Federal Railroad Administration and Transportation Technology Center, Inc - Moving American Railroad Forward

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In the U.S.A., the Research and Development Office of Federal Railroad Administration together with TTCI is trying to promote safe, environmentally sound, and successful railroad to meet current and future needs of all customers by fostering excellence, rising to the challenge of safety and by advancing railroad technologies for the 21st century. From 1992 through 1997, FRA conducted various research and development projects and many projects were conducted in conjunction with the railroad industry. The safety-driven mission of the FRA office of research and development consists of three core goals :

- support for regulatory development
- support for safety enforcement activities
- definition of the potential for new technology and practices to improve safety

Specifically, since 1997 the FRA office of R&D strives to improve railroad safety and advance application of new technology through targeted research in the following major areas;

equipment, operations and hazardous materials

- equipment and components; locomotive safety, passenger car standards, trailer/container securement, advanced braking, improved components and inspection systems, and improved wayside detection
- operating practices; stress and fatigue, grade crossing and operation lifesaver, dispatch training, ergonomics of advanced train control, and yard and terminal safety
- hazardous materials; NDE techniques for tank cars, tank car acceptance procedures, and tank car damage assessment

- track, structures and train control
  - track and components; improvements to rail steel, track buckling analysis and field testing, FAST test operation, special trackwork and advanced track material

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- inspection and detection; advanced inspection technology, track degradation
- track-train interaction; track geometry studies, vehicle track systems
- signals, train control and electrification; loss of shunt, signal system safety studies, advanced train control, electrification safety
- high-speed ground transportation safety
  - high-speed rail systems; train control and system operations, grade crossing risks/ infrastructure, high-speed equipment issues, high-speed test support at TTCI, Pueblo, Colorado
  - environmental issues and environmental impact analyses
  - magnetic levitation(MAGLEV) systems

In the mean time, TTCI has been playing an active and important role in safety-related railway R&D projects. TTCI is a world-class intermodal research and test center that offers a wide range of capabilities. The center is owned by the FRA and is operated in the private sector by the Association of American Railroads. TTCI offers a unique position of acquiring the quality research and analysis knowledge, skills and talents available in the railroad industry. Its staffs perform tasks for clients in a dedicated manner for advancement of railroad technology, efficiency and safety.

1. Staff Overview

TTCI's resource groups include "engineering" to coordinate technical support and program managements; "instrumentation and test services" to provide measurement skills and test equipment maintenance and operation; "operations and facilities" providing a range of specialities including test train operations, rolling stock maintenance, machine shop support; test set-up, as well as maintenance and upgrading of TTC's 52 square miles(135 square kilometers) of property, 48 miles (77 kilometers) of track and numerous office, maintenance shop and laboratory buildings.

2. Engineering

The engineering service department is equipped with a wide range of engineering, knowledge, background and experience. The staff consists of 61 full-time employees and a wide range of engineering and science disciplines are covered in this group, with experiences in the areas of civil, mechanical, electrical, metallurgical and industrial engineering along with economics, physics and computer science. Through use of engineering principles and common sense, TTCI engineers solve railroad and transit problems in the following general areas;

2.1 Track Structures

Turnouts, special track work, rail issues including grinding, fatigue and welding, ties, fasteners and ballast, rail lubrication and heavy axle loads are all areas in which TTCI engineers solve problems for clients.

2.2 Test & Analysis

TTCI Engineers have many years of test design and conduct experience. On-track and laboratory testing of freight cars and components are performed. Over-the-road and other offsite tests to evaluate cars and components are regularly performed. Track components are tested in the lab and in situ at TTC and off site. Data from testing allows TTCI engineers to analyze and solve problems for clients, as well as allowing engineers to develop well-founded computer models which predict vehicle/component responses. Many state-of-art test data analysis tools are utilized, including commercially available packages such as SnapMaster, PV-Wave and MatLab, along with specialty in-house developed tools such as GAKN and PlotView.

2.3 Simulations & Predictions

TTCI engineers develop and maintain various computer models that simulate the dynamic behavior of track, railcars, trains, trucks and components. Through use of the models to solve client's problems, sales and support of the models to the railroad industry and through training of users, TTC engineers stay involved in current industry issues. Computer simulation models enable the study of new concepts, vehicle and track components, vehicle/track dynamic interaction, train operations and train energy consumption in an analytical environment which greatly reduces the cost of field testing.

2.4 Economics

TTCI engineering economists provide expertise to clients in all areas of railroad operations and maintenance. Net Present Value techniques are used to rank all AAR research projects. Custom economic models are built by TTCI to help clients minimize operating/maintenance costs associated with complex engineering decisions.

3. Instrumentation Resources

The instrumentation group is made up of 28 people of highly diverse backgrounds. Areas of expertise include metrology, acoustics and vibration, data acquisition and processing, software development and test automation and control. The skill mix also includes those talents necessary for operation and maintenance of a wide range of testing systems including hydraulics, electro-mechanical devices and component testing machines.

We provide continuous training, education, and measurement system development to allow the instrumentation group to remain the premier railroad instrumentation organization in the country.

3.1 Metrology

The instrumentation group operates and maintains a complete metrology laboratory with standards traceable to NIST. Instrumentation personnel maintain and repair most of the instrumentation support equipment used at the TTC.

3.2 Data Collection

Instrumentation personnel operate and maintain a wide range of state-of-the-art data collection systems. They have developed and built remotely controlled data collection systems, unmanned vehicle mounted data collection systems and portable systems. The instrumentation group has built and sold data collection systems to domestic and international customers. A special feature is TTC's patented high-accuracy instrumented wheelset technology.

3.3 Rail Vehicle Dynamics

Instrumentation personnel have developed specialized data collection and processing systems for monitoring and analyzing vehicle ride quality parameters. They have also developed specialized techniques for characterizing rail car trucks and suspension components.

3.4 Specialized Measurement Systems

Over the last 20 years the instrumentation group has designed, developed and fabricated numerous highly specialized measurement systems. These include angle of attack systems, rail profilometers, wheel profilometers, tie and rail ware measurement systems and switch frog profiling devices.

3.5 Rail Force Measurements

Instrumentation personnel have developed and perfected techniques used to measure the forces induced in rails by passing rail cars. These techniques are currently being used to help identify problem cars before they can cause real damage. They are also being used to weigh cars on the fly and to study truck curving performance.

3.6 Rail System Stress Measurements

The ability of the instrumentation group to measure stresses induced in rail vehicle components and structures and in track structures, is recognized throughout the railroad world. Personnel have refined the application of strain gages and strain measurement systems to a high degree

3.7 Rail Force Measurements

Through techniques developed by the instrumentation group, engineers can now quantify railroad bridge, ballast, sub-grade, tie and rail performance. The group has been instrumental in developing new techniques and equipment used to evaluate these systems.

4. Operations and Facilities Resources

The Operations and Facilities Department is a diverse group that brings to the table a wide range of experience, knowledge and abilities to this business. Most of the skilled craft positions have extensive backgrounds in their respective fields. This experience has added value to the workforce and enable us to cross-train others into high demand positions.

4.1 Railroad Operating and Testing Experience

The 20-skilled professionals involved in Operating and Test functions at TTCI average 14 years of overall experience. There, personnel have ties to eight major US Railroads including four Class I Carriers. These individuals are multi-talented, versatile professionals with backgrounds, not only in Train and Engine Service, but also in many other areas including Mechanical Officer, Safety Officer, Wreck Master, and Yard Master. Several have obtained college degrees including those in Accounting, Business Finance, and Business Management.

4.2 Railroad Mechanical and Testing Experience

TTCI's Mechanical Staff is not unlike the Operating Staff. They currently consist of 19 skilled professional with an average of 15 years of combined experience. They too, are versatile employees with a wide range of talent. Several of these folks have learned much of their trade at the TTC and are considered among the best in the world in regard to their specific crafts. Included are several of the most knowledgeable AC Traction Locomotive Electricians and Repairmen in the world. Most are capable of working in several other mechanical crafts besides the craft their title infers.

4.3 Railroad Track and Testing Experience

The large majority of Track Personnel have learned their trade at the TTCI. The 12 people currently employed in this area represent a combined average of 9 years of experience. TTCI stands proud in the fact these people are also among the finest in the industry. Many times these employees are called upon to do precision track work considered to be impossible elsewhere in the industry. Most are cross-trained in the area of Track Labor, Track Equipment Operation and Track Inspection. One of their most remarkable accomplishments is the completion of four years of work in a very dangerous craft without one lost time injury.

5. Testing Facilities

The Railway Technology Department of the Association of American Railroads, a world leader in railroad and transit research, operates the Transportation Technology Center, in Pueblo, Colorado. TTC offers forty-eight miles of railroad track to test rolling stock, track components, signal and safety devices, track structure, vehicle performance, track and service worthiness, life-cycle and component reliability and ride comfort. TTC also has several one-of-kind laboratory test facilities used for evaluating vehicle dynamics, structural characteristics, and advanced braking systems.

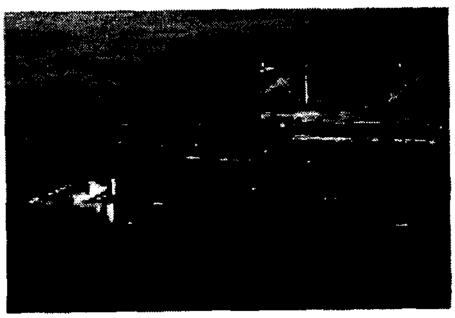
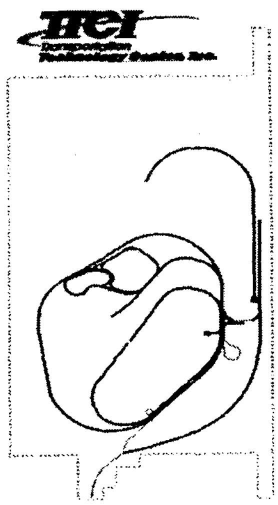


Fig. 1 Aerial view of TTCI's test facilities

TTCI's most valuable asset is its uniquely qualified staff. TTCI employs recognized experts in mechanical, civil, chemical, metallurgical, human factors and industrial engineering and computer science. Staff members enthusiastically offer their expertise in serving our customers. The professional, administrative and technical support staff work together to produce valuable results on time and on budget.

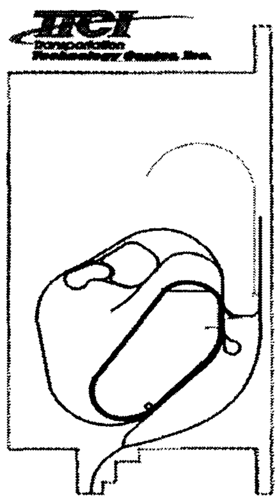


Test Tracks

TTC includes over 48 miles of trackage devoted to testing all types of rolling stock, track components and signal safety devices. The AAR also performs certification testing on freight rail vehicles of various designs at TTC according to specifications in Chapter XI, of the AAR, M-1001, Manual of Standards and Recommended Practices, to ascertain the interchange service worthiness of freight cars. The Wheel Rail Mechanism (WRM) track offers test sections for constant curving (3-, 4-, 5-, 7.5-, 10- and 12-degree curves), curve entry and exit spiral negotiation, dynamic curving (10-degree curve with simultaneous cross level and gage misalignments) and limiting spiral negotiations (10-degree curve with abrupt change in the rate of change in the cross level). The remaining tangent track worthiness tests in Chapter XI of the AAR's M-1001, Manual of Standards and Recommended Practices are performed on the Railroad Test Track (RTT) and Perturbed Test Track (PTT).

The dynamic pitch and bounce response of the test vehicle, excited by vertical inputs from the track, is evaluated on PTT's 400-foot test section with 0.75-inch vertical perturbations in phase at 39-foot intervals on both rails.

The dynamic twist and roll response of the test vehicle is excited by cross- level perturbations in the track, which is evaluated on PTT's 800-foot section with 0.75-inch out of phase vertical profile variations at 39-foot intervals. The dynamic yaw and sway response of the test vehicle, excited by the laterally mis-aligned track, is evaluated on the PTT's 250- foot test section. On this test section, there are sinusoidal track alignment deviations of 39-foot wavelength and an amplitude of 1.25 inches peak-to-peak on both rails at a constant gage width of 57.5 inches. The lateral oscillation instability of the test trucks is evaluated on the RTT 5000-foot tangent section of 39-foot jointed rail, to Class 5 or better.



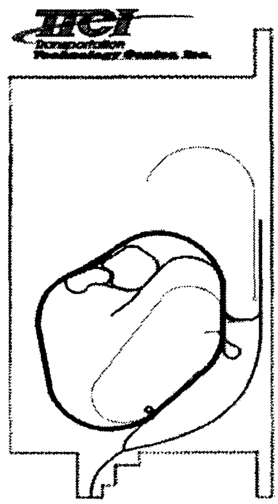
Transit Test Track

The Transit Test Track (TTT) is a 9.1-mile oval track, equipped with a third rail power system, used for vehicle performance and specification compliance testing. Investigation of vehicle performance is possible at speeds up to 80 miles per hour over six segments of different track material construction; e.g., continuous welded rail versus jointed rail, wood versus concrete ties.

The third rail DC electrified power system provides transit and commuter vehicles with a voltage variable from zero to 1,000 volts DC with a 3,500 amp continuous rating. The track includs a 10,000-foot-long overhead DC catenary, suitable for low-speed operation and evaluation of light rail urban vehicles.

Located within the transit loop is the tight-turn or "screech loop." This 150-foot radius - 38 degree, 12 minute - curve test track is used in the investigation of wheel noise, car curving performance, and suspension system stability.

Controlled tests for verification of specification compliance of vehicle performance including spin/slide, propulsion and braking performance evaluation have been performed for numerous transit properties in the U.S., such as Massachusetts Bay Transit Authority, Maryland Transit Authority, LA County Red Line System, Dade County Transportation Administration, and New Jersey Transit Authority (NJTA).



Railroad Test Track

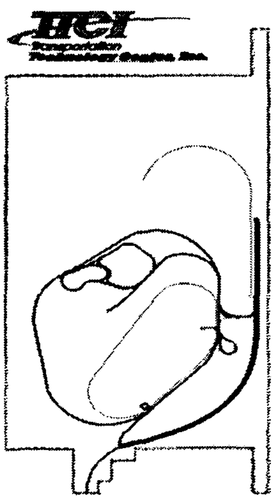
The 13.5-mile oval track with one 1 degree, 15 minute reverse curve and the remaining 50-minute curves. All curves have 6-inches of superelevation. The original design speed for the RTT in the early 1970s was for 160 mph operation. Over the years, the track speeds were reduced to ensure safety. Track restoration work consists of new track components typical of North American design, includes welded 136-pound per-yard rail, new concrete ties and treated hardwood ties with elastic fasteners. We will be capable of running sustained

150 mph operations up to maximum of 165 mph. The track loop is also being equipped with a rail break detection and switch indication system.

The RTT's catenary system can deliver a single-phase, 60 Hz alternating current at 12.5, 25, or 50 kV, in a single or dual voltage condition. The contact wire height is currently set a nominal 22 feet, 6 inch height, but can be adjusted to simulate tunnel or bridge conditions.

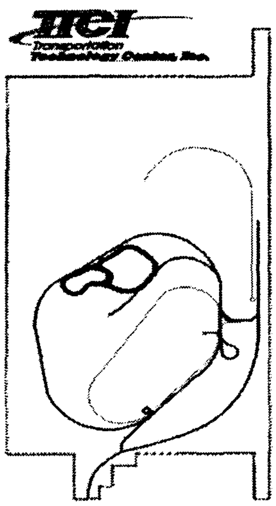
The RTT is the site of frequent high-speed stability and endurance tests for electric powered cars and locomotives. The total performance evaluation of the first AEM-7 locomotive, AMTRAK 900, was carried out on the RTT which included stability tests up to 125 mph and endurance tests simulating the Northeast Corridor schedules accumulating a total of 160,000 miles.

The latest series of tests carried out on the RTT consisted of specification compliance and endurance performance of NJTA AC traction commuter cars, which included high-speed stability tests up to 100 mph, traction, braking, endurance and wheel wear tests. Connected to the RTT and used for turning trains, is a Balloon Loop, which has a 7-degree, 30-minute curve with 4.5 inches superelevation and a 5-degree reverse curve with 3.5 inches of superelevation. The balloon loop is the new site of the rail gauntlet track. This trackage is used for research into methods to detect known track defects.



Precision Test Track

The PTT is a 6.2-mile-long track used primarily for vehicle dynamic behavior, safety compliance and impact tests. Construction consists of standard track materials maintained to include specified track perturbations used in conjunction with the performance of vehicle track wothiness testing.



FAST Facility

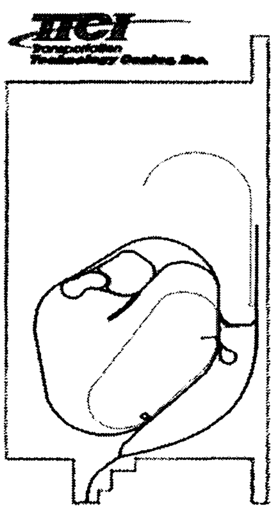
The best known, most utilized, and the most versatile track at TTC was the 4.8 mile FAST loop, the Facility for Accelerated Service Testing. Even though the original FAST programs (1976 thorough 1988) ended under 33-ton axle loads, FAST was a million-gross-ton-per-day durability tester of many types of rails, fasteners, cross-ties, ballasts, subgrade materials, wheels and freight car trucks. Since July 1988, the High Tonnage Loop, 2.7 miles long, was created as an inner loop track within FAST, which is currently used for heavy axle loads of 39 tons.

High Tonnage Loop

The HTL, 2.7 miles long, is used for track component reliability, wear, and fatigue research under heavy axle loads of 39 tons. Operations are restricted to a maximum 40 miles per hour. The HTL is divided into test sections which generally correspond to tangents, spirals, curves (three 5-degree curves and one 6-degree curve) and turnouts. Eight experiments are currently being conducted including rail performance, evaluation of ties and fasteners, frogs, turnouts, ballast and subgrade. Test train operations are designed to accumunlate 1.0 million gross ton (MGT) a day traffic density at a maximum 40 miles per hour operating speed.

Wheel Rail Mechanism

The WRM track is a 3.5-mile loop configured to determine vehicle performance on nominally smooth track and on track with perturbations designed to induce known poor performance modes. The WRM is used primarily for the evaluation of rail vehicle safety compliance in curving.



Impact Track

The Impact Facility Track, a 0.75-mile-tangent track, facilitates destructive impact test projects, in support of Railroad Tank Car Safety research, which yielded major safety related modifications in tank cars carrying hazardous materials. Other projects related to full scale train impacts, in support of modifications for locomotive cabs. The tracks at TTC have been configured to determine vehicle performance on nominal smooth track and on track designed to induce known poor performance modes. These tracks are used in safety performance analysis and for vehicle certification. The AAR performs certification testing on freight rail vehicles of various designs at TTC according to specifications in Chapter XI, of the AAR, M-1001, Manual of Standards and Recommended Practices, to ascertain the interchange service worthiness of freight cars. The WRM track offers test sections for constant curving (3-, 4-, 5-, 7.5-, 10- and 12-degree curves), curve entry and exit spiral negotiation, dynamic curving (10-degree curve with simultaneous cross level and gage misalignments) and limiting spiral negotiations (10-degree curve with abrupt change in the rate of change in the cross level). The remaining tangent track worthiness tests in Chapter XI of the AAR's M-1001, Manual of Standards and Recommended Practices are performed on the RTT and PTT. The dynamic pitch and bounce response of the test vehicle, excited by vertical inputs from the track, is evaluated on PTT's 400-foot test section with 0.75-inchvertical perturbations in phase at 39-foot intervals on both rails. The dynamic twist and roll response of the test vehicle is excited by cross-level perturbations in the track, which is evaluated on PTT's 800-foot section with 0.75 inch out of phase vertical profile variations at 39-foot intervals. The dynamic yaw and sway response of the test vehicle, excited by the laterally misaligned track, is evaluated on the PTT's 250-foot test section. On this test section, there are sinusoidal track alignment deviations of 39-foot wavelength and an amplitude of 1.25 inches peak-to-peak on both rails at a constant gage width of 57.5 inches. The lateral ocsillative instability of the test trucks is evaluated on the RTT 5000-foot tangent section of 39-foot jointed rail, to Class 5 or better.

6. Test Laboratories

TTCI's assets set it apart from other research and testing facilities. One-of-a-kind test machines provide TTCI engineers with the tools to test and evaluate railroad products and/or improvement concepts. Computer models, designed to predict railroad equipment performance, help TTCI to provide clients with a look at proposed designs prior to prototype fabrication.

Through continuous quality improvement, strategic reinvestment and customer-driven acquisitions, TTCI is constantly working to improve its technology assets.

6.1 Rail Dynamics Laboratory

The Rail Dynamics Laboratory is a unique facility for researching vehicle and component dynamics for safety, ride quality, stability and durability. The 55,000-square-foot high-bay building houses highly sophisticated testing rigs, including: the Simuloader, the Vibration Test Unit, the Roll Dynamics Unit, the Mini-Shaker Unit and the Traction Motor Test Stand. Their functions are monitored, controlled and recorded from the RDL control room. The data developed is collected by a computer in the control room. Both the VTU and SMU can transmit 64 channels of data from different types of transducers to the control room where data reduction systems provide both "quick look" and in-depth analysis.

6.2 Simuloader

The SMU is a hydraulic shaker system that inputs vibrations into a test vehicle's car body directly through the body bolsters. The inputs used for this system are truck bolster responses, which can be acquired while traversing railroad track or during testing on the VTU. The SMU is designed to run efficiently for long periods of time, which makes it particularly well suited for fatigue tests. The fatigue life of a railcar (average of 30 years) can be determined from the fatigue data obtained within just a few weeks of Simuloader testing. The resulting fatigue analysis serves as a source of design information and safety data. Typical tests on the Simuloader consist of the evaluation of structural integrity of stub sill tank cars and prototype aluminum coal cars of different U.S. manufacturers. Other structures including highway buses have been tested on this machine

6.3 Vibration Test Unit

The VTU is, effectively, a laboratory simulator of wheel/rail dynamics. A test vehicle 90 feet long and weighing as much as 160 tons can be operated repeatedly over a simulated section of "track," with any combination of vertical and lateral force/displacement inputs by the VTU's hydraulic actuators. The VTU's computer controls can simulate actual track conditions with a library of data from various classes of track or a wide range of mathematical input profiles. The VTU's controls have the capability of inducing vibrations in the frequency ranges of 0.2 to 30 Hz to the test cars. A wide spectrum of tests varying from the dynamic behavior of rail vehicles to lading damage evaluation and evaluation of lading restraint designs can be effectively carried out on the VTU.

6.4 Mini-Shaker Unit

The Mini-Shaker Unit is a computer controlled hydraulic shaker capable of applying static or cyclic loads to one end of a test vehicle of up to 210 kips on its suspension through the full-suspension stroke. The MSU is equipped with special instrumented rail sections to measure wheel/rail forces. The suspension deflection and the reaction measurements from the actuators and rail are used to determine engineering values for the suspension characteristics. The MSU can be configured to perform the rigid and flexible body modal studies or fatigue studies of the strategic components of the vehicle structure. Vehicles of up to 680,000 pounds have been tested on this unit to determine suspension characteristics and rigid body modes.

Fig. 2 Mini-Shaker Unit

7. Other Labs

7.1 Track Loading Vehicle (TLV)

In support of several track research programs, the AAR has recently developed the Track Loading Vehicle (TLV) for measuring track strength from a moving vehicle.

The TLV consists of a single axle suspended from the middle of a long, heavy test car. Vertical and lateral hydraulic actuators are used to apply loads to the rails through the single axle. The axle can be fitted with load measuring wheels to measure the forces between the wheels and rails. Because the trials were completed at the TTC, the TLV has been used extensively on U.S. railroads quantifying the track structure currently in use. The TLV's capabilities have been improved through modifications to allow the load axle to be yawed relative to the rails. This allows in-depth studies of the wheel/rail contact mechanisms under a wide range of conditions. The conditions at the point of flange climb derailment are of special interest and significance.

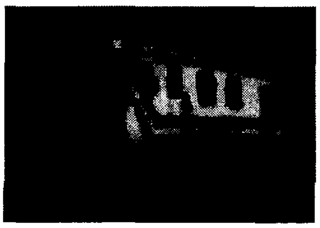


Fig. 3 Track Loading Vehicle

7.2 Metallurgical Laboratory and Components Testing Laboratory

In the field of metallurgy, the TTC is equipped to run laboratory tests on track and rolling stock components and materials. The testing lab contains scanning-electron, stereo-optical and x-ray microscopes. Specimens of rail, wheels and other components are subjected to mechanical testing, micro, Rockwell and Brinell hardness tests. Laboratory capabilities also include non-destructive evaluation to include liquid penetrant, magnetic particle, ultrasonic and visual testing. A Component Test Laboratory (CTL) provides facilities for various tests of track and equipment components. Full-scale wheel saw-cutting facilities, scaled-down drop (impact) test fixture for tank car heads, calibration fixtures for instrumented wheel sets and track components such as ties are also available in the CTL.

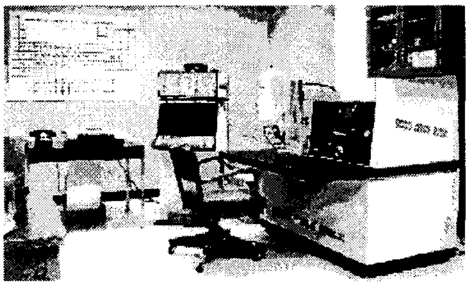


Fig. 4 Metallurgical lab

TTCI engineers also develop and maintain various computer models that simulate the dynamic behavior of track, railcars, trains, trucks and components. Through use of the models to solve client's problems, sales and support of the models to the railroad industry and through training of users, TTCI engineers stay involved in current industry issues. Computer simulation models enable the study of new concepts, vehicle and track components, vehicle/track dynamic interaction, train operations and train energy consumption in an analytical environment which greatly reduces the cost of field testing. TTCI has developed a range of models which are used by TTCI engineers in a wide range of applications such as:

- Evaluation of new trucks for heavy axle load (HAL) and autorack service
- Evaluation of new turnout designs
- Evaluations of flange bearing frogs in crossing diamonds
- Effects of wheel/rail profile design on wear rates and rolling resistance
- Effects of lubrication on train rolling resistance and wheel/rail forces
- Derailment investigation
- Calculation of in-train forces (buff/draft)
- Investigation of mechanisms that cause rail corrugations
- Optimization of train operations for minimum energy consumption
- Estimation of remaining service life in bridges

The first priority of FRA/TTCI is the safety of the United States railroad system, which, in 1996, included 173,000 route miles of track, 19,270 locomotives, 6,500 passenger cars, 1,240,000 freight cars and 205,000 employees. The demand on this system are continuously growing and changing technologies provide the opportunity to improve system effectiveness and efficiency. FRA/TTCI continue to address safety concerns in all phase of railroad operations, through research and development, regulatory and enforcement activities to ensure that railroads in the United States continue to be among the world's safetes. For the upcoming 21st Century, the FRA R&D office and TTCI are together moving American railroad forward.