U.S. Department of Transportation

Urban Mass Transportation Administration

Transportation Test Center

Rail Transit Services

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Rail Transit Services

PREPARED FOR

U. S. DEPARTMENT OF TRANSPORTATION

Urban Mass Transportation Administration

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FOREWORD

This Urban Mass Transportation Administration Capabilities Document is intended as a guide for potential users of the Transportation Test Center's (TTC) transit facilities, and provides information required to initiate a transit test program at the TTC. It also describes TTC facilities for performing intensive transit vehicle and related component testing, technical support capabilities and provisions for detailed data collection.

Further information can be obtained from: Director, Urban Mass Transportation Administration Programs, Transportation Test Center, P.O. Box 11008, Pueblo, Colorado 81001 (303) 545-5660.

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U.S. Department of Transportation

Urban Mass Transportation Administration

May 1981

INTRODUCTION

The urban rail transit test facilities at TTC provide for test and evaluation of urban rail vehicles, subsystems, track and structural components in an environment both safe and free from the scheduling constraints imposed by revenue service operations.

Early in its history, the Urban Mass Transportation Administration (UMTA) recognized the need for transit testing facilities. It found a solution already well under development within the Department of Transportation. The Federal Railroad Administration (FRA) was constructing a test center near Pueblo, Colorado, at that time called the High Speed Ground Test Center. The site and facilities at this Center provided a favorable environment for testing vehicles and equipment for both intra- and intercity transportation. UMTA entered into an agreement with FRA for sharing the Center's space and facilities and proceeded to construct the Transit Test Track and other installations described in this document.

UMTA provides funds for conducting these tests, including related activities such as operational evaluations, establishment of test plans and procedures, and collecting, processing, analyzing, and disseminating test data. A small contingent of Federal employees, from UMTA, FRA, and the Transportation Systems Center, is based at Pueblo for carrying out transit test programs. The bulk of the required labor is provided by an on-site operations and maintenance contractor retained by the FRA.

The FRA manages the facility. UMTA's test activities are coordinated through the Office of Technology Development and Deployment in Washington, and are conducted by the UMTA Program Office at the TTC. The principal Technology Development and Deployment offices involved in transit test planning activities are the offices of Rail and Construction Technology, and Safety and Product Qualification.

UMTA's exhaustive testing and evaluation of urban rail vehicles, subsystems, and track structural components promotes the discovery of operational or safety problems in new rail transit vehicles and equipment. Testing at TTC offers advantages in safety, scheduling flexibility, and sophisticated data collection. Ultimately, the availability and use of the TTC facilities should provide suppliers with additional incentive for producing higher-quality products.

To anticipate and forestall problems that might affect the reliability, maintainability, or quality of new transit vehicles, UMTA has established a policy that, in effect, requires operators to have a married pair or a two-car train from a newly purchased lot of cars subjected to rigorous testing at TTC to supplement the usual tests performed on their own properties. In 1978, UMTA established a policy called the "Light Rail Vehicle (LRV) and Rapid Rail Car Specifications and Testing of Cars at the DOT/FRA Test Center."* UMTA issued Guidelines to implement this policy. The text is in Appendix I to this brochure. This policy applies to all UMTA grantees purchasing or using light rail and rapid rail vehicles, requiring that TTC testing occur as early in the new car delivery phase as is practical, and prior to any public operation of the vehicles. UMTA capital grants for purchase of new transit cars now provide the costs of shipping vehicles to and from TTC as well as participation in the TTC tests.

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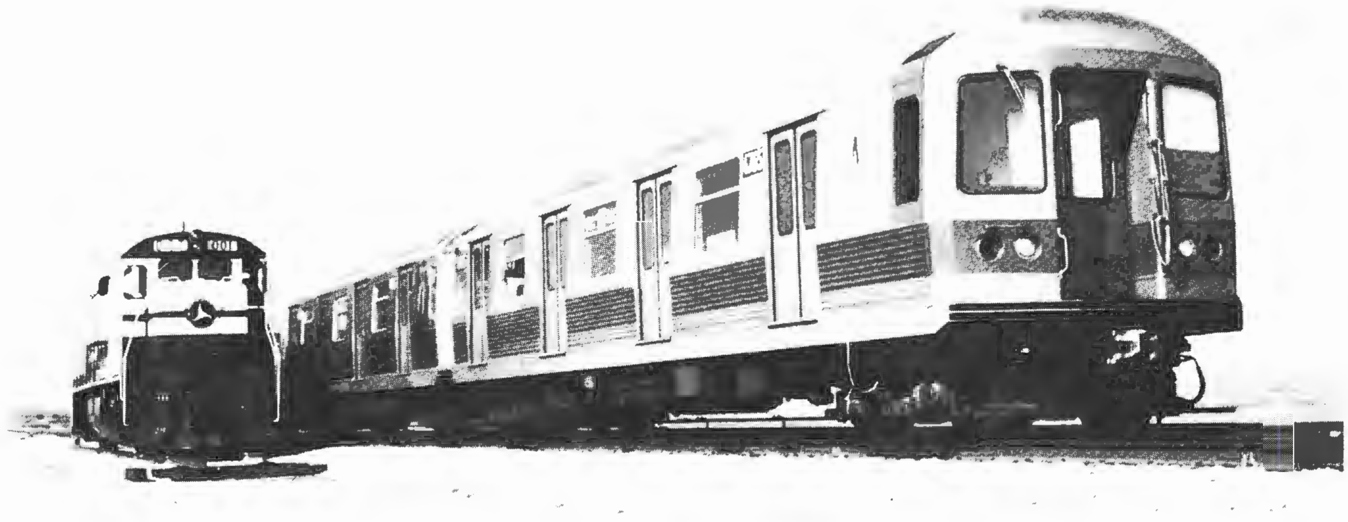
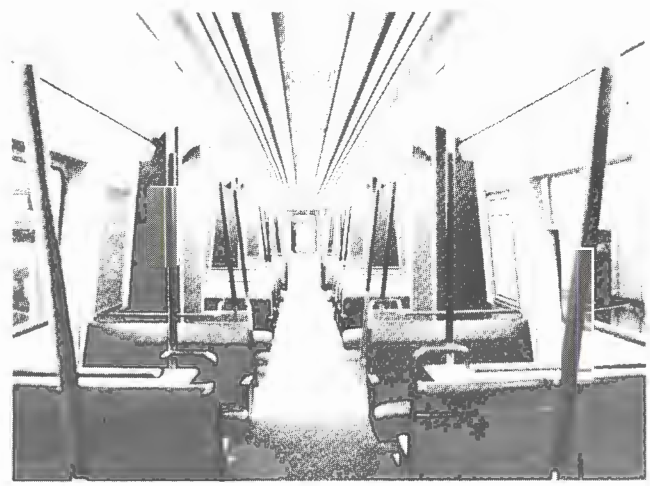
* UMTA Notice 6500.1.

A PICTORIAL HISTORY OF UMTA PROGRAMS AT THE TTC

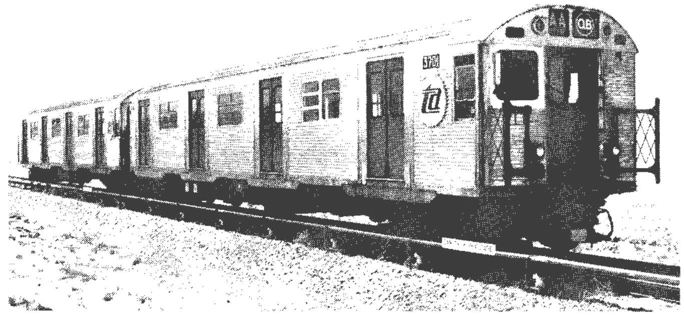


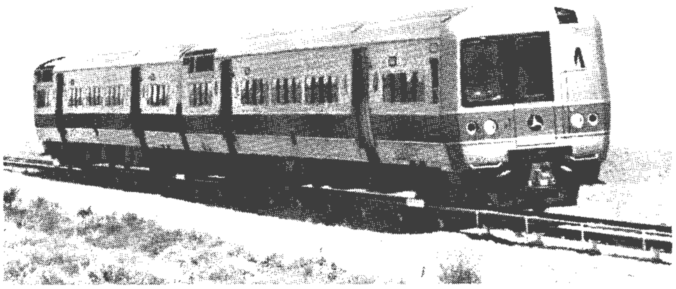
Two New York City Transit Authority R–42 Cars initiated transit program testing at the Center in 1971. These vehicles were used for a variety of test programs before the Transportation Systems Center developed an on-board Track Geometry Measurement System to measure track characteristics which affect rail vehicle performance under actual operating conditions. A cooperative program with the Toronto Transit Commission evaluated the on-board system, which eventually led to this system's use on the NYCTA transit lines. A General Vehicle Test Plan (GVTP) was also developed by TSC using these R–42 cars.



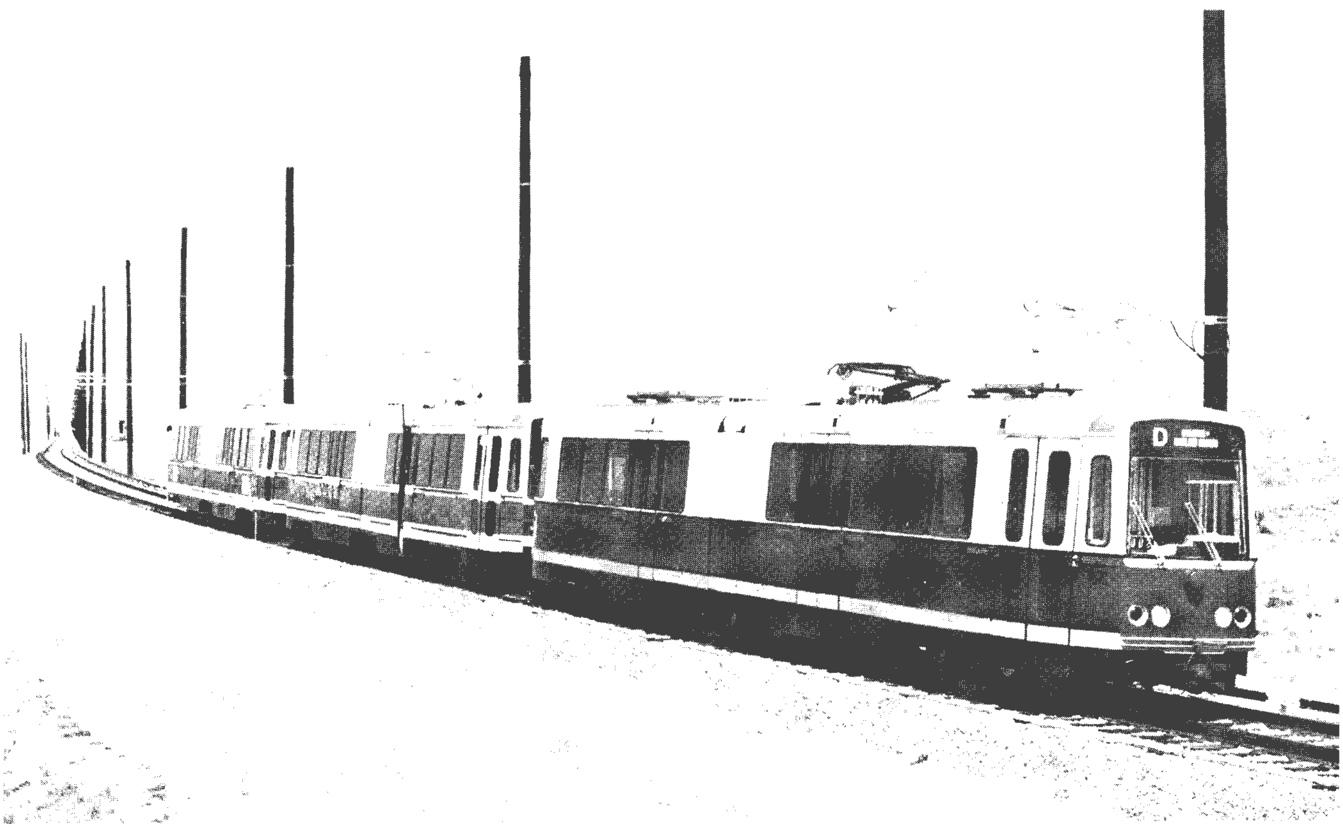
These State-of-the-Art Cars (SOAC) were built by the St. Louis Car Company for UMTA, with Boeing Vertol performing the systems integration. SOAC completed an engineering acceptance test program at the Center in 1974. Incorporating new features such as chopper control and certain acoustical features, SOAC toured five major cities during demonstration operation and gained favorable public reaction. Currently SOAC is part of the TTC's Advanced Subsystems Development Program (ASDP), which is aimed at developing specific subsystems including lightweight trucks, spin/slide control, and braking systems.

Two special types of commuter cars were tested in the early 1970's at the TTC. These NYCTA R–32 cars were outfitted with energy storage equipment which supplemented the conventional electric propulsion in each car.

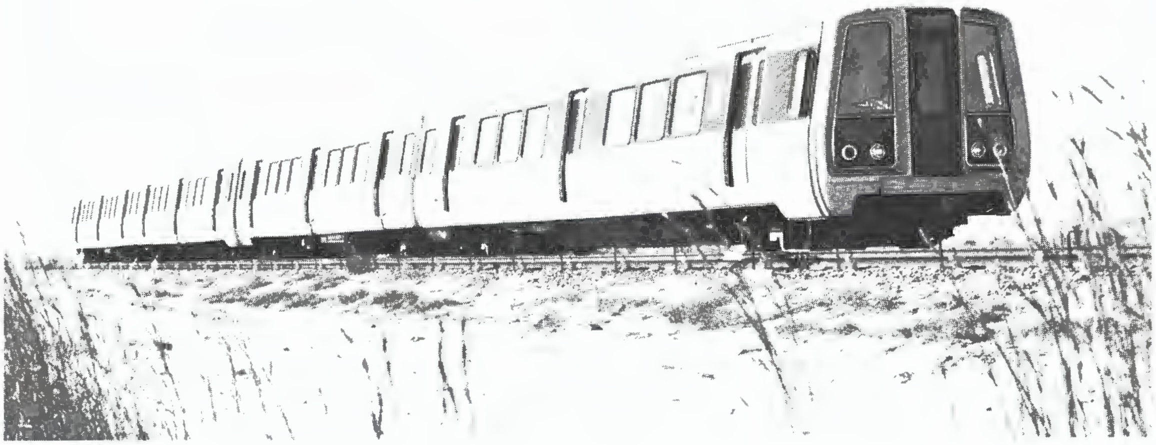




These Gas-Turbine/Electric Commuter cars produce electric power from roof-mounted gas-turbine generator sets in order to provide propulsion beyond the limits of electrified track.



In 1975, the San Francisco and Boston Light Rail Vehicles (LRV's) utilized the Transit Test Track's two miles of catenary as part of the Center's Light Rail Vehicle Test Program. These vehicles represented the first new design in streetcars since the PCC streetcars of the early 1930's.



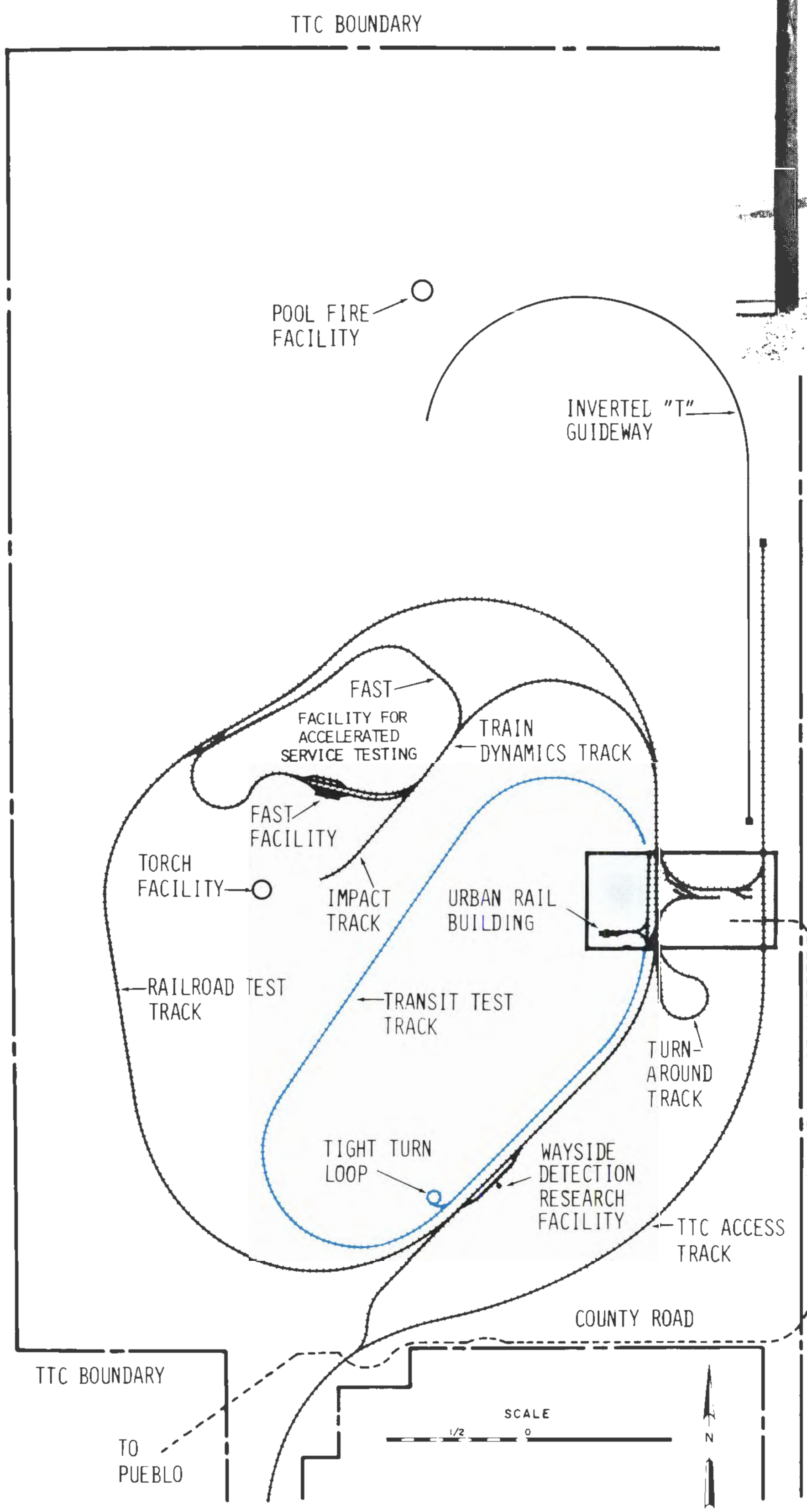
Washington's Metropolitan Area Transit Authority (WMATA) cars were tested at the TTC in 1977, utilizing the General Vehicle Test Plan, in addition to testing operational characteristics during 15,000 miles of simulated revenue service.

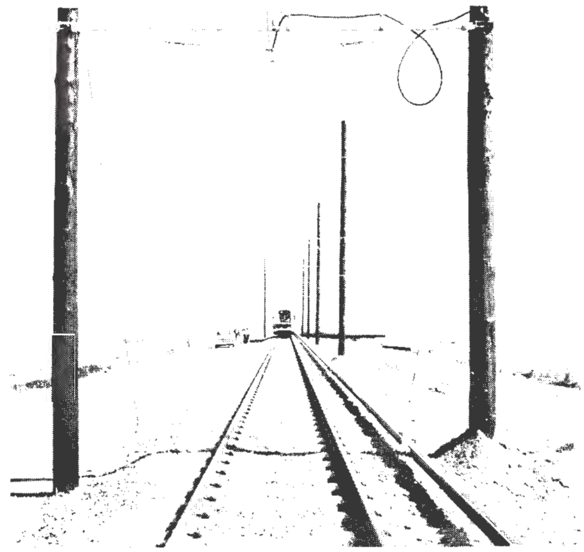
This experimental vehicle, the Advanced Concept Train (ACT-1), was developed for UMTA to evaluate advanced transit car systems for improved safety, performance, and operating economy.

Two Massachusetts Bay Transportation Authority (MBTA) Blue Line cars completed a series of design tests and a variety of special performance tests at the Center in 1979.

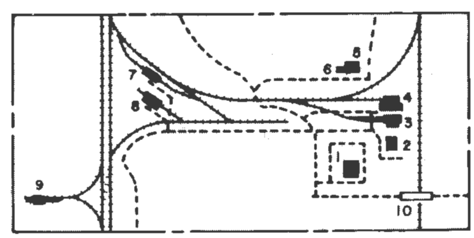
WMATA officials found that the availability of needed support equipment (instrumentation, wheel truing machine, locomotive, ballasts, high speed movie camera, etc.), and the ability of the Test Center personnel to adapt such equipment for WMATA's test needs was a major advantage which would have been very difficult to accomplish on a new property with limited on-site equipment. The TTC was also able to carry out several valuable tests that could not have been performed on WMATA's limited track without disrupting revenue service and other routine test activities. Such interference with ongoing daily activities would have increased WMATA's costs and might have adversely affected the opening date for subsequent operating phases. Another type of saving resulted from the evaluation of the disc brake shoe composition. By following TTC's recommendations, based on the testing, a very significant saving in maintenance costs was achieved.

The MBTA (Boston) cars accumulated 10,000 miles during testing at TTC. MBTA officials stated that, through mileage accumulation, they were able to get an initial "feel" for the reliability they could expect from the vehicles. They reported that, due to the facilities at TTC, they conducted numerous tests which would have been either impossible or too time consuming if done on the Boston system. These included: ride quality, high speed performance, drift characteristics, high speed photography studies, power consumption assessment and alternatives, and brake shoe material evaluations. As a result of the testing at TTC, the MBTA officials expected to make a performance profile modification that would result in energy savings. Also, they felt that the TTC testing enabled them to select a brake shoe material, to further fine tune the cars, and to renew pins on draw bars that test results showed to have excessive clearance.





The Transit Test Track is equipped with two miles of simple catenary which can power light rail vehicles.



TTC ADMINISTRATION-LABORATORY AREA

1. OPERATIONS BUILDING
2. PROJECT MANAGEMENT BUILDING
3. RAIL DYNAMICS LABORATORY
4. CENTER SERVICES BUILDING
5. WAREHOUSE/LABORATORY FACILITY
6. COMPONENTS TEST LABORATORY
7. TRANSIT MAINTENANCE BUILDING
8. STORAGE & MAINTENANCE BUILDING
9. URBAN RAIL BUILDING
10. AUTO OVERPASS

TRANSIT TEST TRACK

The Transit Test Track (TTT) at TTC is a 9.1-mile oval located within the larger Railroad Test Track and is used primarily for testing and evaluating urban rail vehicles. The development, test, and evaluation of vehicle subsystems, as well as the development of (both advanced and state-of-the-art) structures, and instrumentation can also be conducted on the TTT.

The TTT exceeds the requirements for FRA Class 6 and IRT Class 4 track. The loop is made up of three tangent and three curved sections from level to almost 1.5% in grade. The longest tangent section (11,000 feet) is located on the west side of the oval and contains 4,000 feet at zero grade and 7,000 feet at 0.69% grade. This tangent section is equipped with two miles of overhead catenary suitable for low-speed operation and evaluation of urban rail vehicles using overhead power collection systems. The east side of the loop contains about 4,200 feet at 1.47% grade, partially on tangent and on curve. The curves located north and south on the loop are 1°30′ curves with 4.5 inches superelevation. The curve located near the mid-easterly side is 0°50′ with 2 inches superelevation.

The Transit Test Track contains six segments, each with a different type of track construction, duplicating six different track types in use on U.S. transit properties. The basic characteristics of these segments are: 119 lb. (per yard) continuous welded rail on wood ties (three sections); 119 lb. continuous welded rail on concrete ties at three tie spacings; 100 lb. continuous welded rail on wood ties; and 100 lb. jointed rail on wood ties. Investigation of vehicle performance is possible at speeds up to 100 miles per hour. Each of the six sections is adequate in length to provide data on noise, vibration, and ride comfort.

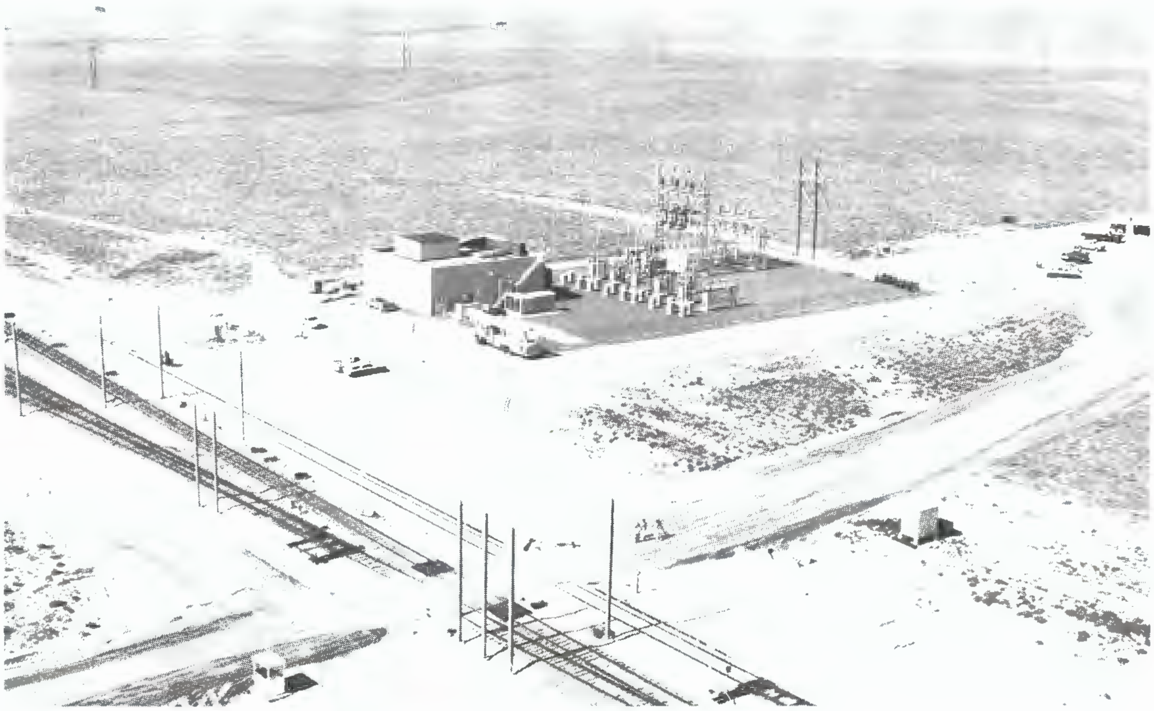
Instrumentation is imbedded in eight different places along the TTT, allowing for measurement of track structures while vehicles are in operation. Instrumentation includes moisture probes, temperature sensors, pressure cells, strain gauges, extensometers, and accelerometers. A section of track located on the easterly side can be intentionally perturbed. This was done initially to calibrate the track geometry measuring system on board the R–42 car. This section is also used to determine the dynamic responses between track and transit vehicles. It is restored to its unperturbed condition after such tests.

Two electrical power substations are located within the transit loop and receive power at 115 kilovolts, three phase, 60 cycles. Each substation provides transit vehicles with a voltage variable from 400 volts dc to 1,500 volts dc with a 2,500 amp continuous rating, and with an 11,250 amp capability for vehicle acceleration. Power to the TTT is through a third rail, with provision for overhead pickup along a 10,000-foot length of simple catenary.

The power stations provide a constant voltage to the TTT that compensates for line drops which may occur during test operations. Typical voltage levels of a section of revenue service line can also be simulated. Test and evaluation of urban rail vehicles at any fixed voltage within the vehicle's operating range are accommodated through a voltage regulating system, designed for both manual and computer-controlled operation. Power to the Test Center is provided via a 115,000 volt overhead transmission line, supplied by Southern Colorado Power Company and distributed from the Center's main power switchyard located to the north of the Rail Dynamics Laboratory. A standby power substation is also available on site.

Located within the transit loop near the southeastern curve is the tight-turn loop (also called "screech loop"). This 150-foot radius test track is electrified, and utilizes 119 lb. continuous welded rail on wood ties with an inner guard rail for support. The loop is joined to the main oval by 488 feet of connector track at a radius of 326 feet. Both the connector track and the tight-turn loop are used in the investigation of wheel noise, car curving performance, and suspension system stability.

TIGHT TURN LOOP



SUBSTATION #1, LOOKING SOUTHWEST

URBAN RAIL BUILDING

URBAN RAIL BUILDING

The Urban Rail Building (URB) provides rail transit test users with a complete maintenance facility unique to servicing transit vehicles. Located within the TTT oval, this 20,000-square-foot building provides convenient access to and from the main test area without interrupting other test programs. Several hundred feet of storage track is located to the west of the facility and a passenger loading platform is located off the URB's main wye track to the east.

Special capabilities of the URB include: two 190-foot service tracks through the building, one over a service pit; floor loading designed for 50-ton power jacking; office space, including accommodations reserved for visiting test representatives; and a 600-volt dc power system.

TECHNICAL SUPPORT

An integral part of any transit test program is the Center's Transit Vehicle Maintenance (TVM) crew. It has responsibility for the care of transit vehicles, from off-loading the vehicle and initial preparation prior to test, to inspection, and preventive maintenance as prescribed by the customer. Other functions of TVM include: modifications to the vehicles under the customer's direction, handling routine car maintenance during the test phase and coordination with other support organizations for specialized work.

The Technical Services Department's Transit Instrumentation group develops each transit program's instrumentation test plan and installs and checks all transducers and associated equipment. The group has a wide variety of electronic test equipment at its disposal. Examples of this equipment are: an adhesion chassis, an electronic recording speedometer, ride quality filters used for data reduction of accelerometer data, and watt-hour meters used to measure transit vehicle power consumption. It also designs and fabricates special test equipment when needed. The Transit Instrumentation group also aids in data reduction and verification of reduced data.

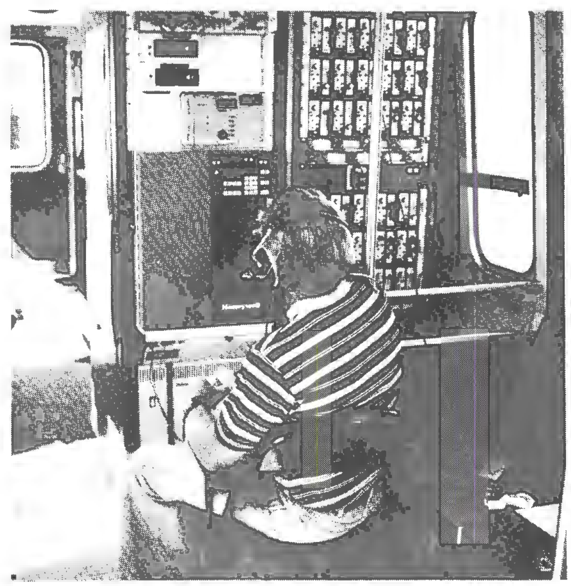
The Center provides a wide range of technical support capabilities to all test programs, with specialized support available for transit testing. The Technical Services Department consists of the Data Processing, Calibration and Electronic Repair, Instrumentation, and Photo-Optical Instrumentation groups. Vehicle testing at the Center comprises six major categories: performance, adhesion, ride roughness, passenger compartment noise, vehicle-generated noise and vibrations, and vehicle reliability and quality control. Data are acquired through experiments in these six areas using transducers, signal conditioning, filtering, recording, specialized equipment, and general electronics test equipment.

ACTIVITIES IN TECHNICAL SUPPORT FACILITIES

Tests on the TTT are conducted both on board the vehicles and at the wayside. Analog and digital data acquisition systems are available. Tests are also documented by the Photo-Optical Instrumentation section which records test events on film at 22,000 pictures per second.

The General Vehicle Test Plan (GVTP), a baseline test plan, provides a standardized document for the planning, execution, data analysis, and reporting of urban rail vehicle tests. The GVTP also provides a standardized document for planning, execution, and data acquisition and analysis. The Plan was evolved at TTC as the result of the early testing activities.

An integrated instrumentation system, called the General Vehicle Test System (GVTS), was developed by the Transportation Systems Center to facilitate vehicle testing. This system is designed to acquire information and data according to test requirements specified in the GVTP. The GVTS instrumentation parameters include vehicle current, voltage, acceleration/vibration, acoustical noise levels, pressure, temperature, displacement, and strain. The GVTS is divided into three parts: the instrumentation system, the digital data acquisition system, and special purpose measurement systems. Thirty-seven of the forty-eight required standard outputs described in the GVTP are provided by the GVTS.



TRANSIT DATA VAN

The Transit Data Van is a road vehicle used for collecting wayside data for the TSC ways and structures program. From the eight stations of buried transducers located along the Transit Test Track, data showing changes in the track bed are collected. The Digital Data Acquisition System (DAS) is an on-board minicomputer with a teletype and tape drive to provide data handling and recording capabilities.

The Instrumentation Section has the responsibility for developing and/or operating a number of additional specialized rail cars and road vehicles. Special test systems and general instrumentation support are also provided. Additional rail vehicles used during test programs include the T–8 Instrumentation Car and the EM80–C Plasser Track Geometry Car.

TRACK STRUCTURES TESTING

Testing on the TTT is not limited to transit vehicles. Track structure and related components are also tested. Results of this testing will be used in the analysis of existing track structure design and the design of new track structures. For example, the Vehicle Induced Forces Test measures wheel/rail loads, concrete tie response, fastener clip response, roadbed response in four areas, and the physical properties of materials employed.

TTC also has available special instrumentation for measuring track characteristics, including an on-board Track Geometry Measuring System.

DATA REDUCTION

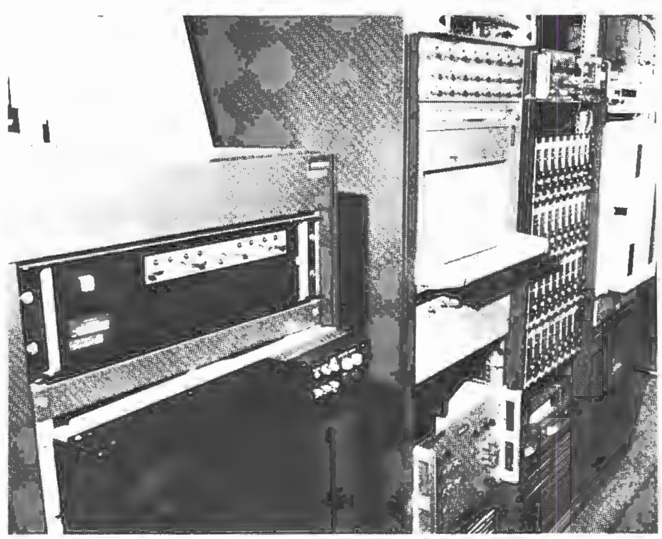
Data collection during test runs of a transit vehicle are processed using computer programs developed by the Center's Data Processing Group located in the Computer Center in the Rail Dynamics Laboratory. These programs perform analyses of the data and produce results in both graphic and high-speed printed form, enabling analysts to accurately determine ride quality and power consumption variables.

Measurement data collected during field testing are recorded on magnetic tape in analog form. This tape is then digitalized and recorded on magnetic tape using the Center's VARIAN V-76 mini-computer system. A mid-size computer (Honeywell 66/05) was recently acquired by the Center and is used in conjunction with the present mini-computer system.

Results of the test programs are written by either the Center's Test Design and Analysis Group or by the user organization as defined by program requirements. Test Center reports may be generated in the categories of formal or informal technical reports.

TEST CENTER GENERAL CAPABILITIES

A variety of Test Center facilities are available to support the specialized transit capabilities and all FRA test programs. In addition to the Center's extensive trackage, a complete complex of shops, laboratories, instrumentation, and computer facilities are available on site. Major facilities also exist for test planning and control, maintenance and evaluation of rail equipment, and emergency services support. The Center is highly self-sufficient for the testing and related services it provides.



SHOP AND LABORATORY FACILITIES

RAIL DYNAMICS LABORATORY

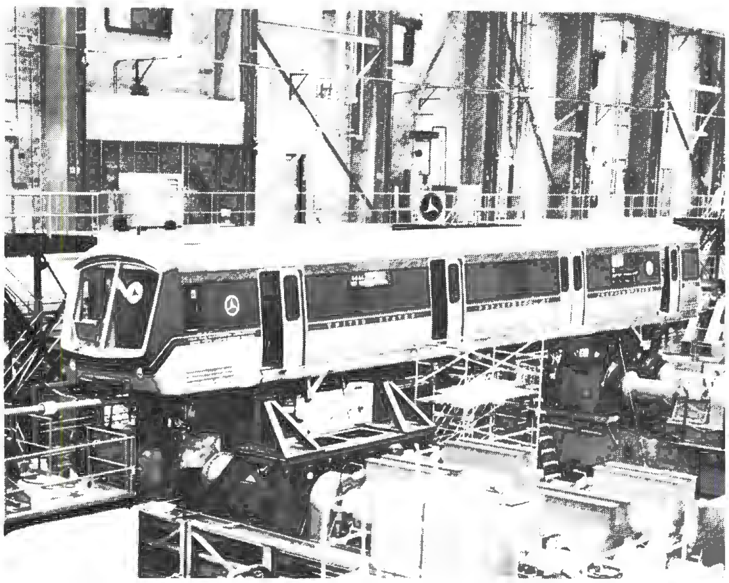
Located in the Center's main area is the Rail Dynamics Laboratory (RDL). This building houses two highly sophisticated test machines and associated equipment used by researchers to study the dynamics of wheel/rail interaction. Both machines can accommodate vehicles designed for either intraurban or interurban service.

Within the large, high bay area (352′ X 108′ X 65′) are the Roll Dynamics Unit (RDU) and the Vibration Test Unit (VTU). By using two 100-ton traveling bridge cranes, vehicles can be placed on either test machine to undergo a variety of test programs.

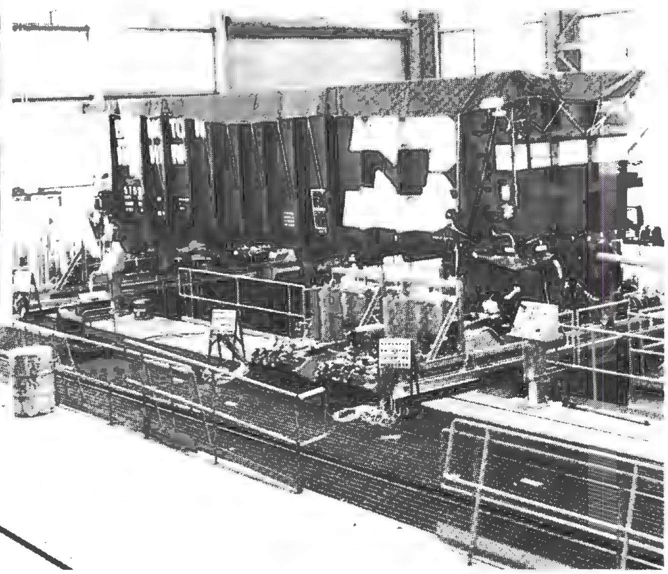
RAIL DYNAMICS LABORATORY

The RDU utilizes a system of drive motors, flywheels, and large rollers to create the effect of perfectly smooth track under the wheels of transit vehicles, locomotives, or unpowered rail cars. Speeds over 144 miles per hour on tangent track or steady-state curve negotiation can be simulated to study the wheel/rail dynamics of acceleration, adhesion, braking, and hunting.

The RDU has special design features which provide for rail and transit cars varying in length, weight, wheel gauge, and axle and truck spacings.



ROLL DYNAMICS UNIT



VIBRATION TEST UNIT

The Vibration Test Unit (VTU) uses a hydraulic shaker system to simulate the dynamic effects of track under a vehicle's wheels. The VTU is used by researchers to study suspension characteristics of rail vehicles, natural frequencies of either components or vehicle body, ride comfort, lading responses, component fatigue, and rock and roll tendencies, by controlled vertical and lateral vibration of the wheels. The system can imitate numerous conditions of track, from perfect to highly irregular.

The VTU's frequency range is 0.2 to 30 hertz and between 0.2 and 2 hertz motions with displacements up to 4″ can be achieved. Computer-generated rail profiles or recordings of actual rail profiles drive the hydraulic actuators. These can be positioned to accept a variety of truck spacings or axle arrangements as on the RDU.

CENTER SERVICES BUILDING

The Center Services Building (CSB) is also located in the Center's main area and provides a facility for the maintenance, repair, and modification of all vehicles and the installation and repair of test equipment and instrumentation on transit and railroad equipment. A variety of shop capabilities, including machining, woodworking, welding, painting, and other services are available in the CSB. Two 30-ton bridge cranes are located in the building's high bay area, as are 465 feet of track over maintenance pits and an additional 350 feet of track on flooring capable of withstanding heavy jacking loads. Within the pit area is an underfloor wheel truing machine which will accommodate a variety of wheel sizes and profiles. Transit wheels developing flat spots or other problems during a test program are reconditioned here.

OPERATIONS AND PROJECT MANAGEMENT BUILDINGS

Administrative functions take place in both the Operations (OPS) Building and the Project Management Building (PMB). Each of the buildings house members of the Test Center's FRA, UMTA, and/or Operations and Maintenance Contractor staff.

Within the Operations Building are conference room facilities, the Center's cafeteria, and the Operations Control Center (OCC).

The OCC is situated in the upper northwest corner of the OPS Building and overlooks the yard tracks and main wye lead track. OCC monitors all tests, logistics moves, security, and emergency services via radio communications. Visual indication of switch positions and control of switchlocks on all tracks are maintained through a switchlock indication system.

TRANSIT MAINTENANCE BUILDING

One additional facility which provides back-up support for transit programs is the Transit Maintenance Building (TMB), which was the original facility for supporting transit programs at the TTC. Located adjacent to one leg of the wye track at the north spur of the Center, the TMB offers an additional 100-foot service pit area, a track running through the building, and three phase ac and 600-volt dc power. Located directly east of the TMB is a 125-ton electronic track scale which is used to verify weights for all test programs.

SAFETY AND QUALITY ASSURANCE FUNCTIONS

To assure the safety and quality of test programs, all test activities are monitored by the Center's Safety and Quality Assurance staffs, according to the documentation required of the individual test program. These groups monitor data generated by the test programs, assuring compliance with test specifications and plans.

In addition, trained members of the Emergency Services Department, consisting of the TTC Fire Department, Security Section, and Medical Staff are on-site 24 hours per day, seven days a week.

WAREHOUSE/LABORATORY FACILITY

The Center's Warehouse/Laboratory facility has three separate functions. It houses the Components Test Laboratory and the Instrumentation and Metrology Laboratories, and provides 40,000 square feet of floor space.

In the Components Test Lab (CTL), mechanical and metallurgical examinations and chemical analysis of transit-related and various railroad components are performed.

In the Instrumentation and Metrology Laboratories, all weights, measuring devices, and instruments are calibrated and tested, and test devices assembled and repaired.

AERIAL VIEW OF TRANSPORTATION TEST CENTER

RAILROAD FACILITIES

Additional trackage and facilities exist at the Center to accommodate many test programs for railroad application.

These include:

- The 14.7 mile electrified Railroad Test Track (RTT) with a turnaround loop, to test motive power and rolling stock to 160 miles-per-hour maximum. The RTT is completely electrified with a high voltage catenary to evaluate wheel/rail and pantograph/catenary dynamics under controlled conditions.

- The 4.8-mile Facility for Accelerated Service Testing (FAST) Track is a cooperative government and industry program designed to improve the economic efficiency of the railroad industry. Wear rates on a wide variety of track structure and railcar components are accelerated by compressing seven years of wear on a railroad into one year on the FAST Track.

- The Wayside Detection Research Facility tests in-motion rail car inspection systems such as dragging equipment detectors, hot box detectors, cracked tread detectors, loose wheel/broken flange detectors, and other associated equipment. The facility is on 1500 feet of tangent track located off the RTT.

- Additional tracks at the Center include the Impact Track, used for vehicle impact and derailment testing; and the Train Dynamics Track, which is used to observe wheel/rail dynamics on intentionally misaligned track.

APPENDIX I

UMTA Guidelines for Rail Transit Car Testing at the DOT Transportation Test Center

POLICY

Because of the repetitive reliability, maintainability, and quality problems encountered with new transit vehicles, it is the UMTA position that all practical means to solve these problems should be employed early in the car delivery schedule. The need for early solution is dictated by the potential costs and impact on system performance if these problems are not recognized and expeditiously remedied.

Accordingly, UMTA has established a policy that grantees make use of the DOT Transportation Test Center (TTC) in Pueblo, Colorado to supplement the usual tests of new cars performed by the purchasing agency. TTC testing should take place as early as is practicable in the delivery phase of new cars and well before any public operation of the cars. This policy applies to all light rail and rapid rail vehicle purchases by new transit purchasing agencies, from new manufacturers, or of a new design. Since grant applications must include costs estimated for this testing, this policy applies to all new rail car purchases.

All grant applications for new transit cars shall contain estimated costs for the purchasing agency and for the car supplier to perform and participate in the TTC tests. The purchasing agency shall also assure that appropriate provisions are included in the procurement document to obtain and secure the necessary material and support from the car supplier as required to accomplish the testing at TTC. An allocation of vehicles and schedule for performing the tests should also be given in the grant application. This schedule should be based on the earliest feasible time to deliver sufficient cars and support to TTC. These tests are to be considered of high priority and their schedule will be subject to UMTA concurrence.

TESTING GUIDELINES

A. SCOPE

A minimum test program of sixteen weeks is required and consists of three major phases. A fourth phase may be added depending on the special requirements or characteristics of the transit car or for testing components and/or equipment. The four phases are defined as follows:

PHASE I Vehicle Preparation
4 weeks (or as required)

PHASE II Specification Compliance and Performance Assessment
4 weeks (approximately)

PHASE III Reliability Tests
8 weeks (approximately)

PHASE IV Special Tests*
(as required)

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* The length of time required for special testing is a function of the number, duration and complexity of the tests to be conducted. For transit cars where a high technical or other type risk can be identified early, an additional two to four weeks should be budgeted for Phase IV. In other cases, these tests can be run concurrent with Phase II or III testing, thus maintaining a sixteen week total program. If the purchasing agency desires to make use of the time and facilities available at TTC during the car testing to have component and/or equipment testing conducted there in lieu of the contractor/subcontractor, such can be scheduled and should be on a cost reimbursable basis to TTC from the contractor.

An eight-hour test day is assumed for all phases; however, should the need arise, twelve to sixteen hour test days are possible depending upon the test track schedule being able to accommodate the extended day. For efficient eight hour test day utilization of the test track, it is frequently necessary for second shift maintenance of the car. This should be provided for in resource planning.

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Phase I, the "Vehicle Preparation" phase, consists of installation and performance of certain static car testing which takes approximately two weeks. The remaining two-week period is for dynamic checkout and final adjustments of the transit car subsystems and instrumentation on the Transit Test Track. At the completion of Phase I, all systems should be properly adjusted, debugged and ready for testing and meaningful data taking. The time allocated to Phase I is based upon vehicles without major unresolved problems. If significant problems are discovered, it may be necessary to extend this phase until the problems are resolved sufficiently so that the objectives of the subsequent phases can be achieved.

II

Phase II, the "Specification Compliance and Performance Assessment" phase, consists primarily of acceptance type testing where the tests are designed to verify that the transit car measured performance is in conformance with certain contractual specifications as defined by the purchasing agency. The purchasing agency is encouraged to define and conduct as thorough a set of acceptance tests as they would within their own property system, except those where TTC cannot adequately simulate the property system interface or conditions. However, it should be emphasized that TTC is able to conduct many of the acceptance type tests with greater accuracy and safety because of the dedicated test nature and without the impact of other activity or special restrictions inherent in the property revenue environment. Further, this phase can encompass those additional tests desired by the purchasing agency where not already covered by the acceptance type testing portion of the phase. TTC can provide assistance in defining both acceptance and special tests to the purchasing agency, based on knowledge of test track capability and previous rail transit car testing experience. Typically a vehicle accumulates 200 miles during qualification testing on a single shift. With an "extended" shift, a vehicle can accumulate 500 miles a day, operating with the revenue service profile. Phase II should be completed before proceeding into Phase III, so that the car is operating properly and satisfactorily to its contractual specification/performance or that problems are recognized. (The estimated duration of both Phase I and II assumes no major unresolved transit car problems.)

III

Phase III, the "Reliability Tests" phase, is designed to accommodate substantial operating mileage under simulated revenue conditions, i.e., loads, speeds, dwell times, door cycling, etc. Again, TTC can provide assistance in defining these tests to the purchasing agency. The purpose is to exercise the transit car in its intended revenue profile to identify real or potential operational or reliability problems and to add to the purchasing agency's experience and familiarity with the transit car as purchased. During these tests, it is preferred to operate the transit car in trainline, i.e., a minimum four-car train if of the married pair configuration. The keeping of failure data, availability data and maintenance records during all test phases will be the responsibility of the purchasing agency, or its representative, but TTC will assist and provide its input.

IV

Phase IV*, the "Special Tests" phase, should encompass the range of testing desired by the purchasing agency but not described above. Some examples of such may be: evaluation of engineering alternatives; simulated failures where the behavior of the transit car under simulated subsystem/component failures is examined; and detailed component life/wear evaluation. These tests could be run concurrent with earlier tests if the test plans permit.

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* Should a Phase IV be determined by the purchasing agency to be desirable, or should the planned duration of Phases I-III be greater than sixteen weeks, concurrence of UMTA will be required.

B. TESTING RESOURCES/REQUIREMENTS

1. Purchasing Agency:

The purchasing agency shall provide and be responsible for including in the grant request and purchasing document provisions for supplying and performing the following:

a. A minimum of two self-contained transit car consists (four cars if of the married pair configuration).

b. Shipment of transit cars and adequate spares to and from TTC.

c. Appropriate insurance coverage of transit cars.

d. Warranty coverage on transit car subsystems/equipment during TTC test period.

e. Define test plans for Phases II and III (and IV, if desired). TTC will assist.

f. Define twenty-five (25) to thirty (30) sensor locations within car equipment which, if constantly monitored (recorded), could provide a high probability of fault diagnosis upon encountering car problems/failures. If the purchasing agency, separately or in conjunction with the the car supplier, defines more than thirty (30) in-car sensors to be continuously recorded/monitored during the test program, specific concurrence of UMTA/TTC will be required.

g. Special tools or test equipment unique to the transit car or unique wayside/track signalling or control equipment.

h. Coupler information and drawings or, if available, coupler adapter for logistic moves at TTC.

i. Documentation of test requirements, vehicle technical descriptions and operator's manuals as early as possible, but not later than sixty (60) days prior to commencement of TTC testing.

j. Final test report. TTC will assist in format and provide input of supportive efforts.

k. Representative personnel for the purchasing agency and, if desired, the car supplier for the duration of the TTC test program to perform the following tasks (approximately four persons are believed adequate):

(1) Supervise overall purchasing agency activity including personnel, equipment, safety, etc.

(2) Test leadership, direction and engineering support to achieve established test program goals and assure adequate data taking. Engineering representation (one full time person is believed adequate) should be knowledgeable of both car and property's operational environment and will interface with the TTC test team. TTC will assist.

(3) Maintenance leadership knowledgeable of car equipment. (TTC will assist in car maintenance activity, but will require the direction of the purchasing agency, car supplier or car equipment contractor personnel.) This same requirement is imposed regarding the proper placement of instrumentation sensors in car subsystems and may be for any unique wayside/track signalling or control equipment.

★ ★ ★

TTC has a standard series of phases governing the testing of all vehicles. These are set forth in Appendix II. These phases are applicable to the testing of transit vehicles unless there might be a conflict between them and the above Guidelines. None is foreseen, but the Guidelines are overriding.

C. COSTS

The costs of testing borne by transit authorities normally include those associated with preparing the vehicles for shipment, the shipping, and the salary of a test engineer assigned to oversee the testing activity. These costs are considered by the Federal Government to be part of the capital costs, and therefore the local share is usually no more than 20 per cent.

TTC will provide the following supplies and services at no cost to the purchasing agency:

a. Test trackage, power, maintenance buildings and all general purpose maintenance equipment and shops.

b. Office space, office furniture and equipment.

c. Car unloading cranes and jacks (no railed rolloff ramp is available at TTC).

d. Instrumentation and data processing equipment including sensors, signal conditioning and on-board recorders. (Test data is recorded in analog form and, where required, digitalized off the car for data analysis and report generation. Approximately 30 sensor locations within the car can be continuously monitored/recorded.

e. Personnel to perform the following support tasks:

(1) Test control and test support engineer to provide overall supervision and coordination of test facility, maintenance, logistics, instrumentation, and data support functions.

(2) Chief test engineer to work in concert with the purchasing agency's on-site supervision to assure all elements of the test complex, including the plan, procedure, vehicle, instrumentation, and personnel are producing the required data results.

(3) Instrumentation engineers and technicians.

(4) Data collection, analysis, and reduction/reporting personnel.

(5) Maintenance building supervision and car/equipment maintenance personnel.

(6) Transit car operators/motormen and locomotive engineers for logistic moves.

(7) Security, safety, fire and first aid personnel on duty at all times.

(8) Assistance in defining the test plans for phases II, III and IV if desired, in performing maintenance, in keeping failure/availability/maintenance records, in data reduction and analysis, and in final report format and generation.

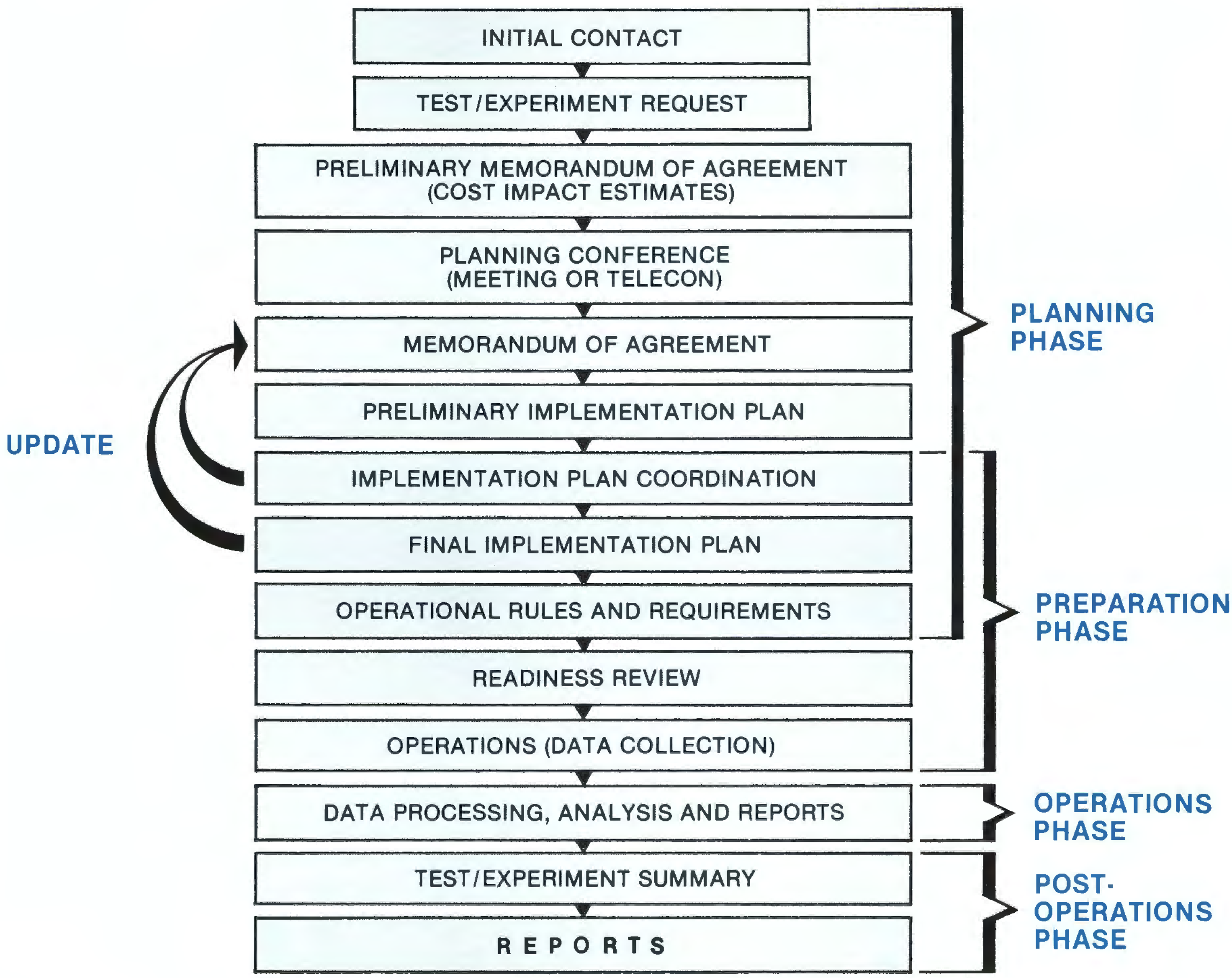
APPENDIX II

TTC TEST PROGRAM PHASES

Each test program conducted at the Center has four phases of implementation. These may overlap in time or may be conducted concurrently.

- **PLANNING**
- **PREPARATION**
- **OPERATIONS**
- **POST OPERATIONS**

The following section details each test program phase and includes the necessary documentation required of that phase, and support information. See flow chart showing typical test/experiment program implementation.



TYPICAL TEST/EXPERIMENT PROGRAM IMPLEMENTATION FLOW

THE PLANNING PHASE

There are eight basic functions to the Planning Phase. These are Initial Contact, Test/Experiment Request, the Preliminary Memorandum of Agreement, the Planning Conference, the Memorandum of Agreement, the Preliminary Implementation Plan, the Implementation Plan Coordination, and the Final Implementation Plan.

During the *Initial Contact,* a prospective user should make his interest known to the TTC's UMTA Program Office by telephone, written correspondence or by personal visit. The address and telephone number are: Director, UMTA Programs at TTC; Transportation Test Center; Pueblo, Colorado 81001 (303) 545-5660. This Initial Contact is usually exploratory and not binding.

The next step toward TTC testing is the *Test/Experiment Request.* This is a statement concerning what the user wants accomplished during the test operation. This document is prepared by the user with Test Center assistance if requested. It is submitted to the TTC UMTA Office by formal letter. The contents of this request includes objectives, participating agencies and key personnel, schedule, description of test articles, facility and logistical requirements, preparational support requirements, operational support requirements, data requirements, maintenance, safety, and other necessary support. This request provides sufficient general and/or specific information concerning the potential program for Test Center evaluation of the capabilities required to satisfy the request, and is used to initiate the TTC planning process. Evaluation of the test request will result in a potential statement of what will be done at the TTC and will be documented in the Preliminary *Memorandum of Agreement.*

A *Planning Conference* follows the Test Experiment Request evaluation; it is carried out by a meeting or a teleconference. Its purpose is to exchange information, identify potential conflicts and long-lead items, determine test documentation requirements, and develop a tentative test operations schedule.

The planning results in the final *Memorandum of Agreement* (MOA) document which will now serve as the statement of work for the contract and will become part of the contract which authorizes the expenditures of designated funds. This document, prepared by the TTC, is signed by both the Test Center and the user, and states what will or can be done at the Center and when. The capabilities, commitments, and responsibilities of the Center, the user and any other participant in the program are defined in the MOA document. The areas covered here include key personnel, their authorities and responsibilities, schedules and milestones, all required TTC support, user commitments, an initial cost estimate which is updated periodically, program documentation, and the identification and liability requirements.

For government agencies, the approved MOA document will be the basis for the expenditure of designated funds against agreed to procurement requests from FRA and reimbursable agreements from other government agencies such as UMTA.

The *Preliminary Implementation Plan* document is based on previous correspondence, prepared by the TTC and/or the user with TTC approval and user review. This document contains the approach concerning how the requirements will be implemented by the TTC as an overview of the total program activity. This includes the test approach, the required preparations, i.e., a time phased list of activities requiring TTC resource expenditures to be accomplished for program operations; implementation of activities which are associated with TTC operations; instrumentation, and photo/video requirements; necessary TTC resources including restoration and/or dismantling; data requirements; safety and quality assurance requirements; work schedules, and any support specialties. Included also will be the required technical procedures to govern these technical activities.

As part of the *Implementation Plan Coordination,* the Preliminary Implementation Plan will be furnished to the user and this plan will be finalized following identification of any problem areas, and additional requirements. Once this *Final Implementation Plan* document is completed, the MOA document, schedule and cost estimates will be updated as necessary. The Implementation Plan Coordination and the Final Implementation Plan may overlap with the Preparation Phase.

THE PREPARATION PHASE

Once the *Final Implementation Plan* is complete, the *Operational Rules and Requirements* (ORR) document is prepared and following approval by TTC, it is reviewed by the user, and used to conduct operations. Its purposes are to supplement and/or document deviations to the TTC Book of Operating Rules and to set forth procedures governing test operations.

At least one week prior to start of the test, a Readiness Review will be held at TTC. This review will assess the readiness of the Center and the user to begin test operations. An events sequence checklist will be used to ensure that all requirements have been met.

THE OPERATIONS PHASE

The *Operations Phase* is the actual conduct of the test operation. Gathering the necessary data satisfying user requirements is its main purpose. All operations are conducted in strict accordance with the developed documentation for that test program as well as with the operating rules and requirements of TTC.

POST OPERATIONS PHASE

The final phase of a test program is the *Post Operations Phase.* This is the period immediately following the test program and lasts until the report is published. Its purposes are to complete data compilation, perform necessary operations and analysis, prepare technical and operational reports, and restore resources as required. The Test Experiment summary is prepared by TTC to document the results of the Post Operations meeting and is submitted within 30 days of completion of the test operation or as otherwise specified.

GENERAL USER RESPONSIBILITIES

Once communication is established between TTC and the user, certain general responsibilities are associated with the user's commitment to test at the Center. The user is to notify TTC of any requirement changes as they occur; communicate with official TTC/UMTA representatives; prepare, review, and comment on all necessary documentation; participate in planning conferences, program negotiations, and program readiness reviews; delegate user authority when necessary; keep the test manager apprised of program changes on a timely basis; become familiar with TTC procedures and requirements relative to the program; provide a representative who is familiar with program plans, requirements, and procedures to monitor activities and make real-time decisions; ensure that data collected satisfies user requirements; and if appropriate, delegate operations responsibilities to TTC.

APPENDIX III

SHIPPING VEHICLES AND EQUIPMENT

The Test Center is connected to the rail lines of the Atchison Topeka and Santa Fe, and the Missouri Pacific Railroads, by a private side track and classification yard at the Pueblo Depot Activity (PDA). A rail spur enters TTC at the southern boundary of the PDA, and Test Center locomotives and crews utilize this track as an access to bring transit cars into the Center on railroad flatcars. Equipment and machinery loaded on flatcars or gondola cars are usually subjected to specific blocking, bracing and tie-down rules. The railroad freight agent at the point of origin must arrange for instructions to the prospective shipper concerning these tie-down procedures. If the shipment is nominally higher than a boxcar, and/or it overhangs the rail car, it is classified as "high and wide," requiring special operating authority from all the railroads handling the shipment. The railroad freight agent must arrange to have the load measured and cleared for movement if necessary. Early contact with the origin freight agent is advisable when shipment in open freight cars is contemplated.

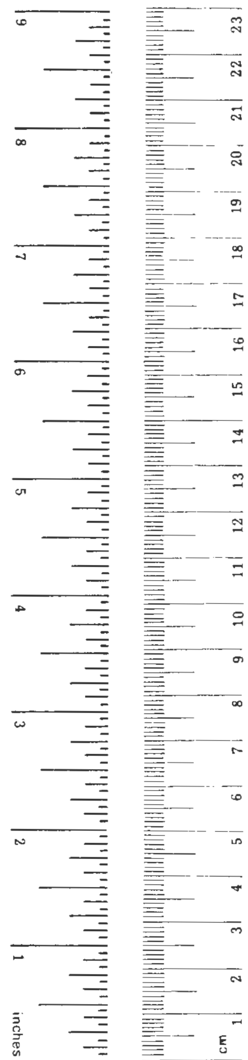
Additional information concerning shipping transit vehicles will be provided to the user during the test planning phase of the test program.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

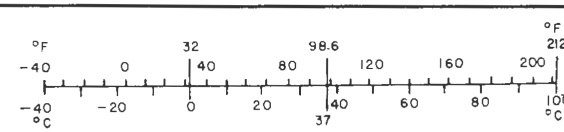
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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15. Supplementary Notes

Boeing Services International, Inc. **

16. Abstract

This document describes the support facilities and technical expertise available to transit authorities and other potential users of the Transportation Test Center (TTC) located near Pueblo, Colorado. These users also are given information concerning transit test program initiation, test track engineering, and cost sharing with the Federal Government. Several rail cars have been successfully tested at the Center. These include the San Francisco and Boston light rail vehicles, the Washington Metropolitan Area Transit Authority Cars, the Massachusetts Bay Transportation Authority cars, and the Metropolitan Atlanta Rapid Transit Authority cars.

Located in the Center's main area is the Rail Dynamics Laboratory (RDL). Within the RDL is the Roll Dynamics Unit and the Vibration Test Unit. By using two 100-ton cranes, vehicles can be placed on either test machine to undergo a variety of test programs. The Transit Maintenance Building provides back-up support and contains a 100-foot service pit area. The Transit Test Track (TTT) at the TTC is a 9.1-mile oval and is used for testing urban rail vehicles. Located within the TTT is the tight-turn loop, a 150-foot radius test track used in the investigation of wheel noise, car curving, and suspension system stability. Power stations provide a constant voltage to the TTT through a third rail.

A minimum test program of sixteen weeks is typical and consists of three major phases: Phase I, Vehicle Preparation; Phase II, Specification Compliance and Performance Assessment; and Phase III, Reliability Tests. A fourth phase may be added depending on the special requirements of the transit car.

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