Report No. UMTA-MA-06-0025-75-1

SOAC

STATE-OF-THE-ART CAR ENGINEERING TESTS AT DEPARTMENT OF TRANSPORTATION HIGH SPEED GROUND TEST CENTER FINAL TEST REPORT

VOLUME I. PROGRAM DESCRIPTION AND TEST SUMMARY

JANUARY 1975
FINAL REPORT

Prepared for

URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Research and Development
Washington, D.C. 20590

NOTICE

PREFACE

This test report, presenting the results of engineering tests on the State-of-the-Art Cars, derives from the efforts of two agencies of the U.S. Department of Transportation: the Rail Programs Branch of the Urban Mass Transportation Administration's Office of Research and Development and the Transportation Systems Center.

UMTA's Rail Programs Branch is conducting programs to improve urban rail transportation systems. The Transportation Systems Center (TSC) is supporting UMTA by providing systems management for the Rail Programs Branch's Urban Rail Supporting Technology Program (URSTP) in the design, construction and operation of UMTA test facilities, the analysis and testing of vehicles and components, and the development of key technological data. This test report stems from the second of the four URSTP tasks: facility development, test and evaluation, technology development, and application engineering.

Boeing Vertol Company had previously been engaged by UMTA as systems manager for the Urban Rapid Rail Vehicle and Systems Program (Contract DOT-UT-10007). One phase of this vehicle and component development program is the design, development, and demonstration of two State-of-the-Art Cars (SOAC) whose primary objective is to demonstrate the best current technology in rail rapid transit car design.

Following selection by Boeing and UMTA, the St. Louis Car division of General Steel Industries built and delivered two SOAC cars to USDOT's High Speed Ground Test Center (HSGTC), Pueblo, Colorado in September 1972 for developmental and acceptance testing. This test facility permits the use of known track and grade conditions for test operations (without interfering with revenue service); it also allows a large-scale test plan to be completed in a relatively short period of time. (UMTA's Rail Transit Test Track at the HSGTC became available for rail rapid transit vehicle testing in August 1972.)

In February 1973, TSC awarded Boeing Vertol Company the contract to perform engineering tests on the SOAC vehicles. The objective of this program is to provide engineering data on the

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SOAC and to develop further the General Vehicle Test Plan methodology for providing vehicle comparisons (defined in GSP-064). This methodology for controlling test variables by standardizing procedures and data requirements was developed in 1972 and was successfully checked by a series of tests using NYCTA R-42 type cars on the initial track section in March 1972.

In performing these tests, Boeing-Vertol called upon the expertise and services of many sources within the industry: Garrett-AiResearch provided an interim instrumentation system (required because of the SOAC schedule), designed and built the final SOAC instrumentation system, and provided data recording and reduction support during the test period; the University of Missouri provided expertise for the voltage measurement tests; and Kentron, Ltd., the operations and maintenance contractor at the HSGTC, provided required support during the test operations. Other organizations and individuals contributed to the successful and timely completion of the test program phase and the HSGTC tests described in this report.

A later phase of the SOAC engineering test program will be to relate the results of the HSGTC tests to vehicle performance on each of five demonstration lines in Boston, Chicago, Cleveland, New York and Philadelphia. SOAC test data and methodology will also be used for the evaluation of future rapid rail vehicles including the Advanced Concept Train (ACT) scheduled for completion in 1976.

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Section 1

INTRODUCTION

The development of the State-of-the-Art Car, an improved urban rail rapid transit vehicle incorporating the best available existing technology, is one of a series of programs directed toward the development of improved mass transportation. Closely related developments include use of the Rail Transit Test Track and the General Vehicle Test Plans for testing and evaluating rail transit vehicles and systems. The State-of-the-Art Car Engineering Tests tested the State-of-the-Art Car using the General Vehicle Test Plans and the Rail Transit Test Track.

1.1 SOAC ENGINEERING TEST PROGRAM

The general objective of the SOAC engineering tests was to associate the SOAC vehicle and the General Vehicle Test Plans (GVTP) GSP 064 from the Urban Rail Supporting Technology Test (URST) Program to:

- Establish a data baseline for the SOAC vehicle obtained in accordance with the General Vehicle Test Plans

- Expand and improve the General Vehicle Test Plans as a useful tool for the testing of any urban rail vehicle

Testing was also directed toward the use of the UMTA Rail Transit Test Track and the application and development of the necessary instrumentation, both in the SOAC vehicle and the test track, to implement the General Vehicle Test (GVT) concept in a known and controlled track system. As another part of the same contract, the data thus obtained were directed toward relating the characteristics of the Rail Transit Test Track to the characteristics of track systems in five cities: Boston, Chicago, Cleveland, New York, and Philadelphia.

The SOAC engineering tests will provide the baseline data for comparing the SOAC capability with that of other vehicles, and will provide data for guidance in the development of the Advanced Concept Train (ACT) scheduled for completion in

FY 1976. The ACT vehicle will be tested on the Rail Transit Test Track under the same procedure as SOAC.

This report of the SOAC Engineering Tests consists of six volumes:

- Volume I Program Description and Test Summary
- Volume II Performance Tests
- Volume III Ride Quality Tests
- Volume IV Noise Tests
- Volume V Structural, Voltage, and Radio Frequency Inteference Tests
- Volume VI SOAC Instrumentation System

1.2 THE STATE-OF-THE-ART CAR (SOAC)

The two SOAC cars (Figure 1-1) demonstrate the state-of-the-art in rapid rail car design. The primary goal in the SOAC design is to provide a passenger with quiet, comfortable and appealing transportation using existing technology. A brief description of the vehicle subsystems pertinent to the Engineering Tests is included below. A detailed description may be found in the SOAC State-of-the-Art Car Development Program Report, Volume 1, Design, Fabrication and Test, UMTA-IT-06-0026-74-1, April 1974.

General

The SOAC exterior features a smooth, brush-finished stainless steel body with molded fiberglass ends. The basic car structure is of all steel welded construction. Each car is 75 feet long and 9.75 feet wide with each of the two trucks mounted 27 feet from the center of the car. There are four 50-inch passenger doors per car side. Performance and design characteristics are shown in Figure 1-2; the operating profile is shown in Figure 1-3. The vehicles depict two types of interiors. The vehicle referred to as SOAC Number 1 features "low-density" seating. It contains 64 cushioned, upholstered seats in four different arrangements. SOAC Number 2 contains 72 seats of molded fiberglass with padded cushions and more standee space, designed for "high-density" operation. SOAC Number 2 was the instrumented test vehicle.

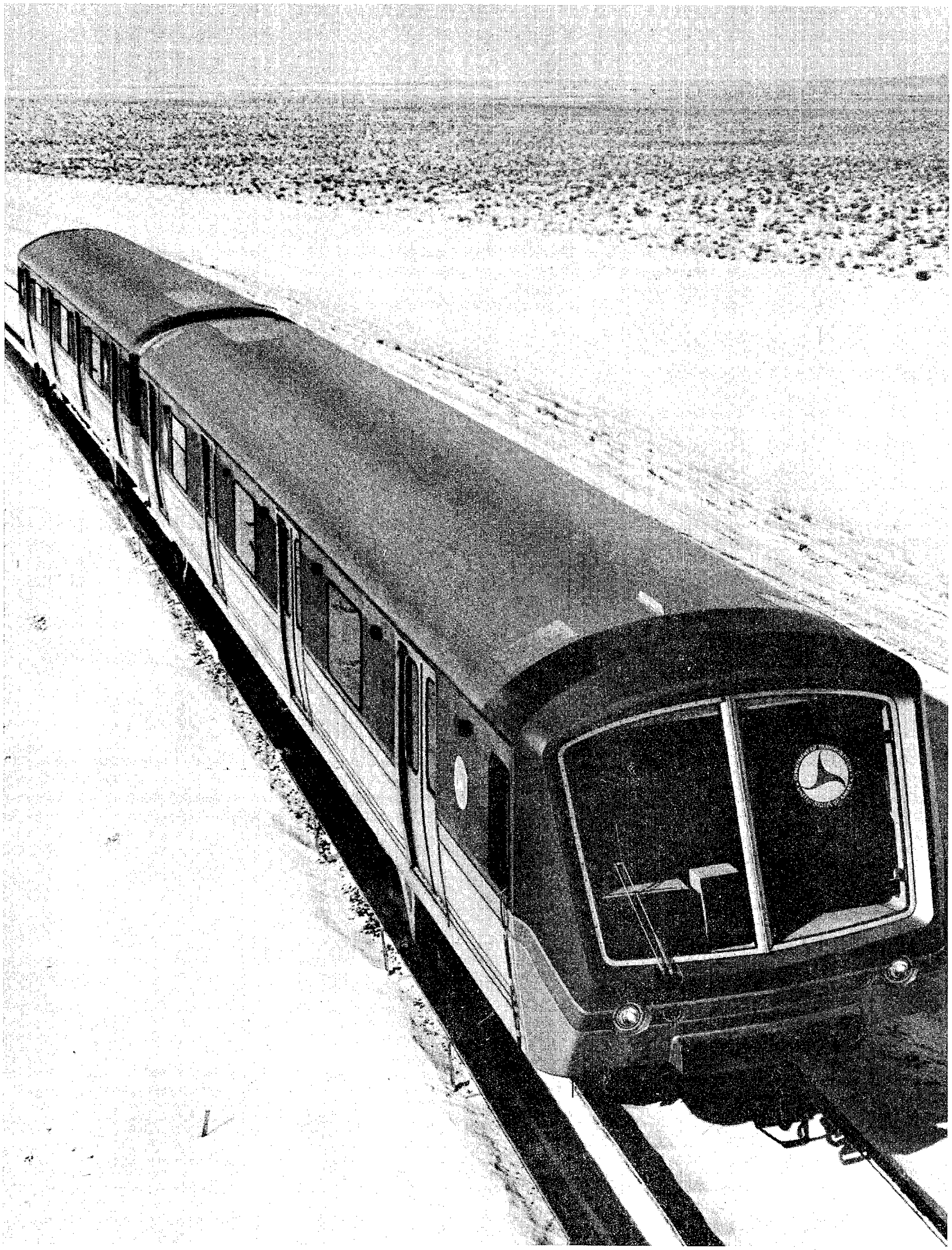
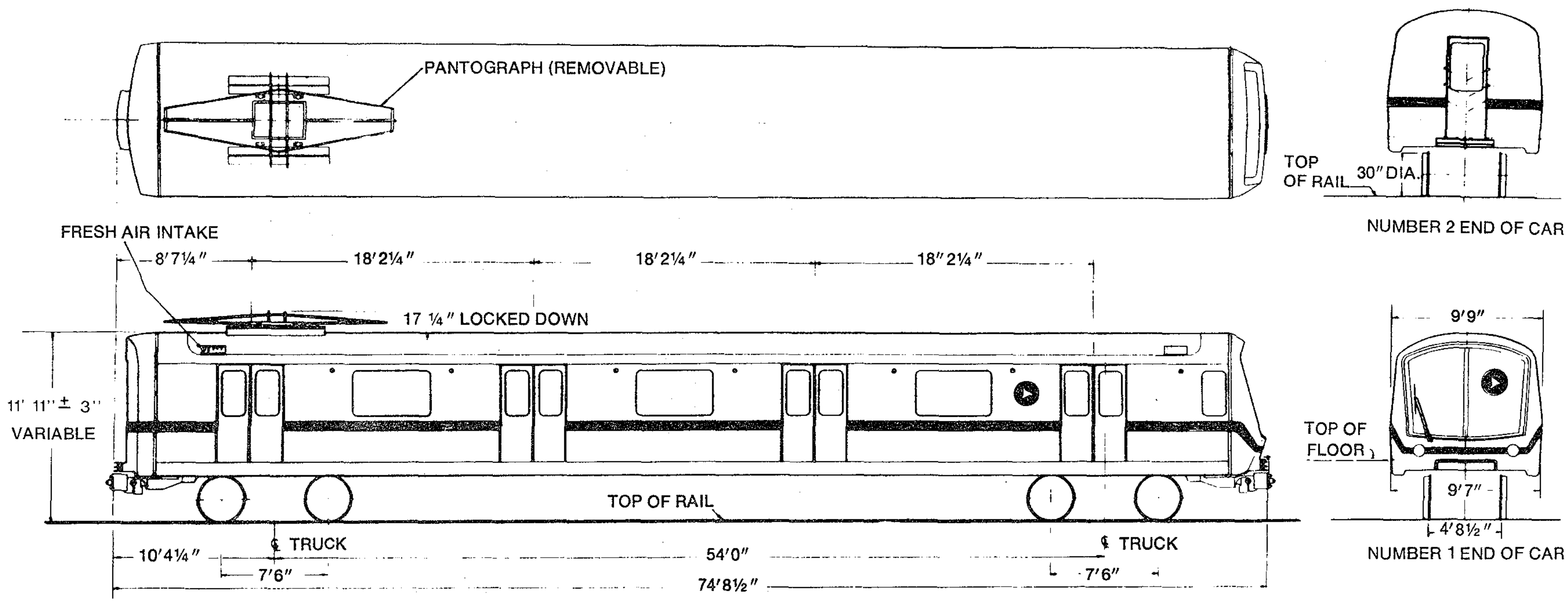


Figure 1–1. State-of-the-Art Car at High Speed Ground Test Center



Length	75 Feet	Passenger Capacity (No. 1 car)	
Width	9.75 Feet	Seated	62
Minimum Track Curve Radius	145 Feet	Nominal	100
Speed	80 MPH	Maximum	220
Acceleration, initial	3.0 MPH/Sec.		
Jerk Rate	2.5 MPH/Sec.^{2}	Passenger Capacity (No. 2 car)	
Power	600 VDC Nominal	Seated	72
Noise Level, interior.	spec 75 dBA @ 50 MPH actual 63 dBA @ 50 MPH	Nominal	100
Noise Level, 50 ft wayside	78 dBA @ 50 MPH actual 73 dBA @ 50 MPH	Maximum	300

Figure 1–2. SOAC Performance and Design Characteristics

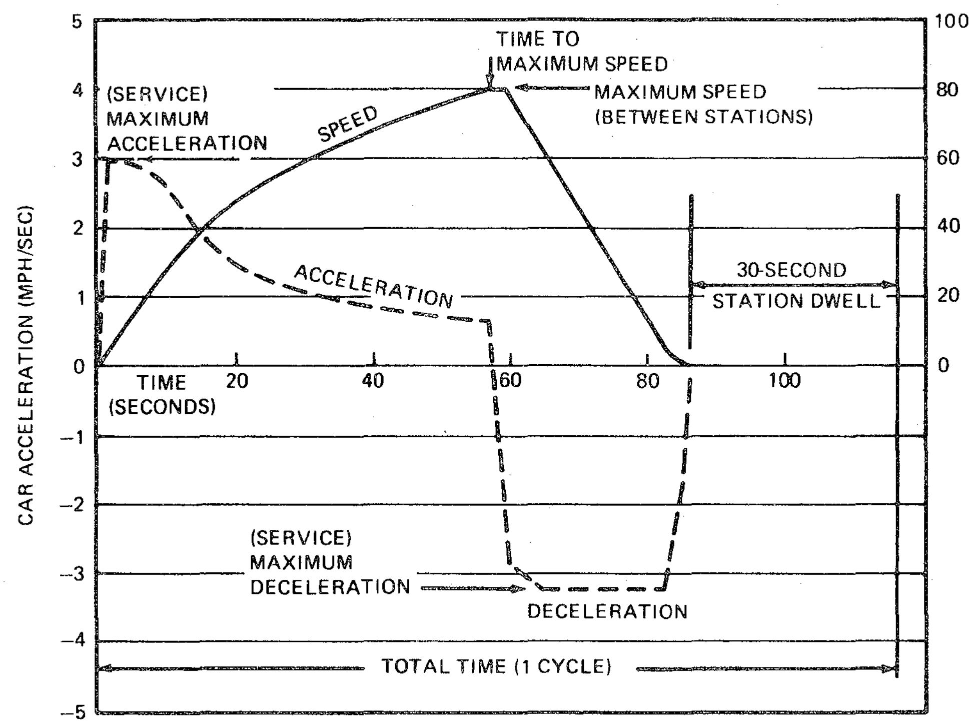


Figure 1–3. SOAC Operating Profile

Propulsion System

The propulsion system consists of traction motors, gearboxes, high and low voltage power supplies, and the control systems necessary to provide operations in both driving and braking modes. The motors are mounted two to a truck and are connected electrically in series. The two truck assemblies are connected electrically in parallel. The motors are fully compensated DC, with separately excited fields. The motors have a continuous rating of 175 hp at 1560 rpm (460 amps).

Control of the traction motors is by force commutated DC-DC chopper in the armature circuit and by AC-DC phase-delay rectifiers (thyristors) in the separate field circuits. AC power is supplied by the auxiliary power motor-alternator set. DC power to the armatures is supplied by the third rail shoes (or pantograph) through the input inductor-filter capacitor. Control subsystems provide for load weigh, jerk rate and wheel spin/slide compensation, as well as dynamic-friction brake blending.

The SOAC gearbox is a double-reduction parallel drive unit using helical gears. The overall gear ratio is 4.781 to 1. Magnetic pickup per axle is provided on the input gear to supply information for the car speedometer and spin-slide detection systems.

An input reactor operates in conjunction with input filter capacitors to limit voltage and current transients through the chopper and low voltage power supply.

Two brake resistor grids are mounted on the SOAC, and provide the electrical load for the traction generators during dynamic braking.

The control of tractive and braking effort is achieved using a tractive effort program which accepts input commands, car weight, etc., and controls the motor torque developed to the desired values. Closed-loop control of motor armature current is the primary method utilized. A P-generator receives input commands from three sources: master controller, speedometer (speed limiter system), or car hostler, and produces an analog signal from 0.0 to 1.0 amps which is trainlined. P-signal sensing is interpreted for braking, coasting, or propulsion modes (0.0 to 0.45 amps is braking, 0.45 to 0.55 is coasting, and 0.55 to 1.0 amps is propulsion). The P command is modified by car weight as sensed by air suspension pressure. A Tractive Effort Program (TEP) operates on the P command and provides a Tractive Effort Command (TEC) which is proportional to the position of the Master Controller (i.e., 100 percent of available tractive effort for P = 1.0 amps, master controller full forward). Jerk Rate Limiting and Spin/Slide protection are provided by monitoring the time rate of change of each of the four axle speedometers and altering the TEC when the 2.5 mph/sec-sec is exceeded.

Braking Systems

The major braking effort is provided by the dynamic braking capability of the SOAC propulsion system. Under normal operation this system alone will bring the SOAC to a complete stop. The friction braking system will hold the SOAC on a slope and will blend with the dynamic system or provide full service braking under adverse operating conditions. The system is comprised of truck mounted air actuated cylinders which apply Cobra composition shoes to the wheel (eight cylinders per car); two analog brake units which accomplish load weigh compensation and separate emergency and service brake functions.

Trucks and Suspension

The truck and suspension system is designed for improved ride quality and reduced noise. The truck has a 7.5-foot wheelbase for standard gauge track with inside wheel-axle bearing supports. Assembled weight of the cast alloy nickel steel truck is 14,500 pounds.

The truck frame is isolated from the axles by rubber chevron primary springs. Air bellows control car body leveling and provide car body to truck isolation.

Rubber bumpers are used to limit the deflections. Variable dampers are provided for all axes and can be adjusted during test to optimize ride quality.

Wheels

Resilient wheels were tested on the vehicle from June 8 through July 2. Model MB12511 Retreadable Acousta Flex Wheels manufactured by the Standard Steel Company were used. This wheel has an aluminum hub, a steel rim, and a steel (tread-flange) tire. There is a layer of silicone rubber between the rim and the hub sections. These sections are connected by a multipoint shunt for electrical continuity. The wheel is 30 inches in diameter with a 1:20 tread contour per NYCTA 703-3001. When the condemning limit diameter of 28 inches has been reached, the steel (tread-flange) tire can be removed from the rim and replacement installed by shrink fitting.

The primary benefit of the resilient wheels is a significant reduction in the squeal that occurs when cars negotiate low radius curves. Some reduction of the higher frequency vibrations induced by the wheel/rail interface in addition to some reduction of the wheel/rail roar and impact noises is an additional benefit.

1.3 RAIL TRANSIT TEST TRACK

The SOAC engineering tests were performed on the UMTA Rail Transit Test Track at the DOT High Speed Ground Test Center near Pueblo, Colorado. The objective of the test track, composed of six different types of track construction and designed for sustained 80 mile-per-hour vehicle operation, is to facilitate testing and evaluating rail transit vehicles and systems. Each of the different types is representative of construction used in operating transit system properties and all sections were used during the majority of SOAC engineering tests. The performance tests however, were done solely on a level, 4,000 foot, tangent part of the track. The test track included test vehicle power supplied by a General Electric model U30C diesel locomotive through a third rail distribution system. Specifications for the Rail Transit Test Track are contained in TSC document GSP 007, Requirements for Design of Balance of UMTA Rapid Transit Test Track, November 1971.

1.3.1 Track Characteristics

The Rail Transit Test Track is a 9.1-mile nearly oval loop of six different types of construction. Track orientation and plan are shown in Figure 1-4 and track profile in Figure 1-5. Table 1-1 shows the characteristics of each of the six different type sections of track.

Vehicle location on the track was determined by a series of markers. Temporary markers were placed at the beginning of each track section (construction type change). Wooden markers mounted on the third rail cover marked each 1,000 feet for a portion of the track, and in addition the track station number was painted on the side of the outside rail at each 100 feet.

The level tangent section of track, Station 300 to 340, was marked additionally to facilitate the Performance Tests. A tie was painted every 500 feet for easy identification and the start of this section on both ends was marked with roadside signs, as was the 700-foot point. This was necessary to ensure that the Performance Tests were completed on the same track section for all conditions and to control or measure the time, speed, and distance parameters during the tests.

During the Energy Consumption Test, additional wooden markers were placed on the third rail cover. These markers enumerated the stations and brake application points for the simulated service route.

Most of the track markers used during these tests were temporary and were generally a compromise based on the expediency of completing the tests. The 1,000-foot marker on the third rail cover proved to be valuable in providing location information during certain tests.

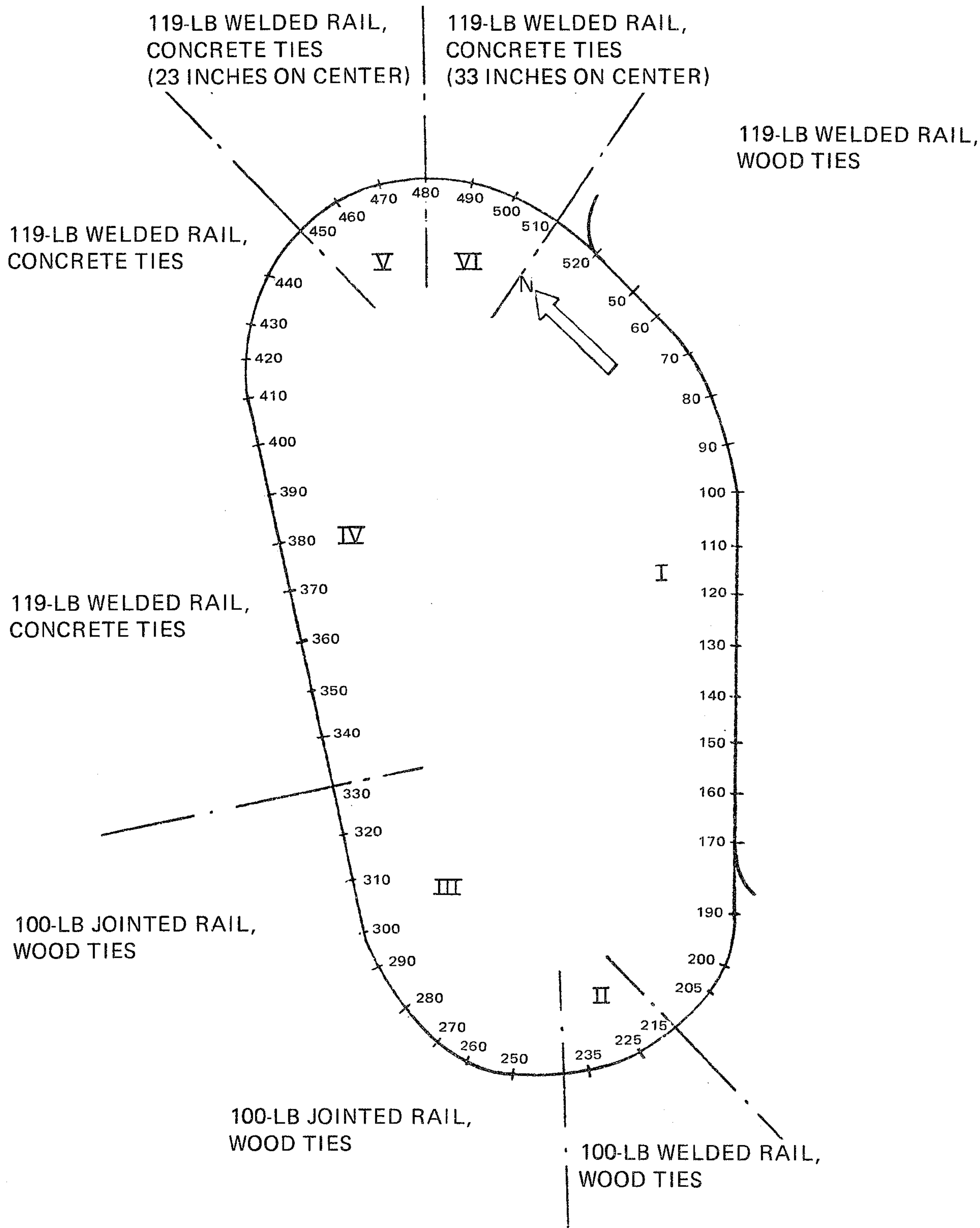


Figure 1–4. UMTA Rail Transit Test Track

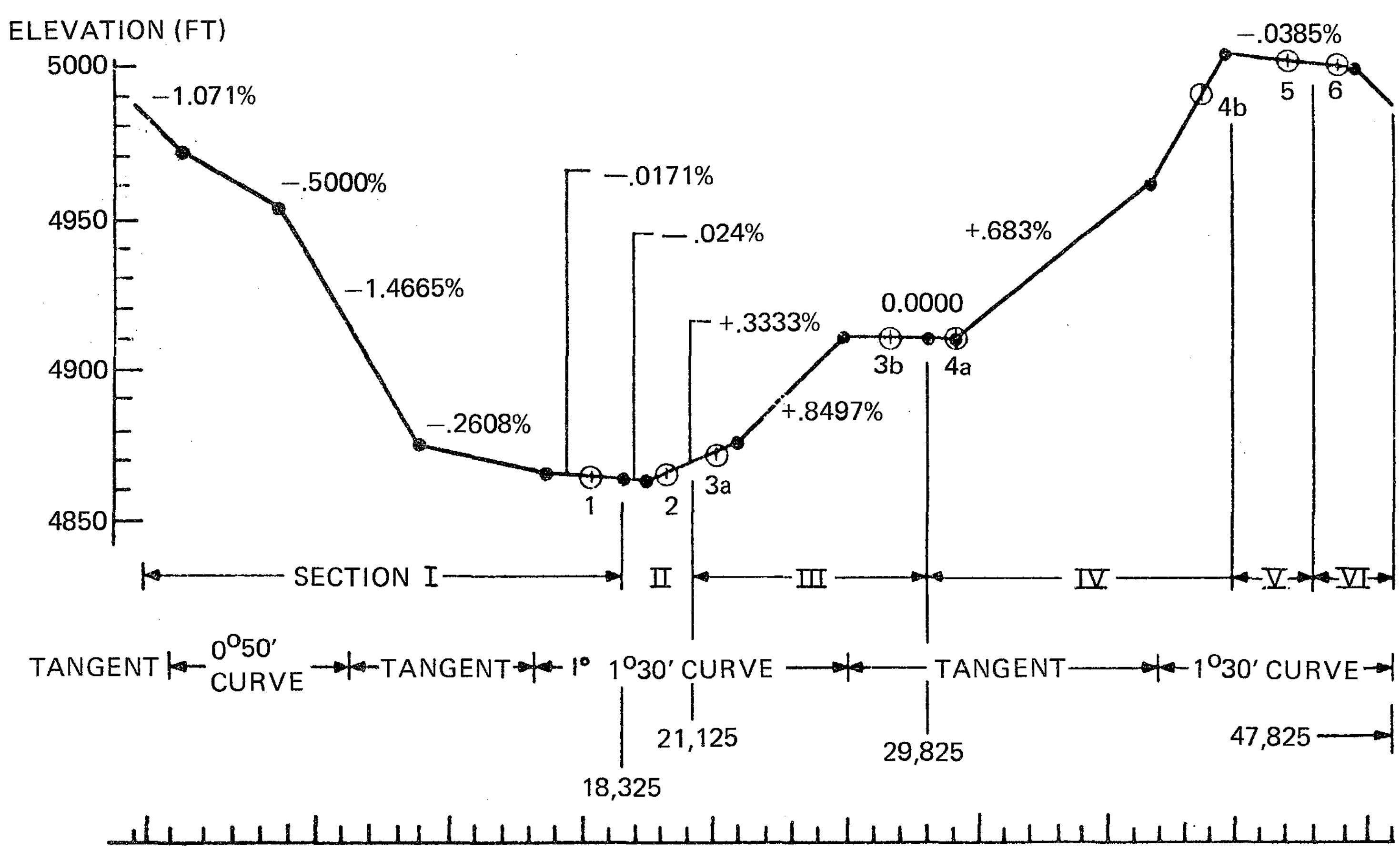


Figure 1—5. Rail Transit Test Track Profile Showing Grades

TABLE 1-1. SUMMARY OF UMTA RAIL TRANSIT TEST TRACK CONFIGURATION

Section	Location (Sta to Sta)		Alignment	Trackage	Fastener	Rail*
I	0	174	Tangent and 0° 50' curve	Wooden ties 24-inches on center on stone ballast	Spike	119-lb CF&I Welded
	174	210	1° 30' curve	Wooden ties 23-inches on center		
II	210	235	1° 30' curve	Wooden ties 23-inches on center on stone ballast	Spike	100-lb RE Welded
III	235	290	1° 30' curve	Wooden ties 23-inches on center on stone ballast	Spike	100-lb RE jointed
	290	325	Tangent	Wooden ties 24-inches on center on stone ballast		
IV	325	405	Tangent	Concrete ties 30-inches on center on stone ballast	Spring clip	119-lb CF&I Welded
	405	440	1° 30'	Concrete ties 27-inches on center on stone ballast		
V	440	470	1° 30'	Concrete ties 24-inches on center on stone ballast	Spring clip	119-lb CF&I Welded
VI	470	500	1° 30'	Concrete ties 33-inches on center on stone ballast	Spring clip	119-lb CF&I Welded

1.3.2 Power Source

Power to operate the Test Vehicle during the Engineering Tests was supplied by a diesel locomotive and two auxiliary diesel generators through a third rail system. Initially the locomotive was used as the sole source of power. The auxiliary generators were added for two-car tests and for performance tests. Some tests were carried out with only one auxiliary generator.

Third Rail

The third rail system was built to New York City Transit Authority Specifications and was compatible with the test vehicle.

Diesel Locomotive

The prime power source at the track was a GE U30C locomotive. The locomotive power characteristics are shown in Figure 1-6.

Auxiliary Generators

The 500 kw DC auxiliary diesel generators were used. Their basic characteristics were as follows:

- Voltage adjustable from 600 to 750 volts DC
- Voltage regulation of ±5 percent maximum
- Ripple at ±5 percent maximum
- Zero to maximum power in nine seconds

The power system used was difficult to regulate and control for many of the off-design Voltage Performance Tests. In addition, the system could not respond fast enough to the test vehicle demand during maximum acceleration tests with two vehicles. The permament power distribution system defined in Specification GSP-065 dated May 1972 would have been of value during these tests. Permanant power will be available late in 1975.

1.4 GENERAL VEHICLE TEST PLANS

The format used in the SOAC engineering tests was based on the DOT Transportation Systems Center General Vehicle Test Plans (GSP 064) which provide the necessary data to prepare evaluation testing for transit cars.

The General Vehicle Test Plan rail car evaluation tests are

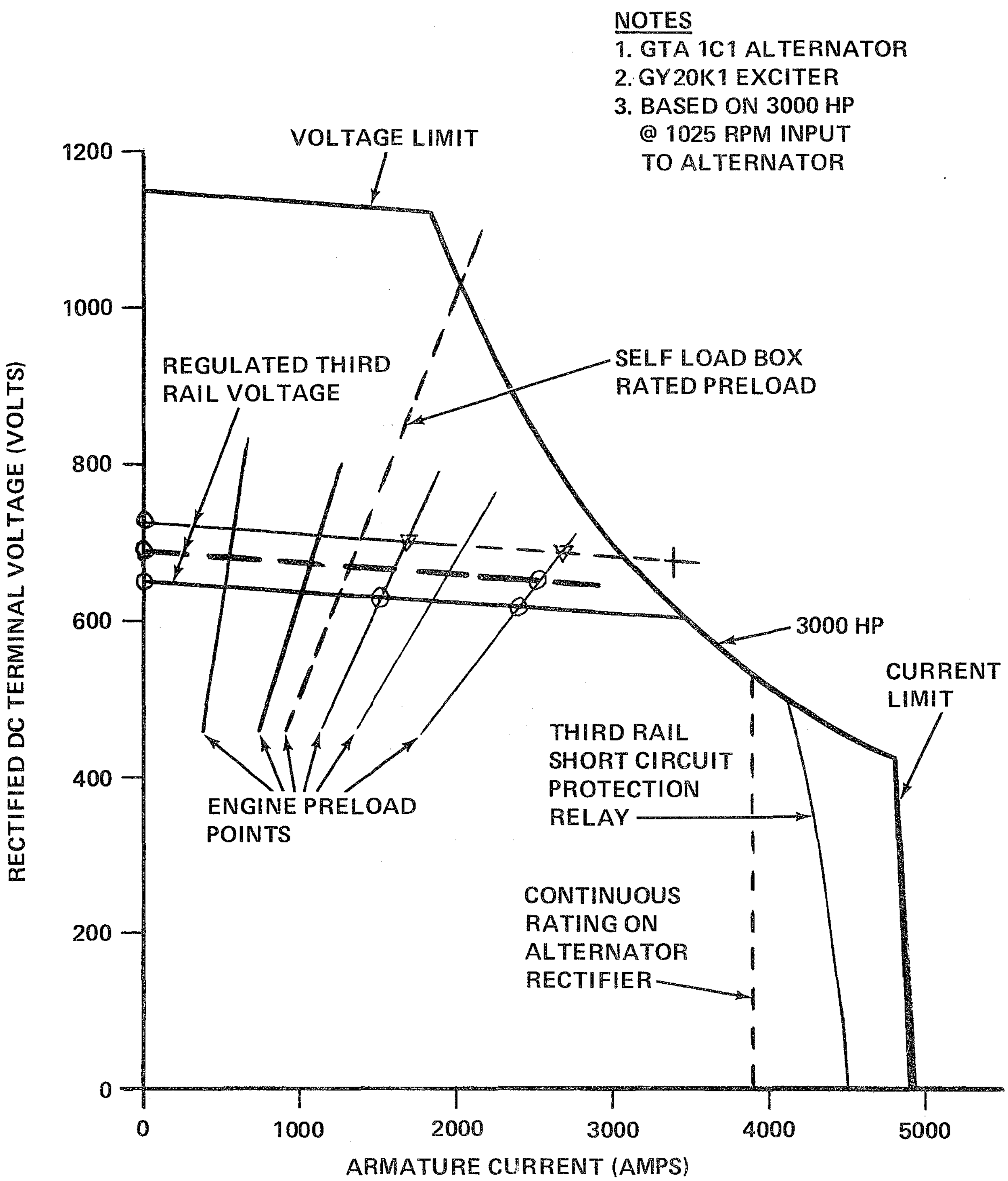


Figure 1—6. Alternator Characteristics of Locomotive Used for Power Source (DOT-001; GE U30C)

related to the natural and the inherent characteristics of the vehicle in such categories as:

- Performance (acceleration, deceleration, traction resistance, spin/slide protection, etc.)
- Power consumption
- Adhesion
- Vehicle dynamics (ride quality, roughness)
- Noise (passenger compartment; wayside, community)
- Structural dynamics
- Power system interactions (voltage and transient spikes)
- Radio frequency interference

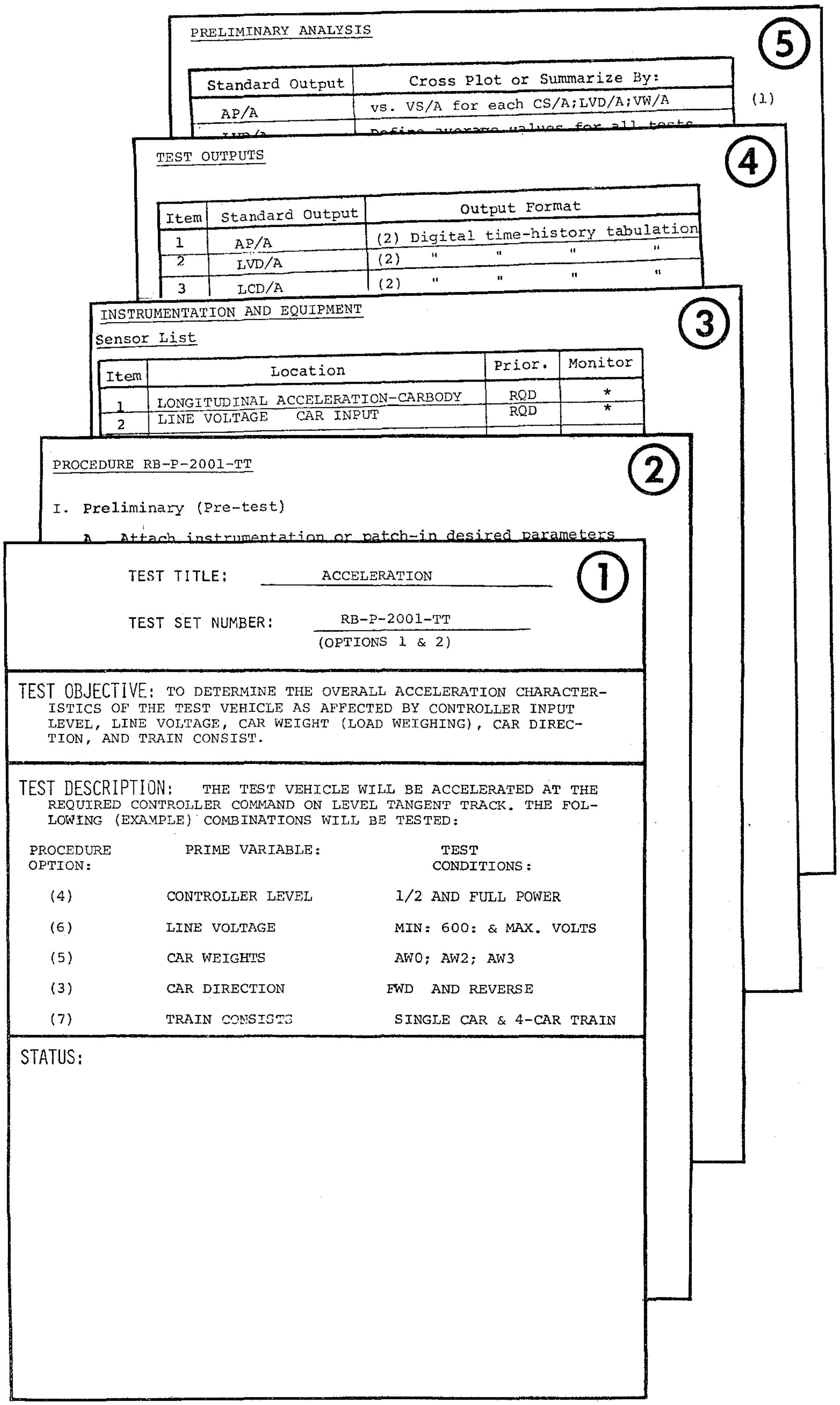
The test plans are basically for a general vehicle, that is, for a typical urban rail car as opposed to a particular or specific car model.

Adaptation of the GVTP to a particular vehicle and subsequent testing will produce a baseline set of data for that vehicle. Baseline data, in this context, is more comprehensive than is required for vehicle acceptance tests but less comprehensive than investigative type testing generally associated with research and development programs. The SOAC tests described here and in Section 2 are somewhere in between. The SOAC vehicles are part of an R&D program and these tests have been planned for use in developing the baseline information necessary. The results of the SOAC tests have been basic to the revision of the GVTP to reflect actual test experience, and to increasing the scope so that future vehicles such as the ACT series can be accommodated.

General Vehicle Test Set

The basic unit of the GVTP is a test set. A specific test, Figure 1-7 for example, is related to one of the test and evaluation categories and it contains a title, operating procedures, instrumentation, and data requirements. The test specifies and control those elements of testing that must be consistent from test to test, and it provides for sufficient flexibility to allow adaptation for specific and for different vehicles.

The GVTP test set contains a unique test set number which identifies:



PRELIMINARY ANALYSIS (5)

Standard Output	Cross Plot or Summarize By:
AP/A	vs. VS/A for each CS/A;LVD/A;VW/A (1)

TEST OUTPUTS (4)

Item	Standard Output	Output Format
1	AP/A	(2) Digital time-history tabulation
2	LVD/A	(2) " " " "
3	LCD/A	(2) " " " "

INSTRUMENTATION AND EQUIPMENT (3)

Sensor List

Item	Location	Prior.	Monitor
1	LONGITUDINAL ACCELERATION-CARBODY	RQD	*
2	LINE VOLTAGE CAR INPUT	RQD	*

PROCEDURE RB-P-2001-TT (2)

I. Preliminary (Pre-test)

(1)

TEST TITLE: ACCELERATION

TEST SET NUMBER: RB-P-2001-TT (OPTIONS 1 & 2)

TEST OBJECTIVE: TO DETERMINE THE OVERALL ACCELERATION CHARACTERISTICS OF THE TEST VEHICLE AS AFFECTED BY CONTROLLER INPUT LEVEL, LINE VOLTAGE, CAR WEIGHT (LOAD WEIGHING), CAR DIRECTION, AND TRAIN CONSIST.

TEST DESCRIPTION: THE TEST VEHICLE WILL BE ACCELERATED AT THE REQUIRED CONTROLLER COMMAND ON LEVEL TANGENT TRACK. THE FOLLOWING (EXAMPLE) COMBINATIONS WILL BE TESTED:

PROCEDURE OPTION:	PRIME VARIABLE:	TEST CONDITIONS:
(4)	CONTROLLER LEVEL	1/2 AND FULL POWER
(6)	LINE VOLTAGE	MIN: 600: & MAX. VOLTS
(5)	CAR WEIGHTS	AW0; AW2; AW3
(3)	CAR DIRECTION	FWD AND REVERSE
(7)	TRAIN CONSISTS	SINGLE CAR & 4-CAR TRAIN

STATUS:

- the type vehicle
- the evaluation category
- the testing procedure category
- the test location

The first page of a test set also contains a test objective and test description for the specific vehicle (Figure 1-7 (1)). The second part, (2) , contains the detailed step-by-step instructions for set-up and running the test point. Part (3) describes the data reduction and analysis through standard output codes defined in GVTP GSP-064.

1.5 TEST OPERATIONS

The basic test team organization and procedures were as established by DOT/HSGTC Policy Order 6371.1, Framework for Conducting Test Operations, January 1973 and DOT/HSGTC Policy Order 5800.1, HSGTC Safety Policy, January 1973. The team was, however, composed of individuals from many different organizations. TSC provided a Project Monitor who reviewed the Test Plans in conjunction with the weekly Test Schedule Request Summary and performed the interface with the HSGTC Support Operations. The Test Controller, also a TSC individual, coordinated the activities of the test team on and off the vehicles during the test, and was responsible for the safe conduct of the test.

The test plan and specific test procedures were developed by Boeing Vertol. GSP-064, DOT/TSC General Vehicle Test Plans, April 1972, was used as a guide for those test procedures. Additions were required for tests not included in GSP-064. Explicit description of the tasks was required to identify the work load and permit test completion in a timely manner. These detailed test procedures may be found in D174-10023-1, SOAC Engineering Test Program Test Procedures, July 1973, Boeing Vertol.

Vehicle operation and control of the test data was under the auspices of a Boeing Vertol Test Engineer. Authenticity or validity of the test data was checked during the test by Boeing Vertol Technology Engineers. The same Boeing Vertol Technology Engineers performed the analysis and reporting. The instrumentation system was designed and installed by Garrett-AiResearch Field Service Engineers. These individuals also performed the daily calibration and operated the system during the test. Garrett also did the data reduction at the request of Boeing Vertol Technology.

Because of the number of people and organizations involved some special operating procedures were developed for this program. An Engineering Test Log Book was maintained by the Boeing Vertol Test Engineer. This log book consists of all the Test Runs performed during the course of the program. Each Test Run is prefaced by a title sheet (Figure 1-8) and contains the manual data sheets used and any special instructions or notes about the operation.

A prerun briefing was conducted prior to a test run in order to cover the day's plan with the test crew and to assign the various work loads.

In addition to the log book, a project board was maintained in the Boeing Vertol Project Offices (Figure 1-9). This board contained the program master schedule, and a daily summary. Special work items and general plans were also included. The purpose of this project board was to indicate test status and schedule to the various organizations at the HSGTC.

As the data tapes were completed, they were sent to Garrett-AiResearch in Torrance, California. Boeing Vertol Technology in Philadelphia reviewed the "quick-look" oscillograph strip-outs taken during the test and developed data reduction requests. The requests were mailed to Garrett and the processed data was returned to Boeing Vertol Technology for analysis and reporting.

SOAC TEST RUN

DATE:

TIME: START STOP

WEATHER CONDITION

WIND SPEED

DIRECTION

AMBIENT AIR TEMPERATURE

VEHICLE CONFIGURATION: CAR 1 CAR 2

CREW:

TEST CONTROLLER ________________

OPERATIONS DIRECTOR ________________ MOTORMAN ________________

DATA CONTROLLER ________________ GROUND CONTROLLER ________

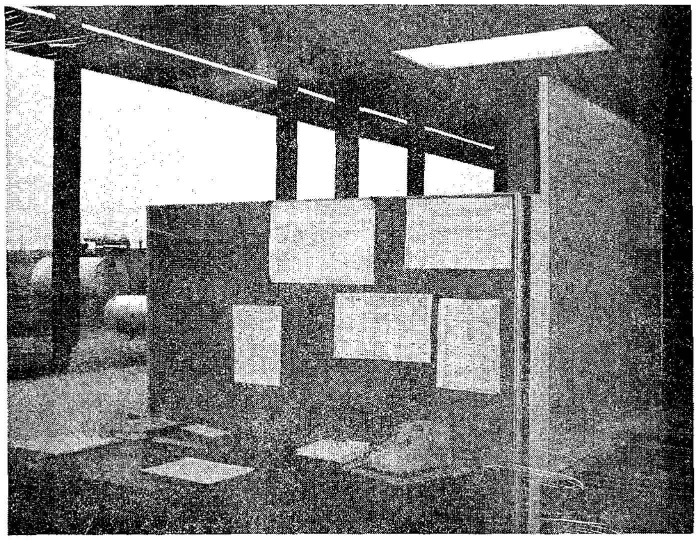
INSTRUMENTATION ________________ REAR MONITOR ____________

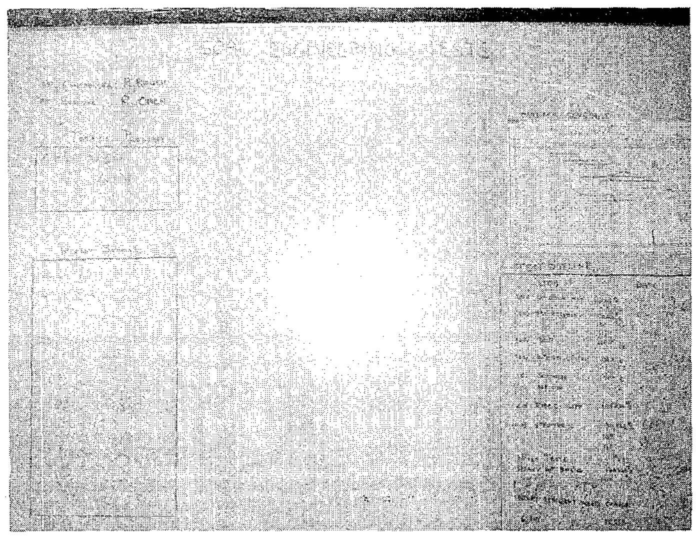
____

ADDITIONAL PERSONNEL ______________________________

ADDITIONAL COMMENTS:

Figure 1—8. Engineering Test Log Book Title Sheet





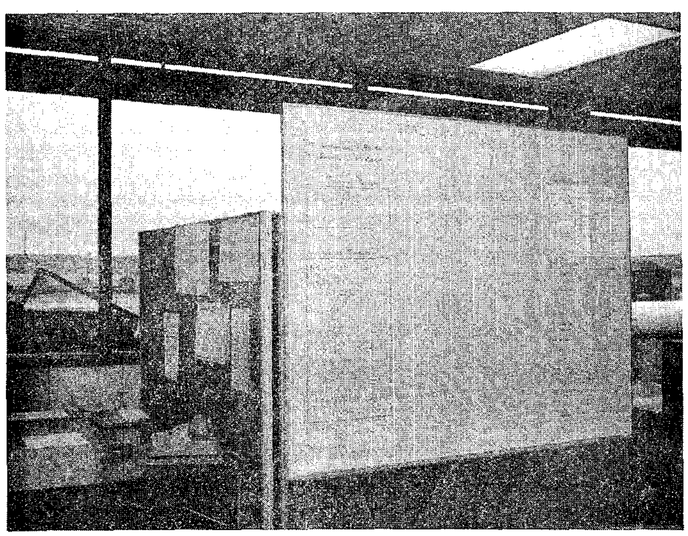


Figure 1–9. SOAC Project Office at HSGTC

Section 2

TEST DESCRIPTION

2.1 OBJECTIVES AND SUMMARY DESCRIPTION

Six areas of testing were accomplished using the concept of the General Vehicle Test Plans, GSP 064. Table 2-1 is a summary of the following SOAC engineering tests at the HSGTC:

Performance

The SOAC was tested throughout its operating limits, and parameters were recorded which enable the complete description of vehicle capabilities under normal and adverse conditions. The tests included drift, spin/slide protection, and wheel/rail adhesion limits.

Power Consumption

SOAC efficiency was tested by measuring power consumption when operating the vehicle in a simulated revenue service configuration.

Noise

Sound levels were recorded at selected passenger and wayside locations and subsequently analyzed. These tests describe the acoustical properties of the SOAC.

Ride Quality

Sufficient car body vibrations were recorded to fully define car body motion during operation. Subsequent data analysis was limited to a few selected test points.

Structural

Measurements were taken to determine the magnitude and phasing of dynamic loads being introduced into the truck.

TABLE 2-1. SOAC ENGINEERING TESTS

Test Area	Test Name	Test Set No.	Main Parameters
Performance	Acceleration ● Option: Line Voltage, Off-Design Testing	SOAC-P-2001-TT	Time, Distance/Speed
	Deceleration ● Blended Braking ● Service Friction Braking ● Dynamic Braking ● Emergency Braking	 SOAC-P-3001-TT SOAC-P-3002-TT SOAC-P-3003-TT SOAC-P-3004-TT	Stopping Distance/ Time vs. Speed/Weight
	Traction Resistance (Drift)	SOAC-P-4001-TT	Drift Resistance vs. Speed/Weight
	Spin/Slide Protection Systems ● Acceleration ● Deceleration	 SOAC-P-2001-TT SOAC-P-3011-TT	Efficiency at 10-80 mph
	Friction Brake Duty Cycles	SOAC-P-5001-TT	(See Power Consumption Tests)
Power Consumption	Power Consumption ● Synthetic Transit Route ● Brake Duty Cycles	 SOAC-PC-5011-TT SOAC-P-5001-TT	Line Volts/Amps/Time, Tread and Shoe Temperatures
Adhesion	Adhesion	SOAC-A-3021-TT	Adhesion Factor
Vehicle Dynamics, Ride Quality (Roughness)	Vehicle Dynamics ● Steady Speed ● Acceleration ● Deceleration	 SOAC-R-4001-TT SOAC-R-2001-TT SOAC-R-3001-TT	Vibration
Noise	Interior (Passenger Compartment) Noise	SOAC-PN-XXXX-TT	Sound Pressure
	Wayside (Community) Noise	SOAC-CN-XXXX-TT	Sound Pressure
Structural Dynamics	SOAC Structures	SOAC-S-XXXX-TT	Load, Motion, Strain
RFI	Radio Frequency Interference	SOAC-PSI-XXXX-TT	Field Intensity
Power Quality	Voltage Transients and Spikes	SOAC-PSI-XXXX-TT	Line Volts

Voltage Measurement

A series of tests were completed to examine the power interaction of the SOAC and source in order to determine SOAC compatibility with the demonstration properties.

2.2 TEST SETS

Within the six areas of testing, a series of discrete tests are described by Test Sets. Those Test Sets performed during the SOAC Engineering Tests at HSGTC are as defined in paragraphs 2.2.1 through 2.2.6.

2.2.1 Performance Test Sets

Acceleration: SOAC-P-2001-TT

Baseline procedure with testing conducted at four controller inputs, three line voltages, and four car weights.

Objective: To determine the SOAC acceleration characteristics, control response, line voltage, and load compensation effects throughout the operating range of the car. To provide baseline data on the SOAC operating on the HSGTC oval for use during ACT-1 and subsequent Rapid Rail Development programs.

Deceleration: Blended Braking, SOAC-P-3001-TT; Service Friction Braking, SOAC-P-3002-TT; Dynamic Braking, SOAC-P-3003-TT; Emergency Braking, SOAC-P-3004-TT

Baseline test procedures used at four controller inputs, four car weights, three line voltages, and with four braking modes.

Objective: To determine the overall characteristics and stopping distances associated with the four SOAC braking modes (blended, dynamic only, service friction only, emergency friction) throughout the operating range of the car.

Traction Resistance (Drift): SOAC-P-4001-TT

Baseline Test Procedure used for single and two-car tests.

Objective: To determine the traction resistance of the SOAC for use in analysis of wheel-rail adhesion factors and traction system propulsion and braking force characteristics.

Friction Brake Duty Cycles: SOAC-P-5001-TT

SOAC-P-5001-TT was utilized to perform the tests for two duty cycles. Cruise speeds of 35 and 50 mph were tested.

Objective: To determine the thermal capacity of the SOAC tread brake system while operating on duty cycles similar to those anticipated during the SOAC demonstration with the dynamic brake disabled. Cycle I simulates NYCTA 8th Avenue Express; Cycle II simulates the Cleveland Airport (CTS) route. Both solid and resilient wheels were tested to determine their capability and to define potential limitation for the demonstrations.

Spin-Slide, Acceleration: SOAC-P-2011-TT; Spin/Slide, Deceleration: SOAC-P-3011-TT

SOAC-P-2011-TT for acceleration testing; SOAC-P-3011-TT for deceleration testing. Procedures used throughout the speed range with blended, dynamic and service friction braking only.

Objective: To determine the efficiency of the SOAC spin/slide protection system throughout the speed range of the car in both drive and brake modes on wetted rail. An additional objective was to define a specific data acquisition and analysis technique to standardize the calculation of efficiency.

Synthetic Transit Route, SOAC-PC-5011-TT; Friction Brake Duty Cycles, SOAC-P-5001-TT

SOAC-PC-5011-TT was utilized for testing on the Synthetic Transit Route; SOAC-P-5001-TT was used to obtain energy consumed during the friction brake duty cycles.

Objective: To determine the SOAC's energy consumption and schedule speed on the Synthetic Transit Route developed for the ACT-1 Program. The test results will provide a baseline for both the SOAC and the route as laid out at Pueblo. The overall efficiency of the traction system will be estimated from this data.

2.2.2 Ride Quality Test Sets

Steady Speed, SOAC-R-4001-TT; Acceleration, SOAC-R-2001-TT; Deceleration, SOAC-R-3001-TT

Objective: To expand and improve the General Vehicle Test Plan (GSP-064) and to provide vehicle ride quality baseline engineering data for the SOAC at the HSGTC. This data will be used for comparison with data recorded at five transit properties: New York, Boston, Cleveland, Chicago, and Philadelphia.

2.2.3 Adhesion Test Set

Adhesion, SOAC-A-3021-TT

Objective: To determine the dry and wetted rail adhesion factors for use in spin-slide system detailed performance analyses. To determine the wetted rail adhesion factor associated with the wetting solution used during spin/slide tests.

2.2.4 Noise Test Sets

Noise, Passenger Compartment Interior: SOAC-PN-XXXX-TT

Objective: To measure the interior noise levels in the SOAC cars operating at the HSGTC under various conditions by sampling car locations representative of patrons and operating crew and probing possible sources. These data will be used to describe the acoustical characteristics of the SOAC vehicles, and for comparison with subsequent noise tests performed at the demonstration properties. A secondary objective was to develop and verify procedures for performing such tests.

Noise, Wayside (Community): SOAC-CN-XXXX-TT

Objective: To measure the wayside noise levels of the SOAC cars operating at the HSGTC under various conditions. These data will be used to describe the acoustical characteristics of the SOAC vehicles and for comparison with subsequent noise tests performed at the demonstration properties. A secondary objective was to develop and verify procedures for performing such tests.

2.2.5 Power System Interaction Test Sets

Radio Frequency Interference: SOAC-PSI-XXXX-TT

Objective: To measure the broadband radiated electromagnetic emissions from a rapid transit train consisting of two SOAC cars coupled together and functioning as a unit. Measurements of internal emission levels were secured to identify sources of significant electromagnetic emission. Wayside emission data were obtained for comparison with the radio frequency interference goals established for SOAC.

Voltage Transients and Spikes: SOAC-PSI-XXXX-TT

Objective: The purpose of this test was to obtain voltage transient and spike data on the SOAC vehicle while at the HSGTC in order to determine SOAC characteristics.

2.2.6 Structural Test Sets

Structural (SOAC Structures): SOAC-S-XXXX-TT

Objective: To develop a method for providing baseline data for structurally evaluating rail cars, and to provide a baseline of structural data for the SOAC.

To achieve these objectives, measured vehicle loads, motions, and strains are required for a variety of weights, speeds, and track configurations.

2.3 INSTRUMENTATION SYSTEM

The instrumentation system developed for the engineering tests and described here is limited to the areas of vehicle dynamics, structural behavior, and performance. The instrumentation relative to the remaining test areas is described in the associated test sections.

The major components of the system are shown in Table 2-2. All of the conditioning and recording equipment are located in a single console. This console was selected to be able to fit through the test vehicle doors and ride in the rear of the car. It is sufficiently stable to warrant no further support during normal vehicle tests. The system was designed and built by Garrett-AiResearch and a detail description and calibration procedures are contained in Volume VI.

TABLE 2-2. INSTRUMENTATION SYSTEM MAJOR COMPONENTS

Item	Type	Quantity (each)
Magnetic tape recorder, 14-channel	Sangamo 3614	2
Light beam oscillograph, 12-channel	Bell and Howell 5-134	2
Temperature recorder, 12-point	Leeds and Northrup Speedomax H	1
Servo accelerometer	Schaevitz LSBC	22
Linear potentiometer	Research, Inc. No. 4046	14
Time code generator	Systron Donner No. 8154	1
Signal conditioning modules	AiResearch Special	3
Power supply, inverter, 5 kw	----	2

Section 3

TEST RESULTS

3.1 SUMMARY

The major objectives of the SOAC Engineering Test Program reported here were to obtain baseline engineering data on the SOAC vehicles and to improve the General Vehicle Test Plan. These objectives were met using UMTA's Rail Transit Test Track at the DOT HSGTC. The value of using the dedicated test facility becomes apparent when the extent of the SOAC Engineering Tests is considered. In 39 available days, 67 separate vehicles runs were accomplished. This entailed slightly more than 150 vehicle operating hours and resulted in 30 hours of test data. The test operations covered the spectrum of SOAC capability, an accomplishment not readily obtainable in any other type of test environment. The range of the test points obtained is evidenced by Figure 3-1, which presents the complete tractive effort capability of the SOAC propulsion system, and was derived from the data found in Volume II of this report.

A substantial portion of the test data has been reduced and is reported in the separate volumes. A synopsis of each test category is found in Section 3.2 (following). The complete set of SOAC baseline engineering test data is contained on magnetic tapes on file at TSC.

3.2 RESULTS

Volumes II through V of this report contain detailed discussions of the Engineering Tests performed on the SOAC at the High Speed Ground Test Center. A summary of each of the categories of tests is presented in the following paragraphs of this section.

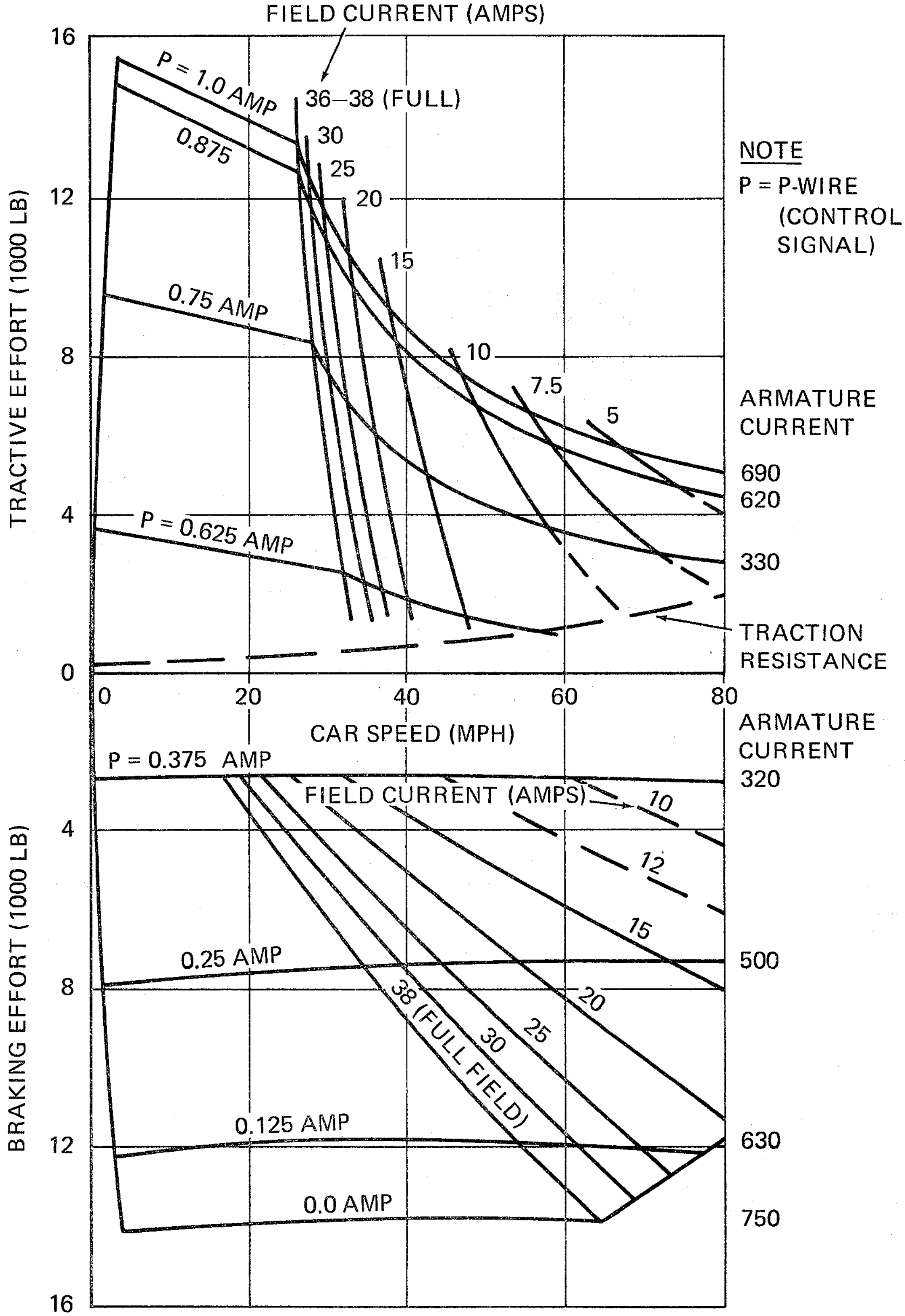


Figure 3–1. Traction and Braking Characteristics (Single-Car, 600 Volts)

Parameter Measurement

The instrumentation system was capable of measuring the parameters listed below for the various types of tests with a minimum change over time between tests configuration. The detail specification for the recorded parameters is given in Volume VI.

- Performance

Channel	Parameter
1	Longitudinal acceleration
1	Car speed
1	Line voltage, third rail at current collectors
1	Line current, third rail at current collectors
2	Traction motor voltage (2 trucks)
2	Traction motor current (2 trucks)
2	Traction motor field current (2 trucks)
1	Trainline signal P-wire current
1	Brake cylinder pressure
1	Brake temperature* (wheel treads)
1	Kilowatt-hour consumption
1	Dynamic brake feedback signal
1	Event marker (distance reference)
-	Time reference

*Brake shoe temperature was used.

- Ride Quality (Vibration)

Channel	Parameter	Direction
	Car Body Linear Accelerations	
1	Fwd car floor, truck centerline	Vert
1	Fwd car floor, truck centerline	Lat
1	Fwd car floor, truck centerline	Long
1	Center line car floor, rear end	Vert
1	Center line car floor, rear end	Lat
1	Fwd car floor LH, truck centerline	Vert
1	Center line car floor, mid-car	Vert
1	Center line car floor, mid-car	Lat
1	Car floor RH, mid-car	Vert
1	Car floor LH, mid-car	Vert
1	Center line car ceiling, mid-car	Lat

Channel	Parameter	Direction
	Car Body Angular Accelerations	
3	Mid-car centerline	Pitch Roll Yaw
	Truck Linear Accelerations	
1	Fwd RH wheel, front	Vert
1	Fwd RH wheel, front	Lat
1	Aft RH wheel, front	Vert
1	Aft RH wheel, front	Lat
1	Fwd LH wheel, front	Vert
1	Aft LH wheel, front	Vert
1	Fwd RH wheel, rear	Lat
1	Aft RH wheel, rear	Lat
1	Fwd motor housing at c.g.	Vert
1	Fwd motor housing at c.g.	Lat

- Structural

Channel	Parameter
	Forward Truck
1	LH airspring vertical displacement
2	RH airspring vertical displacement
3	LH airspring lateral displacement
4	RH airspring lateral displacement
5	LH vertical damper load
6	RH vertical damper load
7	LH lateral damper load
8	RH lateral damper load
9	RH bolster anchor rod displacement
10	LH bolster anchor rod displacement
11	RH fwd chevron vertical displacement
12	LH fwd chevron vertical displacement
13	RH aft chevron vertical displacement
14	LH aft chevron vertical displacement
15	RH fwd chevron lateral displacement
16	RH aft chevron lateral displacement
17	Truck frame strain gage absolute
18	Truck frame strain gage absolute
19	Temperature of RH fwd chevron

Channel	Parameter
	Aft Truck
20	RH fwd chevron vertical displacement
21	RH fwd chevron lateral displacement

- Equipment Temperature Instrumentation

Channel	Parameter
2	Traction motor
1	Blower output air (chopper/traction, motor cooling, system)
1	Chopper output air (chopper/traction, motor cooling, system)
2	Traction output air (chopper/traction, motor cooling, system)
2	Dynamic brake resistors interior air
1	Motor smoothing reactor
1	Chopper interior air
1	Power control unit interior air
1	Propulsion control unit interior air
1	Auxiliary power control unit interior air
1	Motor alternator set output air
1	Air conditioning condenser inlet air
1	Ambient air
1	Ice reference

3.2.1 Performance Tests

The SOAC car was tested throughout its operating range of weight, line voltage, controller level and brake subsystem, as well as in sample service tests to define power consumption, friction brake temperatures, and undercar equipment temperatures. Adhesion levels and performance of spin/slide control systems were also tested. Summaries of the performance testing follow:

- Acceleration and Service Braking Control Characteristics

  Figure 3-2 illustrates the results of control linearity tests for acceleration and blended braking at a car weight of 105,000 pounds.

  The control logic of the SOAC provides essentially proportional control of tractive effort (acceleration) throughout the speed range in both drive and brake. In the drive mode the tractive effort above about 28 mph is proportional to the maximum capability of the system as represented by the P-signal of 1.0 amperes.

  Braking rate is essentially constant throughout the speed range. The curved trend is due to the tractive resistance of the car at speed. The maximum capabilities of the car as represented by P = 1.0 and 0.0 amperes are within the specification requirements.

  Figure 3-3, a cross-plot of Figure 3-2 to illustrate the control linearity, shows weights from 90,000 to 113,000 pounds as well as both blended and friction brake data. The linearity of control is within the ±10 percent (full-scale) band desired for the 105,000-pound car (and generally considered desirable for all weights). The test points illustrate the accuracy of the closed-loop tractive effort control logic of the traction system.

- Acceleration and Service Braking Load-Weigh Compensation

  The results of acceleration and braking tests at car weights from 90,000 to 130,000 pounds are shown in Figure 3-4 for full service acceleration and braking. Figure 3-3 shows the accuracy of the load-weigh system for weights from 90,000 to 113,000 pounds at both full and one-half input commands. When not limited by tractive power (acceleration), the system maintains car performance within the desired 10-percent tolerance band. The full acceleration power capability of

NOTES

1. CAR WEIGHT: AW1 105,000 LB (SINGLE CAR)
2. LEVEL TANGENT TRACK
3. 30-INCH WHEELS
4. SOAC HSGTC ENGINEERING TESTS: RUNS 102, 142

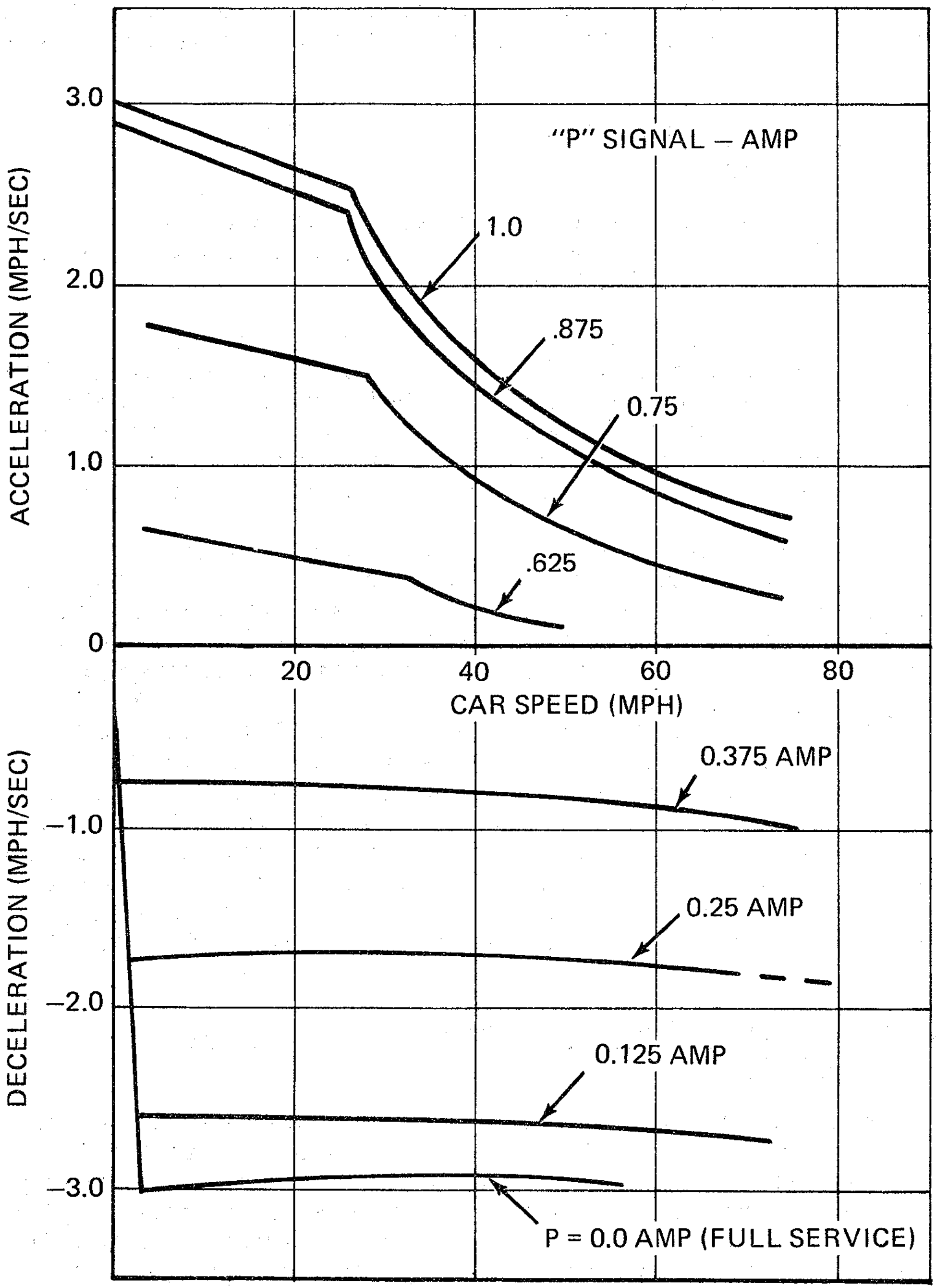


Figure 3–2. Acceleration and Speed Response to Tractive Effort Response

NOTES

1. CAR SPEED 10 MPH
2. LEVEL TANGENT TRACK
3. 30-INCH WHEELS
4. SOAC HSGTC ENGINEERING TESTS:
   RUNS 96, 102, 126, 142, 144, 146, 148, 151

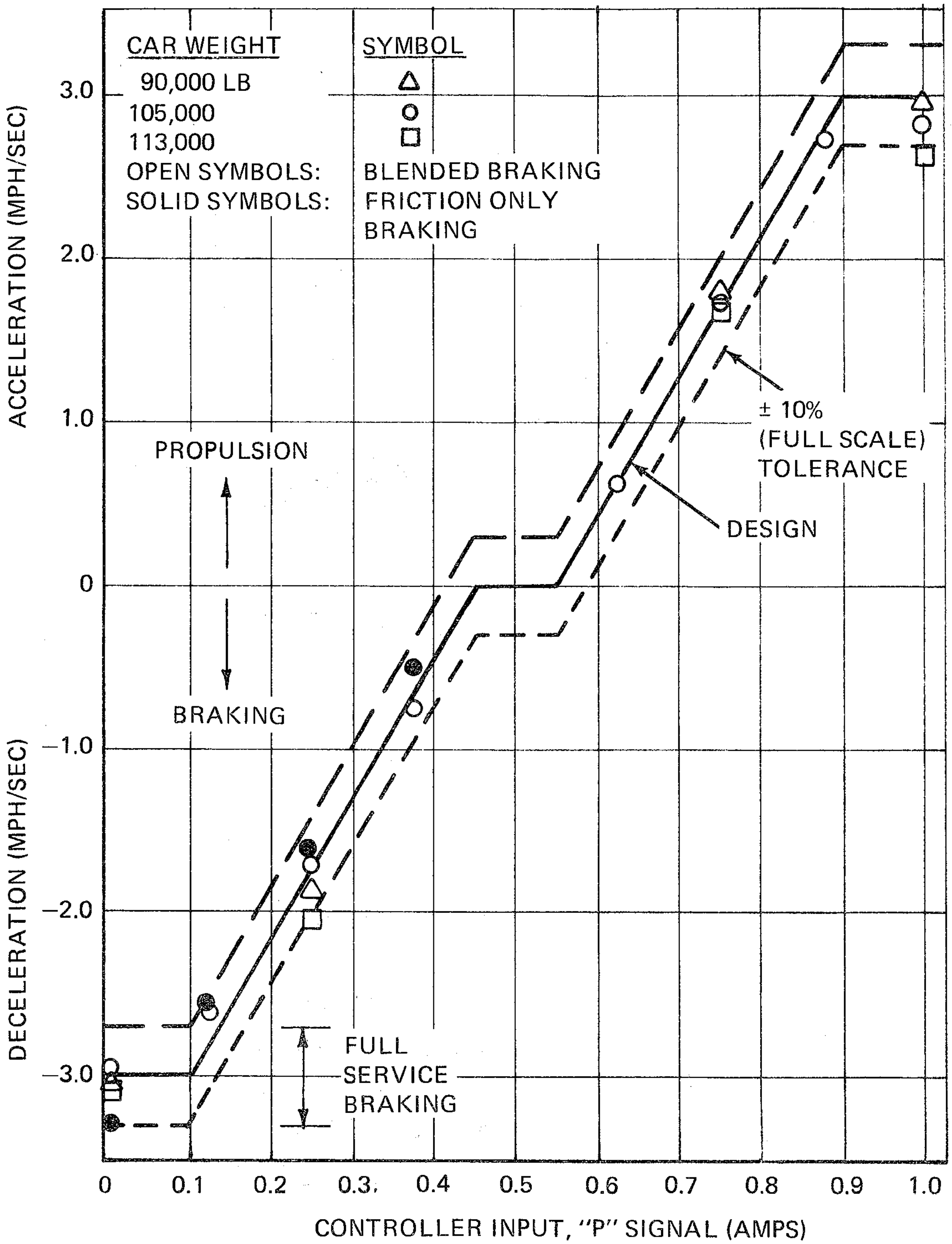


Figure 3–3. Control Linearity ("P" Signal)

NOTES

1. CAR WEIGHT AS NOTED (SINGLE CAR)
2. LEVEL TANGENT TRACK
3. 30-INCH WHEELS
4. SOAC HSGTC ENGINEERING TESTS: RUNS 96, 102, 126, 142, 146, 148, 151
5. "P" SIGNAL = 1.0 AMP

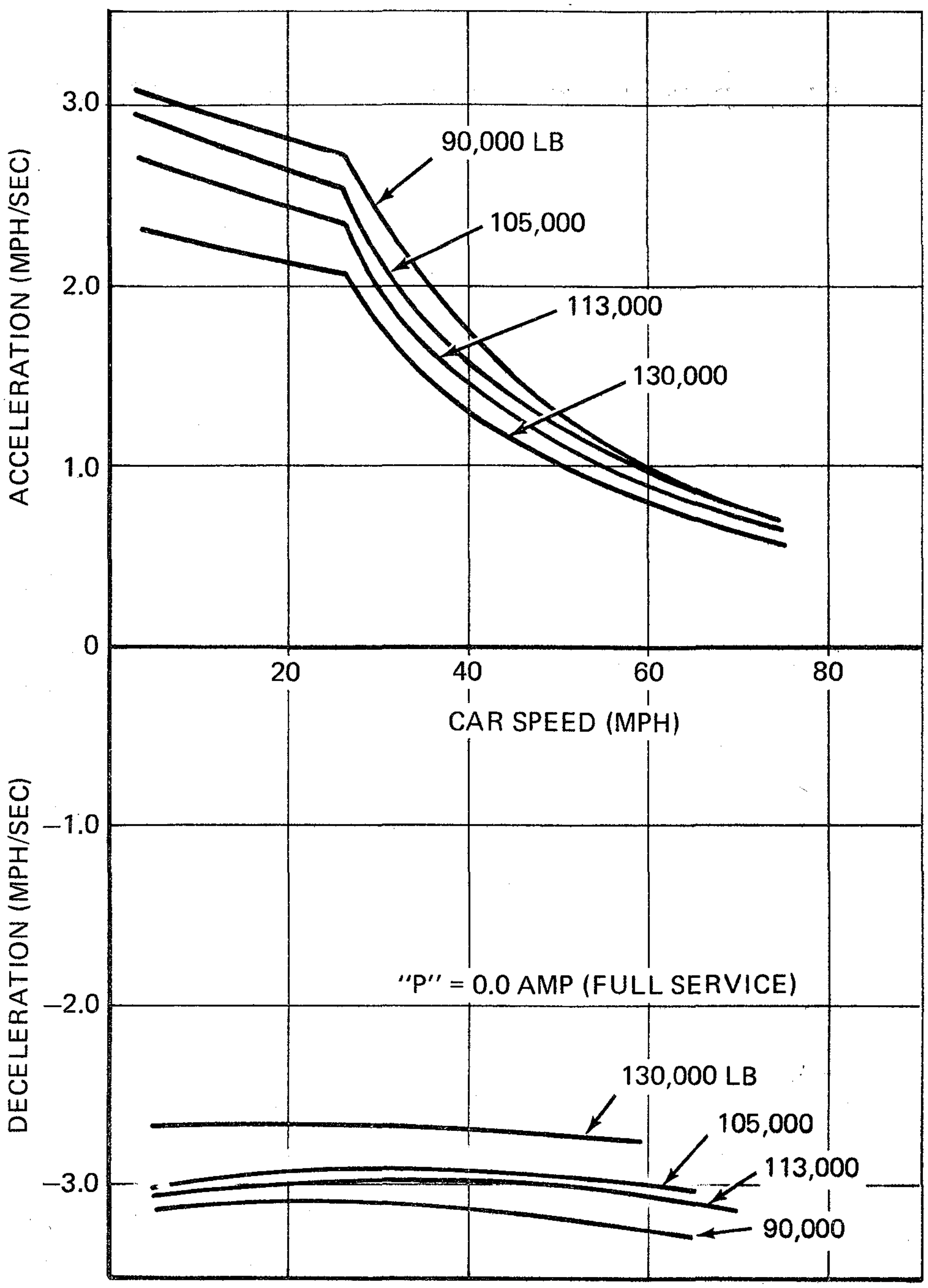


Figure 3–4. Effect of Car Weight on Acceleration and Braking

the SOAC is represented by the 105,000-pound curve of Figure 3-4; above this weight acceleration capability is reduced in proportion to car weight for P = 1.0-ampere commands. For one-half acceleration command (P = 0.75) the acceleration rate for all tested weights is essentially equal as shown in Figure 3-3.

Figure 3-5 illustrates the resulting time-speed-distance characteristics recorded during acceleration tests; the data shown are for full-service acceleration capability.

- Acceleration and Service Braking Line Voltage Sensitivity

The SOAC was tested at line voltages of 475, 600 and 650 volts. Figure 3-6 illustrates the acceleration and braking test results. Figure 3-7 presents the associated time-speed-distance data.

The SOAC traction control system uses line voltage, as measured across the input filter capacitors, to determine the traction motor current (torque) limit. The system was designed for 600-volt operation, and armature currents are limited at that voltage. Unlike the existing series-wound traction motors, the SOAC's separately excited motors (and control system) will not increase their output at higher than 600-volt line input. As a result, the 600- and 650-volt acceleration rates are similar.

Below 600 volts the armature current limit is recalibrated by the control system in proportion to the voltage. This results in the reduced performance shown in Figure 3-6 at 475 volts. However, the top speed of the car will not be reduced below 80 mph. The blended braking rate is unaffected by line voltage, as noted in Figure 3-6.

- Traction Resistance - Drift Test

Drift tests were performed to determine the traction resistance (force versus speed) characteristic for use in the analysis of wheel-rail adhesion test data and to develop the traction forces associated with measured acceleration and deceleration rates.

Figure 3-8 presents the final faired curves of single-car and two-car test data. The single-car data is the primary requirement for adhesion and performance data analysis. The existence of considerable scatter in the basic data may be due to data reduction

NOTES

1. CAR WEIGHT AS NOTED (SINGLE CAR)
2. LEVEL TANGENT TRACK
3. 30-INCH WHEELS
4. SOAC HSGTC ENGINEERING TESTS: RUNS 96, 102, 126, 142, 146, 148, 151
5. "P" SIGNAL = 1.0 AMP

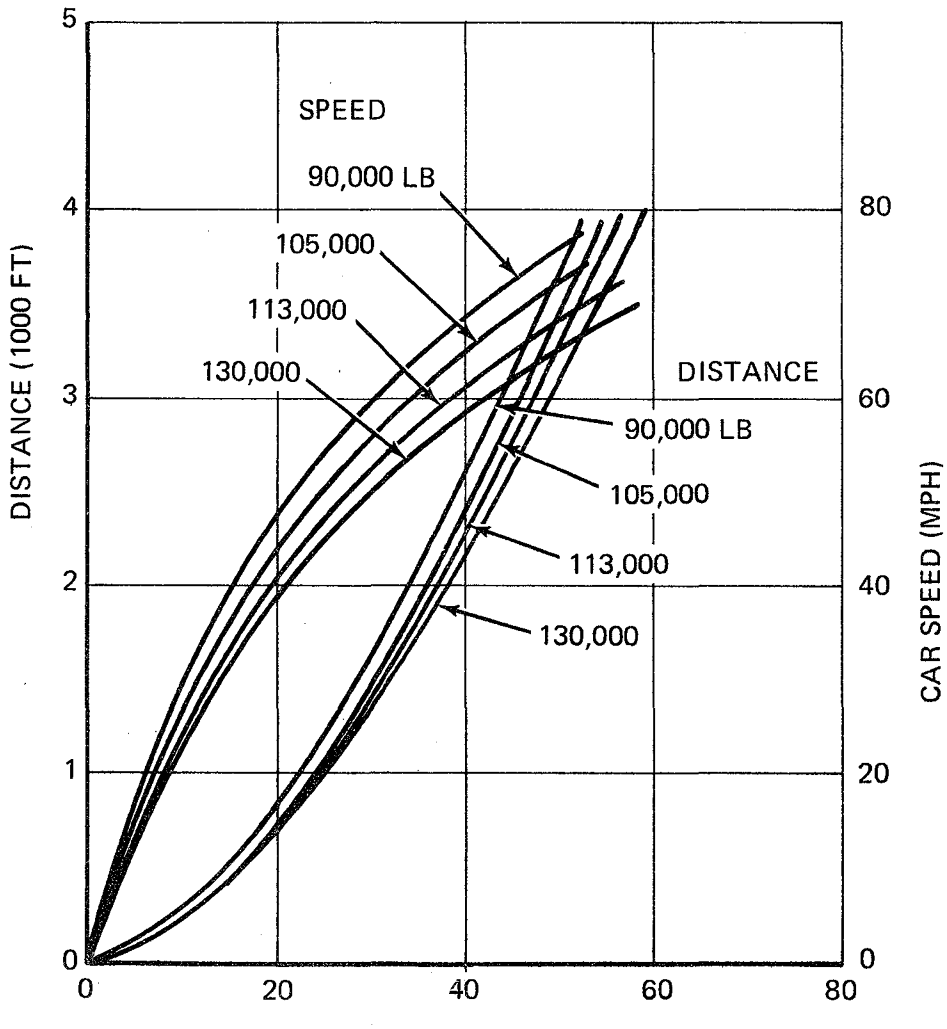


Figure 3–5. Effect of Car Weight on Time and Distance to Speed

NOTES

1. CAR WEIGHT AW1 105,000 LB (SINGLE CAR)
2. LEVEL TANGENT TRACK
3. 30-INCH WHEELS
4. SOAC HSGTC ENGINEERING TESTS: RUNS 102, 103, 104, 142, 143
5. "P" WIRE = 1.0 AMP
6. NOMINAL THIRD RAIL VOLTAGE

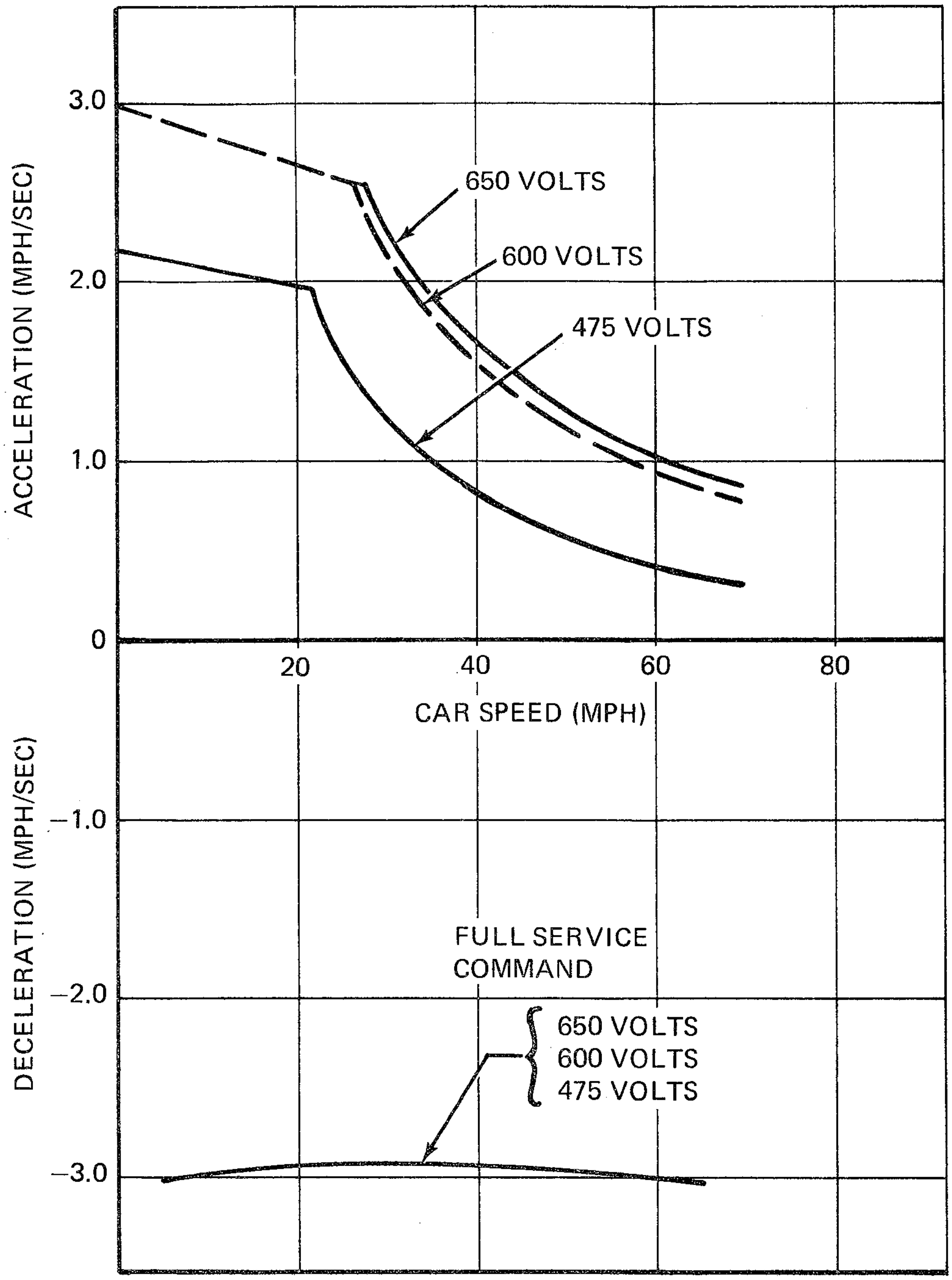


Figure 3–6. Effect of Third Rail Voltage on Acceleration and Braking

NOTES

1. CAR WEIGHT AW1 105,000 LB (SINGLE CAR)
2. LEVEL TANGENT TRACK
3. 30-INCH WHEELS
4. SOAC HSGTC ENGINEERING TESTS: RUNS 102, 103, 104, 142, 143
5. NOMINAL THIRD RAIL VOLTAGE

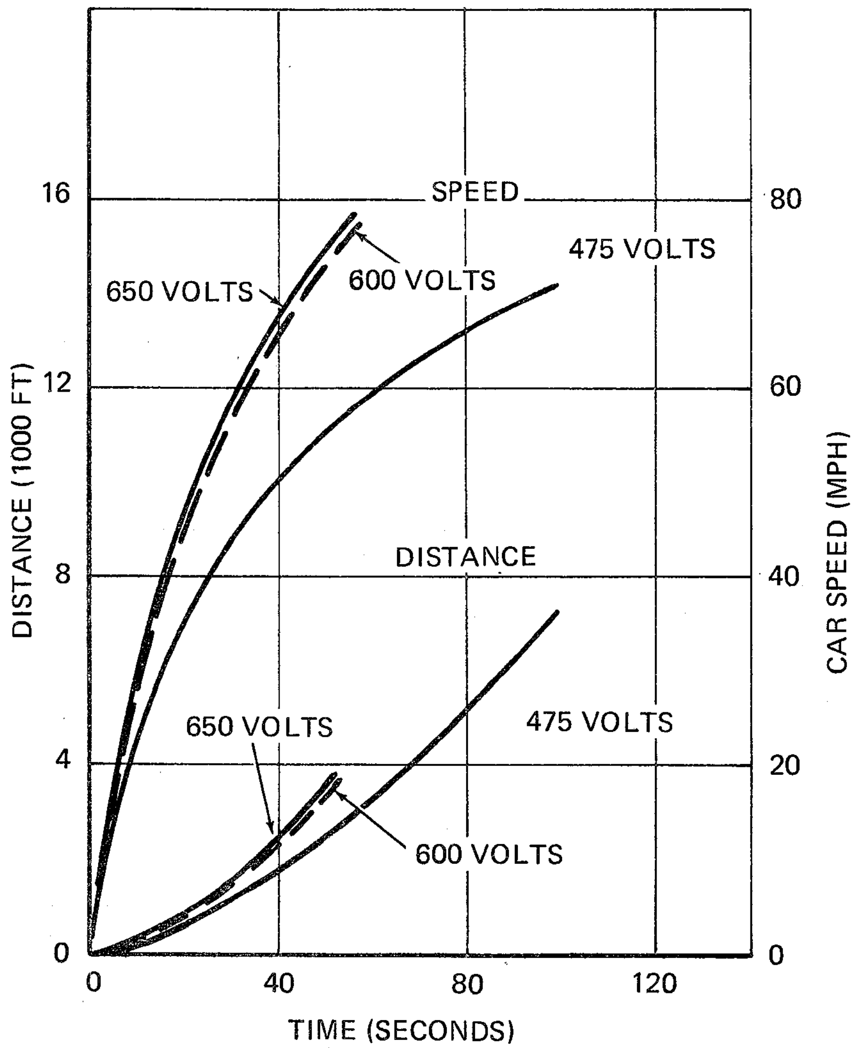


Figure 3–7. Effect of Third Rail Voltage on Time and Distance to Speed

NOTES
1. CAR WEIGHT 105,000 LB
2. AVERAGE OF BI-DIRECTIONAL RUNS
3. LEVEL TANGENT TRACK
4. 30-INCH WHEELS
5. SOAC HSGTC ENGINEERING TESTS: RUNS 102, 121
6. ZERO WIND

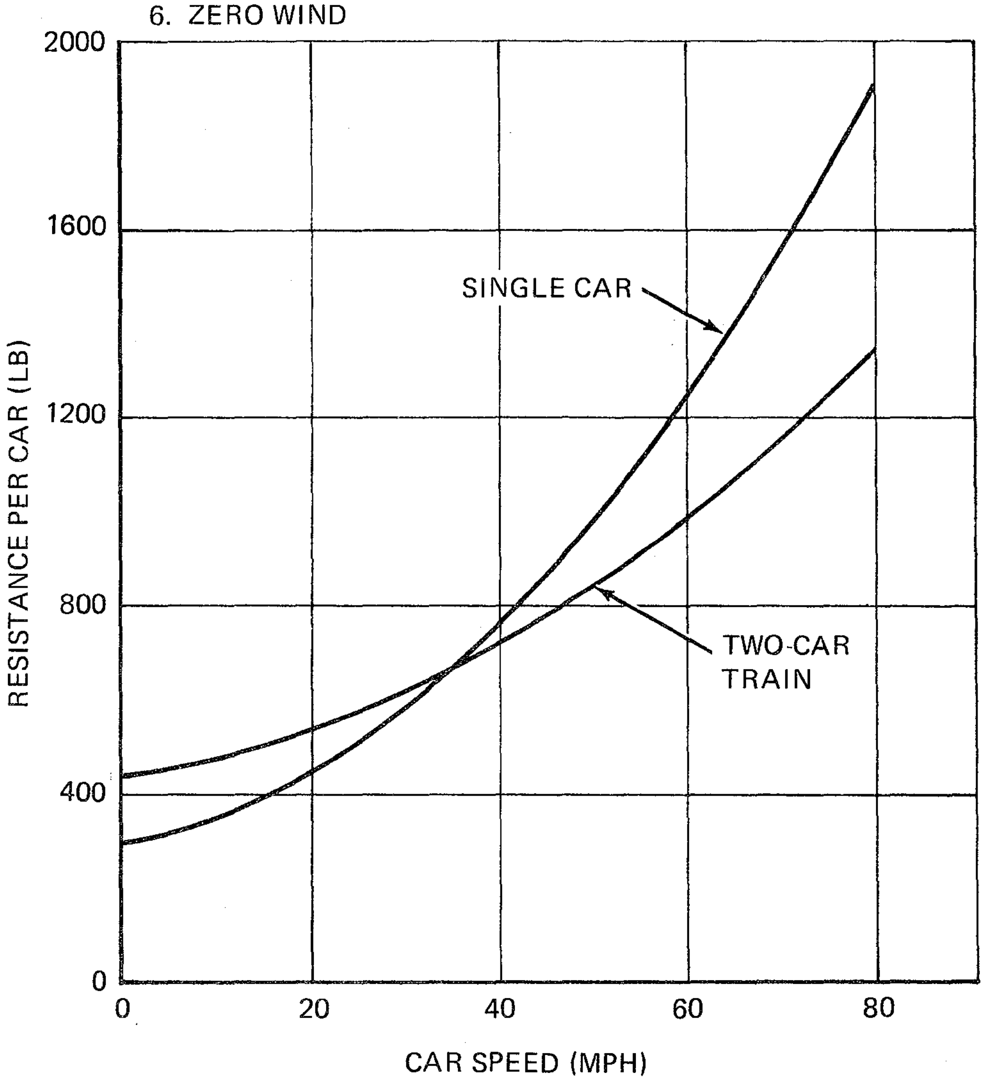


Figure 3–8. Traction Resistance

details of the tape recorded time-speed data. The test fairing is considered sufficiently accurate for use with adhesion data. The 1890 pounds of resistance at 80 mph represents a coasting deceleration rate of 0.37 mphps for the 105,000-pound car.

- Friction Brake System - Duty Cycles

These tests consisted of decelerations at various controller inputs and car weights and simulated schedule service using duty cycles similar in severity to those found on the SOAC test and evaluation routes in New York and Cleveland. A summary of service brake control linearity was shown in Figure 3-3 for three car weights and several controller inputs. The system accuracy is within the desired 10-percent band.

The two duty cycles tested are summarized in Table 3-1, along with the two routes simulated. Results of tests with Duty Cycles I and II with solid steel and resilient aluminum-center wheels are shown in Figure 3-9. As noted, the maximum temperature difference between wheel types occurs early in the simulated service route and is between 30 to 40°F. Final temperature differences are less than 20°F at the end of the cycles. For the two routes simulated, the resilient wheels have sufficient thermal capacity for normal service operation with disabled dynamic brakes.

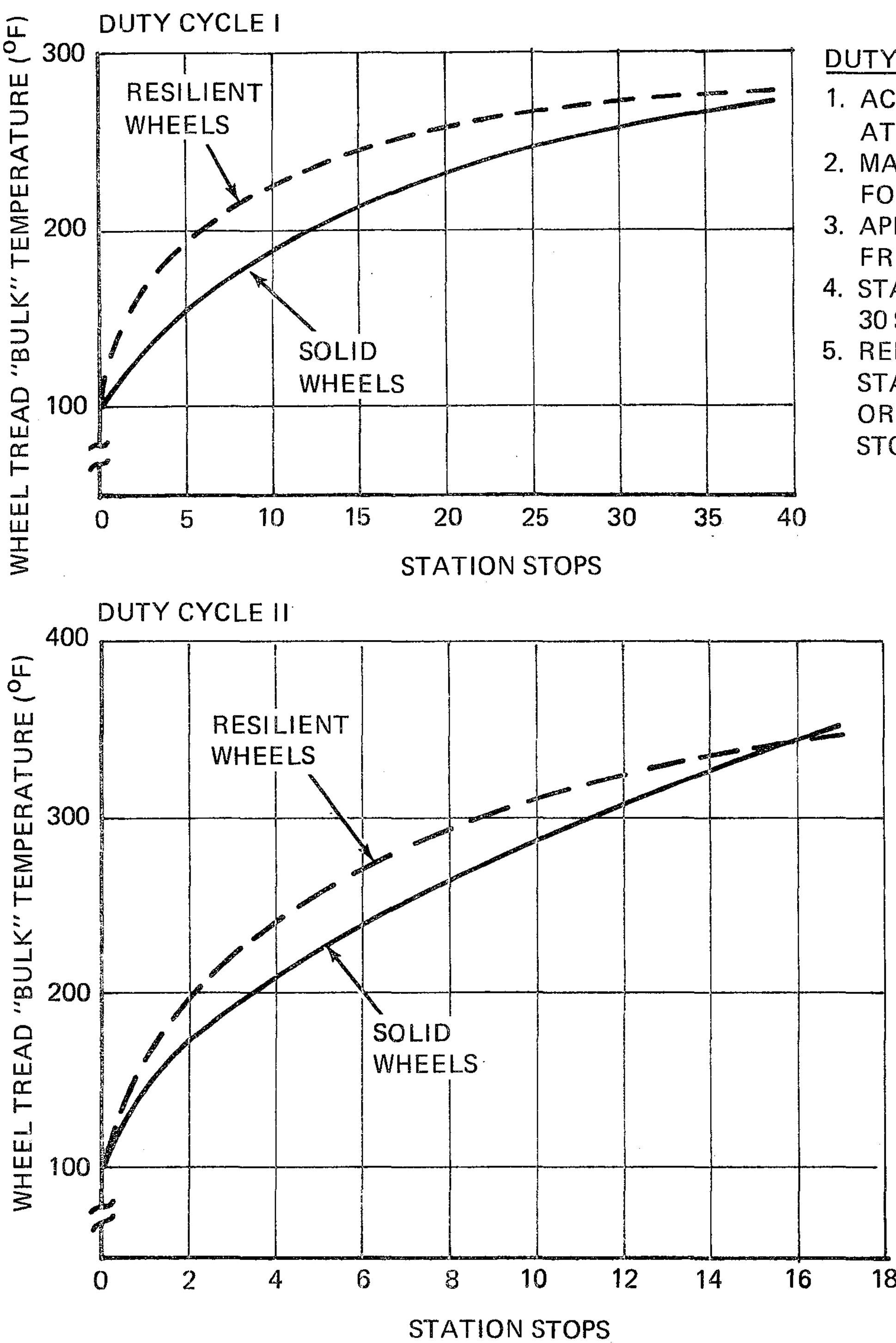
Energy consumption was recorded during both duty cycles and is presented in Table 3-1.

- Power Consumption - Synthetic Transit Route

Schedule service performance in terms of power consumption, schedule speed, and undercar equipment temperatures were evaluated during sample service runs on a 9.25-mile, 15-station transit route at HSGTC. (Figure 3-10 shows the structure of the synthetic route.) Station spacings vary from 0.25 to 1.5 miles; top speeds from 40 to 80 mph. The route was run from Station A to Station O and return for each round trip. Table 3-2 presents the results for each station spacing and for each round trip. SOAC power consumption averages 12.43 kw-hr per car mile for the route, including approximately 34 kw of auxiliary power. This same route will be used during testing of the ACT-1 vehicles which are expected to reduce the power consumption by as much as 40 percent at an equal performance level.

NOTES

1. 30-INCH WHEELS
2. SOAC HSGTC ENGINEERING TESTS:
   RUNS 117,141



DUTY CYCLE (Duty Cycle I)

1. ACCEL TO 35 MPH AT SERVICE RATE
2. MAINTAIN 35 MPH FOR 45 SECONDS
3. APPLY FULL SERVICE FRICTION BRAKING
4. STATION DWELL 30 SECONDS
5. REPEAT TO STABILIZE TEMP OR MAXIMUM 38 STOPS

DUTY CYCLE (Duty Cycle II)

1. ACCEL TO 50 MPH AT SERVICE RATE
2. MAINTAIN 50 MPH FOR 55 SECONDS
3. APPLY FULL SERVICE FRICTION BRAKING
4. STATION DWELL 30 SECONDS
5. REPEAT TO STABILIZE TEMP OR MAXIMUM 17 STOPS

Figure 3–9. Wheel Temperature

TABLE 3-1. SUMMARY OF FRICTION BRAKE DUTY CYCLE TESTS

Test Parameter	Route			
	New York (NYCTA) 8th Ave.	Pueblo Duty Cycle I	Cleveland (CTS) Airport	Pueblo Duty Cycle II
Distance (miles)	22.5	21.8	19.0	17.9
Scheduled time (minutes)	68	65	36	38
No. of start-stop cycles	38	38	17	17
Stops per mile	1.69	1.74	0.9	0.95
Maximum speed (mph)	35 (est avg)	35 (actual)	52 (est avg)	50 (actual)
Schedule speed (mph)	19.8 (est)	20.1	31.6 (est)	28.2
Measured maximum tread bulk temperatures (°F)				
• Solid	N/A	264	N/A	350
• Resilient	N/A	282	N/A	350
Energy consumption (kw-hr/car-mile)	-	6.70	-	6.60

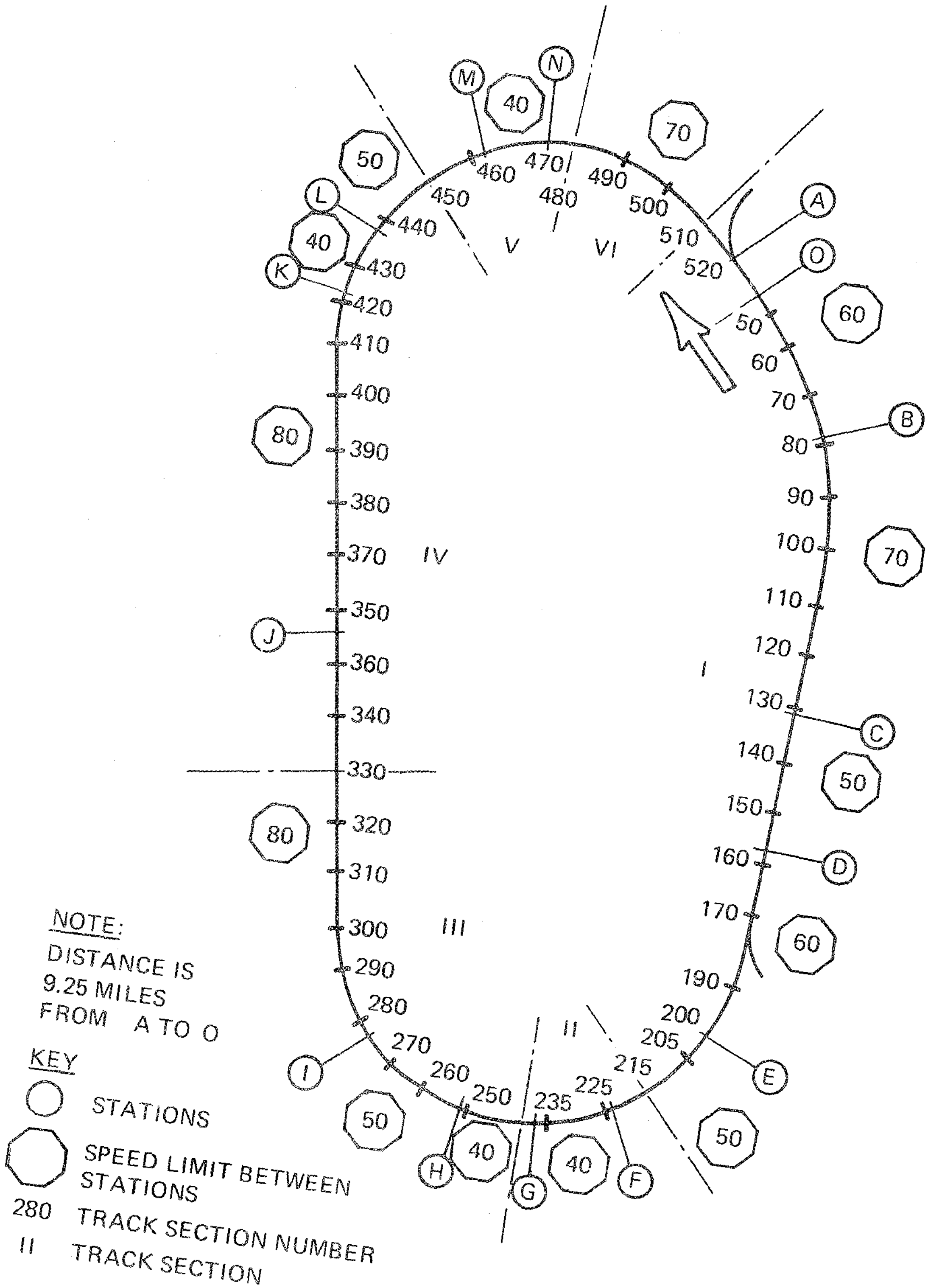


Figure 3–10. ACT-1 Synthetic Transit Route

TABLE 3-2. SUMMARY OF SOAC ENERGY CONSUMPTION ON ACT-1 SYNTHETIC TRANSIT ROUTE

Data From Test Run 153

Station (Two Directions)	Maximum Speed (mph)	Distance (Miles)	Two-Way Energy (kw-hr*) Total	Per Car-Mile
A to B	60	.75	9.35	12.47
B to C	70	1.00	11.55	11.55
C to D	50	.50	6.25	12.50
D to E	60	.75	9.15	12.20
E to F	50	.50	6.25	12.50
F to G	40	.25	4.00	16.00
G to H	40	.25	4.00	16.00
H to I	50	.50	6.20	12.40
I to J	80	1.50	16.20	10.80
J to K	80	1.25	14.70	11.76
K to L	40	.25	4.10	16.40
L to M	50	.50	6.55	13.10
M to N	40	.25	4.40	17.60
N to O	70	1.00	12.25	12.25
	18.5 Mile	Total (x2)	229.9	12.43
Schedule Speed:	27.8 mph			
Data From Test Run 149				
	18.5 Mile	Total	235.1	12.71
Schedule Speed: (Numerous spin/slides on wet rails)	27.3 mph			

*Includes 34 kw auxiliary power.

Equipment temperatures within undercar enclosures were measured during the power consumption test cycles. Peak recorded temperatures are shown in Table 3-3 corrected to a 125°F ambient air temperature (SOAC design specification).

The reduced power consumption recorded during friction brake duty cycles (see Table 3-1) can be expected during the SOAC demonstration on existing properties.

- Spin-Slide Protection System Performance

Tests of spin/slide system characteristics were conducted in drive and brake modes on wetted rails using blended braking, dynamic only, and service friction brakes.

Table 3-4 summarizes the efficiencies of the spin/slide systems in various modes, covering averages of many test runs initiated at speeds from 80 to 20 mph in braking. From an initial speed of 40 mph the average efficiency of the blended braking system is greater than 82 percent, which exceeds the 80 percent goal of the design specification. As noted the efficiency is also greater than 80 percent in the acceleration mode.

The lower efficiency of the service friction air brake subsystem is primarily due to the slower response of the air-operated tread brake units.

- Wheel-Rail Adhesion

The level of adhesion associated with the SOAC on the HSGTC test oval was measured during single-truck friction braking tests on wetted jointed rails. The wetting agent used was similar to that used during spin/slide tests.

The two levels of adhesion noted on Figure 3-11 are due to different mixing criteria with the same wetting agent. These results suggest the level of caution to be exercised during any future wetted rail adhesion or spin/slide testing. Since spin/slide performance calculations are relative to the actual adhesion obtained, the efficiency values of Table 3-4 are considered valid as averages.

The design acceleration and deceleration rates of the SOAC (±3.0 mphps) represent an adhesion demand of 0.1367. This level is not obtainable on an oiled-wetted rail as represented by "complete mixing" (Figure 3-11) but is available up to about 38 mph on an essentially clean, wet rail as represented by "Incomplete Mixing of Wetting Agent."

TABLE 3-3. SUMMARY OF UNDERCAR EQUIPMENT TEMPERATURES FOR SYNTHETIC TRANSIT ROUTE (105,000-POUND CAR)

Parameter	No.	Peak Temperature (°F) Run 149	Run 153
Propulsion Blower, Outlet Air	4	135	146
Chopper Box, Interior Air	8	141	150
Chopper Box, Outlet Air	3	142	148
Traction Motor, Outlet Air	12	183	182
Traction Motor, No. 3 Frame	1	151	151
PCU, Interior Air	6	147	156
PPCU, Interior Air	9	178	177
APCU, Interior Air	10	155	165
Motor Smoothing Reactor	7	167	166
Brake Grid Air	5	820 (2)	850 (2)
Motor-Alternator, Outlet Air	11	169	168
Air Conditioner, Condenser, Input Air	2	162	157
Test Ambient Air		75	79

NOTES

(1) Adjusted to 125°F ambient SOAC design goal.
(2) Peak recorded temperature during brake applications.
(3) Performance level - Duty Cycle: approx 1-hour rating
PCU = Power control unit
PPCU = Propulsion power control unit
APCU = Auxiliary power control unit

NOTES

1. CAR WEIGHT AWO 90,000 LB
2. WET RAILS
3. LEVEL TANGENT TRACK
4. 30-INCH WHEELS
5. SOAC HSGTC ENGINEERING TESTS: RUNS 100, 151
6. ENTRY SPEED / SYMBOL
   - 20 MPH △
   - 40 MPH □
   - 60 MPH ○
   - 80 MPH ◊

OPEN SYMBOLS: RESILIENT WHEELS
SOLID SYMBOLS: SOLID WHEELS

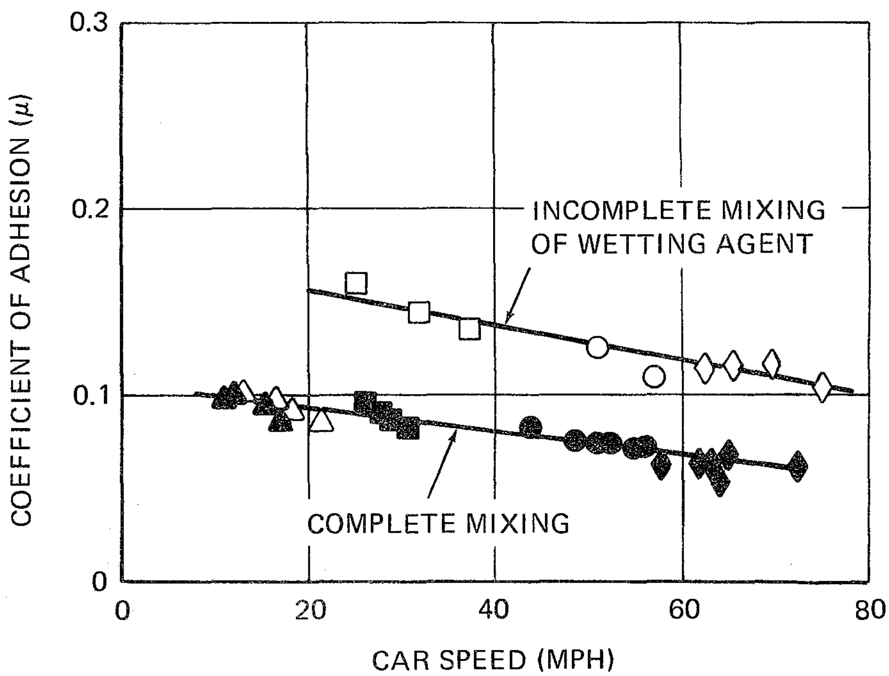


Figure 3–11. Wheel Adhesion

TABLE 3-4. SUMMARY OF WHEEL SPIN/SLIDE SYSTEM EFFICIENCIES* (90,000-POUND CAR)

Braking Mode (Speed Range 80 to 10 mph)	
• Blended Braking	78.5%
• Service Friction Braking	63.4%
• Dynamic Braking Only	77.4%
Accelerating Mode (Speed Range 0 to 35 mph)	
• Full Power Acceleration (solid wheels)	82%

$$\text{Efficiency} = \frac{\text{Actual Deceleration Rate}}{\text{Average Available Deceleration Rate}}$$

*Based on solid and resilient wheel data.

3.2.2 Ride Quality Tests

The ride quality vibration data were recorded on analog tapes and later digitized to obtain spectrum analysis and power spectral density curves. The purpose for this series of tests was to provide an understanding of the car body motions during operations. Spectrum analysis and a power spectral density permits identification of vibration contribution from known modal characteristics of the car body structure. The spectrum analysis and power spectral density curves for the midcar centerline vertical location are shown in Figure 3-12. Both curves indicate that peak amplitudes occur at the following frequencies:

- Response from a rigid body suspension mode 1.5 Hz
- First car body vertical bending mode 7.5 Hz
- Second car body vertical bending mode 15.0 Hz
- Component induced vibration 30.0 Hz

NOTES

1. SPEED 80 MPH
2. TRACK SECTION I
3. GROSS WEIGHT 105,000 LB
4. HIGH-DENSITY CAR
5. RESILIENT WHEELS

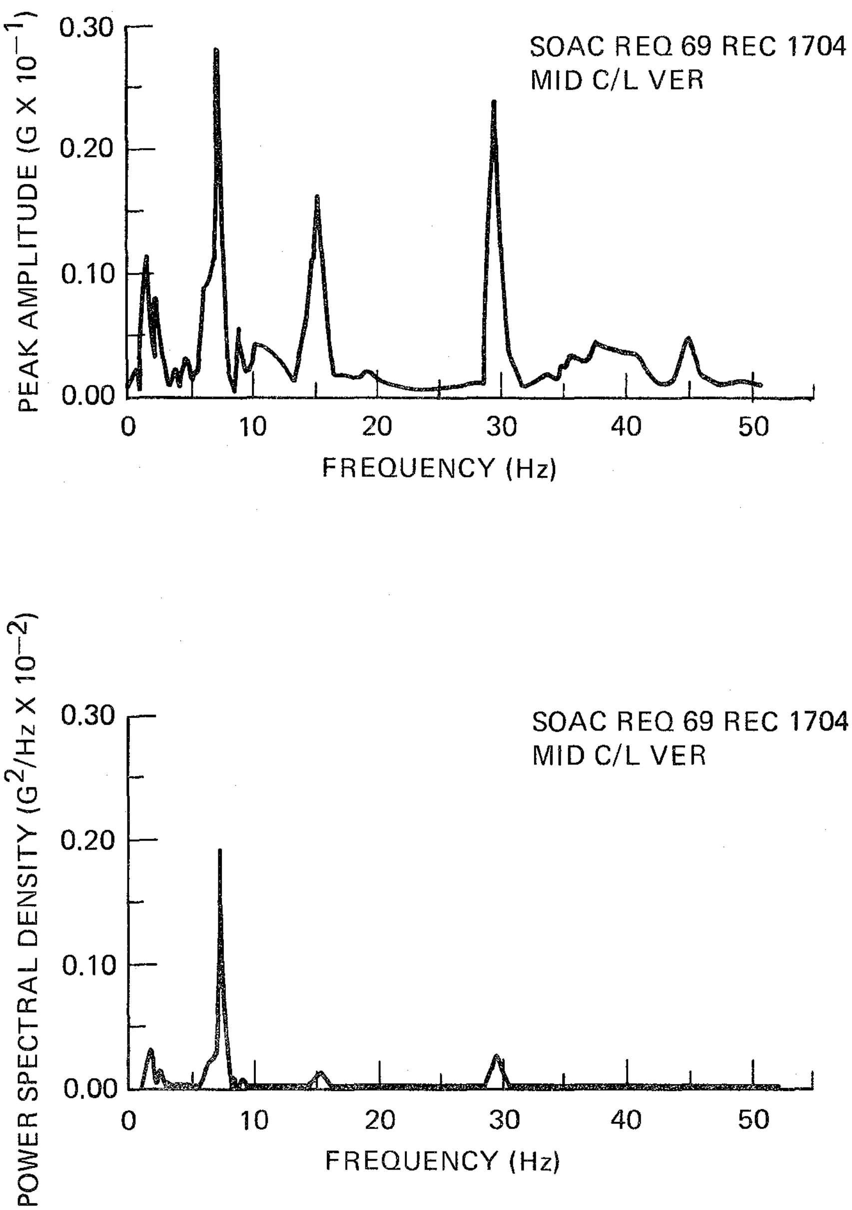


Figure 3—12. Ride Quality Test Baseline Data

Results of the SOAC testing show that for the HSGTC test track, the car body vertical levels provide acceleration indicators for evaluating the effects of speed, weight, and other variables on passenger ride quality. Car body lateral accelerations are low and generally insignificant, as are the longitudinal accelerations. This situation is reversed for the truck where the lateral accelerations are much larger than the vertical. The car body underframe is very rigid laterally, however, and shows very little response to lateral inputs from the trucks.

- Speed Effects

  The General Vehicle Test Plans (GSP-064) define a ride roughness parameter in order to quantify the ride experienced by a typical passenger on a transit vehicle. Figures 3-13 and 3-14 show the SOAC ride roughness values as a function of speed for a 90,000-pound car.

  Figure 3-13 shows the vertical ride roughness experienced at the middle of the SOAC. The chart indicates a peaking (less favorable ride) at 45 and 80 mph. This is due to the wheel revolution frequency inducing a resonance with the first and second bending modes, respectively, of the car body at these speeds.

  Figure 3-14 shows the lateral ride roughness experienced near the end of the SOAC. As indicated, the lateral levels are very quiet throughout the speed range.

  Vertical journal box accelerations are not affected by speed. Lateral acceleration levels, however, are significantly higher than vertical levels and reach their peak amplitudes at 80 mph. Figure 3-15 shows the effect of speed on journal box accelerations.

- Weight Effects

  Mid-car vertical accelerations are significantly reduced with increased car weight (Figure 3-16).

  The effect of increased car weight on the predominant forward car (rigid body) frequency (1.0 to 1.5 Hz) is opposite to the effect on the predominant mid-car frequencies.

NOTES

1) RESILIENT WHEELS
2) 90,000-LB. GROSS WEIGHT
3) TRACK SECTION I

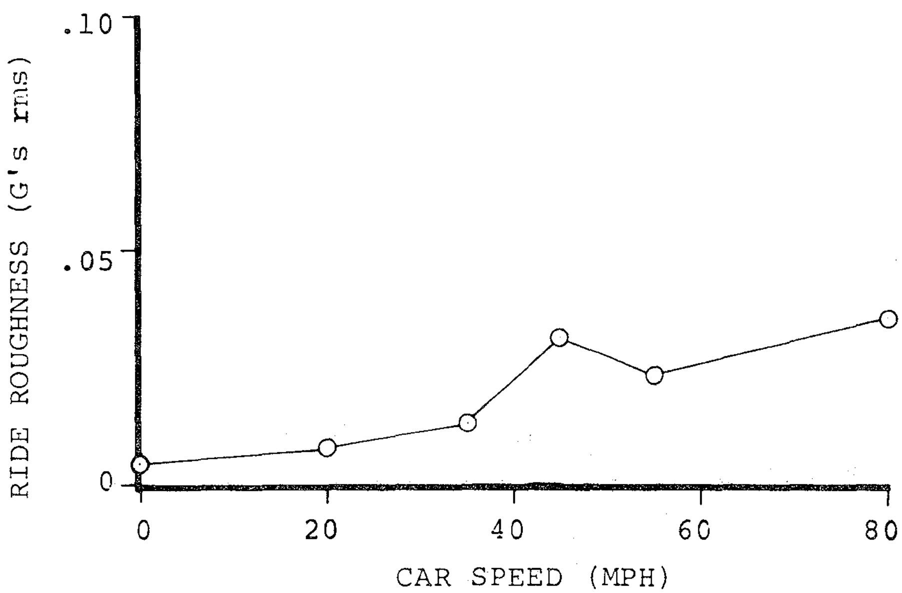


Figure 3–13. Effect of Speed on Mid-Car Centerline Vertical Ride Roughness (High-Density Car)

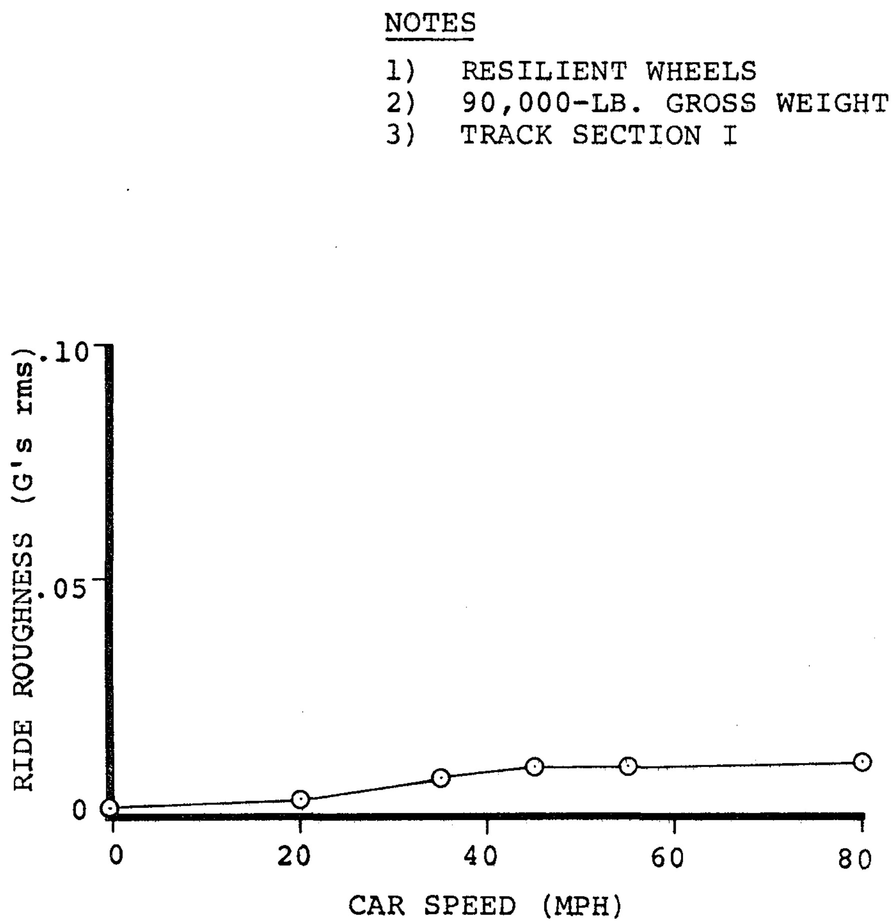


Figure 3—14. Effect of Speed on Aft Car Centerline Lateral Ride Roughness (High-Density Car)

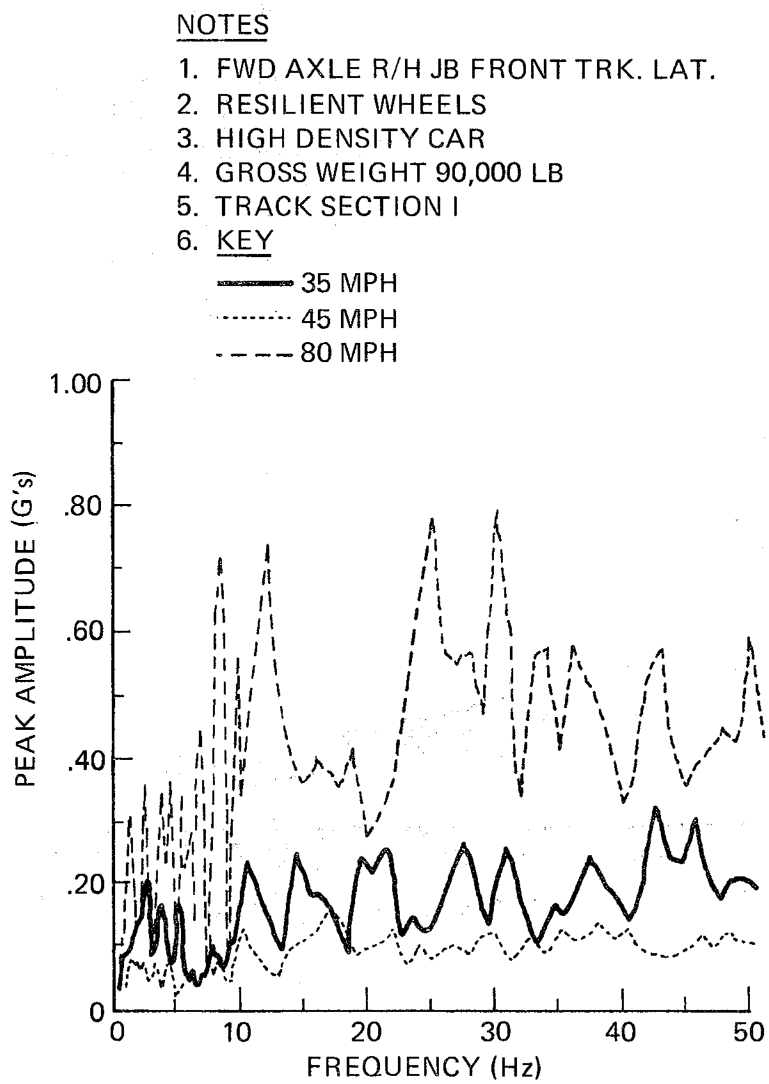


Figure 3–15. Ride Quality Baseline Comparison: Effect of Speed

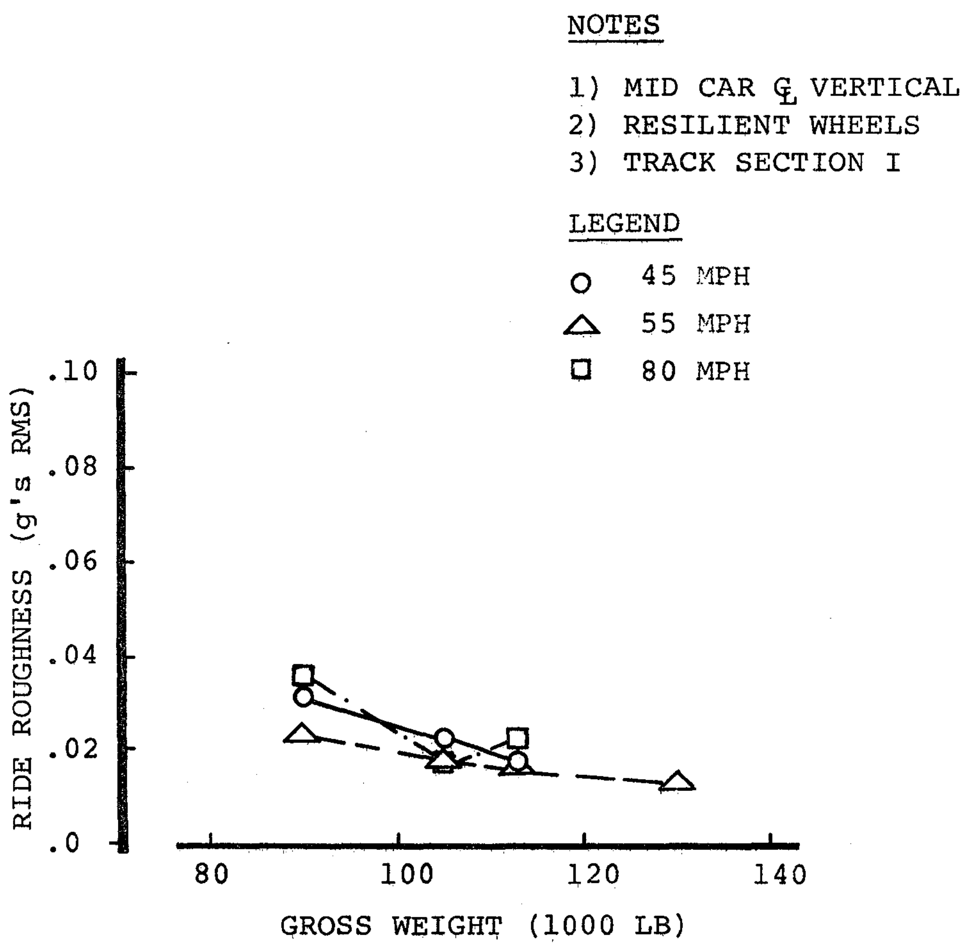


Figure 3–16. Ride Quality Baseline Comparison: Effect of Weight

Journal box accelerations showed little change with car weight variation except for lateral acceleration at 45 mph which increased at a weight of 105,000 pounds compared to 90,000 pounds.

- Track Effects

  The UMTA test oval at HSGTC employs six different track, tie, fastener, and ballast combinations. Comparative vibration data was taken for each track section. No identifiable trend in ride quality was attributable to the type of track, ties, fasteners or ballast. Track Section I gave the lowest mid-car vertical vibration and the highest forward car vertical vibration.

- Train Consist Effects

  Train consist variation between a single car and two-car train showed no effect on ride roughness values.

  As previously noted, the lateral accelerations on the truck are much larger than the vertical accelerations. Comparing lateral acceleration data on the front truck journal bearing for the single high-density car and the two-car train at 35, 45, and 80 mph, the 35 and 80-mph conditions show significantly lower truck lateral vibration for the two-car train across the frequency spectrum. The 45-mph condition shows essentially the same vibration level for the two consists from 0 to 25 Hz, with the single high-density car lower at frequencies from 25 to 50 Hz.

3.2.3 Noise Tests

Interior Noise Levels

Interior noise level measurements of the SOAC were made to define its acoustical characteristics. These tests resulted in the accumulation of over 500 data points showing the contribution of speed, track construction, wheel configuration and equipment on noise levels at various interior locations. Some of the data points were subjected to one-third octave band and narrow band analysis in order to determine the composition of the associated noise levels.

The analyses showed that the interior noise levels are a function of undercar equipment, the air comfort system blowers, and the wheel/rail interaction. When the car is at rest or below 25 mph, the undercar equipment and blowers are the predominant contributors in the "A" weighted noise spectra. Above 25 mph the wheel/rail interaction becomes significant and is a function of wheel construction and tire surface quality. The effect of speed on noise levels for four different car interior locations is shown in Figure 3-17. It is significant that the SOAC vehicle falls 5 to 7 dBA below the design goals.

The effect of wheel configuration on noise levels is shown in Figure 3-18. Below 25 mph, all the wheel configurations are within 1 to 2 dBA of each other. As speed increases, the flats on the steel wheels become a major noise source.

The full advantage of the resilient wheels is not evident in this figure: the data shown was obtained at steady speeds on tangent track, and the resilient wheel is designed to damp high frequency noise, such as generated in tight turns. The full effect of the resilient wheels will be measured in the cities.

<u>Wayside Noise Levels</u>

As with the interior noise, the wayside noise measurements were made to determine the SOAC characteristics and to identify the primary noise contributors. The "A" weighted noise levels were recorded for over 100 data points.

Since the major noise contribution in wayside noise comes from the wheel/rail interaction, an effort was made to understand this contribution. Figure 3-19 shows the effect of rail surface roughness. Since February 1973 when the HSGTC transit track was ground smooth, track Sections II through VI had generally carried only test vehicle traffic; while Section I carried all the rail traffic to Test Center. Since the data in Figure 3-19 was obtained in May and June 1973, the effect of this traffic on rail roughness and noise levels was readily determined.

Figure 3-20 shows the effect of wheel roughness on noise levels. Since Car No. 1 has a larger number of wheel flats than Car No. 2, it has a slightly higher noise level for this condition.

Figure 3-21 compares the speed effect of two-car and single-car operations. The predicted 3 dBA spread for doubling the number of cars is verified over most of the speed range; the divergence at the 70 mph points is probably attributable to wheel flats on Car No. 2 (the single-car data was taken on Car No. 1).

Figure 3-22 compares the wayside noise level of the SOAC vehicle with the design goal which was met or bettered at all speeds above 35 mph. Subsequent noise analyses showed the traction motor blowers to be the major noise contributor below 35 mph.

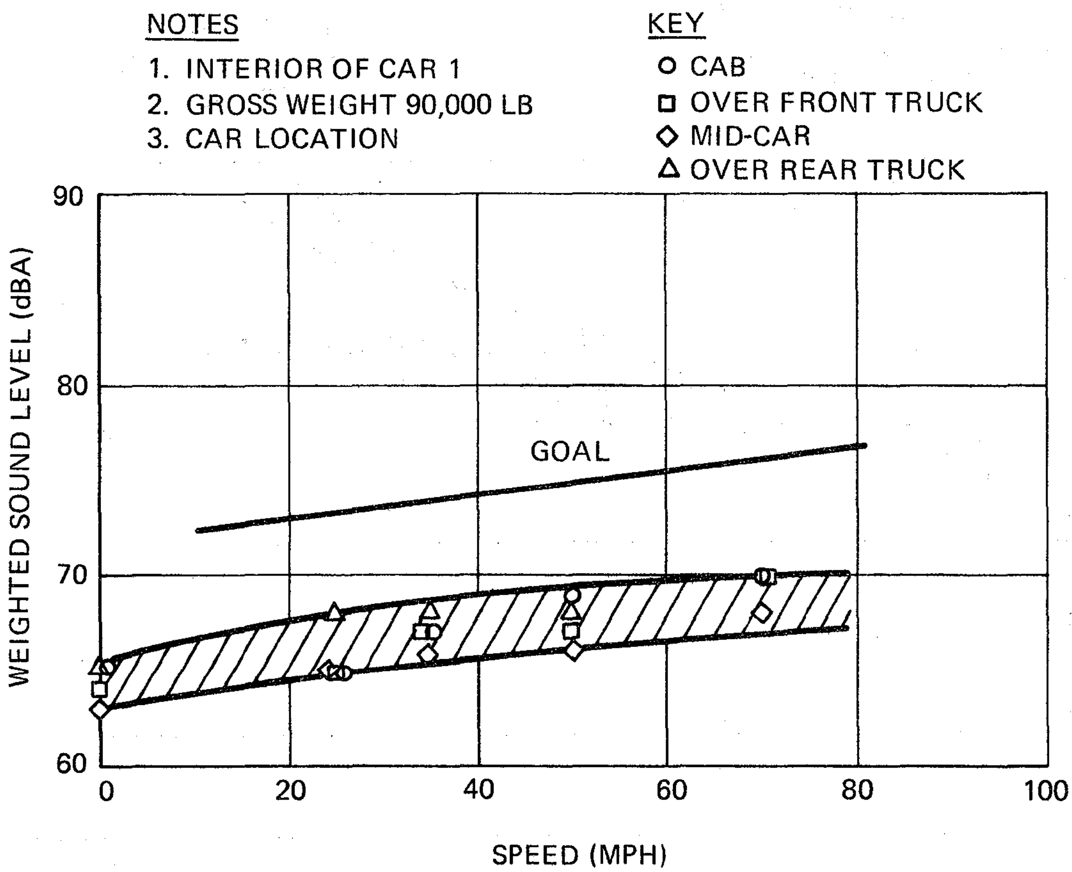


Figure 3–17. Comparison of Interior Noise Levels With Goals

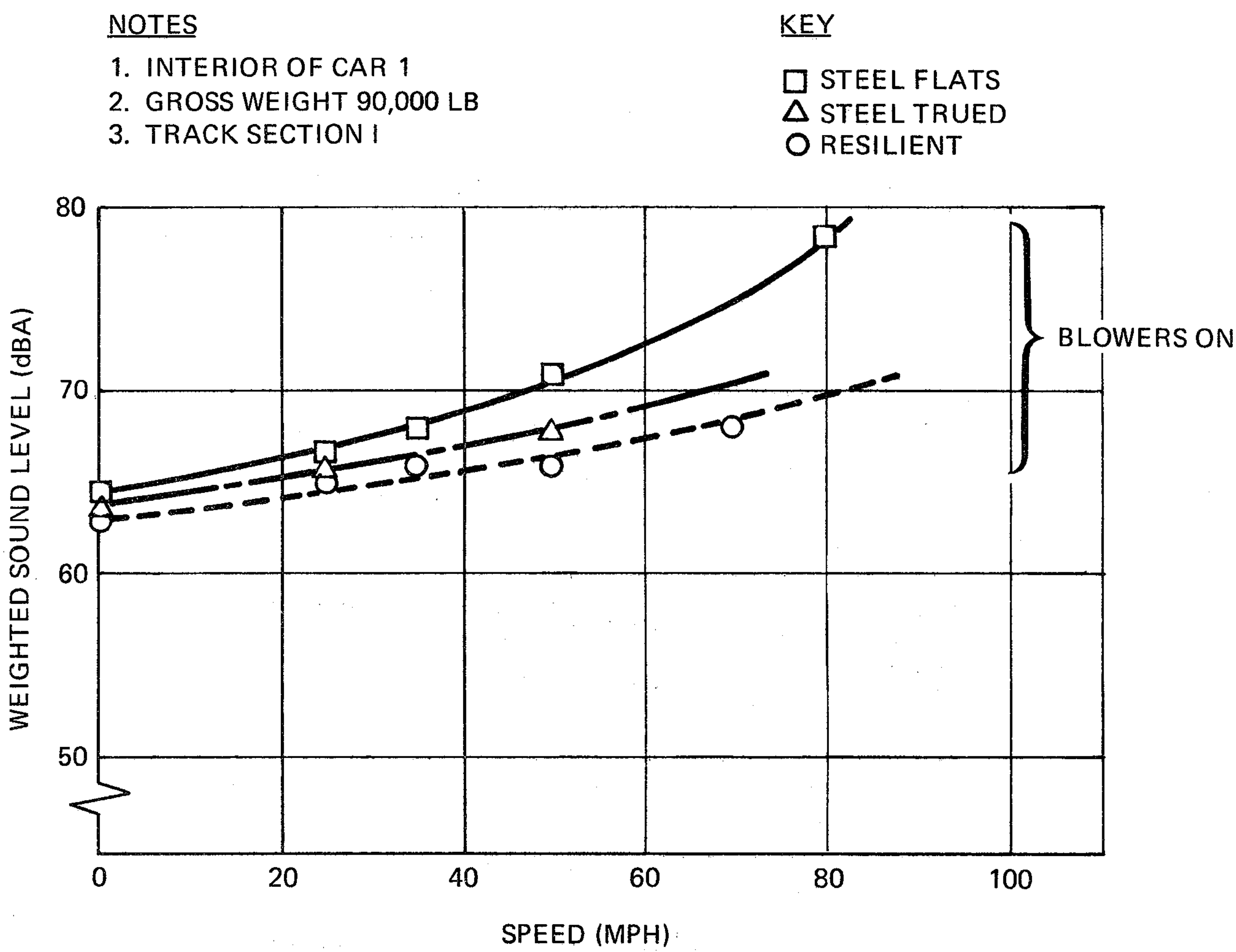


Figure 3–18. Effect of Wheel Configuration on Interior Noise

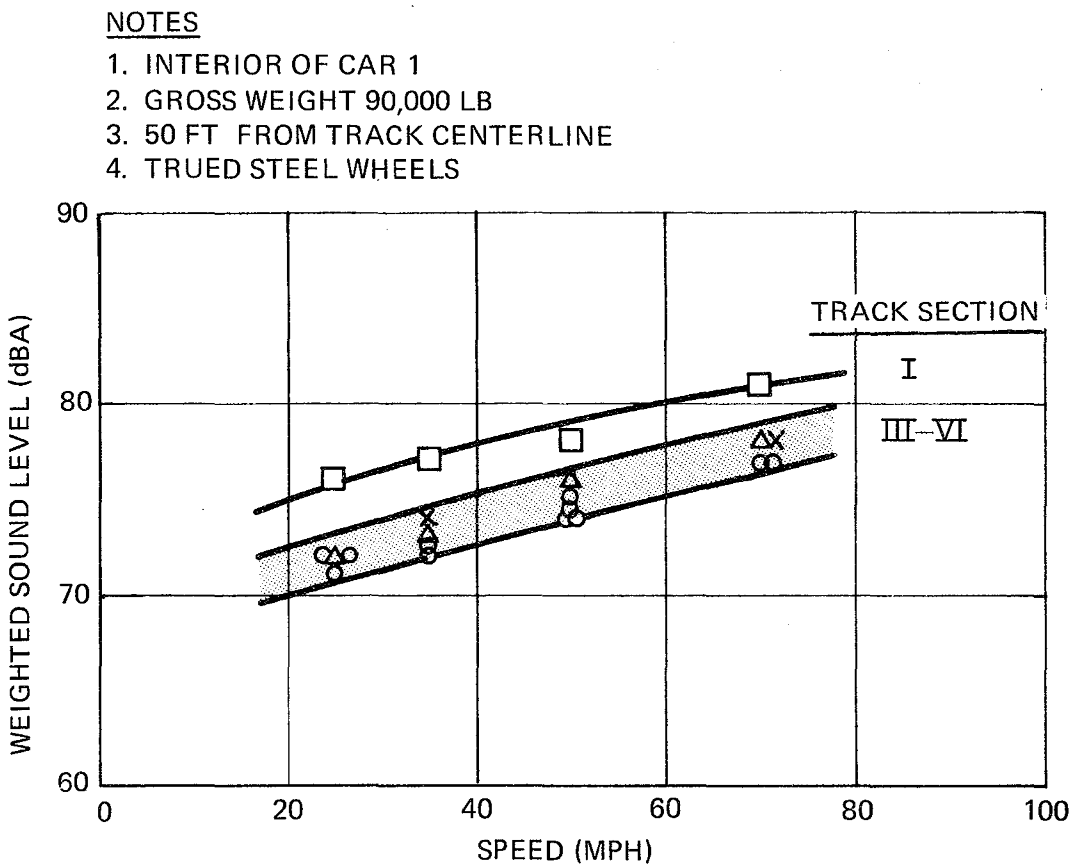


Figure 3–19. Comparison of Rail Surface Roughness to Noise

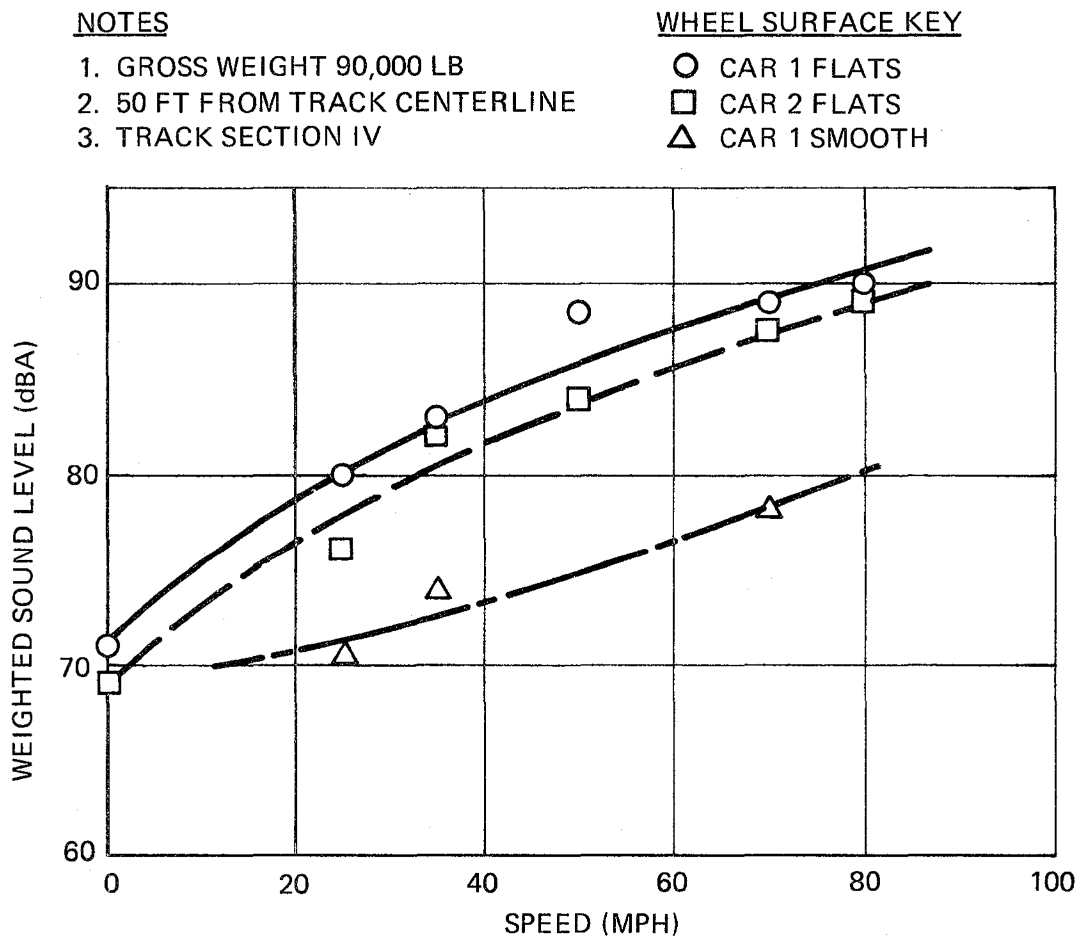


Figure 3–20. Comparison of Wheel Surface Roughness to Noise

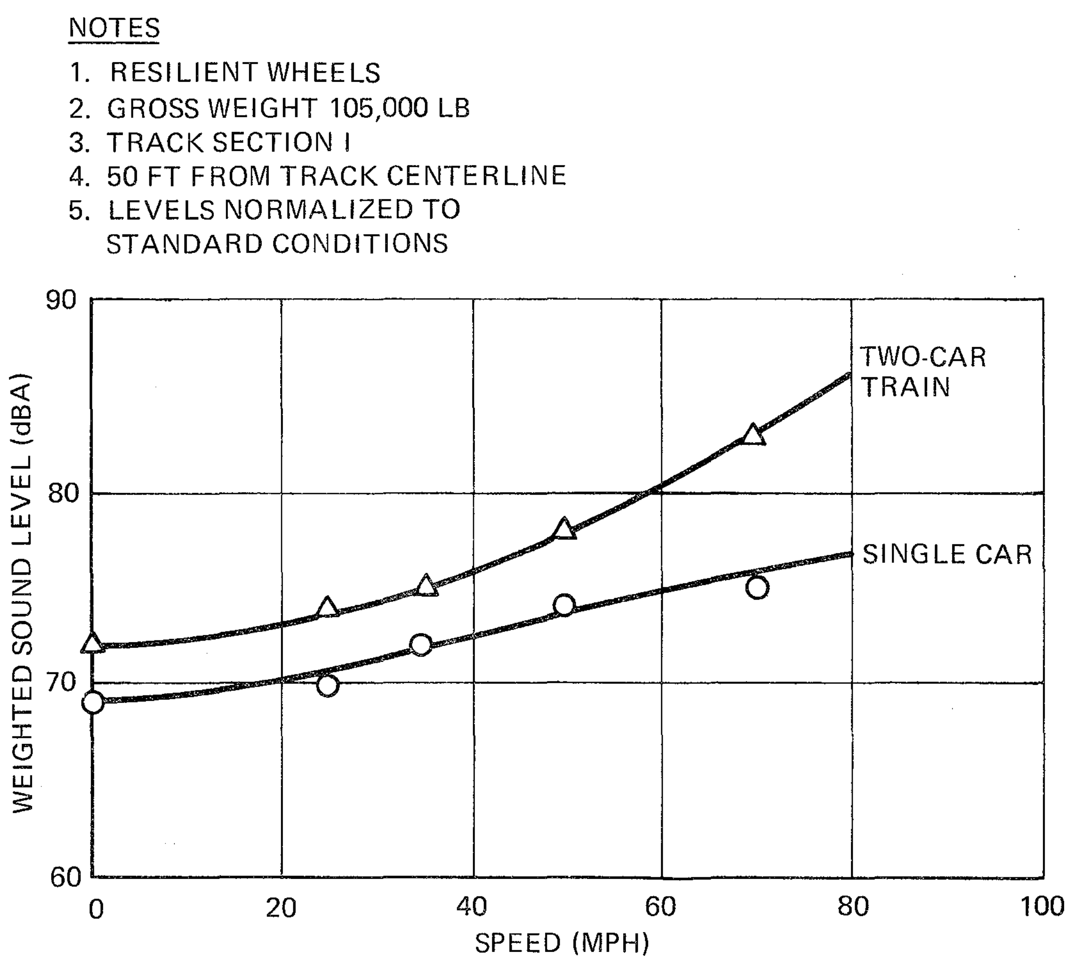


Figure 3–21. Effect of Speed on Wayside Noise

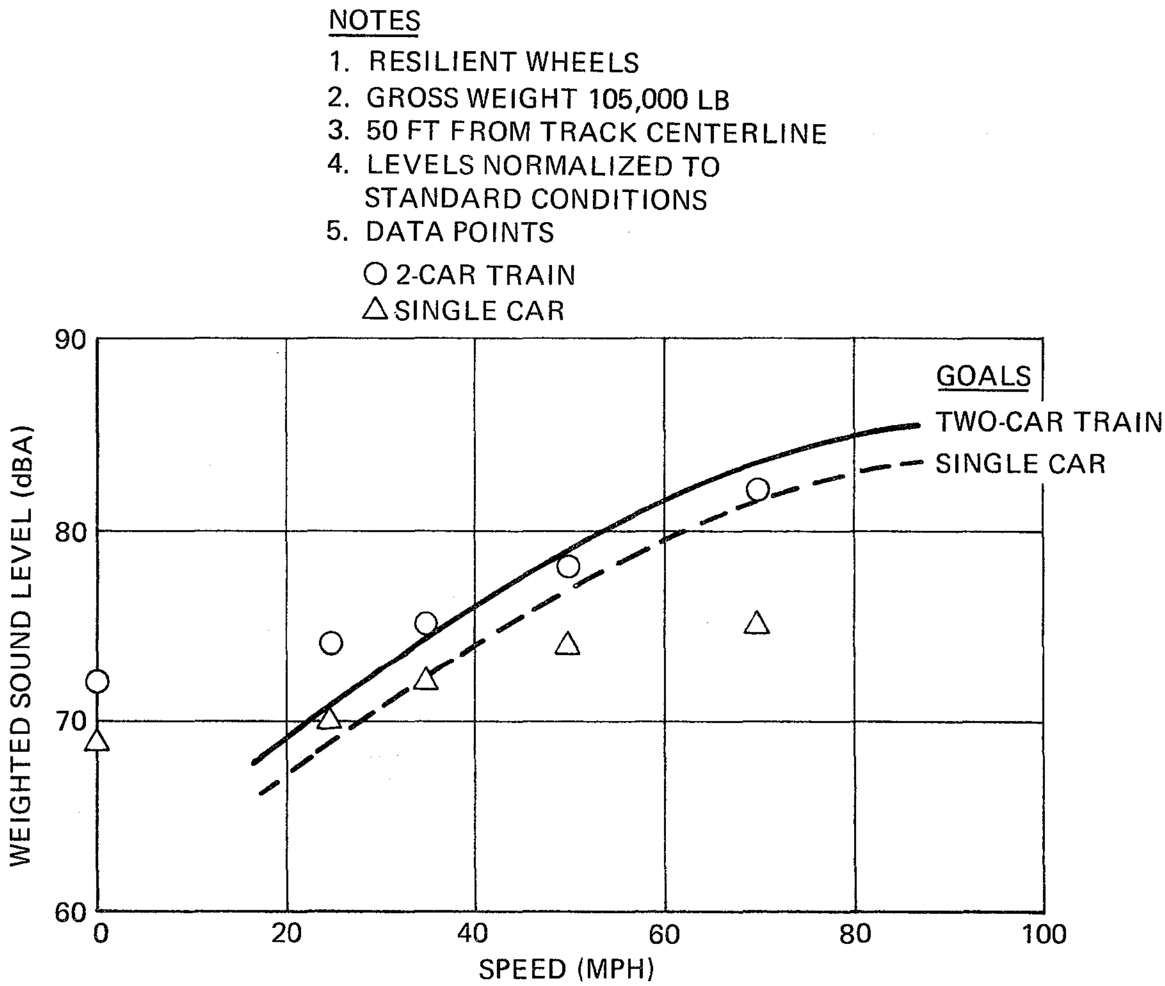


Figure 3–22. Comparison of Wayside Noise Levels With Goals

Radio Frequency Interference (RFI)

A series of measurements was made to determine the broadband radiated electromagnetic emissions of the SOAC vehicles. (This program was identical to one performed on the BART vehicles and was completed during SOAC acceptance testing.) The maximum measured RFI emissions under different operating conditions are compared with the SOAC goals in Figure 3-23.

SOAC measurements were in compliance with the accepted accuracy of ±3 dBA for this type of emission.

Structures

Review of the structural test data reveals that the instrumentation produced data that can be used to determine magnitude, phasing and frequency of truck loads. The data shows that the truck frame stress levels measured at the HSGTC test oval are low in magnitude. Comparative data to be obtained on the five transit properties will show whether the low loads are peculiar to the HSGTC track conditions or are also representative of revenue service on older transit systems.

Although the SOAC Detail Specification does not address the specific question of truck fatigue allowable stresses, the levels apparently existing during testing are considered non-damaging to the truck structure.

The data clearly show the levels of loads that are experienced in equipment items such as the dampers and the suspension elements. Data from these tests have been reviewed on a preliminary basis only. For definitive test results, considerable effort remains to develop the methodologies for reducing, displaying, analyzing, and the interpreting the test data. Once this has been accomplished, data of the type obtained on this program can provide useful information for improved truck design.

Voltage Transients and Spikes

A test program was conducted to obtain voltage transient and spike data on the SOAC vehicle. This program was similar to that accomplished during the summer of 1972 by the University of Missouri on the five demonstration properties. The results of the property tests may be found in Investigation of Voltage Transients and Spikes in Direct Current Rapid Transit Systems (UMTA Report No. IT-06-0026-73-3).

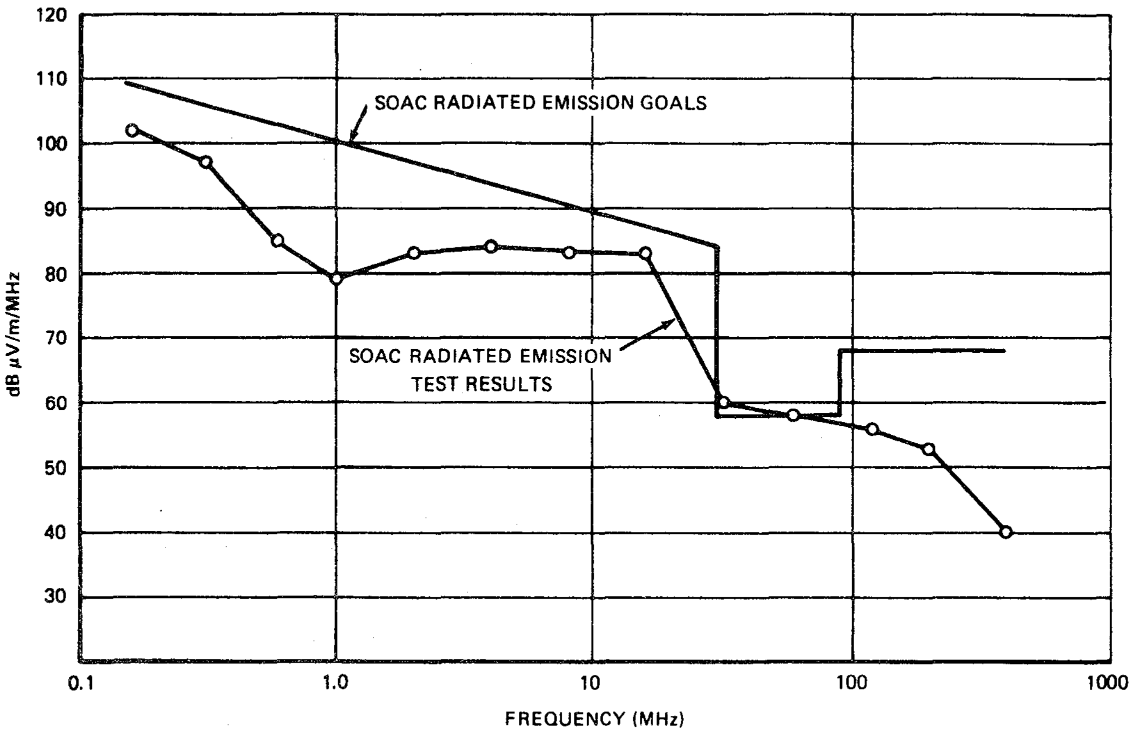


Figure 3–23. Electromagnetic Field Test Data

Unfortunately the power source at the HSGTC was not representative of the sources at the various properties which exhibited a range of voltage spikes from -2700 to +2500 volts. At the HSGTC, positive spikes never exceeded +1600 volts and there were no negative spikes. The HSGTC locomotive also generated short transients in the +800 to +1600 volt range, not typical of the properties. Some long duration transients below +520 volts were also experienced during the performance tests. These can be a function of the SOAC acceleration and the response characteristic of the locomotive power source.

Appendix

TEST SET STATUS

This appendix presents a one-page summary of each of the fourteen test sets completed during the SOAC engineering test program.

ACCELERATION TESTS

Test Sequence

A series of 11 test runs comprising 51 test records were required to accomplish the acceleration tests.

Test Procedures

SOAC-P-2001-TT baseline procedure was used, with testing conducted at four controller inputs, three line voltages, and four car weights.

Objective

The objectives of the acceleration tests were: (1) to determine the SOAC acceleration characteristics, control response, line voltage, and load compensation effects throughout the operating range of the car; and (2) to provide baseline data on the SOAC operating on the Pueblo HSGTC oval for use during ACT-1 and subsequent rapid rail development programs.

Status

Data was recorded with both solid and resilient wheels. However, only the resilient wheel data is considered representative of specification car performance. All acceleration data has been reduced and is available in digitized, tabulated time-history format. Accelerometer "zero" shift and scatter (filtering) problems which occurred during resilient wheel tests necessitate caution in the use of digitized engineering data.

DECELERATION TESTS

Test Sequence

A series of 15 test runs comprising 112 test records were required to accomplish the deceleration tests.

Test Procedures

SOAC-P-3001-TT (through 3004) baseline test procedures were used at four controller inputs, four car weights, three line voltages, and with four braking modes.

Objective

The objective of the deceleration testing was to determine the overall characteristics and stopping distances associated with the four SOAC braking modes (blended, dynamic only, service friction only, emergency friction) throughout the operating range of the car.

Status

All data have been reduced and are available in digitized, tabulated time-history format. The car performance level and data reduction problems noted in the acceleration tests also apply to deceleration testing, although to a lesser extent. Solid wheel data is used to define control response and weight effects for blended and dynamic braking only.

Service friction and emergency braking data are based on resilient wheel tests. Improper brake pressure settings existed during solid wheel tests. (All 105,000-pound data is considered valid since this is the car's design weight and pressures were consistent at this weight.)

TRACTION RESISTANCE TESTS

Test Sequence

- Single Car

  Test Run 102, records 455 through 522.

- Two-Car Train

  Test Run 121, records 1030 through 1145.

Test Procedure

SOAC-P-4001-TT baseline test procedure was used for single and two-car tests.

Objective

The objective of the traction resistance testing was to determine the traction resistance of the SOAC for use in analysis of wheel-rail adhesion factors and traction system propulsion and braking force characteristics.

Status

Single and two-car test data have been reduced. Train resistance versus car speed relationships have been developed. Although there is considerable data scatter for both tests, the SOAC appears to have a higher rolling resistance at low speed and a lower air resistance at high speed than previously estimated during the design phase. The single-car data are considered of prime importance since they are used in the single-car adhesion test data reduction. The two-car traction resistance test data do not appear to conform to the single-car data adjusted to a two-car consist using standard Davis methods.

Since the test data were acquired at the 4,900-foot test site altitude and will be applied to adhesion data taken at the same altitude, no attempt was made to correct for density altitude effects.

FRICTION BRAKING DUTY CYCLE TESTS

Test Sequence

Two duty cycles were tested with solid and resilient wheels at a single-car weight of 105,000 pounds, as follows:

Duty Cycle	Test Run	Record No.	Wheels
I (35 mph)	117	1255 (1-38)	Solid
II (50 mph)	117	307 (1-17)	Solid
I	141	1104 (1-37)	Resilient
II	142	1445 (1-17)	Resilient

Test Procedures

The SOAC-P-5001-TT procedure was used to perform the tests for two duty cycles. Cruise speeds of 35 and 50 mph were tested.

Objective

The objective of the friction brake duty cycle tests was to determine the thermal capacity of the SOAC tread brake system while operating on duty cycles similar to those anticipated during the SOAC demonstration, with the dynamic brake disabled. Cycle I simulates NYCTA 8th Avenue Express; Cycle II simulates the Cleveland Airport (CTS) route. Both solid and resilient wheels were tested to determine their capability and to define potential limitation for the demonstrations.

Status

The test data derived from the above four tests has been reduced and analyzed to show tread temperature and deceleration rate effects on repetitive friction brake stops. The thermocouple data have been adjusted to account for the estimated response time. Deceleration rates from digitized tape data have been plotted for several stops during the duty cycles for both types of wheels.

Energy consumption was recorded during the duty cycles. Data has been reduced.

POWER CONSUMPTION AND UNDERCAR EQUIPMENT TEMPERATURE TESTS DURING SIMULATED TRANSIT OPERATION

Test Sequence

A series of six test runs comprising eight test records were required to accomplish the power consumption tests.

Procedures

SOAC-PC-5011-TT procedure was used for testing on the Synthetic Transit Route; SOAC-P-5001-TT procedure was used to obtain energy consumed during the friction brake duty cycles.

Objective

The objective of the power consumption testing was to determine the SOAC's energy consumption and schedule speed on the Synthetic Transit Route developed for the ACT-1 Program. The test results will provide a baseline for both the SOAC and the route (as laid out at Pueblo). The overall efficiency of the traction system will be estimated from this data.

Status

Test data were obtained from two round trips of the 9.25-mile synthetic route for a single car weighing 105,000 pounds. In addition the energy consumed during the friction brake duty cycles was recorded and has been reduced for both solid and resilient wheel testing. Data reduction consisted of off-car machine combination and summation of the car's input voltage and current.

Undercar equipment temperatures were also recorded during the synthetic route tests. The data were recorded on the 12-channel recorder and peak temperatures were corrected to an ambient temperature of 125°F, the design goal of the SOAC.

SPIN/SLIDE PROTECTION SYSTEM TESTS

Test Sequence

Two test runs comprising 14 test records were required to complete the spin/slide tests with both solid and resilient wheels for single-car tests at 90,000-pound car weights.

Test Procedures

SOAC-P-2001-TT procedure was used for acceleration testing; SOAC-P-3011-TT for deceleration testing. Procedures were used throughout the speed range during testing with blended, dynamic, or service friction braking only.

Objective

The objective of the spin/slide protection system testing was to determine the efficiency of the SOAC spin/slide protection system throughout the speed range of the car in both drive and brake modes on wetted rail. An additional objective was to define a specific data acquisition and analysis technique to standardize the calculation of efficiency.

Status

Data was recorded with both solid and resilient wheels. Sample digital and analog time history standard outputs are contained in this part for three combinations of brake systems and for acceleration on wetted rails. The efficiencies of the spin/slide systems have been calculated and summarized over the speed range from 10 to 80 mph. Methodology for calculating efficiency is detailed in the text. Difficulty in obtaining consistent wetted rail adhesion limits precludes a valid comparison between the solid and resilient wheel tests. (Only subtle variations in wheel deceleration/reacceleration were anticipated.)

ADHESION TESTS

Test Sequence

Three test runs, with 15 data records complete the adhesion tests on wetted and dry rails with both solid and resilient wheels.

Test Procedures

SOAC-A-3021-TT test procedure was utilized during the test program to obtain adhesion data in the braking mode.

Objective

The objectives of the adhesion tests were to determine the dry and wetted rail adhesion factors for use in spin/slide system detailed performance analyses and to determine the wetted rail adhesion factor associated with the wetting solution used during spin/slide tests.

Status

Test data were obtained for wetted rails with both solid and resilient wheels at empty car weights (90,000 pounds). Data from all tests has been reduced and combined with the traction resistance data to define the wheel-rail adhesion factors throughout the speed range from 10 to 75 mph. Due to problems associated with the rail wetting apparatus and wetting solutions, two levels of adhesion are apparent during the tests. These two levels were also noted during the spin/slide systems tests.

The determination of dry rail adhesion factors was not satisfactorily accomplished since brake pressure could not be raised to a sufficient level to slide the wheels repeatedly.

RIDE QUALITY

Test Sequence

Test sequence run numbers were as follows:

Car Weight (lb)	Test Run Numbers: Single Car (High Density)	Test Run Numbers: Two-Car Train
90,000	132	-
105,000	120	139
	140	-
113,000	147	-
130,000	148	-

Test Procedures

Test procedures used for ride quality testing were: SOAC-R-2001-TT, SOAC-R-3001-TT, and SOAC-R-4001-TT.

Objectives

The objectives of ride quality testing were to expand and improve the General Vehicle Test Plan (GSP-064) and to provide vehicle ride quality baseline engineering data for the SOAC at the HSGTC. This data will be used for comparison with data recorded at five transit properties in New York, Boston, Cleveland, Chicago, and Philadelphia.

Status

Ride quality data at seven car body locations and five truck locations has been recorded and collected over the six types of track construction on the 9-mile UMTA test track. The processed data is presented in 167 sets, each set containing spectrum analysis and power spectral density curves. The processed data was selected to obtain baseline comparison plots showing the effect of speed, track section, car weight, and train consist on vehicle vibration levels.

Data was collected for both resilient and steel wheels. However, the steel wheel data was taken prior to a car body structural modification and is therefore no longer valid.

It should be noted that wheel flats may have existed on the SOAC during the ride quality tests with resilient wheels. This may have provided erroneous data at the wheel fundamental rotational frequency. Previous ride quality testing indicated that the vehicle was sensitive to wheel flats near 80 mph.

INTERIOR NOISE

Test Sequence

Interior noise basic test configurations and run numbers were as follows:

SOAC Car No.	Weight (lb)	Test Run Numbers: Steel Wheels	Test Run Numbers: Resilient Wheels
1	90,000	87, 89, 111	134
2	90,000	88, 108, 109	136
1	105,000	112	135
Train	90,000	92	137

Test Procedures

Detailed test procedures are as contained in SOAC Engineering Test Program Test Procedures (Boeing Vertol D174-10023-1, July 1973).

Objective

The objective of the noise testing was to measure the interior noise levels in the SOAC cars operating at the HSGTC under various conditions by sampling car locations representative of patrons and operating crew and probing possible sources. These data are then used to describe the acoustical characteristics of the SOAC vehicles, as well as for comparison with subsequent noise tests performed at the demonstration properties. A secondary objective is to develop and verify procedures for performing such tests.

Status

Interior noise was surveyed for single cars and two-car trains at car weights of 90,000 and 105,000 pounds. The baseline measurements were for cars equipped with steel wheels; selected data points were repeated with resilient wheels. Test procedures were developed and verified.

WAYSIDE NOISE

Test Sequence

Test run numbers for the wayside noise tests were as follows:

SOAC Car No.	Weight (lb)	Test Run Numbers: Steel Wheels	Test Run Numbers: Resilient Wheels
1	90,000	87, 89, 110	134
2	90,000	88	136
1	105,000	-	135
2	105,000	113	-
Train	90,000	90, 91, 92	-
Train	105,000	-	137

Test Procedures

Detailed test procedures are presented in SOAC Engineering Test Program Test Procedures (Boeing Vertol D174-10023-1, July 1973).

Objective

The objective of the wayside noise testing was to measure the wayside noise levels of the SOAC cars operating at the HSGTC under various conditions. These data will be used to describe the acoustical characteristics of the SOAC vehicles and for comparison with subsequent noise tests performed at the demonstration properties. A secondary objective is to develop and verify procedures for performing such tests.

Status

Wayside noise was surveyed for single cars and two-car trains at car weights of 90,000 and 105,000 pounds. The baseline measurements were made for the car with steel wheels; selected data points were repeated with resilient wheels. Test procedures were developed and verified.

STRUCTURE

Test Sequence

Test runs 122, 123 and 125: steel wheels.
Test runs 137 and 138: resilient wheels.

Test Procedure

No procedure number has yet been assigned.

Objective

To develop a methodology for structurally evaluating railcar trucks, to obtain a set of data on the SOAC, and to examine the loads being induced in the SOAC trucks.

Status

The methodology developed consists of tracing the major load paths through a railcar truck by measuring selected displacements and strain levels. The SOAC test car was instrumented to provide this information and the data set obtained. Data has been collected at 90,000, 105,000 and 113,000 pounds at five different speeds for the six track sections on the UMTA Rail Transit Test Track.

VOLTAGE TRANSIENTS AND SPIKES

Test Sequence

Testing was completed on April 18, 1973.

Test Procedure

No baseline procedure number has yet been assigned.

Objective

The purpose of this test was to obtain voltage transient and spike data on the SOAC vehicle while at the HSGTC in order to determine SOAC characteristics.

Status

The measurements and data reduction have been completed. The results of the transient and spike analysis are significantly affected by the relatively high positive spike noise of the locomotive power generator and the short rail gaps at the Pueblo test site. No long duration rail gap transients (where voltage applied to the car decreases to zero) or negative spikes were observed. Also, all positive spikes measured did not exceed +1600 volts. This is in contradistinction to the results of the transit property tests where higher positive and negative voltage spikes were observed. It is believed that the reason for these significant differences is to be found in the different nature of the power supply, power distribution, and car equipment of the Pueblo test site, compared to the nature of the previously investigated installations.

RADIO FREQUENCY INTERFERENCE

Test Sequence

Runs were completed in April 1973.

Test Procedure

No baseline number has yet been assigned.

Objective

To measure the broadband radiated electromagnetic emissions from a rapid transit train consisting of two State-of-the-Art Cars coupled together and functioning as a unit. Measurements of internal emission levels were secured to identify sources of significant electromagnetic emission. Wayside emission data were obtained for comparison with the radio frequency interference goals established for SOAC.

Status

The tests took place on April 2 and 3, 1973, and comprised a series of measurements using Radio Interference Field Intensity (RIFI) meters with appropriate antennas.

Internal ambient electric field intensity measurements were made with all SOAC systems off, for reference, then repeated to assess the emission characteristics of the SOAC systems in operation. Wayside tests were performed under ambient conditions and with the SOAC train in all operating modes: acceleration above and below base speed, constant speed, and braking. More than 150 SOAC passbys were involved.

No significant sources of broadband radiation were identified during the internal tests on the SOAC, and the SOAC demonstrated complete conformance to the wayside radiated interference emission goals.