by Western Paving and Construction Company of Denver,

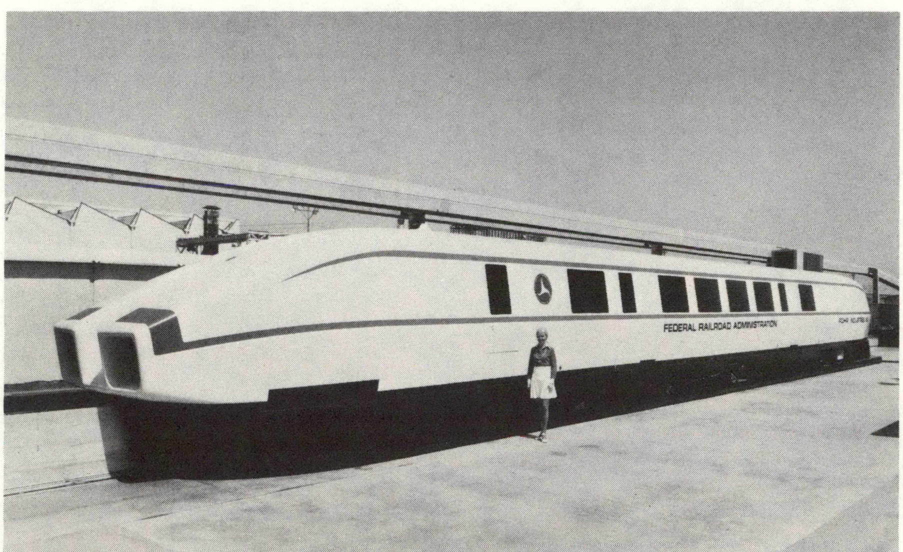


Figure 49. PTACV on Short Test Track at Plant of Rohr Industries, Inc.

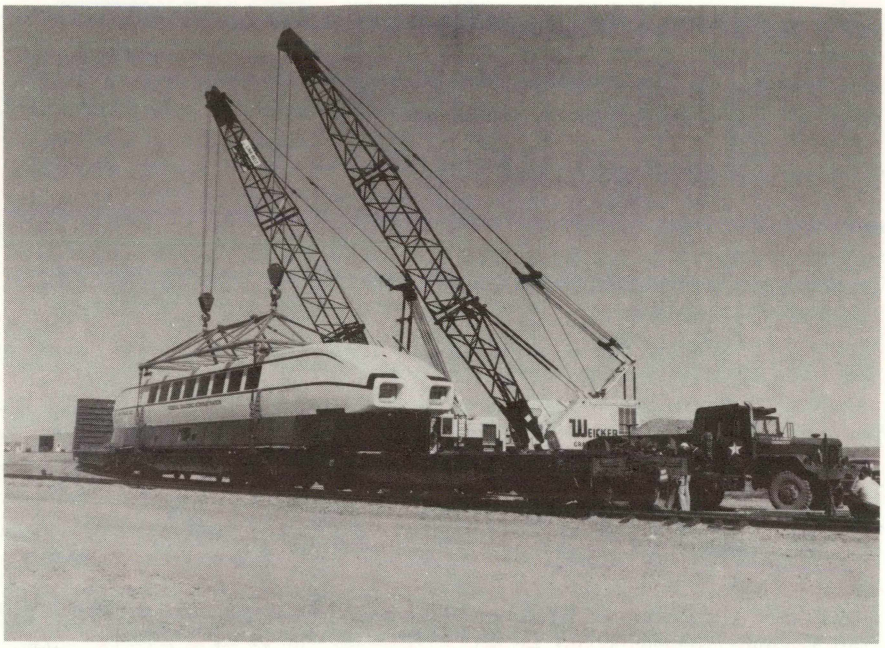


Figure 50. Unloading PTACV from Flat Car onto Dolly for Transport to PTACV Maintenance Building at HSGTC.

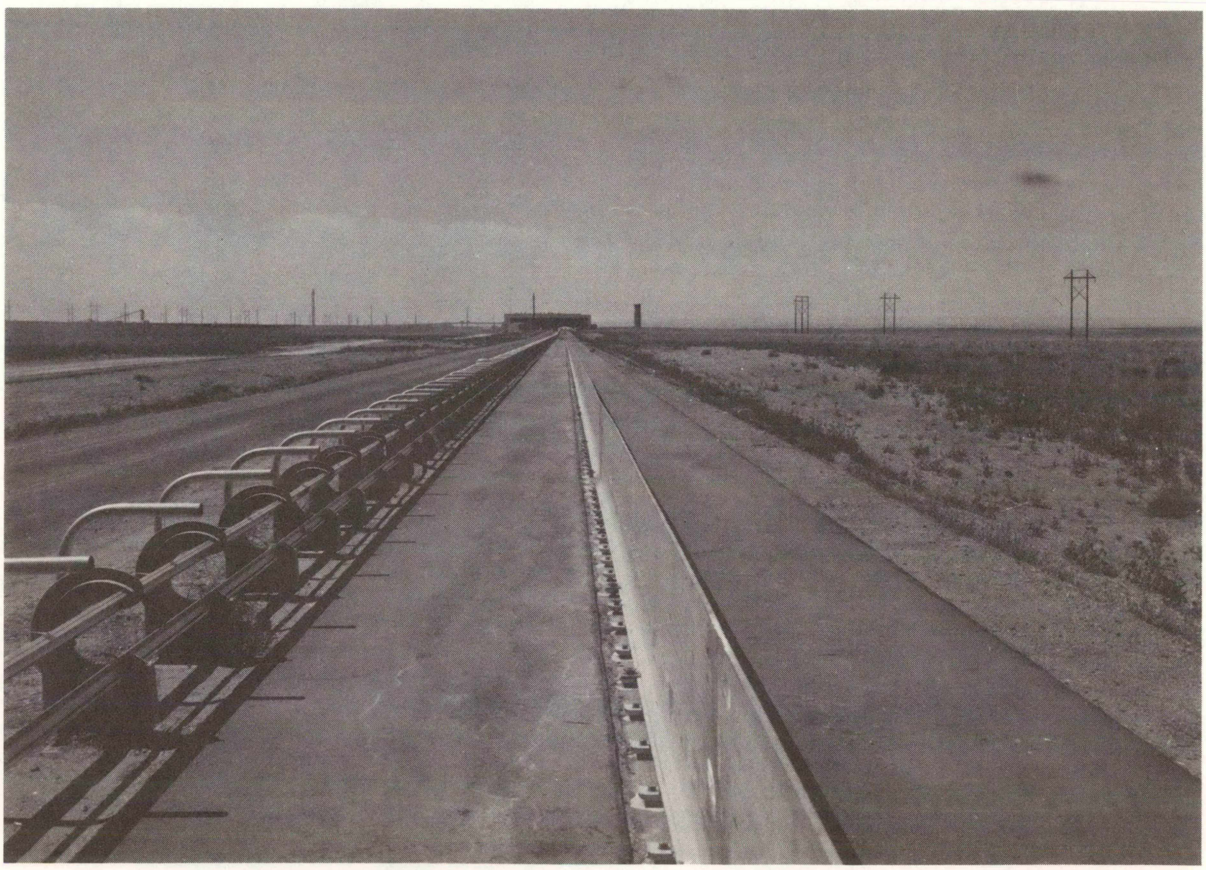


Figure 51. Partially Completed Installation of Reaction Rail and Wayside Power Distribution Rails at HSGTC.

Colorado. The second 2.55 mile (4.10 km) section of guideway was completed by Peter Keiwitt and Sons, creating a 5.68 (9.14 km) length of test guideway which will permit testing at 150 mph (240 km/h) for an approximate 20-second period of time.

Three miles of guideway reaction rail and wayside power rail (Figure 51) and two electrical substations were installed at the Test Center by September. Completion of the entire 5.68 miles (9.14 km) guideway length is expected by early January 1975. The facilities for testing the PTACV includes a maintenance building which houses a control center and workshop. Safety equipment, including warning lights, fencing, emergency power cut-off switches, and position monitoring will be installed.

Planning for the test program at HSGTC has been completed and includes provision for vehicle maintenance, and operating procedures that will achieve a high level of safety during testing. The test program as planned will determine basic system performance characteristics (safety, speed, acceleration, environmental effects, and ride comfort) and establish requirements and characteristics for operating and maintenance procedures and costs. Because the vehicle performance is so dependent on the characteristics of the propulsion system, a major portion of the test program will center around the propulsion system and will consist of testing and evaluating the operating characteristics of the LIM and VVPCU combination. The test program will also permit the PTACV system to be demonstrated to local transportation planning officials, enabling them to evaluate first hand the feasibility of TLV systems as an alternative to more conventional modes of transportation.

5.0 INTERNATIONAL COOPERATION

5.1 Rail Systems

FRA has participated in the past in low-keyed cooperative information transfers with the administrations of the state railways of Poland, France and Romania. A more powerful effort involving the USSR received its initial impetus in 1973 with the signing of an agreement, *Cooperation in Transportation*, by the Secretary of State for the U.S. and the Foreign Minister of the Soviet Union. This agreement provides, in part, a mechanism for the mutual transfer of multi-modal transportation information under which was developed, through preliminary negotiations, the framework of first-phase activities, including the exchange of technical delegations. In June 1974, a DOT/FRA-sponsored track delegation visited the Soviet Union for a period of twelve days for the purposes of evaluating the present state of the art in track research and maintenance in the USSR and isolating those areas of technical accomplishment that can be more closely examined by small teams of specialists for grafting onto domestic practice. In October 1974, a similarly-oriented group from the USSR was to visit the U.S. Further exchange visits on railroad electrification and rolling stock are scheduled for 1975.

Acceleration in the development of technical rapport between the U.S. and Soviet rail communities is viewed at this end with satisfaction. The USSR is the most rail-intensive country in the world, carrying 50% of world ton-miles on 10% of available trackage. Prior to the June visit, in-house familiarity with Soviet accomplishments, particularly in the research domain, was gained through study of technical reports. It was known that Soviet rail research, for example, involved several thousand staff personnel at various institutes throughout the country. A preliminary opinion was that so extensive an effort would have had to produce some results that would be of benefit to the U.S. rail industry if they could be separated from the accomplishments of purely internal value to the Soviet rail complex. This opinion was sustained by the results of the tour.

The DOT/FRA-sponsored delegation was composed of the chief engineering officers of two large railroads; the executive vice-president of a large southeastern carrier; a researcher in the field of railroad track mechanics; a translator-recording secretary who, having participated, provided continuity with earlier non-government team visits to the USSR in the 60's; and an FRA staff member as head of the mission. Extensive pre-visit ground work had been laid by FRA, clearly defining to the Soviet Ministry of Rail those technical and procedural areas in which the U.S. delegation had an interest. As a result, exposure presented in the USSR was largely a response to these expressed desires. The reception accorded the U.S. delegation may be categorized as genuinely open, warm and candid. The high-level Soviet railroad personnel met by the delegation freely discussed certain shortcomings in the Soviet rail system. By the same token, it was obvious to delegation members that the observed portion of the Soviet rail network (and this was extensive) and its ancillary facilities were of high quality and evidently able to fulfill the expectations of the Ministry of Rail.

It became abundantly clear during the visit that the Soviet rail system is today confronting and grappling with problems that inevitably will face the U.S. rail industry in the next ten to twenty years. Currently, some Soviet trunk lines are carrying 146 million metric tons per year. Axle loads are limited to about 70% of those common in the U.S. Yet, the U.S. traffic trend is inexorably upward. As the frequency of train operation increases on a given line, opportunity for maintaining such track subjected to accelerated wear decreases.

The question of "track occupancy" by maintenance personnel is a serious one wherever traffic is intensive and the Soviets, with possibly the most prodigious problem, have developed some unique solutions for track renewal at extremely rapid rates. A very singular characteristic of these approaches is the integration of track design factors with the design of track maintenance equipment to accomplish the goal of fast track rehabilitation. Since 1932, the Ministry of Rail has supported an extensive experimental facility that proves out, under actual service conditions, newly developed track systems and components. Nothing like this exists in the North America.

Given this "window" on likely future problem developments in the U.S., the major thrust of FRA's prospective R&D efforts will be directed toward securing and reporting to the rail industry applicable results of Soviet attempts to contend with the intense-traffic problem as it relates to track in terms of system stability, component wear and system renewal.

International Reference Exchange

The FRA-sponsored Railroad Research Information Service (RRIS) has completed a working agreement with the International Union of Railways (UIC) for the exchange of railroad research references. Details of this agreement are presented in Section 3.8 of this report.

5.2 Advanced Systems

An agreement entered into this year between FRA and the West Germany Ministry of Transportation and Ministry of Research & Technology has resulted in a much more effective exchange of R&D data on high speed transportation systems. Previous exchanges occurred only at the Government managerial level. This procedure was satisfactory for budgetary and program planning information but not for the communication of detailed technical information. The new plan provides for participation of Government experts plus consultants and contractors in bilateral technical discussions, visits to facilities, and observation of test operations. The Germans have provided DOT with status reports on the extensive Maglev developments underway under Government sponsorship. Some of the data provide a check on work already performed by the U.S., while other data are in areas not yet explored and duplication of effort will be avoided. A jont study of high-speed vehicle noise has been formulated by DOT and the Ministry of R&T. As a first step in implementing this study, information obtained during the LIMRV noise tests will be made available to the West Germans in exchange for noise data from their Maglev vehicle test programs. A representative delegation from Dornier Systems, Messerschmitt-Bolkow-Blohm (MBB), Deutsche Bundesbahn (German Federal Railroad) (DB), and the German Research Institute for Aviation and Aerospace (DFVLR) was accompanied by MITRE and FRA representatives to the HSGTC to observe noise tests on the LIMRV. Following the tests, arrangements were made to discuss and make available to the West Germans all information pertinent to the tests including instrumentation, gathering of data, analysis, conducting of tests, and final reports. A tour of the Acoustics and Noise Reduction Division, NASA-Langley Research Center, including laboratory facilities and the Passenger Ride-Quality Simulator, was also provided to the West German group.

During the past year an FRA representative visited the principal electrical propulsion R&D centers in West Germany and participated in an international symposium on high-speed propulsion in France. A detailed report has been prepared based on these visits.

In tunneling research there has been intensive activity with the international community. An FRA representative joined with others from OST, FHWA, and TSC to form a visiting delegation to Japan. The delegation was hosted by the Japan Society of Civil Engineers and visited many of the major tunnel projects now under construction. The FRA staff member, who currently is chairman of the U.S. National Committee on Tunneling Technology of the NAS/NAE, also participated in a conference in Oslo, Norway, to organize an International Tunneling Association. At the conference he was elected a vice-president of the new association. A program is in process of development for exchange of technical reports with all of the major countries of the world having an interest in tunneling technology or construction.

6.0 HIGH SPEED GROUND TEST CENTER

Testing and construction activities accelerated significantly at the High Speed Ground Test Center near Pueblo in southeastern Colorado during 1974. In August, the Linear Induction Motor Research Vehicle (LIMRV) achieved a speed of 255.4 mph (411 km/h) on its precisely-aligned 6.2-mile (10 km) track to surpass the world's speed record for steel-wheel rail vehicles. While a linear induction motor (LIM) was being installed in the Tracked Levitated Research Vehicle (TLRV), a reaction rail and an 8,000-volt wayside power system were installed on some 1500 feet (457 km) of the existing guideway for the vehicle. The first 3.13 miles (5 km) of guideway (including reaction/guidance rail and wayside power system) for the 60-passenger, 150 mph (241 km/h) Prototype Tracked Air Cushion Vehicle (PTACV) were completed, and the vehicle has been undergoing preliminary checkout in preparation for testing.

Other major construction activities during the year included the completion and activation of the 34,000 sq. ft. (3,159 m^2) Storage and Maintenance Building and its railroad spur siding. The large, 355 ft. by 150 ft. (108 m x 46 m) Rail Dynamics Laboratory (RDL) building was completed and progress is being made in equipping and instrumenting the facility. Since February of 1974, power from the local power company's 115 kv high-voltage transmission lines east of the Test Center has been distributed to the RDL, the Project Management Building and the adjacent temporary office quarters (office trailers). Construction is progressing on the 63,000 sq. ft. (5,850 m^2) Technical Services Building.

A building contract has been let for a new two-story Operations Building which is scheduled for completion by the summer of 1975. This building will provide relief from crowded office and working space conditions, conditions which were temporarily alleviated by moving in a dozen additional surplus office trailers (for a total of twenty) for use as offices and for housing other support activities. In addition, facilities were prepared at a remote site on Center property for the tank car torching tests, a continuation of a Tank Car Hazardous Material Program in which the Federal Railroad Administration is participating.

Planned and existing test facilities at the Center now include the following:

(a) Conventional Railroad Test Tracks, approximately 20.7 miles (33.3 km) planned with approximately 6.7 miles (10.8 km) complete.

(b) An electrified, third-rail, rail-transit test-track loop—9.1 miles (14.6 km) around—with additional trackage planned within the loop and consisting of bridge, tunnel, screech loop and perturbed track sections.

(c) A U-shaped guideway with 3 miles (4.8 km) presently constructed and partially equipped with wayside power and reaction rail on which the Tracked Levitated Research Vehicle (TLRV) has operated at speeds up to 90 mph (145 km/h).

(d) An inverted T-shaped guideway, planned for approximately 5.7 miles (9.2 km), with 3.13 miles (5 km) complete, including the center reaction/guidance rail and 4160-volt wayside power system, on which the Prototype Tracked Air Cushion Vehicle (PTACV) will be operating. The additional section of guideway is being electrified.

(e) A precisely-aligned track—6.2 miles (10 km) long, having a center aluminum reaction rail—for the Linear Induction Motor Research Vehicle (LIMRV) is currently being used for operating the vehicle at speeds up to 255.4 (411 km/h). Extension of this track is not planned at this time.

(f) A guideway loop of 3 miles (4.8 km) around, now in the initial planning stage, for testing the Dual Mode System (guideway and highway modes) of automated vehicles in computer controlled operation.

(g) A Tank Car Torching Test facility with a half-mile (805 m) radius safety zone located at a remote site now in operation.

(h) The Rail Dynamics Laboratory for simulator-testing of full-scale rail and advanced vehicles. The laboratory building is in use, although the simulator is not complete.

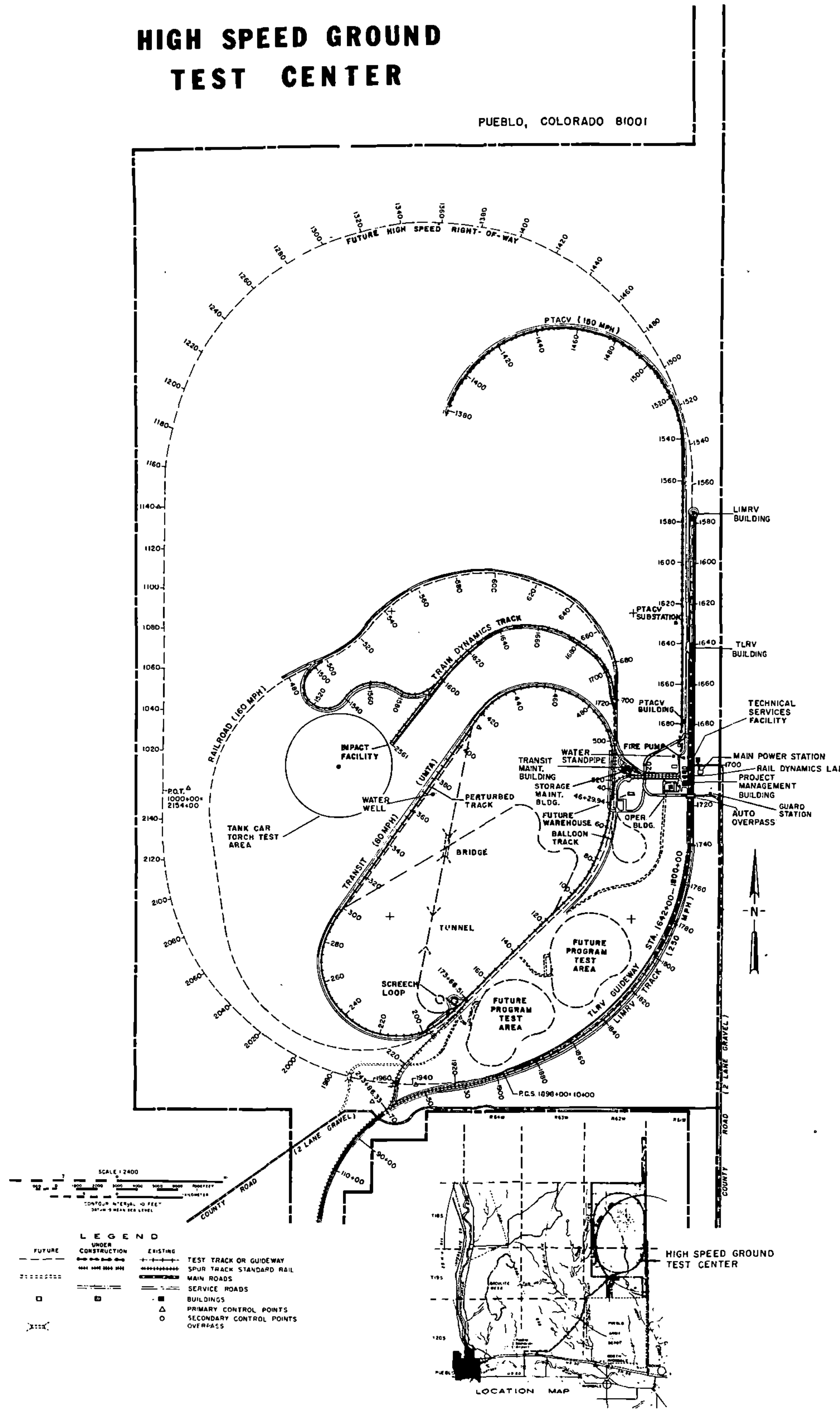


Figure 52. High Speed Ground Test Center, U.S. Department of Transportation, Pueblo, Colorado.

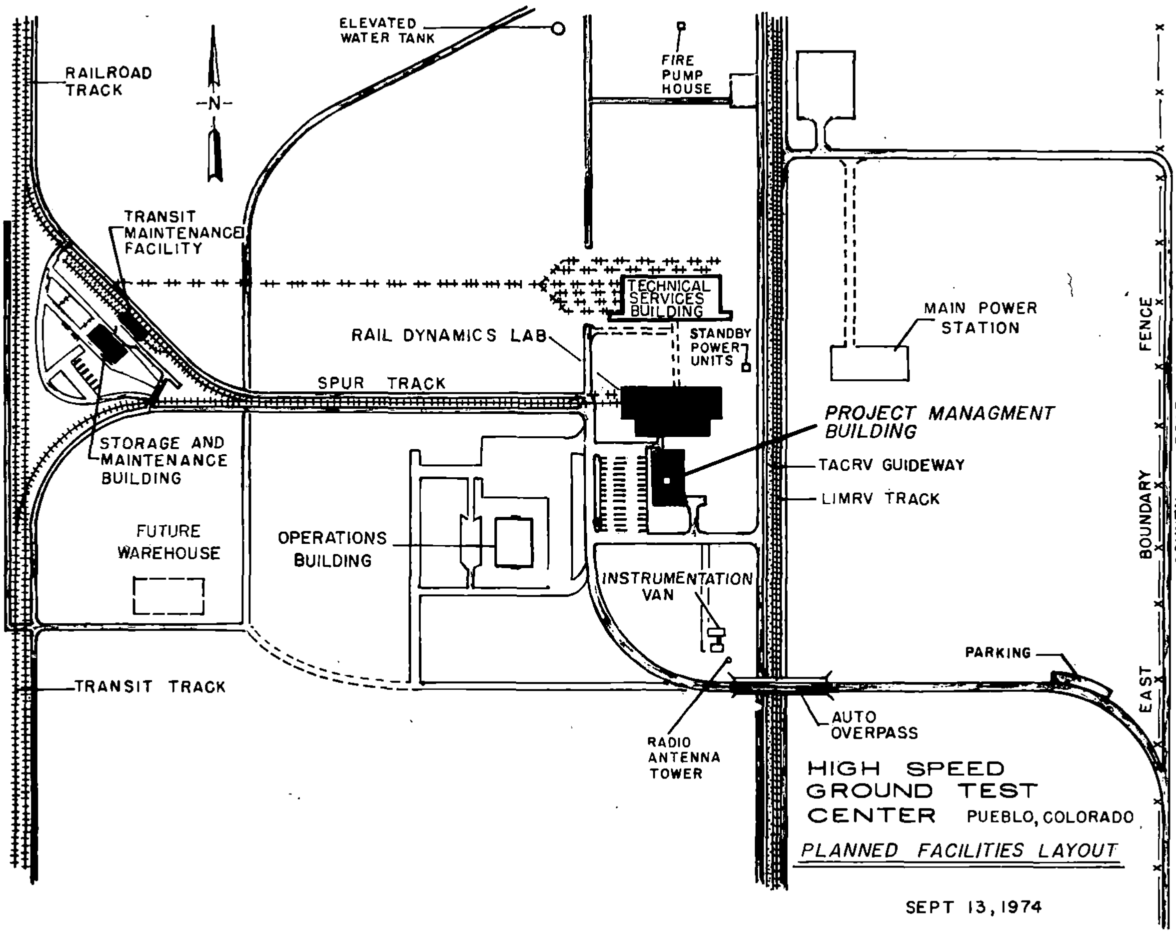


Figure 53. Operations Area—Planned Facilities Layout, HSGTC, Pueblo, Colorado.

Figures 52 and 53 map the existing and proposed test facilities at the Center. These facilities (except the Dual Mode System guideway loop for which final plans have not yet been established) are further described in the following section.

6.1 Test Facilities Status

Railroad Test Tracks and Rolling Stock

Of the planned 20.7 miles (33.3 km) of conventional railroad test tracks, 6.7 miles (10.8 km) have been constructed and are in operation. Included in the completed trackage (Figure 54) are two testing facilities: The Impact Track with a 0.76-mile (1.22 km) tangent and a 5.7 mile (9.2 km) section of the Train Dynamics Track. An invitation for bids for construction of the remainder of the dynamics track was issued in September 1974. Uses of these test track segments were described in the Seventh Report.

The Center's DOT-owned, 1971 General Electric 3,000 hp (2240 kw), heavy road diesel-electric locomotive was modified with high-speed gearing to provide a 120-mph (193 km/h) capability to meet testing needs. In addition, the specially-wired generator of this locomotive permits use of the unit as the primary source of 600-volt electric power for transit operations. This locomotive, as well as a 1945 Alco diesel-electric from the Army and a Government-surplus 1944 General Electric 380 hp (289 kw) yard switcher, is also used for routine car movements on the Center tracks. Two additional 1945 Alco diesel-electric locomotives were received from the Army in 1974 for crash testing and track-train dynamics testing programs and ten more are expected.

Rail Rapid Transit Test Facilities

The rapid transit test facilities operated by the Urban Mass Transportation Administration (UMTA) include a 9.1 mile (14.5 km) transit track loop, electrified via a third rail, plus an adjacent 200 ft. by 40 ft. (61 m x 12.2 m) Transit Maintenance Building with a 100-foot (30.5 m) service pit and with a spur track passing through the building. The transit track is built of six different combinations of welded and jointed rail on wooden or concrete crossties, representative of track construction found on various transit properties. Direct current, 600-volt, electric power for the third rail is temporarily supplied by the generator of the Center's heavy road diesel electric locomotive, supplemented by two 500 kw stationary diesel-powered alternator-rectifier units. A contract has been awarded to provide permanent commercial electric power, with completion in 1977.

Recently added features of the rapid transit complex include a track scale adjacent to the Transit Maintenance Building. This scale has the capacity to weigh a three-axle locomotive truck having a load of up to 70,000 lb. (31,752 kg) per axle and a truck wheelbase of as short as 13 ft. 7 in. (4.14 m). It will be used primarily for test verification of gross weights on railroad and transit equipment.

Additional track work in process or proposed for the near future will provide a 150-foot (45.7 m) radius tight-turn "screech" loop and electrification of a two-mile (3.2 km) stretch of transit track with an overhead catenary system. Long-term plans for rail transit facilities call for concrete slab trackage, elevated structures, tunnels and additional car dynamics structures.

Rail transit test operations are monitored for UMTA by the Transportation Systems Center (TSC) of Cambridge, Massachusetts, under interagency support agreements.

Rail Dynamics Laboratory (RDL)

Development of the FRA/UMTA jointly-sponsored RDL is continuing with the building complete and operating personnel occupying the facility. The Laboratory's end-of-car "vertical shaker table" is being readied for its first test project.

Figure 54. Aerial view, Looking Generally East at the Completed Sections of Conventional Railroad Test Track at the HSGTC. The 5.7-mile (9.2 km) Train Dynamics Track Extends from the Foreground of the Photograph through a Series of Sinuous Curves to the Operations Area in the Right Background. The 0.76-mile (1.22 km) Impact Facility Track Tangent Runs off the Photograph to the Right in the Near Background. Also Visible is the Northeast Curve of the Transit Loop between the Operations Area and the Impact Facility Track.

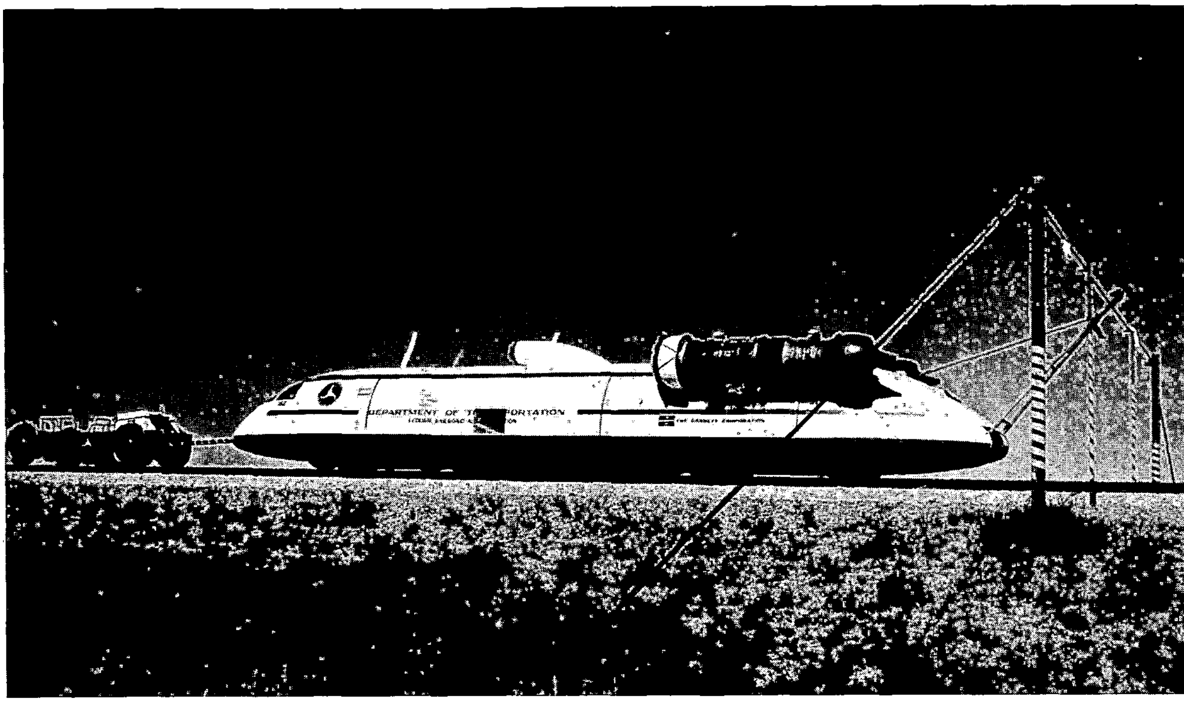


Figure 55. Emergency Arresting Cable Installation for LIMRV.

Linear Induction Motor Research Vehicle Test Facilities

Testing facilities for the LIMRV, which was the first test project at the Center, were described in the Sixth Report of this series, dated 1972. Structures since added include hardstands and jet engine fueling and starting facilities near the north end of the 6.2 mile (10 km) track and the emergency arresting cable installation at the south end of the track (Figure 55). On this track, a new world's speed record for steel-wheel rail vehicles of 255.4 mph (411 km/h) was set by the LIMRV in August of 1974.

Tracked Levitated Research Vehicle Test Facilities

To a 1500 foot (457 m) length of the completed 3 miles (4.8 km) of the U-shaped concrete guideway for the TLRV has been added an 8,000-volt, three-phase, AC wayside power system and a center aluminum reaction rail, 23 inches (58.5 cm) high required for the LIM recently installed in the vehicle. A temporary building, 20 ft. by 30 ft. (6.1 m x 9.1 m), has been erected near the TLRV Maintenance Building at the north end of the guideway to provide additional shop space.

Prototype Tracked Air Cushion Research Vehicle Test Facilities

The first 3.13 miles (5 km) of guideway for the PTACV has been completed and equipped with a 4,160-volt, three-phase, AC wayside power system and a 33-inch (83.8 cm) high, centered aluminum reaction/guidance rail for PTACV operation. A PTACV Maintenance Building is also complete. These facilities are shown in Figure 56. Work on electrification of an additional 2.6 miles (4.2 km) is progressing.

Flame Test Facility

An isolated site (Figure 57) near the geographic center of the HSGTC has been designated for further tests being conducted under the Tank Car Torching Study of the Safety Research Program. A Safety zone, one mile (1.6 km) in diameter, surrounds the site.

6.2 Support Facilities Status

Support facilities construction, both completed and in process, has accelerated in keeping with the increased testing activities during the period of this report. The following paragraphs describe this construction.

Buildings

The Center currently has nine permanent or semi-permanent buildings, two of which are under construction, and twenty office-type trailers which are being used as temporary office quarters. The two buildings under construction are the Technical Services Building, which will be completed late in 1974, and the Operations Building, which is scheduled for July 1975 completion.

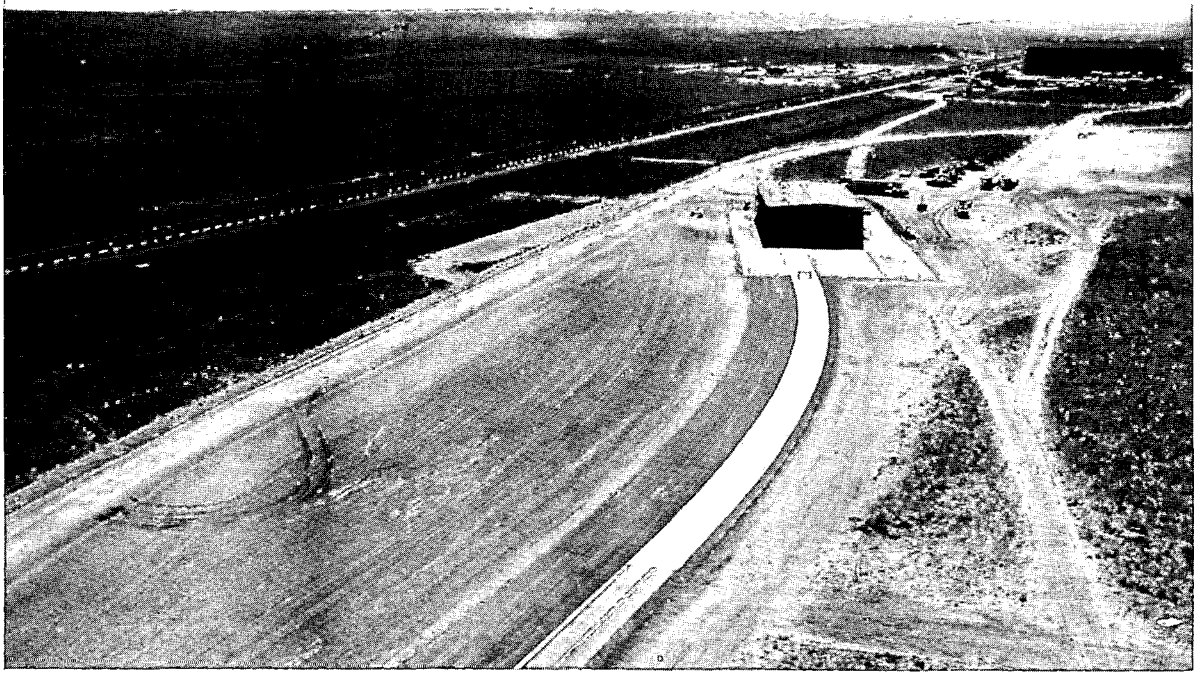


Figure 56. The Prototype Tracked Air Cushion Vehicle Service Building and Guideway at the High Speed Ground Test Center. (Since This Photo Was Taken, the Center Reaction/Guidance Rail and Wayside Power System Have Been Installed to the Guideway as can be seen in Figure 17.)

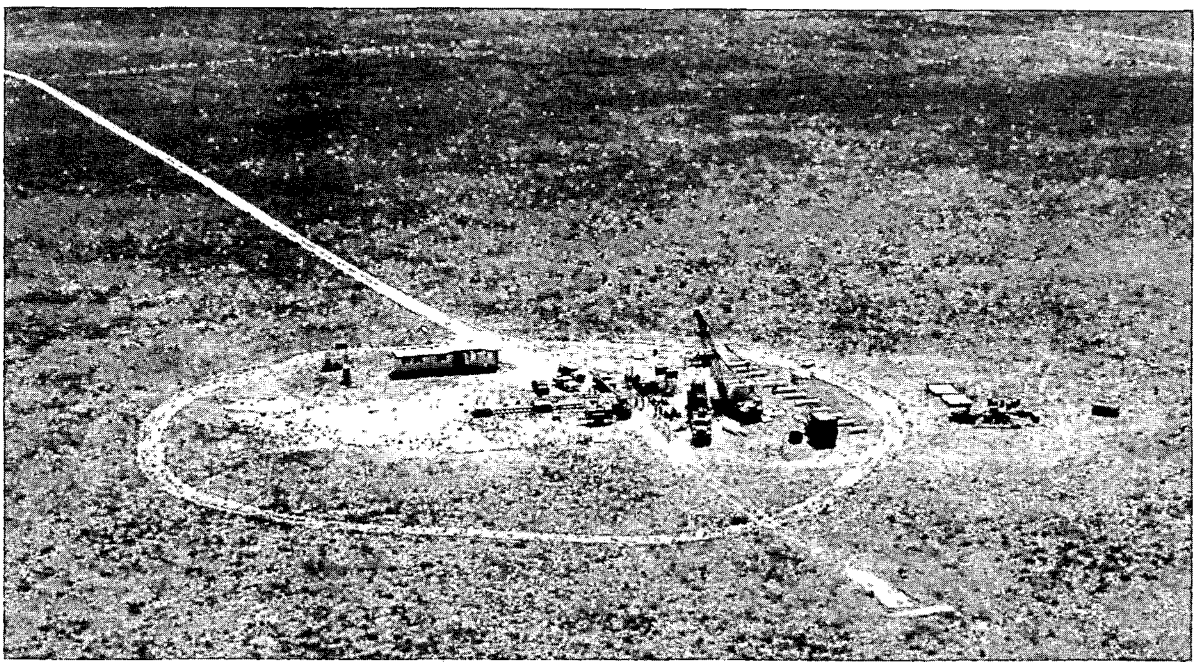


Figure 57. Flame Test Facility.

The Technical Services Building is a large general support facility which was described in the Seventh Report. A new spur line will connect the Center's conventional rail complex with the seven service tracks at the building (Figure 58).

The Operations Building, a 28,700 sq. ft. (2,666 sq. m) structure, will be utilized for the use of Government's and the Operations and Maintenance contractor's staff. A model of this building is shown in Figure 59. Approximately 11,000 sq. ft.

(1,022 m^2) will be devoted to office space with the remainder containing a Central Control/Data Collection area, a cafeteria to feed 500 people, and a conference room with a capacity of 200 people.

The remaining seven buildings have all been described in previous reports. Four semi-permanent (metal) buildings are used for test program support; namely, the LIMRV, PTACV, TLRV and Transit Maintenance Buildings. The other three are the Rail Dynamics Laboratory, the Project Management Building and the Storage and Maintenance Building.

Office-type trailers are used at the Center for support services on a temporary basis and are moved as requirements change. There are currently trailer offices for: Impact Test Area Support, Public Affairs, Test Controllers, Technical Writers, Safety and Federal Highway Administration, First Aid Facility, Radio Communications, Data Van and Tape Storage, Guard Station at entrance road, Maintenance Department, Firemen's Quarters, Center Support Management, Engineering Staff (2 trailers), Track and Guideway Maintenance, Maintenance Storage (2 trailers), Federal Highway Administration Laboratory, TLRV Support and LIMRV Support.

Electrical Power Distribution System

The main electrical power distribution system has been connected to the Rail Dynamics Laboratory, the Project Management Building and temporary office quarters on adjacent property. An extension of this distribution system is intended to supply permanent power to all other test facilities except the LIMRV Building and the remotely-located deep-well pump which will continue to utilize diesel generators for electric power.

Roads and Bridges

Improved maintenance of existing service roads and upgrading with gravel base have made the quality of these roads much better and provided all-weather access around areas that are closed during test periods. Funds have been set aside for paving the gravel county road from the Center to the Pueblo Airport and construction is expected to start in the winter of 1974.

Water Supply and Waste Disposal

The water supply system, put into operation in January of 1972, continues to be adequate for Center needs. Sanitary waste disposal for the seven operational buildings is handled by septic tanks and drain tile fields. Solid waste is currently being hauled away but, with the volume increasing, a sanitary landfill operation is being considered.

Facilities Master Plan

Preparation of a facilities master plan for the HSGTC describing all facilities, test tracks and utilities is under contract with A/E firm in Denver, Colorado. The plan will encourage the orderly development of the Test Center and serve as an aid to management in planning, programming and budgeting for the Center. The plan should also be helpful as a guide to future users of the Center.

6.3 Operations

Advanced Systems

The LIMRV, built for the FRA by Garrett AiResearch Corporation, was equipped with a pair of Air Force surplus J520P3 turbojet engines to serve as thrust boosters. A rear-mounted emergency arresting gear tailhook and frame with an aircraft-type drag chute were also installed. These recent additions can be seen in the view of the LIMRV in Figure 55.

The TLRV, built by Grumman Aerospace Corporation entered its third year at the Center with a newly installed LIM and power conditioning unit (PCU) (built by Garrett AiResearch Corporation) that provides a 4,000 hp (2984 kw) propulsion system to give the vehicle an expected potential in the 240 mph (386 km/h) range. Limited testing, not under electric propulsion, was conducted after the installation of the LIM was completed. For electric propulsion testing, a 1500-foot (457 m) section of the U-shaped guideway is now equipped with wayside power and reaction rail.

Rail Systems

In an operation of special significance because it is the first industry-financed proprietary testing activity at the Center, American Steel Foundries (ASF) used the Rail Transit Test Track to test freight car truck components during the summer of 1974. The ASF four-car consist is shown behind the Center's heavy road diesel electric locomotive on the transit test track in Figure 60. The excellent condition of the transit trackage and roadbed provided truck testing conditions consistently superior to any encountered on other trackage available for testing elsewhere.

FRA test projects conducted at the Center during the period of this report included a series of 120 mph (193 km/h) ride-quality tests of a newly-developed locomotive truck intended for high-speed AMTRAK service, four 50 mph (80 km/h) locomotive-automobile impact tests and Tank Car Torching Study tests which are a continuation of the FRA's Hazardous Material Tank Car Safety Research program.

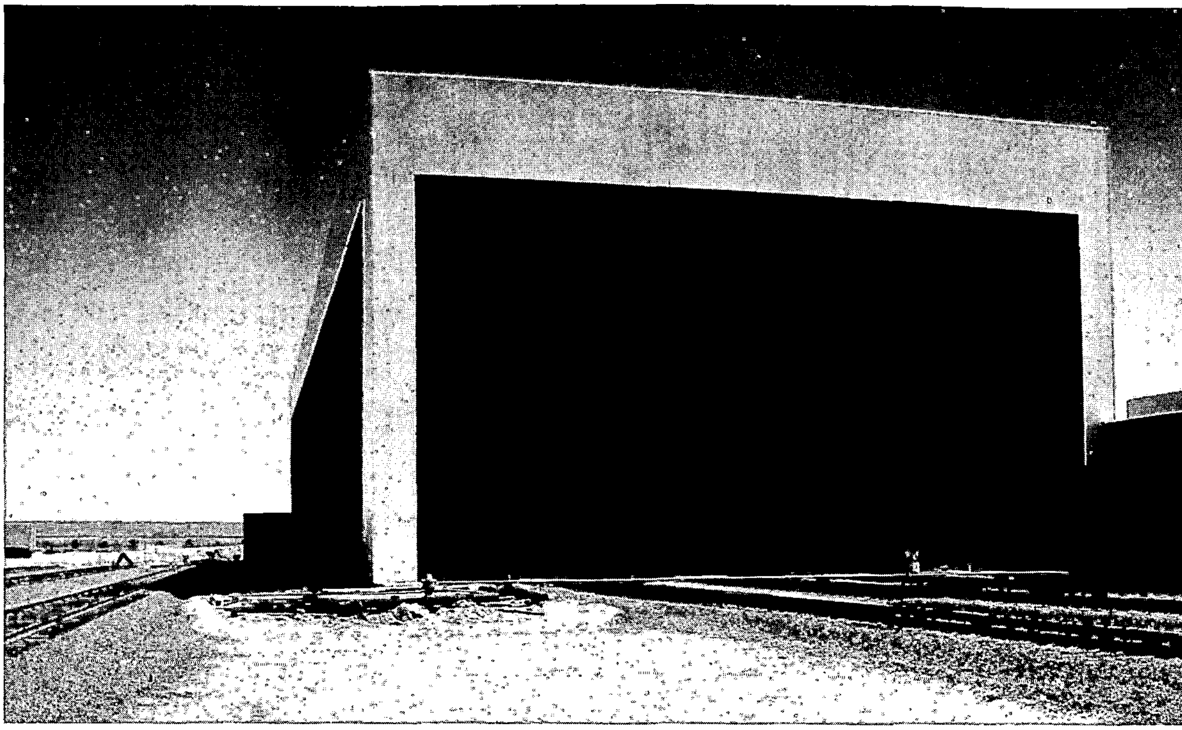


Figure 58. Technical Services Building and Spur Tracks.

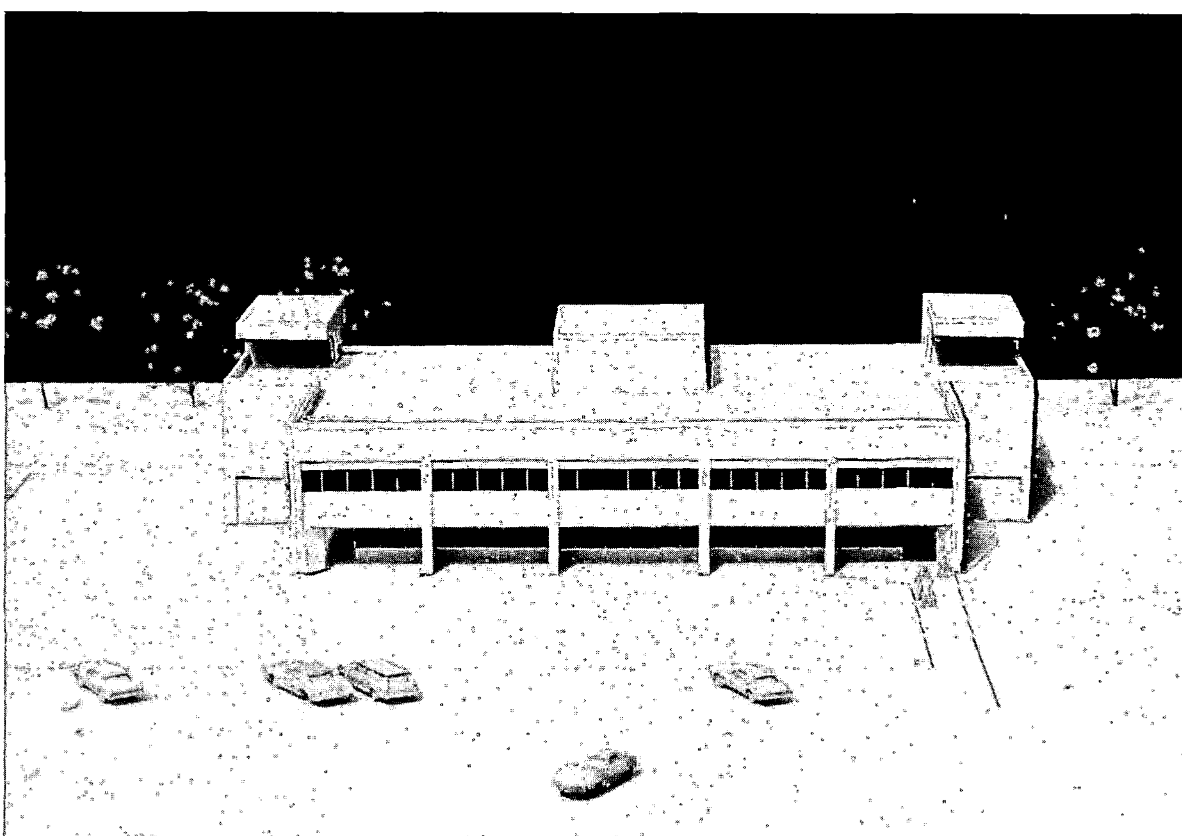


Figure 59. Model of the Operations Building Presently under Construction at the HSGTC.

Figure 60. American Steel Foundries Four-Car Test Train Being Pulled by the DOT 001 3,000 hp Heavy Road Diesel Electric Locomotive on the Transit Loop at the HSGTC in the Summer of 1974.

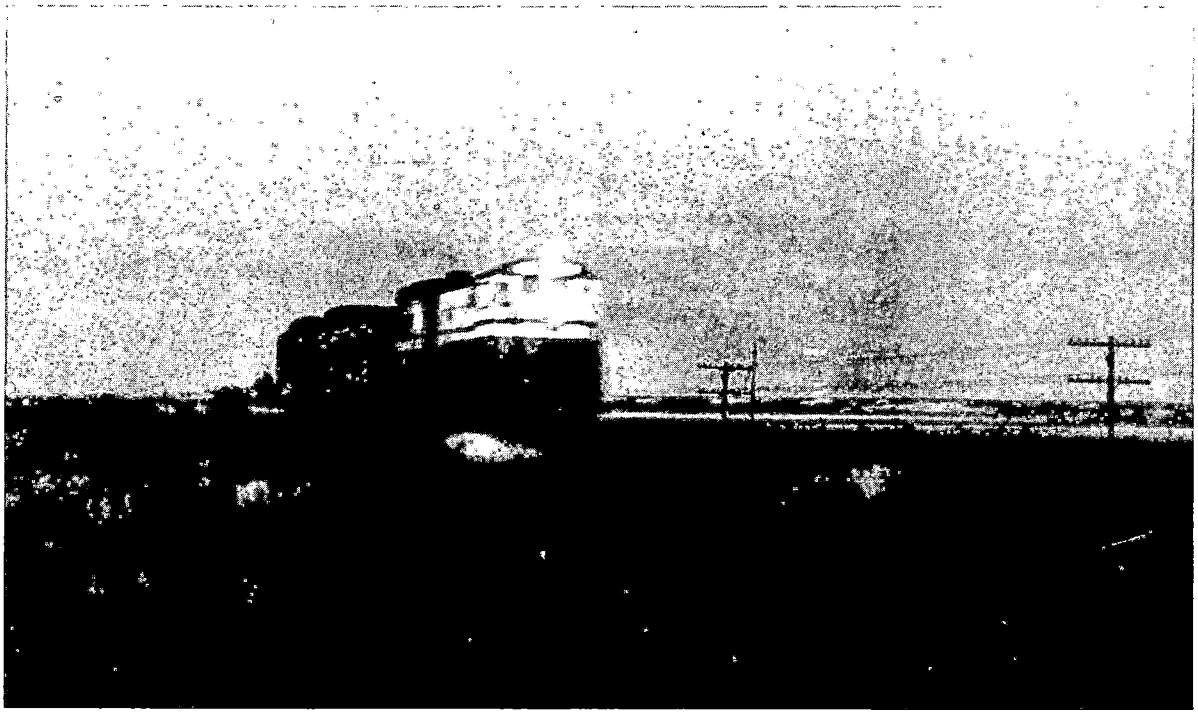


Figure 61. DOT 001 Locomotive Running at 120 mph at Dusk, October 31, 1973, on ATSF Main Line East of La Junta, Colorado, in Tests Qualifying a Locomotive Truck Design for High Speed AMTRAK Service.

The Center's high speed heavy road diesel electric locomotive was used as a test vehicle for measurement of ride quality parameters of a locomotive truck developed by General Electric Company in conjunction with the AAR Track-Train Dynamics Program. Numerous acceleration, displacement and wheel/rail force data were collected at speeds of 120 mph (193 km/h) on The Atchison, Topeka and Santa Fe (ATSF) mainline east of La Junta, Colorado (Figure 61). The tests, completed in October of 1973, validated the mathematical model of the design and qualified it for high-speed AMTRAK service.

A series of four locomotive-automobile impact tests, simulating collisions at rail-highway grade crossings, was conducted in February and March of 1974. The Center's original 1945 Alco diesel-electric locomotive used for the tests was fitted with an automatic control system for remote operation at 50 mph (80 km/h). High-speed motion picture cameras were located on the locomotive, on the ground and on the stationary automobiles (standard-size 1973 four-door sedans, selected because they met all current DOT-required structural specifications) to make visual records of the tests during and after impact. Extensive instrumentation of both the locomotive and the automobile, as well as an instrumented anthropomorphic dummy in the driver's seat of the car, was used in the final two tests. (See Figure 5 (a–d) above).

Tank Car Torching Tests at the HSGTC, a continuation of the earlier tank-car burn tests conducted at White Sands Missile Range and reported in the Seventh Report, are expected to extend through July of 1975. Torching tests on tank car plate and one-fifth scale tank burn experiments are being conducted to obtain guidelines for the reduction of major explosions of hazardous material tank cars. Elements to be investigated include a thermal shield coating of the vessels and modified vent-valve controls. Additional areas of study involve end-shielded mechanical protection against coupler intrusion into the vessel, utilizing full-scale dynamic evaluation of typical road operation and impact testing.

UMTA Rail Transit Systems

Progress has also been made in a number of UMTA projects. The State-of-the-Art Cars (SOAC) (Figure 62) completed as uccessful test program in April of 1974. Test programs are continuing for four Gas Turbine-Electric cars (Figure 63) and a pair of New York subway cars with on-board energy storage system equipment (Figure 64). To other New York subway cars (Figure 65) have been involved in a continuing program of developing track-measuring instrumentation, installations and methods. The arrival of the Standard Light Rail Vehicle in early 1975 should initiate still further activity on the Transit Test Track oval.

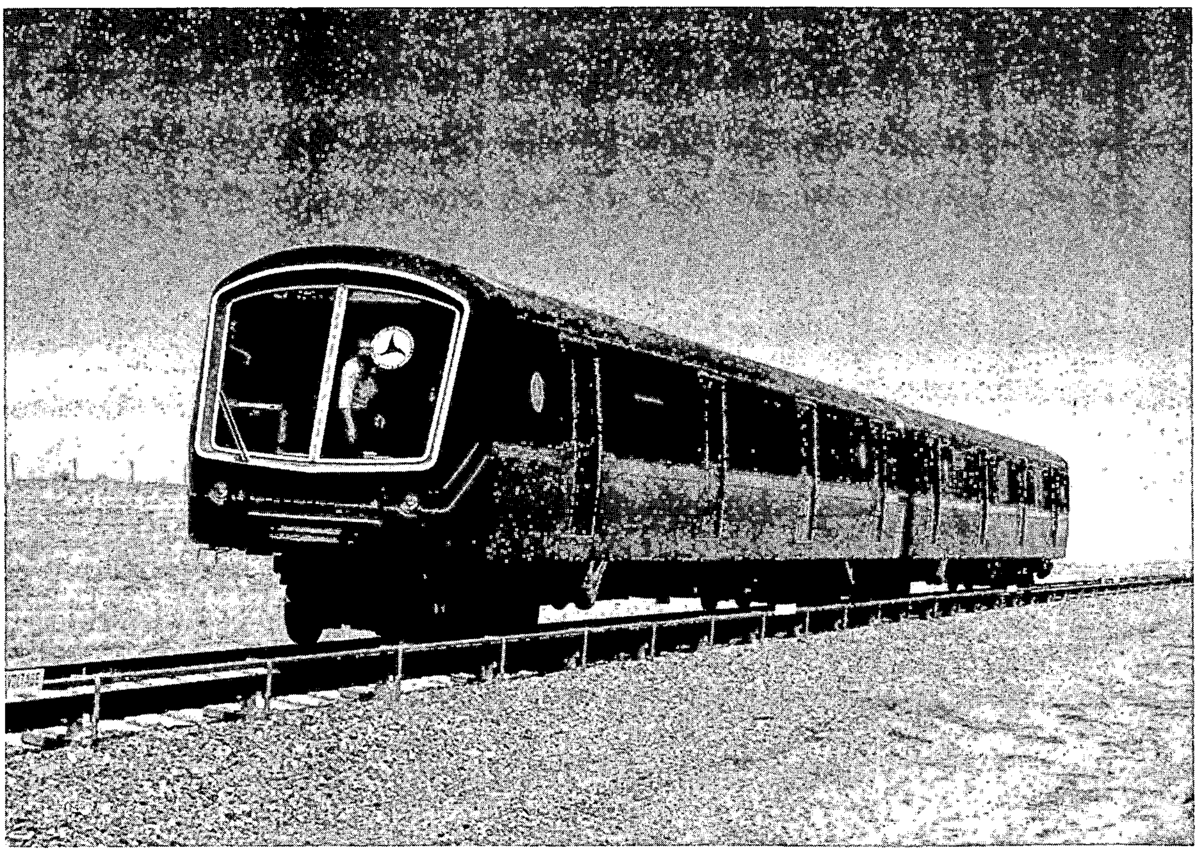


Figure 62. Boeing Vertol's State-of-the-Art Cars Which Completed a Test Program in April 1974 and Subsequently Began a Demonstration Program Scheduled for Five Major Cities: New York, Boston, Philadelphia, Chicago and Cleveland.

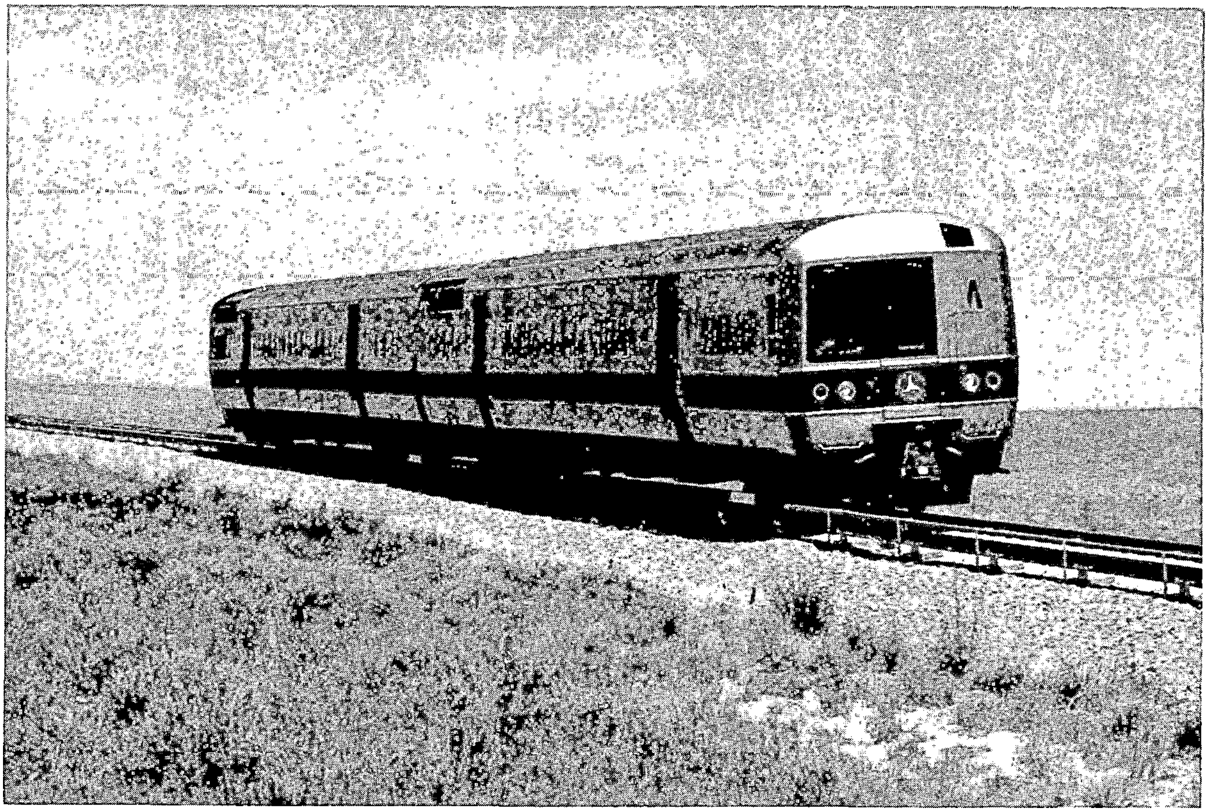


Figure 63. Two of the Four Garrett AiResearch Gas Turbine-Electric Cars Being Tested on the 9.1-mile (14.6 km) Transit Loop. These 100-mph (161 km/h) Rapid Commuter Cars Are Being Developed for the New York Metropolitan Transit Authority for Use on Long Island.

The SOAC, a two-car set designed and produced for UMTA by the Boeing Company, Vertol Division, was developed to demonstrate the optimum in current rapid transit technology.

Approximately 20,000 car miles (32,187 km) were put on the SOACs during the test program which ran from September of 1972 to April of 1974. The program included acceptance tests, extensive engineering tests and approximately 6,000 miles (9,656 km) of simulated transit property operation. Upon completion of the SOAC test operations at the Center, the cars began demonstration service in selected major metropolitan area subway systems.

Four Gas-Turbine-Electric transit cars produced by the Garrett AiResearch Corporation began a test program at the Center in July of 1974. These cars, designed to run on wayside electric power when it is available and to generate their own power for running on non-electrified track, are capable of 100 mph (161 km/h). During testing, they are powered by the Transit Test Track's electrified third rail or by their self-contained gas-turbine electric propulsion system. Following their six-month test program at the Center, they will be used in commuter service over both electrified and non-electrified track in the New York metropolitan area.

Two specially-equipped New York City Transit Authority R–32 subway cars have been undergoing tests at the Center since February of 1974. In these cars, the conventional electric propulsion system has been replaced with a Garrett AiResearch Corporation On-Board Energy Storage System, utilizing a flywheel principle. With this system, the energy normally wasted during dynamic braking is stored in the flywheel and extracted when needed for the next start and acceleration. This system is intended to reduce total energy consumption, reduce the electric peak-rate demand on the wayside power supply and reduce the normal dynamic-braking heat radiated to the subway tunnels and stations. After completion of the test program at the Center, these two cars will be returned to revenue service in New York's subways where more "real life" data will be obtained on the energy-storage-system equipment.

A pair of R–42 subway cars from New York have been used at the Center since 1972 in a continuing program for the development of improved

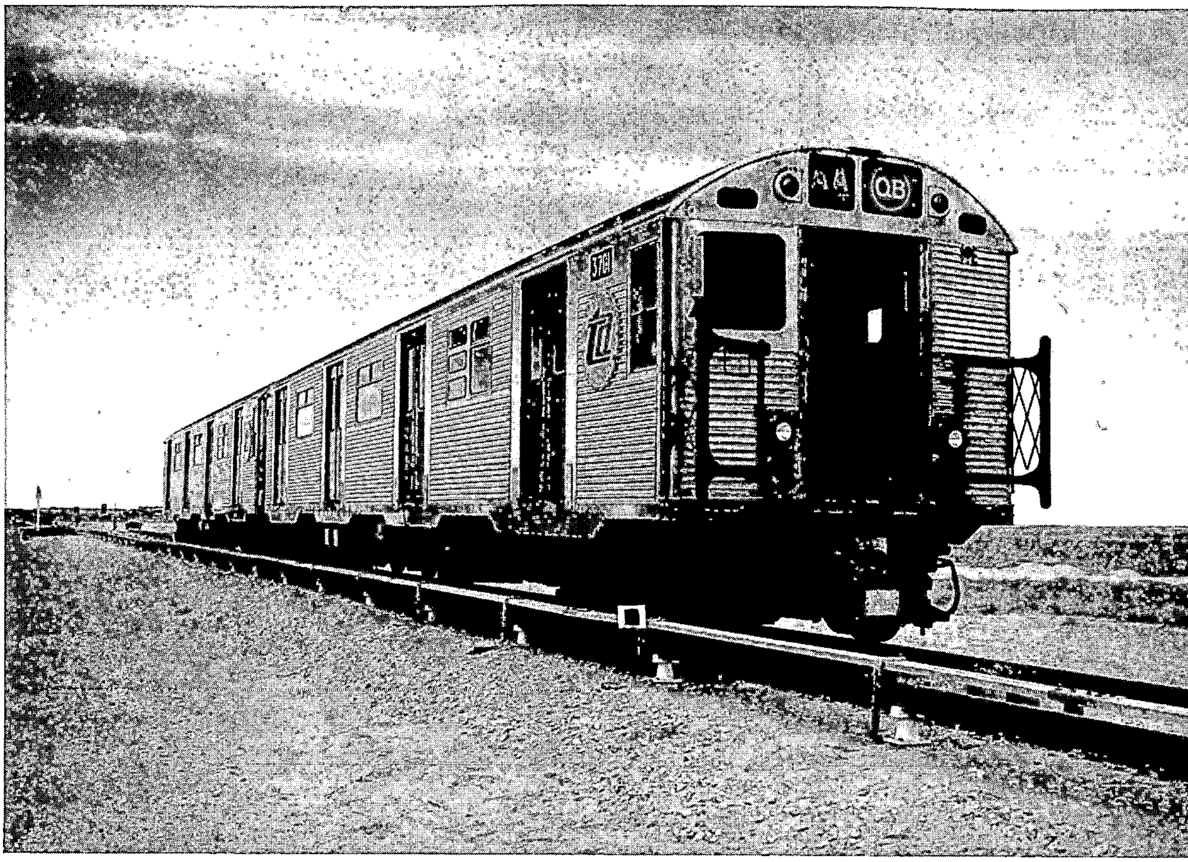


Figure 64. Two R–32 New York City Subway Cars Retrofitted with the Garrett AiResearch On-Board Engergy Storage System Which Uses Energy Normally Wasted by Dynamic Braking to Rotate a Flywheel.

test instrumentation and methodology. This program has a new track geometry measuring system which can accurately determine track structure conditions at normal operating speeds. That system incorporates computerized data acquisition equipment.

The United States Standard Light Rail Vehicle built by the Boeing Company's Vertol Division, the first new light rail vehicle (trolley car) designed in the United States since 1929, will shortly be tested on the Transit Test Track where 2 miles (3.2 km) of overhead catenary will be installed for power.

Operations Personnel

The responsibilities of various Department of Transportation personnel remain essentially as described in the Seventh Report. At the end of Fiscal 1974 (June 1974), the FRA had 14 employees at the Center; there were 4 from TSC (to manage the UMTA programs) and the Federal Highway Administration (FHWA) also had 2. An additional 7 FHWA employees located in downtown Pueblo also work on Center construction projects.

The functions of Kentron Hawaii, Limited, the Operations and Maintenance contractor for the Center, have expanded during the period of this report. Noteworthy additions include staffing the RDL, providing full time fire protection services with a 24-hour seven-day-a-week fire department, and security guard service. At the end of FY 1974, the contractor had 174 people at the Center.

6.4 Conservation and Environmental Activities

The Federal Railroad Administration is continuing the reimbursable agreement with the Soil Conservation Service (SCS), U.S. Department of Agriculture, to receive technical assistance on which to develop and manage a long-range conservation plan for the Center. The agreement includes provisions for on-site assistance by SCS in developing and applying sound conservation practices. Natural resource inventories have been prepared by SCS and include information on climate, soil, vegetation, wildlife, geology, historic and archeological values, recreation opportunities, hydrologic, and revegetation potentials. A joint effort is now

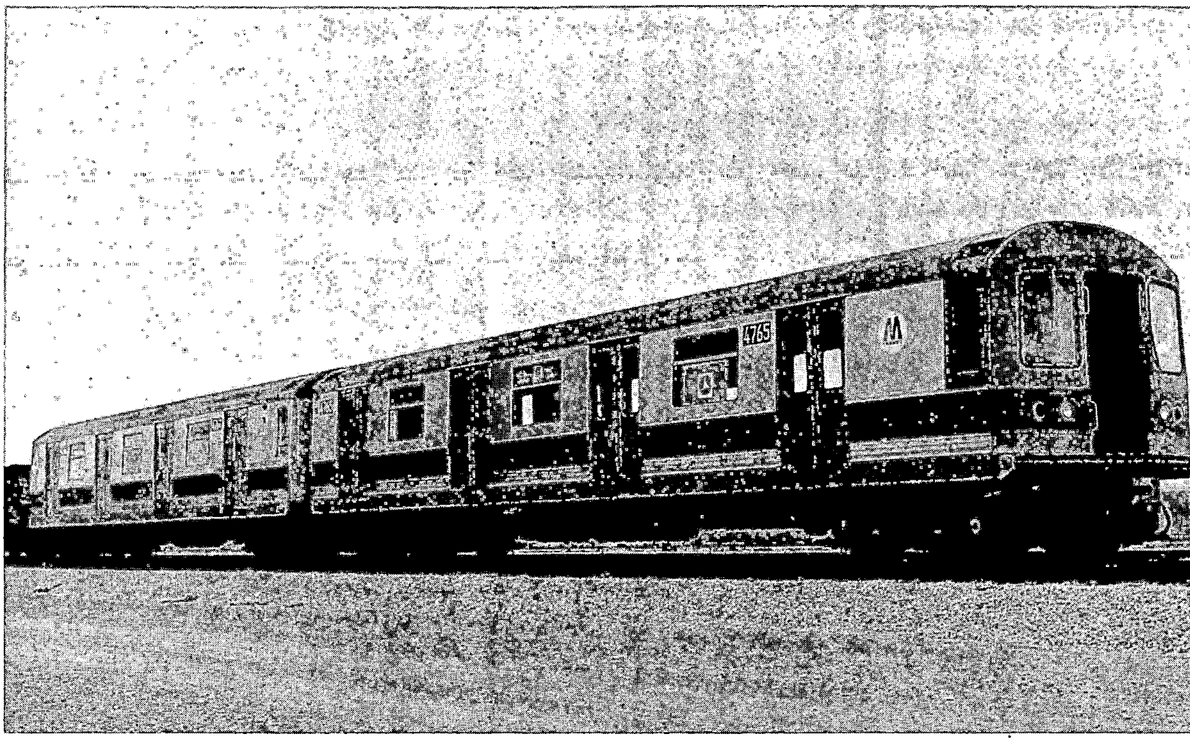


Figure 65. New York City R–42 Subway Cars Used at the HSGTC for the Development of a New Track Geometry Measuring System.

being conducted by Center and SCS personnel for evaluation of plant materials for stabilization of the sandy soils at the site. An area of plantings north of the Technical Services Building has been established at the Center for this purpose. The information obtained will be utilized to implement a sound conservation plan to protect the Government's facilities and make the best possible use of its resources.

6.5 Non-Government Use of Test Facilities

During 1974, a special assistant to the Director of the Center was appointed from a list of candidates from the railroad industry submitted by the Railway Progress Institute as a part of the President's Executive Interchange Program. Bringing to the position skills and experience in marketing, he is responsible for liaison with the railroad industries and is working to encourage their use of the Center facilities. One concrete result of these efforts is the American Steel Foundries freight car test program conducted on the UMTA Transit Test Track oval during the summer of 1974—the first industry-financed project at the DOT facility. This project is described in more detail under "Conventional Rail Systems" in Section 6.3 above.

The Association of American Railroads (AAR) is currently involved in train stability tests related to Track-Train Dynamics Program requirements and will introduce other programs in the future for furthering the state of the art in railroad technology.

6.6 Public Affairs

As testing and construction activities develop, increasing numbers of people have expressed interest in visiting and learning about the Center. The interest is varied, ranging from casual telephone inquiries for information to VIP tours conducted for high-level government and industrial groups and individuals, both domestic and foreign. Over four thousand persons visited the Center in 1974. Notable groups and individuals included:

Congressional

Congressman Brock Adams
Congressman Donald G. Brotzman
Congressman Dan H. Kuykendall
Congressman Dick Shoup

Government

Mr. J. W. Barnum, Under Secretary of Transportation, DOT

Mr. J. W. Barriger, Special Assistant to the Administrator, FRA

Mr. Henry L. Miller, Voice of America

Foreign

Correspondents from Australia, Germany, Great Britain, Brazil, China (Taiwan), France, Italy, Japan, Poland, and Switzerland.

Technical groups from Netherlands, France, Australia, Italy, Germany, Japan, Belgium, Great Britain and Spain.

Individuals included Mr. Fillipo Bardoni, Director General Italian Railroads; Mr. Hans Kalb and Dr. Ing. Heinrich Lehmann, Presidents of Deutsche Bundesbahn; Mr. Francisco Lozano, President of Administrative Council, Spanish Railways.

High Speed Ground Transportation Advisory Committee Tour

The Secretary of Transportation's High Speed Ground Transportation Advisory Committee, accompanied by a party of FRA officials headed by the FRA Deputy Administrator, participated in an Advisory Committee business meeting and tour of the facilities at the Center on Tuesday, October 23, 1973. The group is shown in Figure 66.

Figure 66. The High Speed Ground Transportation Advisory Committee and their DOT Escorts Toured the HSGTC on October 23, 1973. From Left to Right: Dr. William J. Harris, Jr.; Glen A. Reiff;* J. K. Records; Robert M. Jenney; Henri F. Rush;* Harry L. McKee, Chairman; Myles B. Mitchell;* Wallace D. Johnson; Charles J. Chamberlain; and Bunli Yang.* (* DOT Staff).

7.0 ADMINISTRATION

7.1 Funding

Obligations against the HSGT Appropriation and Railroad Research and Development Appropriation in FY 1974 are listed by name, amount, organization, and the contractor's location in Appendix A.

In FY 1975, the budget authority in the combined HSGT and Railroad Research and Development Appropriations is $40.2 million.

7.2 HSGT Advisory Committee

The Advisory Committee established by the Act of 1965 and appointed by the Secretary of Transportation continued to meet during the year in accordance with its charter for reviews and discussions of program developments. The meeting in October 1973 at the Test Center in Colorado provided committee members with a first-hand opportunity to become acquainted with the technological developments there as background for their report of March 1974 to the Secretary on FRA research and development activities in accordance with the requirements of the Advisory Committee Act of 1972. That report stressed energy conservation, the need to adjust to changing national priorities, Government/industry inter-change and the importance of sufficient lead time in new transportation developments. The report recommended strengthening of both FRA and the railroads for fulfillment of their transportation missions, research in advanced systems of ground transportation in anticipation of acceptance because of energy, and R&D in response to emerging investment opportunities. The full report appears as Appendix B.

For the past two years the Advisory Committee has operated under the requirements of the Federal Advisory Committee Act. That Act provides procedures for the establishment, operation and termination of all types of advisory groups utilized by Federal agencies. Under the Act, statutory committees such as the Advisory Committee were required to terminate on January 5, 1975, unless their duration is otherwise provided for by law. As with many other statutory committees, the legislation creating the Committee was silent with respect to its duration.

The chief function of the High Speed Ground Transportation Advisory Committee has been to advise the Secretary with respect to policy matters arising in the Administration of FRA's research and development program. It has no regulatory role and is, therefore, being terminated as of January 5, 1975.

The membership of the Advisory Committee did not change in the past year and includes:

Mr. Harry L. McKee, Chairman of Committee
Corporate Director-Advanced Planning
McDonnell-Douglas Corporation
St. Louis, Missouri 63166

Dr. William J. Harris, Jr.
Vice President
Research & Testing Department
Association of American Railroads
1920 L Street, N.W.
Washington, D.C. 20036

Mr. Robert M. Jenney, President
Jenney Manufacturing Company
P.O. Box 100
Chestnut Hill, Massachusetts 02167

Mr. Wallace D. Johnson, President
Howe, Barnes and Johnson, Inc.
208 South LaSalle Street
Chicago, Illinois 60604

Mr. J. K. Records
5000 A-1 E. Henrietta Road
Henrietta, New York 14467

Mr. Roger Lewis, President
National Railroad Passenger Corporation
(AMTRAK)
Room 8060
955 L'Enfant Plaza, North
Washington, D.C. 22024

Mr. Charles J. Chamberlain
President, Brotherhood of Railroad Signalmen
601 W. Golf Road
Mt. Prospect, Illinois 60056

APPENDIX A

FY 1974 CONTRACT OBLIGATIONS AS OF JUNE 30, 1974

OFFICE OF RESEARCH, DEVELOPMENT AND DEMONSTRATIONS CONTRACT OBLIGATIONS FOR FISCAL YEAR 1974

Scope of Work	*Contract Amount*	*Contractor*	*Location*
RAIL RESEARCH AND DEVELOPMENT			
Track Structures			
Ballast Consolidator Maintenance	$ 18,500	Plasser-American Corporation	Chesapeake, Va.
Study of: 1) Vibration Environment in a Freight Vehicle 2) Sources of Diesel Engine Noise Emission 3) Improved Diesel Locomotive Wheel-Rail Adhesion & Wear	30,000	Illinois Institute of Technology	Chicago, Ill.
Track Stability	57,023	Princeton University	Princeton, N.J.
Experiments with: 1) Cold Weather Performance of Concrete Ties & Tie Fasteners 2) Ballast-Binding Material	99,960	Alaska Railroad	Anchorage, Alaska
Tests of: 1) Internal Track Stability 2) Concrete Tie & Threadless Fasteners	57,226	Chessie System	Cleveland, Ohio
Track Stability	21,723	New York University	New York, N.Y.
Kansas Test Track: Design, Construction, Operation & Maintenance	337,617	AT & S Fe Railroad	Chicago, Ill.
Kansas Test Track: Computer Services	3,500	Control Data Corp.	Rockville, Md.
Railroad Test Track Construction	3,300,000	Federal Highway Administration (Region 8)	Denver, Colo.
Rail Systems Dynamics	325,000	Transportation Systems Center	Cambridge, Mass.
Track Performance Improvements	58,600	Transportation Systems Center	Cambridge, Mass.
Rail Material Evaluation and Utilization	48,000	Transportation Systems Center	Cambridge, Mass.
State-of-the-Art Survey: Rail Joining	43,390	Transportation Systems Center	Cambridge, Mass.
Continuous Measurement of Longitudinal Rail Stress	25,000	University of Oklahoma	Norman, Okla.

Scope of Work	Contract Amount	Contractor	Location
Operation and Maintenance of Test Car Instrumentation & Data Collection Systems	1,037,354	Ensco, Inc.	Springfield, Va.
Test Car Operation & Maintenance	95,000	Penn Central Transportation Company	Philadelphia, Pa.
Test Car Support: Computer Services & Data Processing	325,000	Control Data Corp.	Rockville, Md.
Development of Track Inpedance Measurement Instrumentation	28,500	Batelle Columbus Laboratories	Columbus, Ohio
Miscellaneous	17,245	Various	Various
TOTAL	$ 5,928,638		

Rail Dynamics Laboratory (RDL)

Scope of Work	Contract Amount	Contractor	Location
RDL Building (Construction Contract Changes)	129,142	H. W. Houston Construction Co.	Denver, Colo.
Systems Engineering	1,387,244	Wyle Laboratories, Incorporated	Colorado Springs, Colo.
Computer System	651,283	Datacom, Inc.	Ft. Walton Beach, Fla.
Carriage Assemblies and Reaction Structures	1,011,662	Boeing Company	Seattle, Wash.
Drive Trains	49,500	General Electric Company	Schenectady, N.Y.
Analog Data Acquisition and Control System	1,243,994	EDMAC Associates, Incorporated	Rochester, N.Y.
Communications Systems	140,000	Reaction Instruments, Inc.	McLean, Va.
Miscellaneous	9,438	Various	Various
TOTAL	$ 4,622,263		

Improved Safety

Scope of Work	Contract Amount	Contractor	Location
Full-Scale Tank-Car Fire Test	$ 50,060	Ballistics Research Laboratory	Aberdeen, Md.
Full-Scale Tank-Car Fire Test	13,500	White Sands Missile Range	White Sands, N.M.
Tank Car Safety Relief Valve Tests	35,000	Air Force Rocket Propulsion Laboratory	Edwards AFB, Calif.
Tank Car Thermal Coating Evaluation	225,000	Ballistics Research Laboratory	Aberdeen, Md.
Tank Car Yard Impact Modeling	195,000	Washington University	St. Louis, Mo.
Metallurgical Studies of Tank Car Steels	182,060	National Bureau of Standards	Gaithersburg, Md.
Fatigue Analysis of Tank Car Head Shields	31,000	Louisiana Tech. University	Ruston, La.
Studies of: Cost Benefit of Tank Car Head Shields, Tank Car Coatings, Cryogenic Ethylene Tank Car Specifications	10,000	Calspan, Inc.	Buffalo, N.Y.
Component Failure Prevention	1,050,000	Transportation Systems Center	Cambridge, Mass.
Grade Crossing Research	800,000	Transportation Systems Center	Cambridge, Mass.
Human Factors Research	200,000	Transportation Systems Center	Cambridge, Mass.
Improved Flaw Detection	65,000	Transportation Systems Center	Cambridge, Mass.
TOTAL	$ 2,856,620		

Scope of Work	Contract Amount	Contractor	Location
Improved Freight Service			
Truck Design Optimization	$ 886,672	Southern Pacific Transportation Co.	San Francisco, Calif.
Freight Car Dynamics Performance Model	54,000	Clemson University	Clemson, S.C.
Track-Train Dynamics Program Support	247,618	Association of American Railroads	Washington, D.C.
Improved Rail Freight Service Systems Engineering	271,000	Transportation Systems Center	Cambridge, Mass.
Membership	25,140	International Union of Railways	Paris, France
Membership	2,298	International Railway Congress Asso.	Brussels, Belgium
Technical Information Acquisition	7,000	International Union of Railways	Paris, France
TOTAL	$ 1,493,728		
Metroliner			
New Carrollton Intermodal Station	$ 14,336	Washington Metropolitan Area Transit Authority	Washington, D.C.
Metroliner Improvement	107,751	Penn Central Transportation Co.	Philadelphia, Pa.
Modify Metroliner	692,135	Westinghouse Electric Co.	Pittsburgh, Pa.
Modify Metroliner	143,877	General Electric Company	Erie, Pa.
Modify Trucks	116,011	TLV Aerospace Corporation	Dallas, Texas
Modify Trucks	46,718	Budd Company	Philadelphia, Pa.
Miscellaneous	8,218	Various	Various
TOTAL	$ 1,129,046		
RAIL R&D TOTAL	$16,030,295		
HIGH SPEED GROUND TEST CENTER (HSGTC)			
Investment			
A/E Services for Facility Master Plan	$ 150,000	URS/Ken R. White Co.	Denver, Colo.
Soil Conservation & Environmental Protection Services	22,000	U.S. Dept. of Agriculture Soil Conservation Service	Denver, Colo.
A/E Design Modifications for Operations Building	18,404	Nelson, Haley, Patterson & Quirck, Inc.	Greeley, Colo.
A/E Design Electrical Power Distribution	26,660	Laramore, Douglas & Popham, Inc.	Chicago, Ill.
Technical Services Facility Architectural Display Model	6,000	Nelson, Haley, Patterson & Quirck	Greely, Colo.
Main Site Electrification Contract Modifications	24,752	Gardener Zemke Co.	Albuquerque, N.M.
Storage & Maintenance Bldg. Contract Modifications	32,486	Herbert Pugh & Sons	Pueblo, Colo.
Storage & Maintenance Bldg. Contract Modifications	56,624	Kentron-Hawaii, Ltd.	Dallas, Texas
Soil Investigations for Water Supply System	1,629	Meurer, Serafini, & Meurer, Inc.	Denver, Colo.
Construction of Electrical Power Distribution	121,287	Gardener Zemke Co.	Albuquerque, N.M.

Scope of Work	Contract Amount	Contractor	Location
FRA Share of Transit Track Power Distribution Line	275,000	Transportation Systems Center	Cambridge, Mass.
Construction of Operations Bldg.	1,975,000	Leuder Construction Co.	Omaha, Neb.
Technical Services Facility Spur Track Construction	380,000	H.W. Houston Construction Co.	Denver, Colo.
Electrical Power Distribution to Miscellaneous Facilities	510,000	Gardener Zemke Co.	Albuquerque, N.M.
TOTAL	$ 3,599,842		
Equipment			
Calibration Equipment	$ 10,544	Tektronix	Beaverton, Ore.
Calibration Equipment	7,583	Hewlitt-Packard	Palo Alto, Calif.
Fire & Rescue Vehicle	40,000	General Services Administration	Various
Self-Propelled Sweeper	6,500	General Services Administration	Various
Tractor, Loader-Backhoe	16,000	General Services Administration	Various
Fuel-Light Truck	24,000	General Services Administration	Various
Farm Tractor	17,000	General Services Administration	Various
Road Grader	36,000	General Services Administration	Various
Ambulance	10,000	General Services Administration	Various
Radios	26,345	Motorola, Inc.	Washington, D.C.
Rail Dynamics Lab Furniture	13,201	General Services Administration	Various
Surplus Trailer Procurement	20,545	General Services Administration	Washington, D.C.
TOTAL	$ 227,718		
Operations			
Operations & Maintenance Services	$ 1,696,000	Kentron-Hawaii Limited	Dallas, Texas
GSA Supplies	100	General Services Administration	Various
Pueblo Army Depot Support	40,000	Pueblo Army Depot	Pueblo, Colo.
Fuel Supplies	16,852	Continental Oil Co.	Pueblo, Colo.
Generator Rental	15,766	McCoy Co.	Denver, Colo.
Electrical Power Co. Billings	32,700	So. Colorado Power Co.	Pueblo, Colo.
Security Guard Services	538	Haynes Guardian Security Bureau	Pueblo, Colo.
Shipment of Turbo Alternators	1,873	Solar, Inc.	San Diego, Calif.
Demurrage	630	Missouri Pacific Railroad	St. Louis, Mo.
TOTAL	$ 1,804,459		
HSGTC TOTAL	$ 5,632,019		

ADVANCED SYSTEMS R&D

Tracked Levitated Research Vehicle (TLRV)

Scope of Work	Contract Amount	Contractor	Location
TLRV Guideway Construction at HSGTC (Closing Costs)	$ 60,000	Federal Highway Administration (Region 8)	Denver, Colo.
TLRV Wayside Power Rail System Testing	90,000	U.S. Naval Weapons Center	China Lake, Calif.
Continuation of TLRV Propulsion System Fabrication	196,114	AiResearch Mfg. Co.	Torrance, Calif.
HSGTC Support	32,750	Kentron-Hawaii, Ltd.	Dallas, Texas

Scope of Work	Contract Amount	Contractor	Location
TLRV Reaction Rail Design	23,608	Dow Engineering Co.	Houston, Texas
TACV System Engineering Support	227,572	MITRE Corp.	McLean, Va.
Repair & Shipment of TLRV Turbofan Engine	7,620	Grumman Aerospace Corp.	Bethpage, N.Y.
Field testing of TLRV Electrical Propulsion System	786,523	AiResearch Mfg. Co.	Torrance, Calif.
TLRV Power Rail Fabrication	610,000	Advanced Machine Corp.	Los Angeles, Calif.
Transportation for Phase Delay Rectifier & Inverter	760	AiResearch Mfg. Co.	Torrance, Calif.
Shipments of TLRV Components and Fixtures	3,000	AiResearch Mfg. Co.	Torrance, Calif.
Computer Services	10,000	DOT Working Capital Fund	Washington, D.C.
TOTAL	$ 2,047,947		
Tracked Magnetic Levitated Vehicle (TMLV)			
Magnetic Levitated Vehicle (Maglev) Study	$ 30,034	Stanford Research Institute	Menlo Park, Calif.
Air Cushion & Magnetic Vehicle Suspensions Research (partial)	24,000	Mass. Institute of Technology	Cambridge, Mass.
Maglev Study	14,120	Ford Motor Co.	Dearborn, Mich.
TMLV Systems Engineering Support	153,817	MITRE Corp.	McLean, Va.
TMLV Repulsion Study	754,261	Ford Motor Co.	Dearborn, Mich.
Aerodynamic Studies of High Speed Ground Transportation	7,500	Andrew Hammitt Associates	Palos Verdes, Calif.
TOTAL	$ 983,732		
Prototype Tracked Air Cushion Vehicle (PTACV)			
PTACV Guideway Construction at HSGTC	$ 17,000	Federal Highway Administration	Denver, Colo.
PTACV Engineering	382,000	Transportation Systems Center	Cambridge, Mass.
Advanced Air Cushion & Magnetic Vehicle Suspension Research (partial)	24,000	Federal Highway Administration (Region 8)	Denver, Colo.
HSGTC Support	9,700	Kentron-Hawaii, Ltd.	Dallas, Texas
Construction of PTACV Guideway	3,501,123	Rohr Industries, Inc.	Chula Vista, Calif.
TOTAL	$ 3,933,823		
ADVANCED SYSTEMS R&D			
TOTAL	$ 6,965,502		
SUPPORTING TECHNOLOGY			
Propulsion			
Numerical Analysis Method for Linear Induction Motor	$ 50,000	NASA, Jet Propulsion Lab.	Pasadena, Calif.
LIMRV Cost For Two J52–P3 Engines	18,000	Dept. of the Air Force	Kelly Air Force Base, Calif.
Electrical Power & Propulsion	260,000	Transportation Systems Center	Cambridge, Mass.

Scope of Work	Contract Amount	Contractor	Location
Research on Synchronously Operating Linear Motors	75,000	Poly. Inst. of New York	Brooklyn, N.Y.
Field Testing of LIMRV	750,113	AiResearch Mfg. Co.	Torrance, Calif.
Computer Services	11,800	DOT Working Capital Fund	Washington, D.C.
Translation of German Documents	1,840	Information Company of America	Philadelphia, Pa.
TOTAL	$ 1,261,716		
Communications			
Communications Research	$ 80,000	Transportation Systems Center	Cambridge, Mass.
Obstacle Detection Study	16,633	Applied Metro Tech., Inc.	Barrington, N.J.
Communications Support	21,035	MITRE Corp.	McLean, Va.
TOTAL	$ 117,688		
Tunneling & Guideways			
Tunneling Research Committee Support	$ 9,000	National Academy of Sciences	Washington, D.C.
Laser Rock Kerfing Research Investigation	99,716	United Aircraft Research Lab.	East Hartford, Conn.
Water Cannon Test Program	71,596	Terraspace, Inc.	Rockville, Md.
Tunneling Support	98,949	MITRE Corp.	McLean, Va.
Vehicle/Guideway Interactions	35,000	Duke University	Durham, N.C.
Computer Services	1,000	FHWA	McLean, Va.
TOTAL	$ 315,261		
Miscellaneous	$ 2,999	Various	Various
SUPPORTING TECHNOLOGY TOTAL	$ 1,697,664		
ORD&D GRAND TOTAL	$30,325,480		

APPENDIX B

A REPORT BY THE HIGH SPEED GROUND TRANSPORTATION ADVISORY COMMITTEE

Preface

This report is respectfully submitted by the Advisory Committee on High Speed Ground Transportation in accordance with Federal Railroad Administration Order 1120.1. As instructed by the Secretary of Transportation, this Committee has endeavored to examine the content, balance, and purpose of Research and Development carried on under the aegis of the Federal Railroad Administration (FRA).

The Advisory Committee Act of 1972 directs that every advisory committee submit a written report to the Secretary of the sponsoring department annually. This report is the first report in response to that Act. Prior to the Act of 1972, the Committee has provided only verbal reports.

While primarily addressing the research and development activities of the FRA, the Committee has found it necessary to review these activities with the relative role of rail and other transportation modes in mind.

The Committee has from the outset taken the posiitón that research and develop-activities are dedicated to finding significant answers to problems arising from present and future needs for intercity ground transportation. Consequently, our concern has been whether the present programs are in reasonable balance with present and future preceived needs.

The Committee deeply appreciates the excellent support it has received from the staff of FRA Administrator, John W. Ingram.

A REPORT BY THE HIGH SPEED GROUND TRANSPORTATION ADVISORY COMMITTEE

Introduction

The national transportation system of the United States has been developed in response to transportation requirements and social and political forces so that we now have in our highways, airways, railroads and waterways the most far reaching transportation system of any nation—one which provides a wide choice to the shipper and the traveler. This system has been built on the assumption of the universal availability of cheap energy. As this report is being written, it is obvious this assumption can no longer be made as cheap energy has disappeared. This changing energy availability is resulting in the changing of national priorities to place a greater importance on the use of mass transportation. In ground transportation, as in any mature technology, lead times for development of new systems are very long. In order to have responded quickly to the energy crises with the implementation of new systems, R&D would have to be completed and operational planning would have had to have started a decade ago.

The present research and development activity of the Federal Railroad Administration can be divided into two primary categories. The first of these is aimed at developments which, if adopted and put into use, might significantly improve present railroads for both freight and passenger service. The second category is aimed at new high-speed systems which would presumably be deployed in selected locations to provide potentially viable alternatives to air and highway passenger movement.

When the High Speed Ground Transportation Act was passed in 1965, there was essentially no R&D activity in the Federal Government on ground transportation. When R&D started under the High Speed Ground Act, it was passenger oriented. The first R&D programs undertaken were on railroad and were followed quickly by studies of possible advanced ground transportation systems. After the establishment of FRA in 1967, the R&D program was broadened to include freight service. This broadening took place gradually at first with small efforts in the first 2–3 years, but freight R&D has now grown to become the largest part of the program today. While the FRA R&D program was developing into its present form, the Federal Government's philosophy on R&D change underwent a major change. The philosophy which could be characterized as ever expanding R&D was abandoned and the budgeting became more short term management objective oriented.

Railroad Improvement

Information made available to the Committee during its meetings indicated that the FRA is confronted by a variety of problems in its management of a research program that are quite different from those confronted by many other government institutions. The primary users of the output from FRA research are:

(a) The regulatory groups within government, thus FRA research must be directed toward establishing safety-related issues in a fashion so as to provide a sound technological underpining for future regulatory action.

(b) The private railroad companies and Amtrak—since these companies are severely cash limited, the output from FRA cannot expect to be translated into an immediate response without careful examination of the cost-benefit elements and the capital cost requirements of devices or systems arising from new technology. This situation is different from other industries such as atomic energy or aeronautical where industry and government have worked together from inception of the industry. There are almost no people in the railroads who have been in government, and there is no well-established tradition relating to the use by railroads of government-sponsored research.

The recently enacted legislation to establish a regional railroad corporation may create early opportunities for application of the results of the FRA R&D program and at the same time may establish special requirements.

Under these circumstances, it is particularly important for FRA to insure that its research is relevant to the needs of the industry. However, we note the extent to which FRA is establishing a sound working relationship with the private sector and encourage further development in this direction. In observing the overall allocation of funding to transportation in this country, however, the Committee is aware of the very sharp difference between the dollar volume of research committed to air transport and to highway transport and that committed to the rail mode of transportation. In view of the great potential for the rail mode to serve a variety of important national goals, an increase in funding for rail R&D programs would seem warranted.

There are a number of supporting technologies relevant to rail transportation, including those listed below. The FRA does not plan to create independent groups to pursue these because mechanisms have been established to use the work already being performed in these supporting technologies by other industries or government agencies.

1. Structural Dynamics
2. Electrical and Electronics
3. Materials
4. Structural Analysis
5. Fabrication, Joining and Assemblying Technology
6. Propulsion Technology
7. Aerodynamics
8. Human Factors, such as information displays to pilots, applicable locomotive engineers and others whose action affect rail movement
9. Operational analysis methods to identify "weak link" subsystems or poorly interactive subsystems.

It is quite obvious that in its work on behalf of an improved railroad system the FRA will be devising technology and systems that can increase the efficacy of the use of performance specifications for the definition of new equipment and components. This we support.

High Speed Ground Systems

There are emerging requirements for moving people at high speeds to provide attractive public transportation from remote suburbs and at the same time preserve the central cities as well as to provide alternates to short haul air and highway for intercity travel.

The Committee recognizes that early revenue service of high speed systems cannot be anticipated at this time. New ultra high speed ground transportation systems require new guideways which are not necessarily compatible with the existing rail or highway networks. However, electric power increasingly fueled by coal or nuclear reactors can be used in these ultra high speed systems thus decreasing dependence on petroleum products. The technologies for ultra high speed movements should continue to be developed. The budgets should be established at a sufficient level to ensure that the technologies will be available within a few years for appropriate applications.

Recognizing the need for a continuing increase in the overall budget of FRA for research some proportionate fraction of that work should continue to be committed to ultra high speed systems. It is essential to have such technology available in this country not only to insure that we have a domestic capability for design, but to permit exercise of several existing international agreements for the exchange of information with countries who are expending tens of millions of dollars on advanced systems. If FRA has a program producing sufficient technology to participate meaningfully in these information exchanges, then the multiplying power of the program budget is considerable. Without information to exchange, the output of the programs in the other developed countries will not be available to the U.S. Further, the technology should be well enough understood with some hardware available for experimentation in order that parametric studies on potential transport systems can take into account prototype operational experience and not solely technical studies.

FRA Test Center, Pueblo, Colorado

The Committee believes that the FRA test facility at Pueblo, Colorado, can become a vital asset in rail research and development. The Pueblo facility offers great promise as an experimental, developmental and demonstration facility where the more promising ideas can be promoted from an analytical state to the practical in a realistic environment.

We would urge completion of test loops at the earliest possible date and would urge consideration of expansion of the Railway Dynamics Laboratory to include experimental facilities supportive of the backbone technologies discussed above. Facilities devoted to work on tracked levitated vehicles should be expanded to the point necessary to insure a satisfactory experimental basis for these programs.

General Considerations

While not directly concerned with the content and priorities of research and development per se, the Committee has observed a number of factors which might act to either thwart or promote acceptance and use of successful research and development:

New Order of National Priorities

The changed energy situation is causing a reordering of national priorities. The use of energy conserving transportation and the development of systems to further conserve energy is now high on the national priorities list. The attached chart shows the relative effectiveness of rail freight and passenger service vis a vis other modes. Consequently, the FRA R&D program should give special attention to fuel utilization along with environmental impact, safety, and economy.

The effort to preserve city centers has been given new urgency by the fuel shortage, and the possible role of high speed ground transportation whether it be new high speed rail or the advanced system needs to be explored for its ability to preserve the city centers by making it feasible for residents of areas remote from the city to commute in a reasonable time.

Economic Consideration

The long lead time in developing new systems and the cost of replacement of the existing right-of-way which is incalculable dictate the need to make maximum use of the existing railroad system for both passenger and freight movement. The desire for improved public transportation is opening means of funding for passenger systems which heretofore have not been considered attractive.

Intermodal Problems

It would appear useful to increase the extent of liaison between the FRA and other agencies, especially the Federal Highway Administration, the Federal Aviation Administration, and the Maritime Administration similar to that with the Urban Mass Transit Administration. Such cooperative efforts might particularly deal with extensions of such methods as "standardized" containers, "piggyback" rail-highway trailers, etc. Added benefits might accrue from technology interchange on, for example, insulation techniques which might be adapted to cryogenic shipping by rail and motor freight and ocean-going ship, and various communication and control techniques.

It is of prime importance that terminals for each mode be designed to permit ease and speed of interchange for both freight and passengers. Many technical advances in intra-modal performance are not being applied because of problems at interchange nodes.

Conclusions

1. The need to conserve energy offers economic opportunities for early application of the results of the FRA R&D program.
2. There is a requirement for adjusting the national transportation system makeup to reflect changing national priorities.
3. FRA is a relatively new organization. Its constituency is deeply rooted in the private sector and there has been little interchange of people from government to industry.
4. The lead time to develop advanced ground transportation systems is measured in decades.

Recommendations

1. In order to optimize the national transportation system and to make maximum utilization of the rail network already in place, both FRA and the railroads need to be strengthened to fulfill their missions.
2. Research must be started long before there is a fully defined requirement for advanced ultra high speed ground transportation systems in order that the relevant technologies can be available when energy and economic considerations dictate their use.
3. The FRA railroad R&D budget needs to be increased to take advantage of the economic opportunities now emerging.

Passenger Transportation
Average Fuel Consumption

	Seat Miles per gallon
Automobile—intercity	75
Bus—intercity (Greyhound)	260
urban	230
Rail *—	
E-8 Locomotive with 6 coaches (60–80 seats)	225–300
E-8 Locomotive with 3–5 overnight sleeper cars, etc.	50 **
Rail diesel car—commuter configuration	250
Rail turbine train	110
Autotrain	(30 auto mpg)

* Includes idling
** Based on heavy loading during holiday season; assumes 100% load factor