RESEARCH, TESTING, AND TRAINING AT THE TRANSPORTATION TECHNOLOGY CENTER

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For nearly three decades, the Transportation Technology Center (TTC), near Pueblo, Colorado, has been at the forefront of a government–industry collaboration aimed at advancing railroad safety. This successful partnership among the U.S. Department of Transportation, the nation's railroads, and the railroad supply industry has contributed to a nearly 60 percent reduction in the train accident rate since the early 1980s (see Figure 1), and continues to pursue further reductions in accidents and employee injuries.

TTC is owned by the Federal Railroad Administration and operated by the Association of American Railroads through its subsidiary, the Transportation Technology Center, Inc. (TTCI). In addition to conducting railroad safety research and testing, TTCI helps the railroads and their suppliers incorporate the results of those efforts in improved products, better maintenance practices and techniques, and more effective employee training. Current work at TTC addresses the safe operation of heavy freight and high-speed rail systems, the safe transport of hazardous materials, and effective accident emergency response.

Heavy-Axle-Load Technologies

The Heavy Axle Load Research Program began in 1988 at TTC's Facility for Accelerated Service Testing (FAST). The program addresses the safety, performance, and economic aspects of operating freight cars with heavier axle loads (up to 39 tons, as compared with the current typical load of 33 tons). The objective is to quantify, through full-scale testing, the effects of heavier loads on railroad track and vehicles.

Track performance is measured under a 75-car train operating on the 2.7-mile high-tonnage loop at 40 mph (see Figure 2). The train accumulates 125 million gross tons (MGT) of traffic annually, allowing FRA and TTCI researchers to determine the long-term effects on track component wear and fatigue and on track degradation and failure modes in a controlled environment within a relatively short time period.

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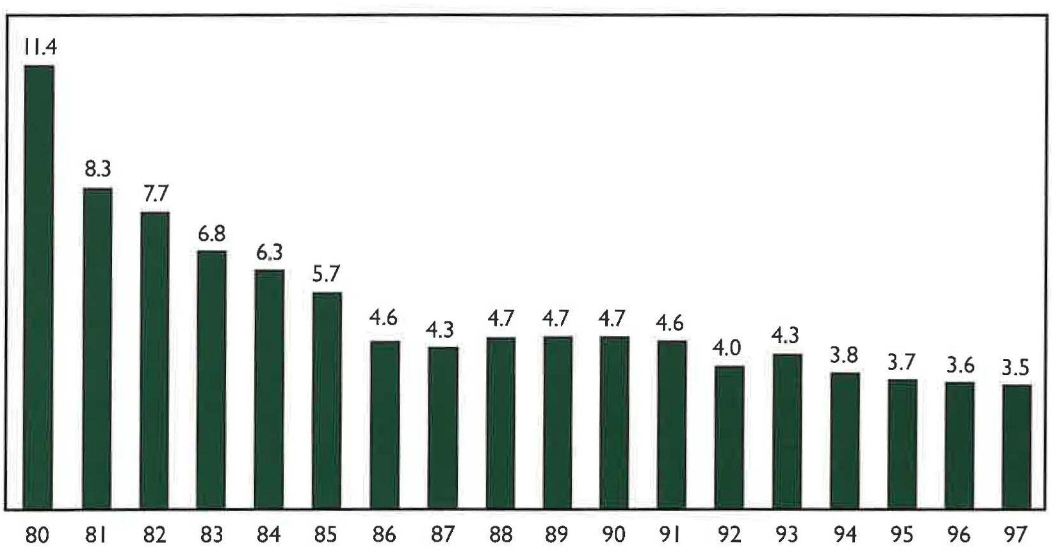

SOURCE: *Federal Railroad Administration, Railroad Facts, 1998 Edition.*

FIGURE 1 Total accidents per million train-miles.

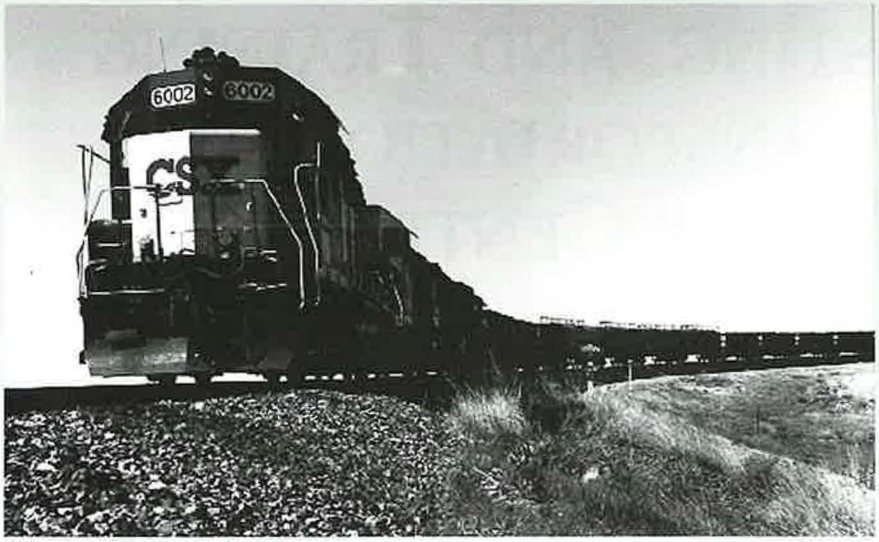

FIGURE 2 Track performance under 39-ton, heavy-axle loads is measured at Transportation Technology Center's Facility for Accelerated Service Testing to determine safety and performance benefits of improved suspension trucks.

The latest phase of the program addressed the performance benefits of improved suspension trucks—the wheel assemblies on which the cars ride. The FAST test train was equipped with trucks that had enhanced wheel set steering to improve performance when traveling around curves. It was found that after 425 MGT of applied tonnage, lateral forces and wheel set angles of attack (horizontal wheel-to-rail alignment) on 5- to 6-degree curves are up to 50 percent below those with standard suspension technology. The result is significantly reduced rail wear and fatigue. This improved performance should also result in a significant reduction in track gage widening tendencies.

With respect to the track structure, FAST tests also show that clean, premium rail steels are more resistant than conventional rail steels to internal rail defects and to rail surface damage. Additionally, track with marginal support conditions can be improved by using substructure remedies such as geowebs[1] and optimum granular (ballast) layer designs.[2] Improved materials and designs for turnouts (a means to divert rolling stock from one track to another) have produced substantial increases in durability, and new geometric designs have reduced the dynamic vehicle forces upon entry into the turnout, improving the safety and performance of special track under heavy axle loads.

Detection of Internal Rail Flaws

Internal defects in rails occur as a consequence of either the rail manufacturing process or the accumulation of fatigue under repeated loading. FRA derailment reports indicate that rail defects are the third-highest-ranking cause of train accidents.

Rails are regularly inspected for internal defects from moving vehicles that use ultrasonic and/or magnetic transducers. Although ultrasonic inspections prevent many failures, conventional inspection technologies can be compromised by loss of signal transmission due to rail surface defects and contamination. Detection of defects in thermite welds (a type of field weld produced from an aluminothermic reaction) and prevention of cold-weather pull-aparts (rail breaks from cold-weather contraction) are major safety concerns. So, too, is detection of rail base defects, which cannot be accomplished with current rail inspection systems. TTCI is developing improved rail inspection and maintenance practices, with the goal of reducing derailments related to internal rail defects.

A Rail Defect Test Facility (RDTF) has been installed as a gauntlet track on TTC's Balloon Loop (see Figure 3). The test track includes tangent and curved track with service-induced rail defects, including transverse defects, defective field welds, vertical and horizontal split heads, and bolt hole cracks. Six state-of-the-art hi-rail vehicles equipped with ultrasonic inspection technology have been operated over the RDTF in an effort to benchmark their performance. Results suggest that the reliability of defect detection is within the minimum performance guidelines of the American Railway Engineering and Maintenance of Way Association. These results will serve as a baseline for comparison against improvements incorporated in existing and emerging technologies.

Other new technologies are being evaluated to determine their potential for further enhancing the reliability of rail inspection techniques and practices. These efforts feature improved operator training in the use of computer software and neural networks to enhance signal interpretation.

Detection of Roller Bearing Defects

Each year 40 to 60 derailments result from overheating of railcar axle roller bearings. Currently, bearings are checked periodically by wayside thermal sensors or hot-bearing detectors. Although these detectors have prevented many failures, their performance could be improved. Occasionally they trigger costly false alarms, which account for the majority of detector-caused train stops. Existing detectors may also identify faulty bearings too late in the failure (burning-off) process to prevent damage,

[1] A geoweb is made from material consisting of honeycomb shapes that is placed in the roadbed to stabilize weak soils.

[2] Optimum granular ballast and subballast form a granular layer of sufficient thickness to reduce traffic load-induced stresses to the subgrade to an acceptable level.

given that many hot-bearing failures have occurred within a few miles of operational detectors.

TTCI's Roller Bearing Defect Detection Program has the objective of reducing roller-bearing-related derailments by up to 50 percent by using acoustic techniques to improve the reliability of the detection of bearing defects. These systems incorporate new signal-processing and detection techniques developed by TTCI and others. One such system is currently being evaluated at a Conrail test site near Middlesex, New Jersey (see Figure 4). This system uses an array of microphones to collect "noise information" from bearings on passing trains. The microphones are housed in specially designed enclosures that enhance acoustics and protect the equipment from vandalism. Once the acoustic information has been collected, it is computer-analyzed by neural networks that can recognize the type, severity, and location of defects within the train.

TTCI research engineers are also investigating the use of on-board systems to identify poorly performing cars and their components, including roller bearings. These systems work with the communications system used by the electronically controlled brakes. Their feasibility is being tested at FAST using the heavy-axle-load train.

Track Geometry and Strength

While their number is declining, derailments related to track geometry continue to be the leading category of derailments on the basis of both frequency and severity. To address this problem, several North American railroads use modern high-speed inspection vehicles to take accurate measurements of track geometry—the relative position and alignment of the rails along the track. These state-of-the-art vehicles use computerized electronic and optical instruments, such as lasers, accelerometers, and linear displacement transducers, to monitor track geometry. Although this monitoring provides an assessment of track against defined track geometry standards, it does not provide information on track load-carrying capacity or strength.

Research efforts are aimed at developing an automated means of measuring three track strength parameters: gage-holding strength, panel shift strength, and buckling resistance. AAR's Track Loading Vehicle and FRA's Gage Restraint Measurement System have demonstrated that in-motion measurement of

FIGURE 3 Performance evaluation of state-of-the-art rail detector cars at Transportation Technology Center's Rail Defect Test Facility will improve reliability and accuracy of internal rail defect inspection.

FIGURE 4 Development and implementation of new-generation wayside acoustic bearing-defect detectors are expected to facilitate early detection of defective bearings.

FIGURE 5
Development of track strength measurement systems and maintenance methods will reduce derailments caused by inadequate track strength and vehicle–track interaction.

track strength is feasible. These vehicles provide additional information on strength and load-carrying capability, and can identify weak spots for repair before further degradation occurs (see Figure 5).

A major safety and performance issue for railroads is the loss of track lateral strength after track or ballast maintenance, a condition that can result in track buckling. Temporary slow orders (i.e., reductions in authorized track speed) are employed while the track is reseated under traffic and regains its lateral resistance, but these slow orders also produce train delays. Research is now under way to better determine the total lateral resistance of track as a system of ballast, crossties, fasteners, and rails. This effort to improve understanding of track strength is aimed at reducing track-buckling frequency and severity and at optimizing the assignment of slow orders after track maintenance.

Tank Car Safety

Research aimed at improving tank car safety has focused on the application of damage tolerance principles in tank car management and design, assessment of nondestructive test methods for tank car inspections, and validation of current guidelines used by emergency responders for assessing the structural integrity of damaged pressure tank cars involved in accidents. In 1992 the National Transportation Safety Board recommended that tank car structures be designed using a damage-tolerant philosophy similar to that employed by the aircraft industry. This approach is based on the assumption that flaws exist in tank car steels and welds (as is the case in all steels and welds). Fixed inspection intervals are used to ascertain when cracks that threaten a tank car's structural integrity will become critical and require repair. The tank car industry is currently assessing the results of the validation work at TTC to ensure successful implementation of the damage tolerance methodology in practice.

A Tank Requalification and Inspection Center is being established at TTC to provide the tank car industry with a tool for developing and evaluating nondestructive evaluation (NDE) techniques. This facility will assist in:

- Determining the reliability of inspections.
- Improving safety through technology development.
- Addressing industry needs in the areas of maintenance, inspection, and damage tolerance.
- Validating NDE technologies developed by government, academic, and commercial organizations.
- Conducting cost-benefit analyses.
- Promoting technology transfer.

The Center's primary objectives are to baseline NDE processes currently allowed, develop a validation methodology and determine the probability of detection for those processes, and establish a defect library containing tank car test samples for service- and artificially induced flaws.

Another program addresses the problem of how to determine whether pressurized tank cars damaged in an accident can be moved safely without their contents being unloaded. Other hazardous materials safety projects recently carried out by TTCI researchers include crack growth and damage tolerance evaluation on tank cars, tank car damage assessment for emergency response safety, use of cutting explosives to remove products from badly damaged tank cars, and surge suppression of corrosive products in tank car safety vents.

Evaluation of nondestructive testing (NDT) methods is also pursued by TTCI to improve tank car safety. TTCI has been instrumental in testing and evaluating the effectiveness of standard NDT procedures for determining the probability of detection of cracks in tank cars. These procedures have included use of fluorescent liquid penetrant, fluorescent magnetic particles, shear-wave ultrasonics, optically aided techniques, and acoustic emissions.

Transportation of Hazardous Materials

Center for Hazardous Materials Transportation Safety

TTCI has established a Center for Hazardous Materials Transportation Safety. This new organization offers a variety of services for customers who must deal with issues related to the safe transport of hazardous materials. These services encompass research, development, testing, training, and consultation.

An integral part of the Center is the Bureau of Explosives (BOE). BOE consists of 10 field inspectors in the United Sates, 1 in Mexico, and 4 in Canada. The organization was founded by the railroad industry in 1905 as a self-policing body to increase railroad safety, and is managed by TTCI. The inspectors are supported by a director, a chief inspector, a hazardous materials specialist, and an administrative staff. BOE provides companies with training, regulatory compliance audits, and safety inspection services. In addition, rail carrier members are assured of emergency response assistance from BOE inspectors, who also conduct quality assurance audits and certification inspections of tank car repair facilities.

Hazmat Publications and Annual Seminar

TTCI publishes a series of documents related to hazardous materials transportation. Among these are *Hazardous Materials Transportation Regulations* of the U.S. Department of Transportation, *Emergency Handling of Hazardous Materials in Surface Transportation, Emergency Action Guides for Hazardous Materials, Annual Report of Hazardous Materials Transported by Rail, Intermodal Loading Guide for Products in Closed Trailers and Containers, Field Guide to Tank Car Identification, Police and Emergency Responders' Hazardous Materials Pocket Response Guide,* and *Hazardous Materials Shipping Description Data Base.*

TTCI also sponsors an annual seminar for hazardous materials manufacturers, shippers, carriers, container manufacturers, environmental cleanup contractors, and regulators, as well as others interested in the field. During the seminar, papers are presented on a variety of relevant topics, short training sessions are given by BOE inspectors and TTCI trainers, and equipment vendors and consultants exhibit new technologies and services.

Emergency Response Training

TTCI offers advanced hazmat-related emergency response training at its facilities in Pueblo and at shipper and carrier facilities. Courses are designed to give responders hands-on experience with rail, highway, intermodal, and marine equipment used to transport hazardous materials. Since the program's inception in 1985, more than 20,000 emergency responders from railroads, hazardous materials manufacturers and shippers, and public emergency response organizations have received this training.

Safety Testing of Railcars

TTC has a full range of capabilities for testing the safety and performance of trainsets and individual railcars—both freight and passenger. For freight car testing, AAR took steps in the mid-1980s to enhance the safety of new and untried rolling stock being introduced in interchange revenue service. A new set of trackworthiness test and analysis requirements was introduced, and various tracks at TTC were modified to allow the full range of required tests. For many of these tests, a wheel and rail load-measuring wheel set is required to provide continuous data on vertical and lateral forces.

Similarly, TTC trackage has been upgraded to assess the performance of high-speed trainsets. Developing safe, high-capacity, high-speed rail systems is an objective of FRA's Next Generation High Speed Rail Program, which conducts independent tests and assessments of high-speed rail systems using performance-based criteria in a controlled, full-scale, on-track testing environment. Typical performance-testing regimes include vehicle suspension characterization and evaluation of trackworthiness, structural integrity, ride quality, propulsion/brake system performance, and environmental impacts. Performance tests and evaluation of Amtrak's new Pacific Northwest Talgo trains have been conducted, and Amtrak's new Northeast Corridor high-speed trainsets and electric locomotives are currently being tested.

Conclusion

The success of the government–industry collaboration at TTC provides a model for focusing the strengths of a primary industry and those of its suppliers and regulators to achieve common goals. Technology has played a key role in the remarkable safety records achieved by North America's railroads. Partnerships such as that at TTC can serve to accelerate the development and use of new technologies to further enhance the safety of rail transportation.