FEDERAL RAILROAD ADMINISTRATION

OFFICE OF RESEARCH AND DEVELOPMENT

1988
RESEARCH AND DEVELOPMENT PROGRAM

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FEDERAL RAILROAD ADMINISTRATION'S OFFICE OF RESEARCH AND DEVELOPMENT

Introduction

The Office of Research and Development formulates anticipatory and responsive technical programs, institutes projects and conducts the research, development, test and evaluation activities necessary to promote and ensure the safe performance of railroad equipment, track, trains and operations. Of particular concern is providing for the protection of the public and railroad employees from the railroad environment. A large portion of the safety testing is performed at the Transportation Test Center at Pueblo, Colorado. Contracts for the conduct of research are awarded to qualified private sector firms and to other Government agencies. Technical assistance, on a reimbursable cost basis, is provided to other Government agencies concerning railroad safety issues of mutual interest.

The staff personnel in the Office of Research and Development are predominantly engineers with experience and expertise in a variety of engineering disciplines relating to railroad technologies. The major staff tasks include project research, planning and management in order to produce the practical means for converting advances in technology into standards or systems to be used either voluntarily by the railroad industry or by the Federal Railroad Administration (FRA) in its rulemaking actions to improve railroad safety. Assisting in these activities are high caliber technical personnel of the U.S. Department of Transportation's Transportation Systems Center at Cambridge, Massachusetts. At the Center, the Railway Safety Division and the Structural and Dynamics Division provide the Office of Research and Development with engineering and analytical assistance, a quick response capability, the flexibility for accommodating changing work requirements and an interdisciplinary team approach to problem solving.

Background

The High Speed Ground Transportation Act of 1965 mandated Federal research and development activities to demonstrate the feasibility of high speed ground transportation technologies. Originally under the Department of Commerce, the Office of High Speed Ground Transportation became a part of the Federal Railroad Administration when the Department of Transportation was formed in 1967. Shortly afterward, because the industry lacked appropriate test facility capabilities and there existed an urgent need to test and demonstrate emerging new technologies, plans to construct a test center near Pueblo, Colorado, were developed and approved.

The Safety Act of 1970 contained a further mandate that research and development be carried out to support the goals of improving railroad safety and reducing accidents. To this end, previous Federal Railroad Administration research and development work was augmented with specific projects to support the development of safety standards and subsequent regulatory actions. One of the more successful and far-reaching of these research activities was directly responsible for the dramatic reduction in catastrophic consequences to the public from the derailment of tank cars carrying hazardous materials.

Today, the regulations covering tank cars carrying the most hazardous commodities and the resulting improved safety performance of the industry tank cars are tangible evidence of the effectiveness of a cooperative Federal Railroad Administration-industry research program.

In the mid-1970's, when the research and development aimed at high speed ground transportation reached demonstration stages, and initial technological feasibility had been shown, a change in the direction of the research was indicated. During this period, the economic condition of the Nation's railroads worsened and an increasing number of accidents occurred. It became evident that a major threat to safety was being posed by the deterioration of equipment and of the physical plant. In response, the emphasis of the Federal Railroad Administration's Research and Development program was shifted to produce countermeasures to the adverse safety and economic trends being experienced by the railroads. High speed transportation research was curtailed and new projects were implemented to improve track and equipment safety, operating practices and safety inspection devices. Research and development efforts during this period also contributed to implementation of actions under the Regional Rail Reorganization Act of 1973 and the Railroad Revitalization and Regulatory Reform Act of 1976. In 1975, the Office was redesignated as the Office of Research and Development (OR&D) in recognition of its much broader mission.

Early in 1981, after the Staggers Act partially deregulated the railroad industry and improved a rail carrier's ability to deal with predominantly economic issues, the research and development program became focused exclusively on safety-related problems. Consistent with this shift in mission, a planned transfer of the Test Center from Government to private sector operation was completed in October 1982. A sole source contract was awarded to the Association of American Railroads (AAR) for the care, custody and control of the Test Center with the Federal Railroad Administration retaining ownership of the facility. Today, the Federal Railroad Administration has only one employee located at the Test Center for engineering management and liaison in the conduct of FRA research, testing and evaluation. By 1985, the Washington, D.C., Office of Research and Development had been streamlined to 14 people.

During 1985, as the result of an internal Federal Railroad Administration management review, the Office of Research and Development was realigned from an independent program office under the Office of the Administrator to an office under the executive direction of the Associate Administrator for Safety. The realignment was done to produce more effective use of limited research resources and enhance the supportive efforts of research in the rulemaking process.

Throughout the years, in the process of achieving research goals, the Office of Research and Development has relied upon cooperative and coordinated programs with other research organizations, other Government agencies, railroads, industry associations, labor organizations and suppliers. Examples of these cooperative programs include: full scale replication of tank car explosions, development of tank car protective systems such as head shields and shelf couplers and recommendations for regulatory actions to

improve puncture resistance of tank cars in accidents; establishment of employee safety training programs with industry; continuing efforts to avoid car derailments through the Government/Industry Vehicle Track Systems (formerly Track Train Dynamics) Program that includes Canadian Government, supplier and railroad participation; development of performance-based track safety standards; and, construction of a research and locomotive evaluator/simulator (RALES) facility which began operating in the fall of 1983 under private sector control. Although an operating entity of the Office of Safety, the Office of Research and Development has established working relationships within the Federal Railroad Administration's Offices of Policy, Chief Counsel and Passenger and Freight Services. This enables the Office of Research and Development to be responsive and furnish direct support to regulatory actions, safety investigations, issuance of emergency orders, international inquiries/technical information exchanges and bilateral agreements, as well as to decisions affecting the procurement of hardware, equipment and track components for the Northeast Corridor.

Appropriation History

As seen in the table below, the development and early operation of the Test Center at Pueblo is reflected in relatively large appropriations necessary to provide for construction during the period 1973 through 1981. Since the turnover of the Test Center to the private sector in 1982 and the focus of research restricted to purely safety-oriented issues, there has been a marked decline in railroad research and development appropriations.

High Speed Ground Transportation		Railroad Research and Development	
Fiscal Year	Amount ($000)	Fiscal Year	Amount ($000)
1967	22,000	1975	47,550
1968	11,750	1976	79,800
1969	13,000	1977	52,900
1970	11,000	1978	53,600
1971	18,000	1979	51,980
1972	25,000	1980	54,750
1973	52,500	1981	50,000
1974	25,100	1982	30,000
		1983	17,000
		1984	16,225
		1985	15,525
		1986	10,144
		1987	9,581
		1988	9,286
		1989	9,286

Current Mission

The Office of Research and Development's Director and staff are responsible for the management and execution of railroad research and development related to improved railroad safety and enhanced intercity ground transportation through beneficial advances in railroad technology.

An effective safety research program is essential to the Federal Railroad Administration's safety assurance and regulatory efforts. The Office of Research and Development conducts research and development as an integral

part of the Federal Railroad Administration's mandated safety responsibilities to ensure the continued and enhanced safety of railroad transportation. While the railroad industry has the fundamental obligation for transport safety, the Federal Railroad Administration establishes and maintains safety standards and regulations and monitors the safety performance of the Nation's railroads. The Office of Research and Development employs its research resources to ensure protection of the public under five criteria for Federal involvement:

1. Quick Response to Safety Issue--projects requiring immediate action as a result of a major accident or the sudden widespread development of hazardous conditions involving new technology or operating practices that indicate a high potential for creating a safety threat to the public or railroad personnel.

2. Regulatory Action--projects that derive from a proposed regulation or a petition to develop or change a regulation that will improve the rail industry's safety performance.

3. Regulatory Review--projects that meet the need to determine the cause and effect aspect surrounding an accident statistic, the effectiveness of an existing regulation as a preventive measure or the adequacy of existing regulations in light of new operating or technological developments.

4. Potential for Voluntary Industry Safety Improvements--projects with a high potential for having the results voluntarily adopted by the industry and where the high risk or high cost burden indicates that a cooperative Government-industry research effort is desirable to encourage the development of a safety enhancement or corrective action for a developing safety problem.

5. Intergovernmental Response--projects arising out of a request by another Government agency to provide technical support for railroad safety issues of mutual interest. This is done on a cost-reimbursable basis in accordance with provisions of the Economy Act.

In recognition of the role that human factors plays in accident causation, increased emphasis is being placed on research to reduce accidents due to these causes.

Nature of Research

The safety of rail transport in the United States has improved dramatically over the last several years. In this achievement, the research program made valuable contributions to the Federal Railroad Administration's mainstream safety improvement efforts carried on with the railroad industry.

In response to earlier high accident rates, effective technical solutions were eventually produced and implemented. Overall, the Government and the railroad industry were very successful in "reacting" to the major safety problems of the past. The research program produced the mechanisms and technical support for rulemaking activities which led to the implementation of remedies or, in many cases, led to the voluntary introduction of changes by the railroad industry.

As a result of these advances, the nature of the Federal Railroad Administration's research and development program has undergone a transition.

More research can now be directed toward anticipating future safety threats rather than in reaction to statistical accident patterns although the trends are still closely watched.

Since it is impossible to predict all the safety threats likely to develop, the Office of Research and Development maintains the flexibility in its research program to also investigate sudden threats or unexplained causes of catastrophic accidents.

In those circumstances where the public interest will not be compromised, Federal Railroad Administration and industry research resources are pooled and safety testing is coordinated and progressed hand-in-hand with the development of new systems by the railroads, suppliers and manufacturers.

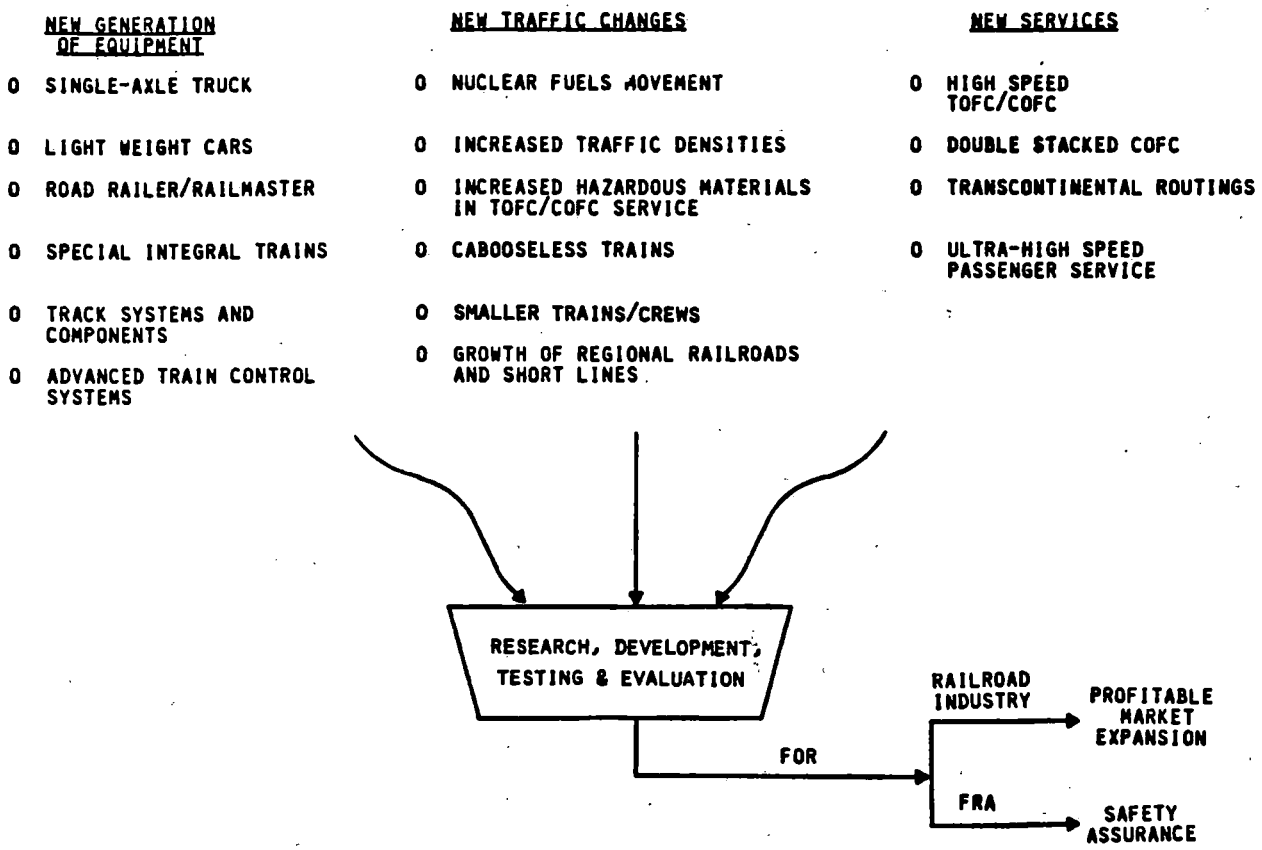
Within the accepted criteria for Federal involvement, Federal Railroad Administration research seeks to eliminate the introduction of systems with basic incompatibilities between track, vehicles or operators and to prevent sudden track, equipment or human failures which may cause major derailments or collisions. Recognizing that the complete elimination of derailments is unrealistic, the research further attempts to ensure that employees, passengers and that segment of the public in close proximity to hazardous materials carried in trains are protected--even in the event of an accident.

Essential testing and simulations are carried out at two major facilities which were built by the Federal Railroad Administration and are currently being operated by the private sector. Notably, most testing of track structures and rail vehicles is accomplished at the Transportation Test Center (TTC) near Pueblo, Colorado, and a significant portion of train handling evaluations, locomotive environment assessments and engineer training experiments are performed at the Research and Locomotive Evaluator/Simulator (RALES) in Chicago, Illinois. In addition, a special purpose dynamometer apparatus, owned by the Association of American Railroads, has been a key element in the research sponsored by the Federal Railroad Administration to arrest the rate of wheel failures on railroad cars while in service.

Future Research Directions

Since being granted much greater economic freedom, United States railroads are striving to greatly expand their individual transport market shares. In order to reduce costs and otherwise compete with coexistent and equally energetic railroad systems, as well as to attract segments of highway truck business, individual railroads are instituting or will institute a wide range of drastic changes in equipment, track systems, operations and maintenance. The end products embody innovative approaches to new generations of equipment designs, radical departures from traditional service offerings and the attraction of traffic with characteristics and commodities previously uncommon in rail movements or previously lost to truck service. Examples of the types of changes expected are illustrated below. It is important that changes of the magnitude now underway be thoroughly analyzed and that the potential safety implications be explored prior to widespread implementation.

As a part of the research addressing new technology and services, emphasis is also placed on evaluating the human factors aspects, assessing the role and capabilities required of engineers, dispatchers and others who must implement these industry changes. Ideally, from both timeliness and efficiency viewpoints, the research, development, testing and evaluation of next generation systems should be coincident with safety assurance proofs. In this context, the Federal Railroad Administration and the industry have separate primary roles as shown below.



THE CHANGING RAILROADS AND THE ROLES OF INDUSTRY AND GOVERNMENT

In summary, the Federal Railroad Administration intends to fulfill its overall safety mission in a way which establishes cooperative interactions early in the industry's concept formulation and design process. There are obvious benefits to the industry, the public and the Federal Railroad Administration in attaining a status wherein the new concepts introduced are consistently both cost effective and safe in actual service. One of the best ways to accomplish such a favorable outcome (without incurring inordinate delays or costs in the development process) is to imbed safety assurance in the routine analytical and testing phases of development. Safety research sponsored by the Federal Railroad Administration looks toward the kind of up-front cooperative ventures which will maximize the likelihood that new railroad products and procedures will not inadvertently introduce unacceptable safety hazards.

The Federal Railroad Administration's Safety Research and Development Program is one part of an overall industry/Government safety improvement effort which is increasingly focusing on prevention of the outbreak of problems in a future replete with unprecedented innovation. Safety assurance will be accomplished through more anticipative research and testing and less traditional forms of regulation, enforcement and inspection.

The following sections provide functional overviews of the research conducted by the Office of Research and Development.

EQUIPMENT, OPERATIONS AND HAZARDOUS MATERIALS SAFETY PROGRAM

The Equipment, Operations and Hazardous Materials Program directly supports the rail safety responsibility and authority specifically conferred in the Federal Railroad Safety, Hazardous Materials Transportation and Occupational Safety and Health Acts of 1970, as amended. It focuses on that research necessary to provide for the safe performance of critical equipment, components, operating practices and hazardous materials transport in the railroad environment. In general, this research program aims at rail vehicles and their operation and the hazardous materials transportation aspects peculiar to railroad operations.

This program is conducted with the cooperation and cost-sharing from private sector organizations including: Research and Test Department, Hazardous Material Systems (formerly BOE) and Railroad Safety Officers Committee of the Association of American Railroads (AAR); Railway Progress Institute (RPI); Brotherhood of Locomotive Engineers (BLE); United Transportation Union (UTU), and individual railroads.

The current program elements, associated research objectives and examples of current projects are as follows:

1. Equipment and Components -- Provides sound technical information, analytical procedures and applied methods and techniques necessary for the test and evaluation of railroad equipment components in the determination of the cause and effect of accidents and development of preventive measures and improved inspection methods and procedures for application to existing or new equipment.

Safety Aspects of High Speed Passenger Trains

An analysis and test was conducted to evaluate the safety of operating the French Rame Turbine á Gaz (RTG) train set at higher than normal speeds in curves. This higher speed was achieved without physical track changes by permitting the operation of the train set at higher cant deficiencies. Present track standards permit three inches of cant deficiency in curves. Amtrak requested a waiver of that rule to test the safety and ride comfort of

the train set operating at higher cant deficiencies not to exceed seven inches. The objective of operating at a higher cant deficiency, hence higher permitted curve speed, is to reduce the trip time between Boston and New York City where the test was conducted. Non-banking, French-designed RTG train sets have been in service in the U.S. for more than a decade. Similar analysis and testing also included Canadian LRC (light, rapid, comfortable) and Spanish Talgo train sets with the same objective.

Safety Aspects of New and Untried Freight Cars

Work is complete on the Base line, Car 1 project to develop safety tests and mathematical models that will reduce the cost and time required to evaluate the safety aspects of new and untried cars. Tests were conducted on the tracks and Vibration Test Unit (VTU) at the Transportation Test Center to partially validate the New and Untried Car Analytical Regime Simulation model (NUCARS). The physical characterization of the base line car as input to the model and the track tests provide a standard procedure designed to evaluate the safety aspects of new and untried cars. The Prototype, Car 2 project, using a different new and untried car design, is following the Car 1 program. The purpose of the Car 2 project is to further validate the NUCARS Model and to test a car having the potential for a less than desirable safety performance.

Automatic Train Control in the Northeast Corridor

In the aftermath of the Chase, Maryland, collision, the Department of Transportation has determined that all trains operating on the Northeast Corridor shall be equipped with automatic train control. The train control system is to automatically apply the train brakes if train speed exceeds the speed permitted by the signals. Questions were raised concerning the effect of automatic train control on the safety of heavy freight train operation. An analysis was needed to determine if rapid and severe braking could lead to additional derailments as a result of the large longitudinal train forces that can be experienced under emergency stopping conditions.

An evaluation of the safety aspects of automatic train control applied to freight train operation was conducted. This evaluation included computer simulation of various freight train braking scenarios to estimate likely in-train forces and stopping distances at selected corridor locations judged to represent the most severe conditions.

Improved Air Brake Systems

Two major railroads have petitioned for waiver of FRA regulations concerning air brake systems. They request use of the "air flow meter" method for checking a train's air brake system at the beginning of a run and want to place air brake repeater cars in the middle of long trains. The safety implications of these proposed changes are being evaluated through the computer simulation of a variety of operating scenarios in the air braking simulation model developed for RALES. The results of these simulations are expected in the fall of 1988. An associated field evaluation employing limited equipment is also under way to gather empirical data.

Brake Rigging Study

A braking study was completed which investigated the reasons for uneven braking forces being applied within a freight car braking system. This condition can result in a thermal input to the individual wheels varying substantially within a railcar truck as well as between the trucks of a car and from car-to-car in a train. Individual wheels can easily become severely overheated and fail while in service thereby causing potentially catastrophic accidents.

Tests were performed on the Roll Dynamics Unit (RDU) at the Transportation Test Center. This was followed by an extensive series of drag braking tests. Specific studies included the determination of the reasons for (1) braking energy input variation due to location of the brake shoe on the wheel; (2) wheel-to-wheel brake force variations within the same truck; and (3) variations in braking force due to variations occurring in the brake rigging (bends, wrong piece installed, misaligned holes, etc.).

Wheel Inspection Systems

A project to determine the feasibility of measuring the residual stress in railroad wheels using a magnetic ultrasonic acoustic technology device developed by the NASA-Langley Research Center was completed. The pre-prototype inspection equipment developed by NASA will permit a field demonstration of the use of magnetoacoustic interactions in evaluating railroad wheel samples for residual stress at the Transportation Test Center. It is planned that 21 wheels will be tested, followed by saw cutting of the wheels to determine actual residual stress and a comparison made with the results obtained by nondestructive testing.

A parallel research project will also continue using an ultrasonic birefringence residual stress measurement system developed by the National Bureau of Standards (NBS), Boulder, Colorado. Again, 21 wheels will be tested and subsequently saw cut for determination of residual stress and comparison of results.

Work will also continue on a roll-by inspection system to detect cracked railroad wheels using electromagnetic acoustic transducers (EMAT) and a high-current pulsar. The EMAT and pulsar system will be evaluated to determine the efficiency and sensitivity of this approach in detecting cracks and tread shelling prior to wheel fracture.

The inspection equipment and techniques developed based on the NASA-Langley and NBS research will significantly contribute to increased railroad safety. Identification of wheels with high residual stresses and defects permitting their timely removal and replacement will result in decreasing the probability of a wheel failure occurring in service.

Roller Bearings

Roller bearing research began as a result of a series of failures of hollow axle bearing assemblies used on the commuter cars of: Metro North, M-2; New Jersey Transit Arrow II and III; and SEPTA, Silverliner IV fleets. This initial investigative research indicated that a roller bearing failure appears to proceed through three stages with loss of radial interference fit

between the bearing cones and the axle being the first stage. Further study revealed that a great deal of care must be taken to assure the proper fit during bearing installation on an axle. Research was also carried out to determine the cause of grease observed leaking from double stack container car roller bearings. This problem is now believed to have been associated with a particular composition of grease being used.

Research recently initiated will identify the most common causes of freight car bearing overheating and failure. Tests will be conducted at the AAR Technical Center (Chicago) and at the Test Center (Pueblo). An initial 5,000 mile test of 16 bearings, known to be defective, will be performed to observe any unusual occurrences or signs of imminent failure. Following that, a considerably longer period of testing, making use of the Facility for Accelerated Service Testing (FAST), will be considered.

2. Operating Practices -- Provides the information, methodologies and/or aids necessary to enhance the safety of railroad operating practices with special emphasis on human factors and develops guidelines and tools to improve the ability of railroad management and employees to safely and efficiently complete maintenance and train handling tasks in the railroad environment.

RALES: Operation and Maintenance

The Research and Locomotive Evaluator/Simulator (RALES) originally developed and constructed under contract to the FRA is operated and maintained by the Illinois Institute of Technology Research Institute (IITRI) in Chicago, Illinois. All costs are covered by a user fee charged by IITRI. The FRA contract for the care, custody and control of this facility extends to early 1994 and provides for FRA issuance of task orders to accomplish research as needed. Projects described elsewhere in this document indicating the use of RALES are accomplished under such a task order arrangement. Several task orders were initiated recently in support of the FRA Operating Practices Research Program; however, principal RALES use has been by the private sector. From July 1, 1986, to June 30, 1987, a total of 2,465 RALES operating hours were used by railroads for training. Similar use is expected for at least the first half of 1988.

Engineman Alertor/Emergency Braking System

A project has been designed to test, on RALES, a state-of-the-art engineman vigilance device linked to a prototype emergency brake pedal. The utility and effectiveness of both devices, separately and as a system, will be determined. Tests should be completed in the fall of 1988.

Innovative Engineman Alertor System

Under the Small Business Innovation Research Program, a unique, nonintrusive device is being developed to determine the vigilance of locomotive engineers. The system consists of three or four sensors, of the type used to focus automatic cameras, wired to a microprocessor. The sensors are located at strategic locations in the locomotive cab where they are oriented toward the engineer's work station and transmit posture and movement information to the microprocessor. The microprocessor then compares this information with pre-programmed standards for alertness. As long as the engineer is determined to

be alert, the sensing process keeps repeating with no other response other than normal movement required of the engineer. Detection of nonalertness will result in the flashing of a visual signal followed, if necessary, by an audible signal to gain the attention of the engineer. If the engineer reacts appropriately, the system is reset. If he does not, the microprocessor is programmed to stop the train. Field testing has been completed and a final report is being prepared.

Selection of Locomotive Engineer Trainees

This project was initiated in 1986 to develop and validate tests for screening candidates for training to become locomotive engineers. The tests are being designed to determine the likelihood that these individuals will become safe and efficient train handlers after receiving appropriate training. The Union Pacific Railroad is a primary participant in this effort. Several other railroads have recently expressed an interest in becoming involved in this project. Concurrent validation of the tests is expected to be completed in 1988. Predictive validation is planned as an ongoing activity to mid-1992.

Railroad Employee Safety

The proper use of observation and motivation techniques by management, particularly first line supervisors, can improve employee work habits and reduce accidents and employee injuries. This has been established in a variety of industrial settings. In 1985, this project was initiated to demonstrate the application of these techniques in the railroad environment. In a cooperative effort between the FRA and the Association of American Railroads, demonstrations have been conducted on the Burlington Northern and Duluth, Missabe and Iron Range Railroads. This project has been completed.

Accident Site Management System

Efficient and effective handling of a railroad accident site involving hazardous materials requires the ready availability of quantities of accurate essential elements of information. FRA sponsored this project to demonstrate the feasibility of using a microcomputer driven laser video disc system to store, manipulate and provide a map overlay of the types of data that might be desired for this purpose. Included are maps, aerial photography, photographs, video taped information and a variety of textual materials. The hardware configuration and the basic software for the Accident Site Management System were adapted from earlier Department of Defense research. The project was completed in January 1988.

Hazardous Materials on Short Lines

Local and regional railroads generally have very limited resources to prepare for emergencies created by accidents involving hazardous materials. This project was initiated in 1986 to determine the level of preparedness these railroads should attain; evaluate the level of preparedness that exists; and, identify the sources and resources available to assist in achieving the desired level of preparedness. Particular attention is being given to creating an awareness of the potential hazards presented by the materials transported, employee training and emergency response planning and coordination with local emergency response agencies. The project is planned for completion in the spring of 1989.

Highway-Railroad Grade Crossing Safety

Educational materials designed to increase public awareness of the hazards present at highway-railroad grade crossings are developed, prepared and distributed through the National Operation Lifesaver Program. In every state, a significant reduction in grade crossing accidents has occurred following initiation of the program. Volunteers distribute the materials and use them for presentations to a wide variety of organizations such as schools and civic groups. FRA has endorsed and encouraged this program since its inception in the early 1970's. FRA is providing financial assistance to help support the joint industry cooperative program. The goal is to have the program become self-sustaining with private sector resources in the future.

Dispatcher Function Evaluation

A multifaceted project to evaluate the railroad dispatcher function and the safety implications of consolidating dispatching territories and functions, more frequent and longer trains operating over fewer lines of railroad and changes in train control technology such as the Advanced Train Control System (ATCS) is planned to begin in 1989. Dispatcher selection, training and workload will be examined under varying conditions of the work environment and relevant work rules.

Locomotive Engineer Stress and Fatigue

An effort will be initiated in 1989 to identify and evaluate those conditions most likely to cause or significantly contribute to stress and fatigue sufficient to adversely affect the train handling performance of locomotive engineers. It is anticipated that the following factors will be among those examined: work/sleep cycles, noise, vibration, irregular work schedules, conditions at away-from-home layovers, boredom and cab environment (fumes, temperature, etc.).

3. Hazardous Materials -- Provides factual data concerning tank car failures and accidents involving hazardous materials, including determination of cause and development of measures to prevent failure and protective countermeasures to minimize potentially catastrophic results that may occur in a railroad accident.

Tank Car Research

A research program has been initiated to determine the puncture resistance of DOT Specification 105 tank cars that carry chlorine. The puncture resistance of these cars is being compared to that of the DOT Specification tank cars that currently are required to have head shield protection. Testing includes one-fifth scale, full scale and actual car tests. The preliminary data analysis has indicated a problem with the design of the head brace weld. On DOT Specification Tank Cars for liquid petroleum gas (LPG), the weld is designed to "break away" under an impact such as occurs in a puncture situation. On the DOT Specification 105 cars the weld caused a tear in the tank shell at 14.5 miles per hour. The test data is currently being analyzed.

A similar research program is being initiated to determine the puncture resistance of aluminum tank cars and to study the effects of cold temperature on the puncture resistance of all tank car head materials.

Tank Car Damage and Nondestructive Evaluation

An investigation continues on tank cars damaged in accidents to determine causes for the failure and of the release of hazardous materials. Work on a means to non-destructively evaluate damaged tank cars prior to accident site clean-up has been completed. However, no means currently exist to evaluate tank car shells when the tank car is insulated and jacketed.

Frangible Disk Failure Evaluation

A research project has been initiated to determine why tank car frangible disks are failing and releasing small quantities of hazardous materials under normal train operating conditions. Tests will investigate the effects of pressure and corrosion on the disk materials. Laboratory tests and field tests will be conducted.

Hazardous Materials Detection System

A cooperative program with the United States Coast Guard to fabricate a portable device to detect the release of 25 hazardous materials has been completed. The device is undergoing evaluation.

A Phase II, Small Business Innovation Research project is ongoing to develop a transponder type device for use on railroad tank cars to aid in the identification of the car and its contents in the event the car is involved in an accident. The device will be operational from 2,000 feet by emergency response personnel using a hand-held locator device. A breadboard of the system will undergo vibration and environmental testing. Testing in a fire environment will be necessary.

Another project will investigate countermeasure methods used by emergency response personnel when tank cars are releasing hazardous materials.

Transportation of Spent Nuclear Fuel

Investigation of the performance of a spent nuclear fuel cask in a typical rail fire environment continues. The thermal codes used for cask analysis are being validated with actual tests. A study of the rail fire environment versus the Nuclear Regulatory Commission regulatory fire test is being conducted. A risk assessment of the probability of a nuclear cask being involved in a rail fire is also being conducted.

Stub Sill Tank Cars

A project has been initiated to investigate the design of stub sill tank cars to determine if there is a design problem that is causing cracks to develop in the stub sill area. Testing will be conducted after a finite element analysis has been accomplished.

Welding of Tank Car Attachments

As a result of inspections performed by FRA safety inspectors in March 1986, a number of DOT Specification 111A100W tank cars were found to have repairs and alterations not in conformance with applicable standards and specifications. A project was initiated to assess the structural integrity and safety of the tank cars' "as-built" alterations. Included in this project is a study of the welds and the stress relief process used.

TRACK SAFETY PROGRAM

The Track Safety Program focuses on improving the safety of the track structure, including all of its critical components, railroad bridge structures, signal and train control systems, relationships between track and the dynamic response of railroad vehicles, safety requirements for track for new very high speed (125-200 mph) passenger train operation and all other elements of the railroad right-of-way or guideway having any influence on the safe operation of trains.

This program is conducted with the cooperation and some cost-sharing from private sector organizations including the American Railway Engineering Association (AREA), Association of American Railroads (AAR) and several individual railroads and suppliers.

The current Track Safety Program elements, their associated research objectives and examples of current projects are as follows:

1. Track and Components -- Provides sound technical information, analytical procedures, and guidance that will improve the reliability of track/guideway structural components and associated signal and train control systems and determine their safe operating limits.

FAST-HTL Safety Testing

The Facility for Accelerated Service Testing-High Tonnage Loop (FAST-HTL) located on the grounds of the Transportation Test Center near Pueblo, Colorado, provides a closed loop track where the influence of concentrated rail traffic can be closely observed. A recent project involving a variety of track experiments under 100-ton equipment (33,000-pound wheel loads) has been completed. This will be followed by a series of tests, known as FAST-HAL (high axle load), using 125-ton equipment (39,000-pound wheel loads) to compare track component performance under increased train loads. Experiments performed on FAST support several specific research projects including rail fatigue, track degradation and track buckling. This project is conducted in cooperation with the Association of American Railroads and the railroad industry.

2. Inspection-Detection -- Provides the inspection equipment, techniques and methodologies necessary to ensure early and reliable detection and warning of unsafe track, guideway or structure conditions.

Track Degradation Research

This area of research seeks to determine the rates at which railroad track degrades toward safety limits and the factors which cause it to degrade, and to define reasonable inspection strategies to control the risk of unsafe track, guideway or structure conditions.

A track degradation test is underway at the Transportation Test Center on the newly-installed High Tonnage Loop. A portion of the loop track has been intentionally installed at only "moderate" track quality. The condition of the track is being closely monitored under controlled traffic conditions to determine the rate at which the track degrades toward safety limits. The information obtained at the Test Center will be compared with similar information collected at several railroad revenue service track locations, allowing a determination to be made of the factors causing track degradation.

In addition, agreements are in place for obtaining data from several track locations on a major northeast freight railroad. Maintenance work which may affect accuracy of the data taken over a recorded time frame will be closely monitored. Changes in track conditions over time and loading situations will be measured and comparisons made with measurements from the High Tonnage Loop.

Validation of Improved Rail Flaw Detection Device

Recent trends toward higher tonnage freight car loads and the extension of rail life through revised lubrication processes have emphasized the need for improved rail flaw detection techniques. A project for demonstration of an ultrasonic rail flaw detection device has been underway. The project incorporated current state-of-the-art technology in electromagnetic acoustic transducers (EMAT) into a track-mounted fixture for use in rail inspection. The device is designed to induce directed acoustic waves into the rail with no direct contact or fluid couplant, and to take advantage of improved signal transfer in areas where lubricant buildup or excess cold work properties exist. On-track trials have been made and the breadboard device is being evaluated for effectiveness as an advanced flaw inspection technique.

Simulation of Rail Defects for Measurement Calibration

Improved methods for calibration of rail flaw detection systems are necessary to enhance the efficiency of ultrasonic detection techniques. A project for simulation of commonly occurring rail flaws in a programmable manner was sponsored by the Federal Railroad Administration under the Small Business Innovation Research program. The project was intended to develop an innovative device for varying the effective ultrasonic wave reflectivity for simulated cross-head fatigue cracks in rail material. Such a device has the potential for wide application in the industry by providing uniform calibration of inspection devices used in flaw detection. Unfortunately, the initial exploratory effort has not proven as promising as originally believed.

Rail Force Measurement Technique Development

A Small Business Innovation Research project is being conducted under Federal Railroad Administration sponsorship to develop methods for measuring the longitudinal force existing in the rails of a track structure. The longitudinal force measurement method is essential to predict the potential buckling of continuous welded rail track due to thermal expansion during hot weather or the occurrence of rail breaks due to contraction during extremely cold weather. Developing a practical force measurement system is extremely challenging technically, and an innovative solution is sought which may overcome the severe technical difficulties which have caused many prior efforts to fail. The current efforts will apply the best of recently developed technologies in ultrasonic and electrical measurement techniques to attempt to successfully accomplish the required measurement.

Track Geometry Car Testing

Track geometry cars are now widely used in the railroad industry to provide a quantified, objective assessment of track conditions while the track is actually under load. Many varieties of geometry cars are in use including heavy locomotive-hauled cars, self-propelled specialized railroad vehicles and highway-rail vehicles. Each form of car produces quantified data about the track, but each loads the track structure in a different way. The comparability of data from such differing measurement systems has been an issue within the industry. As a result, the American Railway Engineering Associaton (AREA) has formed a technical committee, with Federal Railroad Administration participation, to assess the capabilities and usefulness of such track inspection systems. FRA has participated in testing designed to show the differences in various geometry car types and the effect those differences may have on the evaluation of actual track conditions.

Rail Restraint

The basic consideration in rail restraint is cross-tie soundness to secure the rails against sliding sideways or rolling over. Full-scale tests to measure restraint capacity were carried out with a modified wheel set riding under a conventional hopper car. This wheel set, having two independent axles and a pneumatic-hydraulic forcing mechanism, has the capability of exerting substantial (to 16,000 pounds) and continuous, closely-controlled lateral force on the rails of track over which the hopper car is passing. Continuation of these tests over several sections of revenue track are planned to demonstrate the feasibility and reliability of the system. This type of system permits the evaluation over long segments of track of the ability of crossties and rail fasteners to fulfill their function of restraining rail lateral movement.

3. Track-Train Interaction -- Unlike the preceding projects which focused essentially on the rail vehicles or the track structure on which they travel, the Track-Train Interaction Program contributes to the understanding of the system operating as a whole. Each of the previous projects concentrate on

research intended to control accidents which can be directly isolated to deficiencies in vehicle design and operation or to mechanical failure of the track structure. Another category of accident, less easily understood, is caused by uncomplementary vehicle and track interactive responses to each other under certain speed or operating regimes. This adverse interaction is often presumed to be traceable to track profile or alignment irregularities (geometry), to undesirable train actions or to certain car characteristics. Violent derailments attributed to adverse track-train relationships have occurred in the past.

Track-Train Interaction provides for the collection of historical information, analysis and production of factual data that accurately portrays the effect of the dynamic interaction that occurs between a train, the individual vehicles and the track and bridge structures over which they ride.

Vehicle-Track Interaction

A compact second generation of the Harmonic Crosslevel Measuring System has been completed. This tool, which mounts with minimum effort on most locomotive types, is being used to recognize patterns of track crosslevel variation that are capable of exciting certain types of freight cars to rock off the track. These occurrences of crosslevel change are often difficult to detect visually since it is the small but repetitive nature of the defects that influence the unacceptable behavior of certain railroad cars. Effort is currently underway to develop a manual device to be used for the same purpose.

Articulated Covered Hopper Car Prototype Testing

A covered hopper car incorporating several safety concepts in its design was received from the manufacturer and both on-track and laboratory testing of those concepts have been completed. The design of the articulated car includes a lower center of gravity, lighter wheel and rail loading, variations in curving capabilities and other features which are being compared with those of a "base line" car, representative of conventional car designs in use. The information gained will aid in assessing the operational safety of articulated freight car designs which are being used more frequently in railroad service. Safe allowable limits for truck hunting and curving and carbody rock-and-roll performance have been established. The test results indicate significant improvement in several aspects of the prototype car response. A recently developed mathematical model for analysis of new rail cars will be used by the Rail Dynamics Laboratory at the Transportation Test Center to obtain a thorough understanding of the prototype car safety performance.

Laboratory Testing of Two 100-Ton Covered Hopper Cars

Analysis of the results of laboratory tests of two 100-ton covered hopper cars has been completed. This testing had been conducted to define the dynamic properties of the test vehicles and the effects of those properties on safe operations. Dynamic response of the rail cars was determined by creating an increasingly severe test environment to the point where wheel lift or truck centerplate lift began to occur. Critical speeds and operational safety limits were defined for several different vehicle configurations. Testing was accomplished on the Vibration Test Unit at the Transportation Test Center. The analysis included establishment of data handling and data comparison techniques.

Accident Statistics Analysis

A study of railroad accident statistics is underway to provide information and determine trends in accident causes and their relationship to specific rail car types and configurations. The data is taken from the Federal Railroad Administration's Railroad Accident/Incident Reports. Methods are being developed for use of the data to effectively identify critical areas for increased safety research or to direct attention to needs for safety improvements. The study is nearing completion at the Transportation Systems Center.

Track Geometry Data Analysis

An analysis of track geometry data, recently measured by the Federal Railroad Administration in the Automated Track Inspection Program (ATIP), has been used to estimate the effect that a proposed new concept for crosslevel measurements would have on railroads across the nation. This concept was developed in an effort to control "rock and roll" derailments. Further analysis will be used to evaluate the impact of the proposed new measurement concept following use by the railroads in meeting track safety requirements. Similar analysis of ATIP data and of data supplied by an operating railroad has been made in support of development of the Gage Restraint Measuring System (GRMS) at the Transportation Systems Center.

Freight Car Fatigue Demonstration

A means for estimation of fatigue life of a freight car and a demonstration of equipment capabilities to test for fatigue failure of critical car components are being developed. A freight car design known to have experienced fatigue failure has been analyzed. A vehicle of that design has been received on loan from the owner/user and its construction characteristics reviewed. The vehicle, a coal hauling car, is being equipped with instrumentation for measuring material stresses and vibration frequencies which occur while traveling, loaded, over the route where failures were experienced. The data gathered will be used as input for further analysis of the car components and for input into the "Simuloader" rail car fatigue testing system at the Transportation Test Center. Analysis of the rail car design, determination of limits for each component and car fatigue life and evaluation of the ability of the test device to efficiently replicate fatigue conditions is being undertaken by the Technical Center of the Association of American Railroads.

Fatigue Failure Characteristics for Car Components

A study of the materials used in current and anticipated future rail car construction and the need for improved fatigue life prediction data for various sections and component shapes constructed from those materials has been made. Testing of the fatigue failure characteristics for a series of ferrous component shapes has been completed and testing of a series of aluminum alloy shapes is being undertaken. The data is being converted to a standard mathematical prediction format and disseminated to industry through the Association of American Railroads' "Manual of Standards and Recommended Practices."

Derailment Test and Analysis

To increase understanding of the contribution to derailments by conditions at the wheel/rail interface, a special test device is being constructed. The device will permit study of track strength, flange climbing, angle-of-attack effects and other conditions at the interface. Testing is to be conducted to establish safe limits for interface parameters and to determine uniform track safety evaluation techniques. The test device is being developed by the Association of American Railroads at the Chicago Technical Center.

New Train Designs and Consists

Marketing activities within the railroad industry are encouraging the development of new train systems for economic and efficiency purposes. These systems are expected to be different from existing trains in a variety of operating areas. In order to ensure safe performance of these trains upon their introduction into use, test requirements and a methodology for testing future trains are being developed. The generic safety test plan is being developed to permit evaluation of safe performance of new train consists in conjunction with the Association of American Railroads' Chicago Technical Center. A prototype train consist furnished on loan by a contributing manufacturer will be tested to determine safety characteristics and validate the generic safety test plan.