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ENGINEERING TESTS FOR ENERGY STORAGE CARS AT THE TRANSPORTATION TEST CENTER
Volume I - Program Description and Test Summary

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MAY 1977

FINAL REPORT

DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

Prepared for

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16. Abstract

The primary purpose of the tests documented herein was to demonstrate the principles and feasibility of an energy storage type propulsion system, and its adaptability to an existing car design. The test program comprised four phases of tests on two New York City Transit Authority R-32 cars where the conventional propulsion system was replaced by an energy storage system. The four test phases were: verification of safe arrival, debugging procedures, performance verification tests, and expanded test program. This report contains test data collected during the performance verification and expanded test program phases. Testing was conducted at the DOT Transportation Test Center, Pueblo, Colorado. The data was collected and processed in accordance with the General Vehicle Test Plan for Urban Rail Transit Cars.

Volume II, Performance, Power Consumption, and Radio Frequency Interference Tests; Volume III, Noise Tests; and Volume IV, Ride Roughness Tests.

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PREFACE

This document describes testing conducted on the Energy Storage Car (ESC) at the Transportation Test Center, Pueblo, Colorado, by the AiResearch Manufacturing Company, Torrance, California, a division of The Garrett Corporation.

The Energy Storage System (ESS) was installed onboard two New York City Transit Authority R-32 transit cars for use as a test bed confirming ESS adaptability to rail cars, and also to demonstrate the the principles and feasibility of the concept of energy storage. AiResearch is conducting the ESC program under a contract from the Metropolitan Transportation Authority. The program is sponsored by the Urban Mass Transportation Administration (UMTA) Rail Technology Division, the Metropolitan Transportation Authority, and the State of New York.

This report is derived from the efforts of two agencies of the U.S. Department of Transportation: the Rail Programs Division of the UMTA Office of Research and Development and the Transportation Systems Center (TSC).

As Systems Manager for the Urban Rail Supporting Technology Program, Rail Programs Division, UMTA Office of Research and Development, TSC is responsible for the development and conduct of a comprehensive program of test and evaluation of vehicles, structures, and related components.

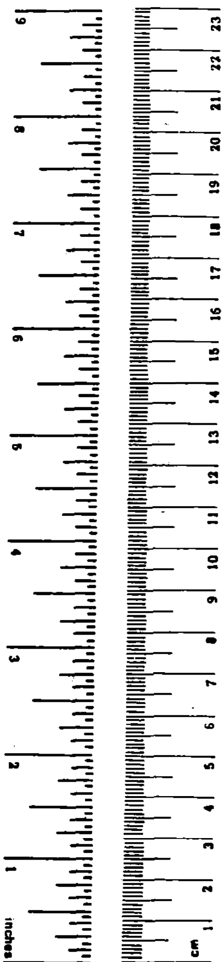
The Energy Storage Car Test Program at the Transportation Test Center (TTC) was accomplished under TSC sponsorship and guidance. Mr. G. Neat, Assistant Program Manager for Test and Evaluation, Urban Rail Supporting Technology Program, provided technical guidance as contract monitor. Also acknowledged are the efforts of key TSC personnel onsite at TTC such as Mr. R. Parker and Mr. R. Brush.

Program responsibility at AiResearch was vested in the Ground Transportation and Industrial Power Systems Department, headed by Mr. W. H. Sutton, Chief Engineer; Mr. E. E. Nickel, Program Manager; Mr. R. W. McConnell, Data Reduction; and Mr. G. McClure, Test Engineer.

Approximate Conversions to Metric Measures

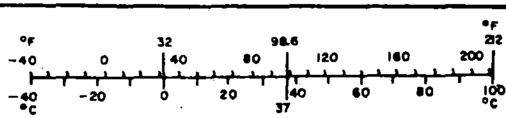
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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

METRIC CONVERSION FACTORS



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



CONTENTS

ILLUSTRATIONS

1. INTRODUCTION

1.1 GENERAL

The AiResearch Manufacturing Company prepared this report for the Transportation Systems Center of the Department of Transportation. It covers energy storage car (ESC) tests performed by AiResearch from May 1974 through January 1975 at the Transportation Test Center, Pueblo, Colorado. (See Figure 1-1.

The report consists of four volumes.

Volume I	Program Description and Test Summary
Volume II	Performance, Power Consumption, and Radio Frequency Interference Tests
Volume III	Noise Tests
Volume IV	Ride Roughness Tests

All tests reported herein were conducted in accordance with the procedures defined in the TSC General Vehicle Test Plan, GSP-064[1] (draft version), 21 May 1974. These test procedures are delineated in AiResearch documents 73-9373 (Energy Storage Cars Test Program) and 74-10441 (Expanded Testing on Energy Storage Cars).

The vast amount of data recorded during these tests is stored on magnetic analog tape and will contribute to UMTA's growing data bank for urban rail vehicles.

1.2 TEST CRITERIA

The objectives of the tests were:

Verification of system performance

Confirmation of system adaptability to rail cars

Evaluation of system noise (exterior, interior)

Evaluation of system ride roughness

Evaluation of system structural dynamics

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[1] This document has since been formally published as General Vehicle Plan (GVTP) for Urban Rail Transit Cars, September 1976 (Report No. UMTA-MA-0025-75-14) PB251-086.

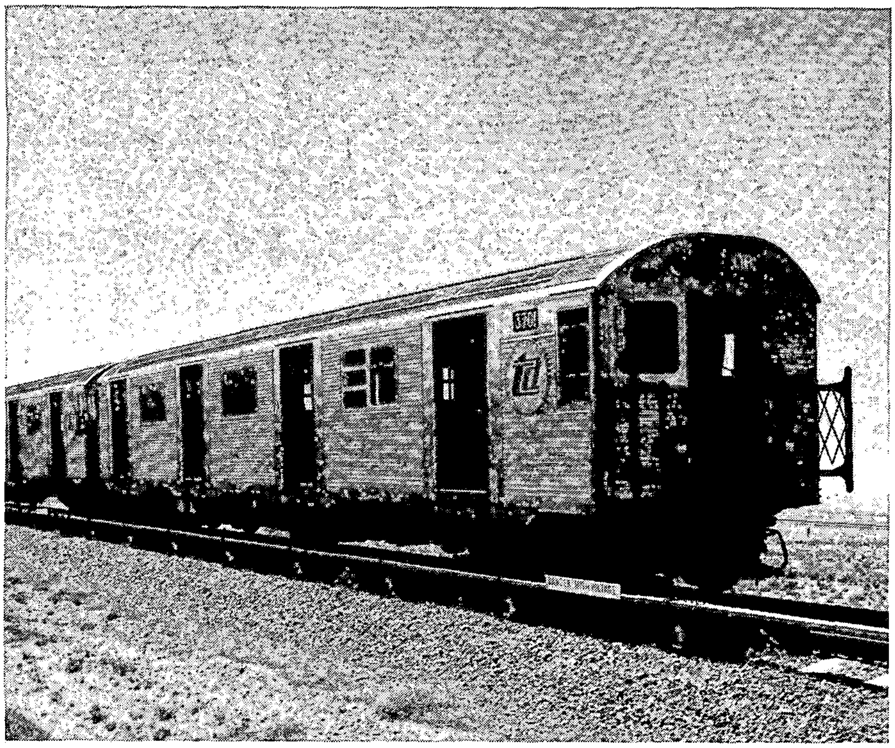


Figure 1-1. Energy Storage Car at Transportation Test Center

1.3 SYSTEM DESCRIPTION

The energy storage system (ESC) developed by AiResearch uses two motor-driven flywheel assemblies per car to supply electrical energy to the separately excited traction motors for car acceleration. During car deceleration (braking), the electrical energy from the traction motors (now generators) is returned to the flywheel motors, increasing flywheel speed. The makeup electrical energy required is supplied to the traction and flywheel systems by a solid-state dc chopper, which is regulated to draw only an average amount of power during normal accleration and deceleration. The primary advantages of an energy storage system are:

Reduced energy consumption

Reduced peak power from substations

Reduced tunnel heating due to less need for dynamic braking

The ESC is mounted onboard an R-32 transit car. This car, first built in 1964, was originally powered by series traction motors and a camshaft controller. The energy storage car conversion was accomplished at the AiResearch facilities, Torrance, California. The energy storage unit is shown in Figure 1-2.

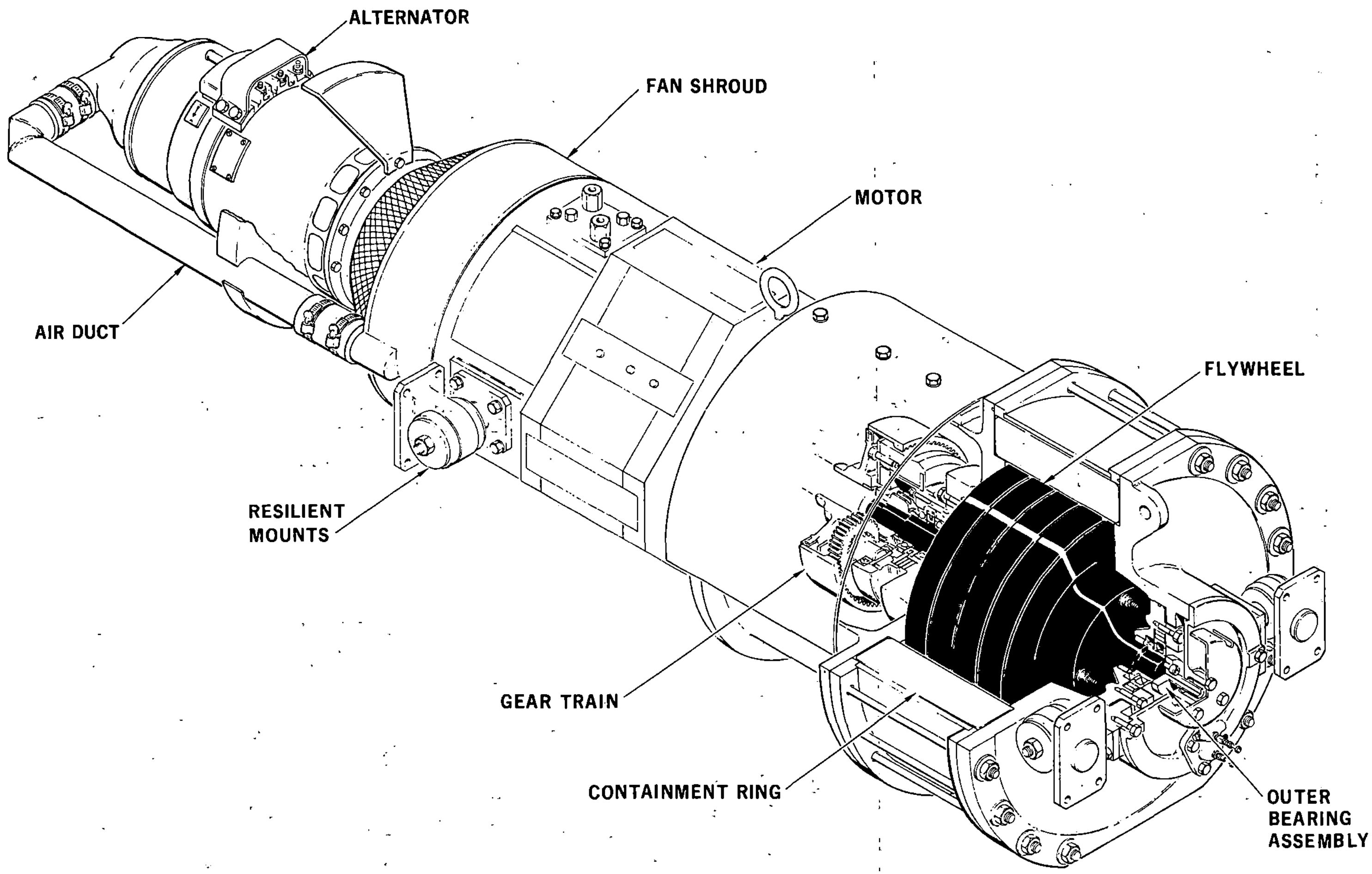


Figure 1-2. Energy Storage Unit

1.3.1 CAR WEIGHT

Definition for car weight abbreviation description is as follows:

(a) AW0--Empty weight: car 3700, 42.5 tons (including instrumentation estimated at 1.35 tons); car 3701, 41.4 tons

(b) AW2--Full load (AW0 + 15.4 tons)

(c) AW3--Crush load (AW0 + 21 tons)

1.3.2 EQUIPMENT LIST AND INTERFACE DETAILS

The major system components are listed in Table 1-1.

Table 1-1. Energy Storage System Components

Component	AiResearch Part No.	Qty per Car
Motor/flywheel unit	543122-1	1
Motor/flywheel unit	543122-2	1
Traction motor	2000756-1	4
Chopper	2001000-1	1
Smoothing inductor	542551	1
Input inductor	542553	1
Propulsion control	2000997-1	1
Power control unit	542540	1
Auxiliary control unit	542542	1
Flywheel field supply	2015368	
Traction field supply	2015367	
Alternator regulator	NA	
Brake resistor	NA	2
Air duct assembly	523050	
Air duct filter		
Cooling fan		
System instrument panel	543121	1

Figure 1-3 is a simplified circuit schematic that shows major system interfaces for a single-car system.

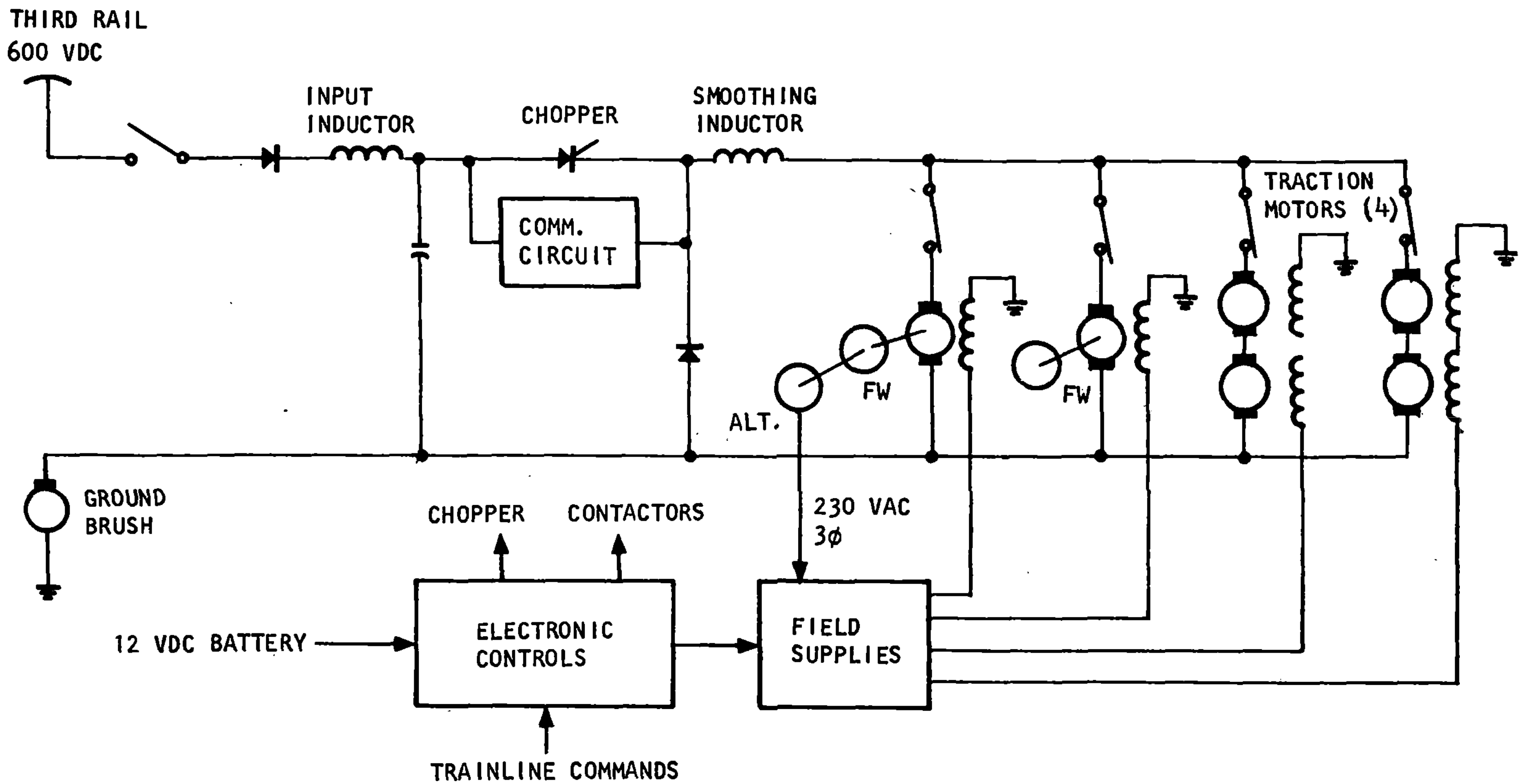


Figure 1-3. Energy Storage System Simplified Circuit Schematic

2. TEST DESCRIPTION

2.1 FACILITY

Energy storage car testing was accomplished at the Transportation Test Center (TTC), Pueblo, Colorado. Actual running of the ESC was performed on the UMTA test track under existing environmental conditions.

The UMTA test track is a 9.1-mile, nearly oval loop embodying six different types of construction. Track layout and construction are shown in Figure 2-1 and the track profile in Figure 2-2.

2.2 INSTRUMENTATION

The vehicle was instrumented to record data on magnetic tape for future retrieval and on an oscillograph for quick-look monitoring of selected parameters. In addition, system component temperatures were recorded on a strip chart recorder for a limited number of test conditions. System input power was integrated on a digital readout to provide kilowatt-hour data for power consumption runs. Figure 2-3 is a block diagram of the onboard data acquisition system. (Refer to Table 2-1 for details.)

Retrieval of taped data was usually accomplished by playback on an eight-channel recorder in the manner shown in Figure 2-4. (Refer to Table 2-2 for details.) Data reduction was then carried out using the analog information provided from these playbacks. In some cases (e.g., power consumption) data was manually tabulated directly from the digital readouts.

The bandwidth resolution and sensitivity ranges of the recording equipment and the sensors are summarized in Table 2-3.

An example of the parameters recorded and the instrumentation used for the performance tests is shown in Table 2-4.

Other volumes of this report include block diagrams of instrumentation related to individual parameters when additional details are required.

2.3 PROCEDURES

ESC test procedures are described in TSC General Vehicle Test Plan, GSP-064. Detailed requirements for these tests are covered in AiResearch documents 73-9373 and 74-10441.

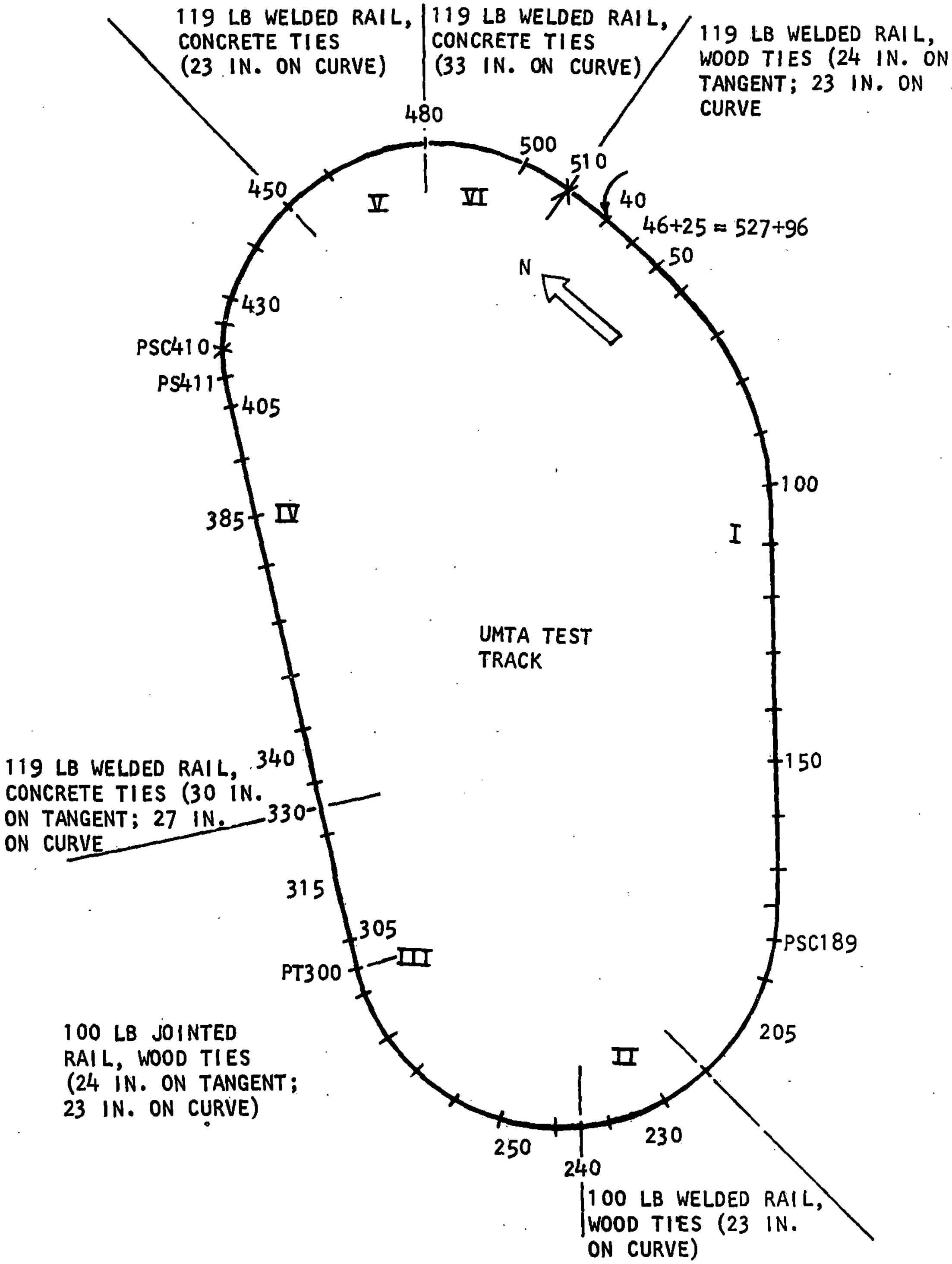


Figure 2-1. Rail Transit Test Track Layout

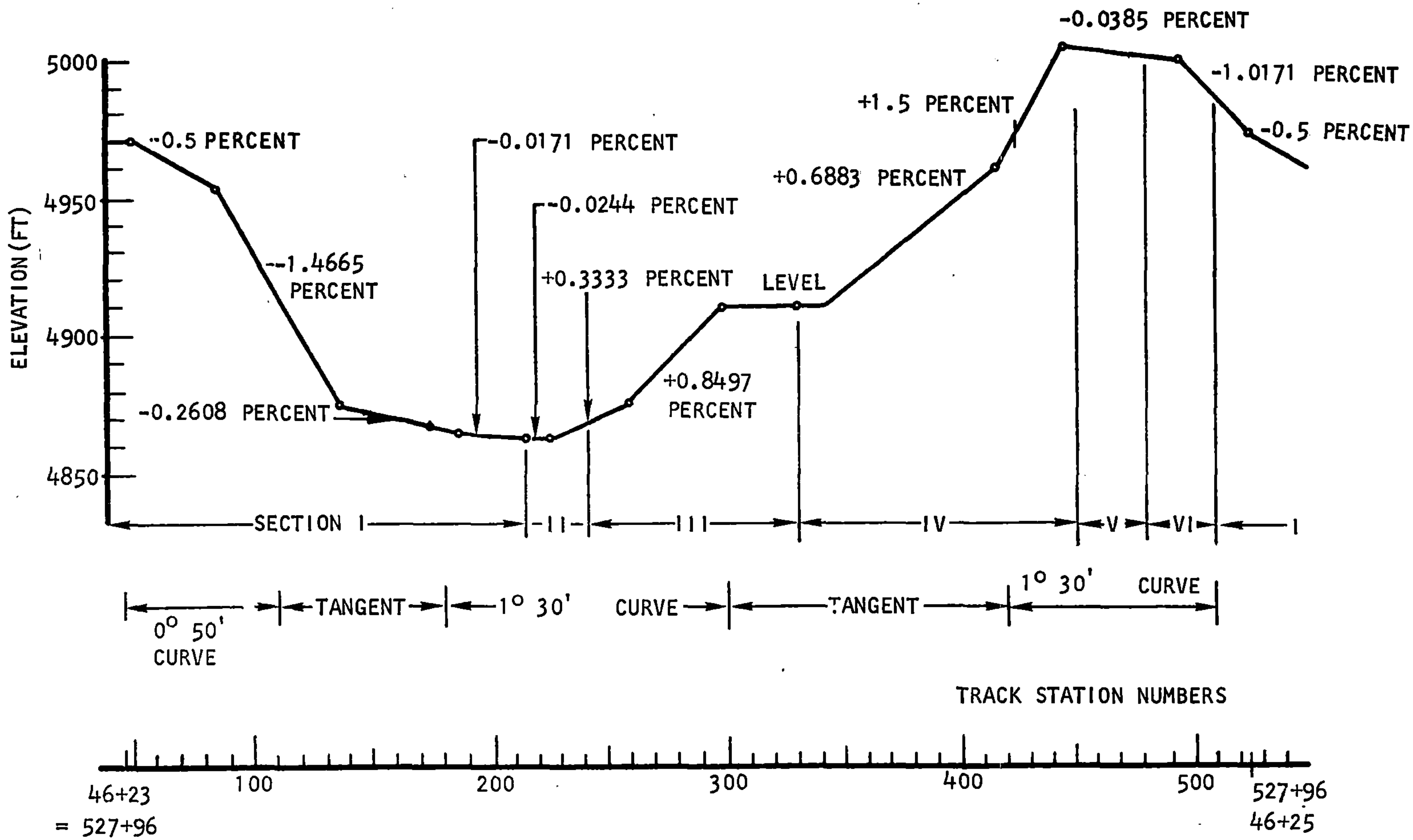


Figure 2-2. Nominal Track Profile

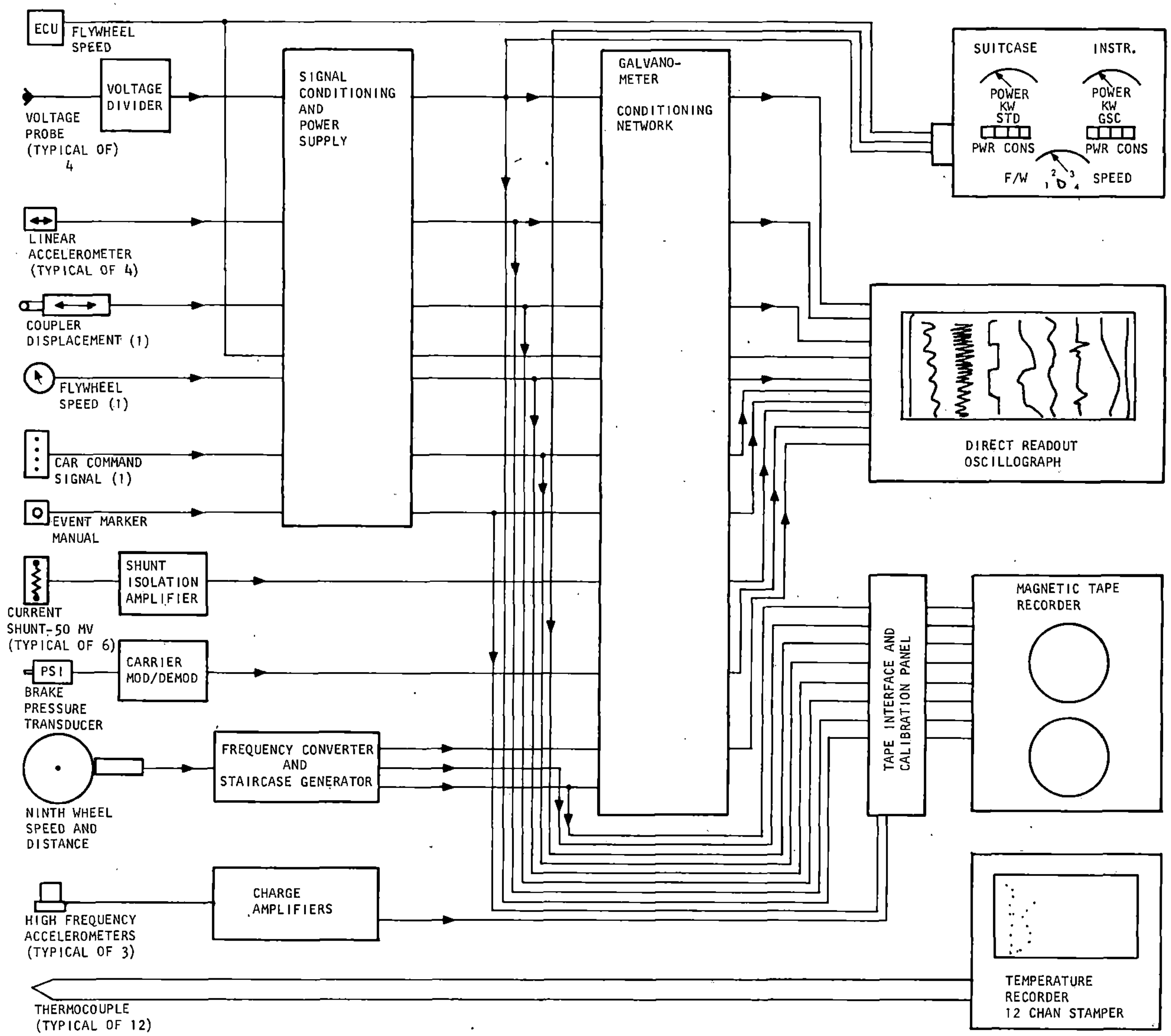


Figure 2-3. Data Acquisition System

Table 2-1. Data Acquisition System Instrumentation

Item No.	ESC Instrumentation Description	Model No.	Mfg.	Response Range	Sensitivity	Calib.	Notes
1	Oscillograph Recorder (36 Chan.)	5-119	Bell & Howell	0 to 500 Hz	≈ 2.5 v per in.	0 to 2 in. for F.S. signal	
2	Oscillograph Recorder (12 Chan.)	5-124	Bell & Howell	0 to 500 Hz	≈ 2.5 v per in.	0 to 2 in. for F.S. signal	
3	Multipoint Temperature Recorder (12 Chan.)	Speedomax "H"	Leeds & Northrop	N.A.	≈ 50^0F per in.	0 to 1200^0F (Type E Sensor)	
4	Tape Recorder	2114	Precision Instruments	0 to 10 kHz	≈ 10 mv minimum	±5 v F.S. signal	
5	Strain Gage Signal Conditioning	LSK 36398	AiResearch	0 to 10 kHz	≈ 10 $\mu\epsilon$ minimum	Depends on Sensor	
6	General Signal Conditioning	LSK 36052	AiResearch	0 to 500 Hz	N.A.	±5 v F.S. signal	Provides buffering for voltages and accels.
7	Accelerometer Charge Amplifiers	D11	Unholtz Dickie	0 to 10 kHz	1g to 1000g F.S.	5 v = 3g	
8	Speed & Distance Signal Conditioning	LSK 36220 & LSK 36054	AiResearch	0 to 1 kHz	≈ ±0.1 mph & ≈ ±1.0 ft.	0 to 50 mph -	

Table 2-1. Data Acquisition System Instrumentation (Continued)

Item No.	ESC Instrumentation Description	Model No.	Mfg.	Response Range	Sensitivity	Calib.	Notes
9	Charge Accelerometers	2272	Endevco	0 to 5 kHz	≈ .01 g minimum	AiResearch Certified	
10	Linear Accelerometers	LSBC 39-2	Schaevitz	0 to 40 Hz	≈ .001 g minimum	5 v = 2 g	
11	Current Shunts	PR1000	Quality Electric	0 to 500 Hz	≈ 0.1 mv minimum	50 mv = 1000A	
12	Current Shunt Isolators	6271A	Scientific Columbus	0 to 120 Hz	≈ 0.5% of F.S.	50 mv = 5v	
13	Voltage Dividers	-	AiResearch	0 to 1 kHz	≈ 0.5 v minimum	750 v = 9 v	0.1% Resistive Divider
14	Calibration Power Supply	LS513	Lambda	0 to 40 v	100 μv	AiResearch Certified	
15	Calibration Frequency Counter	CF601R	Anadex	1 Hz to 99,999 Hz	±1 count	AiResearch Certified	
16	Calibration Oscillator	204C	Hewlett Packard	5 Hz to 1.2 mHz	±1%	AiResearch Certified	
17	Calibration RMS Voltmeter	427A	Hewlett Packard	0.01 v to 300 v 10 Hz to 1 mHz	≈ 0.5 mv minimum	AiResearch Certified	
18	Calibration DC Voltmeter	DS100	Doric	0 to 1000 v	0.1 mv	AiResearch Certified	
19	Inverter	1000 GCCWD	Topaz	DC to 60 Hz	N.A.	N.A.	

Table 2-1. Data Acquisition System Instrumentation (Continued)

Item No.	ESC Instrumentation Description	Model No.	Mfg.	Response Range	Sensitivity	Calib.	Notes
20	Oscilloscope	503	Tektronix	DC to 1 mHz	10 mv minimum	AiResearch Certified	
21	Coupler Displacement	WR8	Lockhead Electronics	DC to 50 Hz	≈ 1.0 v per in.	5 in. F.S.	
22	Kilowatt Hour Meter	LSK 36129	AiResearch	0 to 99,999.9 KWHR	0.1 KWHR	1.5 MEGA Watt F.S.	

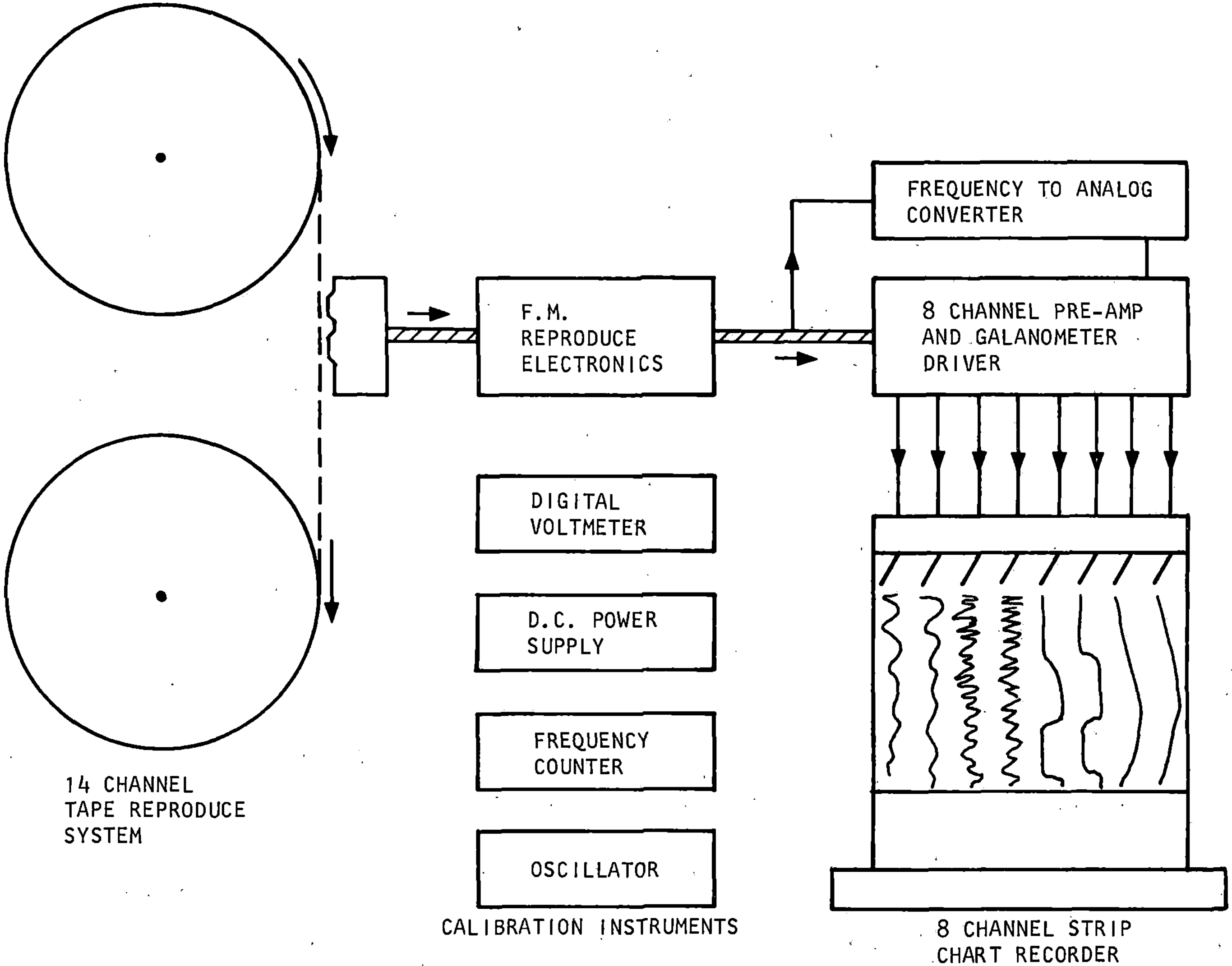


Figure 2-4. Data Recovery System

Table 2-2. Data Recovery System Instrumentation

Item	Instrument	Model	Sensitivity	Range	Description
1	Magnetic Tape Recorder/Reproducer	Honeywell No. 7600	0.5 to 10 v peak for full deviation	3-3/4 ips - 0 to 625 Hz 7-1/2 ips - 0 to 1250 Hz 15 ips - 0 to 2500 Hz	14-channel FM reproduce medium band system.
2	Strip Chart Recorder	Beckman-Offner Typer Dynograph	1.0 mv/mm max.	0 - 200 Hz ±20%	8-channel direct writing oscillograph
3	Digital Volt Meter	Doric-DS 100	0.1 mv to 1000v	-	Dc voltmeter
4	DC Power Supply	Lambda LS 513	100 μv to 40v	-	Precision, programmable, digital adjust
5	Frequency Counter	Anadex CF601R	±1 count	1 Hz to 99.999 kHz	Digital Counter
6	Oscillator	Hewlett-Packard 204B	±1% of scale	5 Hz to 560 kHz	Solid state, battery-operated
7	Frequency	Anadex P1-408R	0.01v RMS threshold voltage	5 Hz to 51.2 kHz	Frequency to analog converter with zero suppression

Table 2-3. Parameter Calibration Ranges

Parameter	Calibration Range	Calibration
Voltages	1000 v = F.S. (750 v = 9.000 v)	Resistive Divider (0.01% Resistors) Lambda Power Supply and Doric Voltmeter
Currents	1000 A = 50 mv - 5 v	Certified Current Shunt Lambda Power Supply and Doric Voltmeter
Linear Accelerometers	±0.5 g = ±5 v	Calibrated Accelerometer Lambda Power Supply and Doric Voltmeter
Speed	0 to 50 mph	H.P. Oscillator and Anadex Counter
Charge Accelerometers	± 3 g	Calibrated Accelerometer H.P. Oscillator and H.P. RMS Voltmeter
Temperature Recorder	0 to 1200 ^{o}F Type E Thermocouple	Ice Bath Reference Lambda Power Supply and Doric Voltmeter
Oscillograph Recorders	5 v = 2 in.	H.P. Oscillator & H.P. RMS Voltmeter or Lambda Power Supply and Doric Voltmeter
Tape Recorder	±5 v = F.S. (±40% deviation on FM)	Lambda Power Supply and Doric Voltmeter

Total power consumption for the entire instrumentation system is ≈ 1.5 kw.

Table 2-4. Performance Test Parameters and Instrumentation

Recorded Parameter	Accel Tests	Decel Tests (Blended)	Decel Tests (Friction)	Drift Tests	Duty Cycle Tests	Power Consumption Tests	Misc.
Event and Time Mark	0 T	0 T	0 T	0 T	0 T	0 T	
Volts, 3rd Rail	0 T	0 T	0 T	0	0	0 T	
Volts, Capacitor Bank				0	0		
Volts, Flywheel Mtr. A	0 T	0 T	0 T	0	0 T	0	
Volts, Trac. Mtr. A	0	0	0	0 T	0 T	0 T	
Current, 3rd Rail 3700	0 T	0 T	0 T	0	0	0	
Current, 3rd Rail 3701	0	0	0	0	0	0 T	
Current, Trac. Mtr. A	0(A)T	0(A)T	0(A)T	0(A)T	0(A)T	0 T	
Current, Trac. Mtr. B				0(B)	0(B)		
Current, Flywheel Mtr. A	0(A)T	0(A)T	0(A)T	0(A)T	0(A)T	0 T	
Current, Flywheel Mtr. B				0(B)	0(B)		
Vibration, Carbody Vert.				0	0		
Vibration, Carbody Lat.				0	0		
Vibration, Carbody Long.							
Vibration, Flywheel Vert.				T			
Vibration, Flywheel Lat.				T			
Vibration, Flywheel Long.							
Acceleration, Vehicle Long.	0 T	0 T	0 T	0 T	0 T	0 T	
Displacement, Coupler				0	0	0	
Car Command Signal	0 T	0 T	0 T	0 T	0 T	0 T	
Distance, Vehicle	0 T	0 T	0 T	0 T	0 T	0 T	
Speed, Vehicle	0 T	0 T	0 T	0 T	0 T	0 T	
Speed, Flywheel A	0 T	0 T	0 T	0 T	0 T	0 T	
Lock-out Magnet	0 T	0 T	0 T	0	0 T		
Pressure, Brake Cylinder	0	0	0	0 T	0 T		
Voice	T	T	T	T	T	T	
Temperature Wheel, Brake Shoe	S	S			S		
Temperature Vehicle Components							S

NOTE: T = Recorded on Magnetic Tape
0 = Recorded on Oscillograph Paper
S = Recorded on Strip-Chart Temperature Stamper

(A) Car 3700
(B) Car 3701

TEST ORDER

Test effort at the TTC was conducted in the following sequence:

(a)	Verification of safe arrival	AiResearch Document 73-9373 (Tests planned prior to Contract DOT-TSC-838.)
(b)	Debugging procedure	
(c)	Performance verification tests	
(d)	Expanded test program	AiResearch Document 74-10441 (Tests added for Contract DOT-TSC-838.)

Only the tests in categories c and d are reported herein.

2.4 TEST DESCRIPTION AND RESULTS

2.4.1 VERIFICATION OF SAFE ARRIVAL

Upon arrival at the TTC the ESC were subjected to a thorough preliminary checkout and processing by representatives of AiResearch and NYCTA. Particular attention was given to the newly installed equipment and wiring.

The checkout included a thorough functional examination of the mechanical and electrical devices and their controls. The air brake system was functionally tested per NYCTA Car Setup Procedures. Miscellaneous auxilliary equipment and the propulsion system were also functionally checked out, followed by a car clearance check that consisted of towing the cars on a track equipped with a third rail to confirm proper alignment of the third rail shoe. The clearance check was performed on both the tangent and minimum radius track for the third rail shoe and other external car-mounted equipment.

The run logs included herein in Appendix C, provide a record of the sequence of events. Test results in each category are compiled by test set, not necessarily in chronological order. The order of testing was selected to assure efficient scheduling and to minimize the shifting of ballast.

2.4.2 DEBUGGING OPERATIONS (FOUR-CAR TRAIN)

Initial operation was conducted to functionally check out the car's control system by verifying the stability of a four-car system (two ESC's coupled to two R-42 cars) under AWO conditions (empty weight) throughout the ESC's speed regime. Compatibility testing of the ESC vehicles was conducted at Pueblo with the R-42 cars because they were available. The R-42 vehicles are trainline-compatible with the original R-32 cars and are similar in size and performance characteristics. Calibration and trimming of the controls were also performed during the debugging operation. A copy of the log for the trainline test is included in Appendix C, run 32.

All runs from the initial run through run 31 were conducted for the purpose of thoroughly checking the ESS and its associated instrumentation for proper operation and integrity; also, these runs were utilized to familarize the car operator with the ESS operation and handling characteristics. The logs and all data recorded during the first 31 runs were not relevant to the test program. Therefore, they are not included herein.

2.4.3 PERFORMANCE VERIFICATION TESTS

The following verification tests (refer to Table 2-5) were conducted in accordance with the procedures described in AiResearch Proposed Test Program, document 73-9373 and Expanded Testing, document 74-10441, on two R-32 cars (3700 and 3701) converted to energy storage cars.

NOTE

Instrumentation for these tests is listed in Table 2-1.

2.4.4 FAILURE MODES AND SAFETY DEMONSTRATION

Cars 3700 and 3701 demonstrated safe ESS response when various fault sensors and critical control signals were actuated or interrupted. Initially, the condition of both cars was established at (1) zero speed on energized third rail, (2) flywheels operating at steady-state speed, and (3) controls in the OFF position. Thereupon, the transient conditions of AiResearch document 75-9373, were introduced.

2.4.5 RESULTS

All safety features of both cars performed successfully. The QSD and safety devices operated as specified for the respective design application. Both cars were given a safety clearance to continue testing. Refer to test log 32, Appendix C.

2.5 TEST SETS

Each of the 21 ESC test sets listed in Table 2-5 incorporates a test objective, description, procedure, and a definition of instrumentation and data processing requirements. The information that makes up the test set is defined in General Vehicle Test Plan, GSP-064. This same information, along with the processed data and discussion of the results are packaged together to form a compact sub-report of each test set.

The other volumes of this report each include the test sets applicable to the subject matter covered by that specific volume. Each test set is preceded by a summary sheet which includes the test set number, title, objective, description, and status of results. Summary sheets for the performance, power consumption, and radio frequency interference tests are provided in Volume II; noise test summary sheets, in Volume III; and ride roughness summary sheets in Volume IV. To provide and overview of the ESC test results, all of the summary sheets are presented in Appendix B of this volume.

Table 2-5. Test List

Para No.	Test Area	Test Title	Test Procedure Reference*		
			GSP-064 (Set No.)	AiR 73-9373 (Para No.)	AiR 74-10441 (Page No.)
2.5.1	Performance	Acceleration	P-2001-TT	4.4.7.3	3
2.5.2		Deceleration - Blended Braking	P-3001-TT	4.4.7.4	4
2.5.3		Deceleration - Service Friction	P-3002-TT	--	4
2.5.4		Traction Resistance (Drift)	P-4001-TT	4.4.7.2	5
2.5.5		Friction Brake - Duty Cycles	P-5001-TT	--	5
2.5.6	Power Consumption	Power Consumption	PC-5011-TT	4.4.7.11	-
2.5.7	Radio Freq Interference	Radio Frequency Interference	PSI-6001-TT	--	11
2.5.8	Exterior Noise	Equipment Noise Survey-Wayside	CN-0001-TT	4.4.7.7	7
2.5.9		Effect of Car Speed-Wayside	CN-1001-TT	4.4.7.7	-
2.5.10	Interior Noise	Effect of Speed-On Car	PN-1001-TT	4.4.7.8	-
2.5.11		Effect of Track Section-On Car	PN-1101-TT	--	8
2.5.12		Interior Noise Survey	PN-1301-TT	4.4.7.8	8
2.5.13		Acceleration Effect-On Car	PN-2001-TT	4.4.7.8	9
2.5.14		Deceleration Effect-On Car	PN-3001-TT	4.4.7.8	9
2.5.15	Ride Roughness	Dynamic Shake Test-Vertical	R-0001-XX	--	9
2.5.16		Dynamic Shake Test-Lateral	R-0002-XX	--	9
2.5.17		Dynamic Shake Test-Longitudinal	R-0003-XX	--	10
2.5.18		Component Induced Vibration	R-0010-TT	4.4.7.8	10
2.5.19		Worst Speeds	R-1101-TT	--	10
2.5.20		Acceleration	R-2001-TT	--	10
2.5.21		Deceleration	R-3001-TT	--	10

*TSC General Vehicle Test Plan, GSP-064
AiResearch Proposed Test Program for Energy Storage Cars, 73-9373
AiResearch Expanded Testing on Energy Storage Cars, 74-10441

A brief outline of the GSP-064 test sets used in the energy storage car test program are provided in paragraphs 2.5.1 through 2.5.21.

2.5.1 ACCELERATION - ESC-P-2001-TT

2.5.1.1 Objective

To determine the overall acceleration characteristics of the test vehicle as affected by controller input level, line voltage, car weight (load weighting), car direction, and train consist.

2.5.1.2 Description

The test vehicle was acclerated at the required controller command on level tangent track. The following combinations can be tested:

Procedure Option	Prime Variable	Test Conditions
(4)	Controller level	Half and full power
(6)	Line voltage	Min, 600, & max. volts
(5)	Car weights	AW0, AW2 and AW2
(3)	Car direction	Forward and reverse
(7)	Train consists	2-car train

2.5.1.3 Procedure

The tests were performed in accordance with procedures described in AiResearch documents 73-9373 and 74-10441 in conformance with Test Set Number ESC-P-2001-TT of TSC General Vehicle Test Plan GSP-064.

2.5.1.4 Results

The cars completed the acceleration tests successfully. A copy of the log for test runs 49 and 55 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume II.

2.5.2 BLENDED BRAKING DECELERATION - ESC-P-3001-TT

2.5.2.1 Objective

To determine the overall deceleration characteristics of the test vechicle utilizing the blended braking system as affected by controller input level, line voltage, car weight (load weighting), car direction, and train consist. Regeneration capability will be tested at varying line load.

2.5.2.2 Description

The test vehicle was decelerated at the required controller command on level tangent track. The following test combinations can be tested:

Procedure Option	Prime Variable	Test Conditions
(5)	Controller level	Half and full brake
(6)	Car weights	AW0, AW2, AW3
(7)	Line voltage	Min, 600, & max. volts
(8)	Train consists	2-car train
(4)	Car direction	Forward and reverse
(10)	Regeneration (Load)	100% and 50% line receptivity

2.5.2.3 Procedure

Cars 3700 and 3701, under AW0, AW2 and AW3 conditions were subjected to deceleration tests in accordance with procedures described in AiResearch documents 73-9373 and 74-10441 in conformance with Test Set Number ESC-P-3001 of TSC General Vehicle Test Plan GSP-064.

2.5.2.4 Results

The cars completed the blended braking deceleration tests successfully. A copy of the log for test runs 55 and 76 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume II.

2.5.3 SERVICE FRICTION DECELERATION - ESC-P-3002-TT

2.5.3.1 Objective

To determine the overall deceleration characteristics of the test vehicle utilizing the friction braking only system as affected by controller input level, car weight (load weighting), car direction, and train consist.

2.5.3.2 Description

The test vehicle was decelerated at the required controller command on level tagent track. The following test combinations can be tested:

Procedure Option	Prime Variable	Test Conditions
(5)	Controller level	Half and full brake
(6)	Car weights	AW0, AW2, AW3
(7)	Train consists	2-car train
(4)	Car direction	Forward and reverse

2.5.3.3 Procedure

Cars 3700 and 3701 under AW0, AW2 and AW3 conditions were subjected to deceleration tests contained in AiResearch document 74-10441 in conformance with Test Set Number ESC-P-3002-TT of TSC General Vehicle Test Plan GSP-064.

2.5.3.4 Results

Runs 1 through 8 of the service friction deceleration tests were successfully completed. During run No. 9, a QSD was initiated due to a fault in car 3700, flywheel No. 1 Testing was discontinued for approximately the next four weeks while both cars were subjected to a thorough checkout under AW0 conditions.

A copy of the log for test runs 54, 55, 67, and 76 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume II. Runs 56 through 66 were conducted to check out the ESS and its associated hardware and were not considered germaine to test results, therefore, data and log sheets for runs 56 through 66 are not included herein.

2.5.4 TRACTION RESISTANCE (DRIFT) - ESC-P-4001-TT

2.5.4.1 Objective

To determine the traction (train) resistance of the test vehicle for use in the analysis of adhesion test data, to check the coefficients used to calculate the design performance of the vehicle, and as a baseline for analysis of the vehicle tractive and braking effort values.

2.5.4.2 Description

During the drift tests the test consist was allowed to coast from an initial speed on level tangent track. Both propulsion and friction brake were disabled to attain a true coast. The speed-time-distance data is the source of the final resistance values.

Procedure Option	Prime Variable	Test Conditions
(2)	Car weight	AW0 and AW2
(3)	Train consist	2-car train

2.5.4.3 Procedure

Cars 3700 and 3701 under AW0 conditions were subjected to the drift test contained in AiResearch documents 73-9373 and 74-10441 in conformance with Test Set Number ESC-P-4001-TT of TSC General Vehicle Test Plan GSP-064.

2.5.4.4 Results

The cars completed the drift tests successfully. A copy of the log for test runs 34, 71, and 74 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume II.

2.5.5 FRICTION BRAKE DUTY CYCLES - ESC-P-5001-TT

2.5.5.1 Objective

To determine the thermal capacity of the vechicle's friction braking system during a sample service run. The dynamic brake system will be inoperative during the tests with the friction brake providing all of the decelerating force, as applicable.

2.5.5.2 Description

The test vehicle was accelerated to a target cruise speed, cruised for a defined time, then brake was applied to a simulated station stop. Following a defined station dwell the cycle was repeated.

Procedure Option	Prime Variable	Test Conditions
(1)	Cruise speed and time	35 mph for 45 sec. 50 mph for 55 sec.
(2)	Car weight	AW2 (or AW3)
(3)	Brake type	Solid wheels
(5)	Brake blending	Blended & friction only

2.5.5.3 Procedure

Cars 3700 and 3701 under AW2 conditions were subjected to the friction brake duty cycle test contained in AiResearch document 74-10441 in conformance with Test Set Number ESC-P-5001-TT of TSC General Vehcile Test Plan GSP-064.

2.5.5.4 Results

The cars successfully completed the friction brake duty cycle tests. A copy of the log for test runs 77 and 81 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume II.

2.5.6 POWER CONSUMPTION - ESC-PC-5011-TT

2.5.6.1 Objective

To determine the power consumption of the test vehicle while operating on a sample service route at a defined level of schedule performance. The tests will provide a measure of car schedule performance, power consumption (regeneration), and overall traction system efficiency.

2.5.6.2 Description

The cars were operated over a simulated route with stops at specified stations. Normal service performance will be used. Power consumed by the traction and auxifliaries will be measured for each stop and the round-trip. The following test combinations can be tested.

Procedure Options	Prime Variable	Test Conditions
(1)	Car weight	AW2
(2)	Regeneration	100% and 0%
(3)	Regeneration (Load)	100% and 50%
(4)	Line voltage	Min, 600, & max. volts
(5)	Train consists	2-car train

2.5.6.3 Procedure

Cars 3700 and 3701 under AW0 and AW3 conditions were subjected to power consumption tests contained in AiResearch document 73-9373 in conformance with Test Set Number ESC-PC-5011-TT of TSC General Vehicle Test Plan GSP-064.

2.5.6.4 Results

The cars completed the power consumption tests successfully. However, during these tests there were QSD`s that were traced to underrated SCR`s and a zener causing a malfunction to the No. 2 flywheel alternator stator on car 3700. These SCR`s and zener had not been updated to the latest configuration due to their unavailability.

A copy of the log for test runs 35 through 48 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume II. The data obtained also includes power for the motor-generator set air compressor.

2.5.7 RADIO FREQUENCY INTERFERENCE - ESC-PSI-6001-TT

2.5.7.1 Objective

To determine levels of broadband radiated electromagnetic emission from the test vehicle to the wayside.

2.5.7.2 Description

This test to be performed with test vehicle passing by a wayside station under each of the following conditions:

(a) Acceleration above and below base speed

(b) Constant speed

(c) Braking

2.5.7.3 Procedure

Cars 3700 and 3701 under AWO conditions were subjected to the radio frequency interference test contained in AiResearch document 74-10441 in conformance with Test Set Number ESC-PSI-6001-TT of TSC General Vehicle Test Plan GSP-064. The following operations were performed during EMI evaluation:

(a) Power consumption

(b) Duty cycles

(c) Reliability

(d) Acceleration/Deceleration

(e) Constant speed

2.5.7.4 Results

The cars successfully completed the radio frequency interference tests. A copy of the log for test runs 80 through 82 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume II.

2.5.8 WAYSIDE EQUIPMENT NOISE SURVEY - ESC-CN-0001-TT

2.5.8.1 Objective

To determine the contribution of equipment noise to total test vehicle signature.

2.5.8.2 Description

This test was performed at a boarding platform area.

2.5.8.3 Procedure

Cars 3700 and 3701 under AW3 conditions were subjected to the external noise level tests contained in AiResearch documents 73-9373, and 74-10441 in conformance with Test Set Number ESC-CN-0001-TT of TSC General Vehicle Test Plan GSP-064.

2.5.8.4 Results

The cars completed the wayside equipment noise survey tests successfully. During the performance these tests there were several malfunctions; the main malfunction was on car 3700, flywheel No. 2, which required replacement.

A copy of the log for test runs 51 through 54 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume III.

2.5.9 WAYSIDE EFFECT OF CAR SPEED - ESC-CN-1001-TT

2.5.9.1 Objective

To determine wayside noise levels during vehicle passbys during constant speed conditions.

2.5.9.2 Description

This test was performed at a wayside station 50 feet from the track for the following conditions:

(a) Car weights of AW0 and AW3

(b) Single car and multiple units

(c) Five selected speeds

2.5.9.3 Procedure

Cars 3700 and 3701 under AW3 conditions were subjected to the external noise level tests contained in AiResearch document 73-9373 in conformance with Test Set Number ESC-CN-1001-TT of TSC General Vehicle Plan GSP-064.

2.5.9.4 Result

The cars completed the wayside effect of car speed tests successfully. A copy of the log for test runs 51 through 54 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume III.

2.5.10 ON CAR EFFECT OF SPEED - ESC-PN-1001-TT

2.5.10.1 Objective

To determine noise levels inside the test vehicle while operating at various speeds.

2.5.10.2 Description

This test was performed at the following conditions:

(a) Car weights of AW0 and AW3

(b) Four car interior locations

(c) Five car speeds

2.5.10.3 Procedure

The tests were performed in accordance with procedures described in AiResearch document 73-9373 in conformance with Test Set Number ESC-PN-1001-TT of TSC General Vehicle Test Plan GSP-064.

2.5.10.4 Results

The cars successfully completed the effect of speed test a copy of the log for test run 72 is included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume III.

2.5.11 ON CAR EFFECT OF TRACK SECTION - ESC-PN-1101-TT

2.5.11.1 Objective

To determine the effect of the track construction on interior noise levels.

2.5.11.2 Description

This test was performed at one test vehicle weight (AWO) and one speed on all sections of the UMTA test track.

2.5.11.3 Procedure

The tests were performed in accordance with procedures described in AiResearch document 74-10441 in conformance with Test Set Number ESC-PN-1101-TT of TSC General Vehicle Test Plan GSP-064.

2.5.11.4 Results

The cars successfully completed the effect of track section test. A copy of the log for test run 72 is included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume III.

2.5.12 INTERIOR NOISE SURVEY - ESC-PN-1301-TT

2.5.12.1 Objective

To determine the noise characteristics of the test vehicle by a survey of various passenger locations.

2.5.12.2 Description

This test was performed at a single test vehicle weight (AWO) while operating at a constant speed.

2.5.12.3 Procedure

Cars 3700 and 3701 under AWO and AW3 conditions were subjected to interior noise level tests contained in AiResearch documents 73-9373 and in conformance with Test Set Number ESC-PN-1301 of TSC General Vehicle Test Plan GSP-064.

2.5.12.4 Results

The cars performed th interior noise survey tests successfully but experienced a malfunction during the noise level run. The QSD encountered during the test was due to a faulty diode in the auxiliary generator circuit of car 3701. This diode was of a lower rating than that specified by the latest design configuration.

The faulty diode was replaced with ahigher rated diode per latest drawing. Car 3701 now has a complete diode set per latest drawings.

A copy of the log for test runs 50, 71, and 72 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume III.

2.5.13 ON CAR ACCELERATION EFFECT - ESC-PN-2001-TT

2.5.13.1 Objective

To determine noise levels inside the test vehicle while accelerating.

2.5.13.2 Description

This test was performed on selected interior test points at test vehicle weights of AW0 and AW3.

2.5.13.3 Procedure

The tests were performed in accordance with procedures described in AiResearch documents 73-9373 and 74-10441 in conformance with Test Set Number ESC-PN-2001-TT of TSC General Vehicle Test Plan GSP-064.

2.5.13.4 Results

The cars successfully completed the acceleration effect tests. A copy of the log for test runs 53, 67, and 72 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume III.

2.5.14 ON CAR DECELERATION EFFECT - ESC-PN-3001-TT

2.5.14.1 Objective

To determine noise levels inside the test vehicle while decelerating.

2.5.14.2 Description

This test was performed on selected interior test points for various braking configuration at test vehicle weights of AW0 and AW3.

2.5.14.3 Procedure

The tests were performed in accordance with procedures described in AiResearch documents 73-9373 and 74-10441 in conformance with Test Set Number ESC-PN-3001-TT of TSC General Vehicle Test Plan GSP-064.

2.5.14.4 Results

The cars successfully completed the deceleration effect tests. A copy of the log for test runs 53, 67, and 72 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume III.

2.5.15 VERTICAL DYNAMIC SHAKE TEST - ESC-R-0001-XX

2.5.15.1 Objective

To determine the vehicle vertical natural modes and frequencies.

2.5.15.2 Description

This test will include performing frequency sweeps of the vehicle by using a shaker to provide excitation forces. These sweeps will be generated for selected locations of the vehicle to determine the natural frequencies. At these natural frequencies detailed probes of the vehicle are necessary to determine the associated mode shapes. This test will be performed at car weights of AW0, AW2 and AW3.

2.5.15.3 Procedure

Cars 3700 and 3701, under AW0, AW2, and AW3 conditions, were subjected to the vertical shake test described in AiResearch document 74-10441 in conformance with Test Set Number ESC-R-0001-XX of TSC General Vehicle Test Plan GSP-064.

2.5.15.4 Results

The cars successfully completed the vertical shake tests. A copy of the log for test runs 83 through 86 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume IV.

2.5.16 LATERIAL DYNAMIC SHAKE TEST - ESC-R-0002-XX

The lateral shake test was not performed due to the lack of a mounting fixture. (See log for test run 83 in Appendix C.)

2.5.17 LONGITUDINAL DYNAMIC SHAKE TEST - ESC-R-0003-XX

The longitudinal shake test was not performed due to the inability of the shaker to produce a measurable effect on the car body. (See log for test runs 83 through 86 in Appendix C.)

2.5.17.1 Objective

To determine the vibration levels of the test vehicle components while sationary on the UMTA test track.

2.5.17.2 Description

This test was performed on a stationary car at a known level section of track.

2.5.17.3 Procedure

Cars 3700 and 3701 under AW0 conditions were subjected to the component induced vibration tests described in AiResearch documents 73-9373 and 74-10441 in conformance with Test Set Number ESC-R-0010-TT of TSC General Vehicle Test Plan GSP-064.

2.5.17.4 Results

The cars successfully completed the component induced vibration tests. A copy of the log for test run 72 is included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume IV.

2.5.18 WORST SPEEDS - ESC-R-1101-TT

2.5.18.1 Objective

To determine worst steady vibration levels of the test vehicle on the UMTA test track.

2.5.18.2 Description

The following configurations were tested:

(a) Vehicle weights of AW0, AW2, and AW3

(b) All track sections including grade crossings and switches as required to simulate revenue service

(c) Select discrete vehicle speeds simulating revenue service and include V (max)

(d) Select other speeds as required to identify known or suspected acute vibration levels associated with carbody characteristics

2.5.18.3 Procedure

The tests were performed in accordance with procedures described in AiResearch document 74-10441 in conformance with Test Set Number ESC-R-1101-TT of TSC General Vehicle Test Plan GSP-064.

2.5.18.4 Results

The cars performed the worst speed tests successfully. A copy of the log for test runs 73 through 75 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume IV.

2.5.19 RIDE ROUGHNESS ACCELERATION - ESC-R-2001-TT

2.5.19.1 Objective

To determine the most servere vibration levels encountered during car acceleration.

2.5.19.2 Description

The test was performed on Track Section I at vehicle test weights of AW0, AW2, and AW3.

2.5.19.3 <u>Procedure</u>

The tests were performed in accordance with procedures described in AiResearch document 74-10441 in conformance with Test Set Number ESC-R-2001-TT of TSC General Vehicle Test Plan GSP-064.

2.5.19.4 <u>Results</u>

The cars successfully completed the ride roughness acceleration tests. A copy of the log for test runs 73, 78, and 79 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume IV.

2.5.20 RIDE ROUGHNESS DECELERATION - ESC-R-3001-TT

2.5.20.1 <u>Objective</u>

To determine the most severe vibration levels encountered during car deceleration.

2.5.20.2 <u>Description</u>

The test was performed on Track Section I at test vehicle weights of AW0, AW2, and AW3.

2.5.20.3 <u>Procedure</u>

The tests were performed in accordance with procedures described in AiResearch document 74-10441 in conformance with Test Set Number ESC-R-3001-TT of TSC General Vehcile Test Plan GSP-064.

2.5.20.4 <u>Results</u>

The cars successfully completed the ride roughness deceleration tests. A copy of the log for test runs 73, 78, and 79 are included in Appendix C. Details and data reduced from tapes recorded during these tests are presented in Volume IV.

3. TEST RESULTS

3.1 PERFORMANCE TESTS

The performance goal for acceleration and deceleration (blended braking) was to match the performance of the standard R-32 cars. Baseline data taken prior to modification indicated a full service braking rate of 3.45 mph/sec and an acceleration of 2.7 mph/sec at AW0 weight. The energy storage car demonstrated performance of 3.7 mph/sec and 3.0 mph/sec respectively for these single point conditions. General car performance characteristics for acceleration and deceleration rates are shown in Figures 3-1 and 3-2. The acceleration data shown is indicative of system operation without weight compensation of tractive effort.

Deceleration rate for the AW0 weight typically shows a high deceleration rate at the start of braking. This was caused by the jerk limit setting which permitted the friction brakes to apply before energization of the lockout magnet, which cuts out the friction brake system. In subsequent dynamic brake tests, this setting was corrected by reducing the jerk limit to closely coincide with the response time of the friction brake application.

All of the dynamic brake tests show a sharp rise in deceleration as the car speed approaches zero. This is again caused by the lockout magnet deenergizing, thus cutting out dynamic braking and applying friction braking at approximately 4 mph. The energy storage cars were purposely configured in this manner to permit trainlining with the standard R-32 cars.

Refer to Volume II for details concerning the performance tests.

3.2 POWER CONSUMPTION TESTS

The primary goal of the energy storage car is to reduce the power consumption required for the conventional car. The overall results of the tests show that the advantages listed in Section 1 are attainable in practice, while still retaining the basic performance characteristics of the R-32 vehicle.

A typical 3000 foot run shown in Section 7 of Volume II, provides a means of comparison for the ESC and the unmodified R-32 (no unmodified R-32 test data was taken at Pueblo).

Figure 3-3 shows selected parameters from test run 78 record 1317. A plot of the traction motor armature current, multiplied by 2 is superimposed on the 3rd rail input current. Although not an exact comparison it is closely representative of R-32 car versus ESC 3rd rail input current and

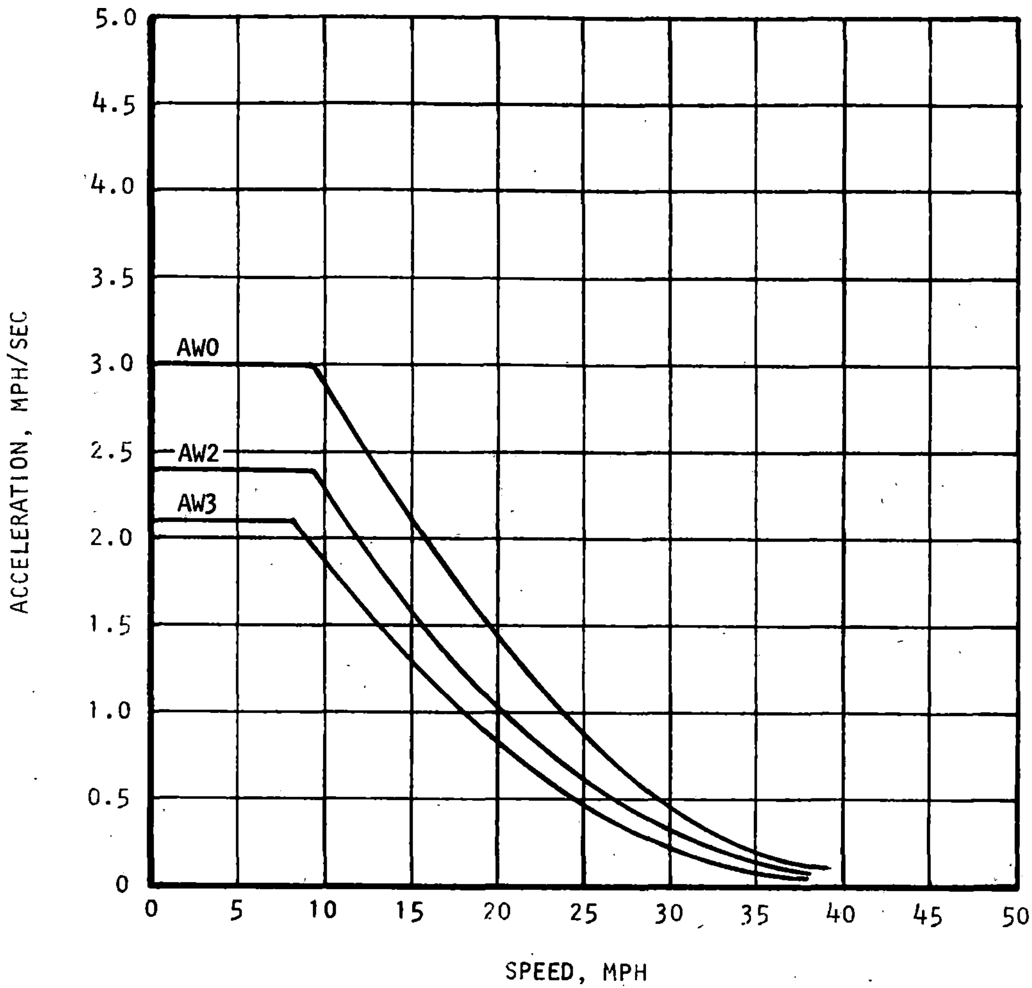


Figure 3-1. Parallel Mode-Acceleration vs Speed

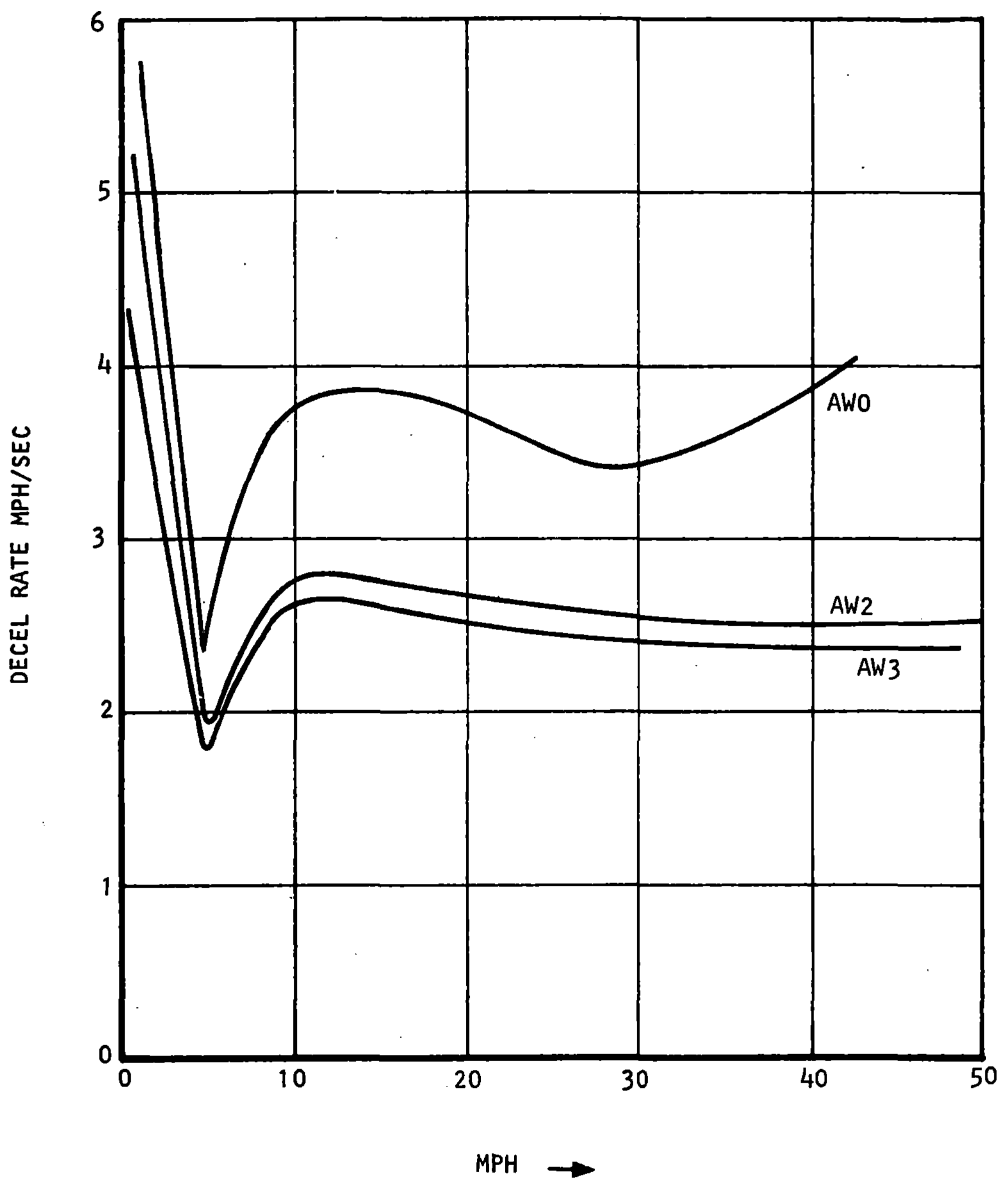


Figure 3-2. Full Service Brake-Deceleration Rate vs Speed

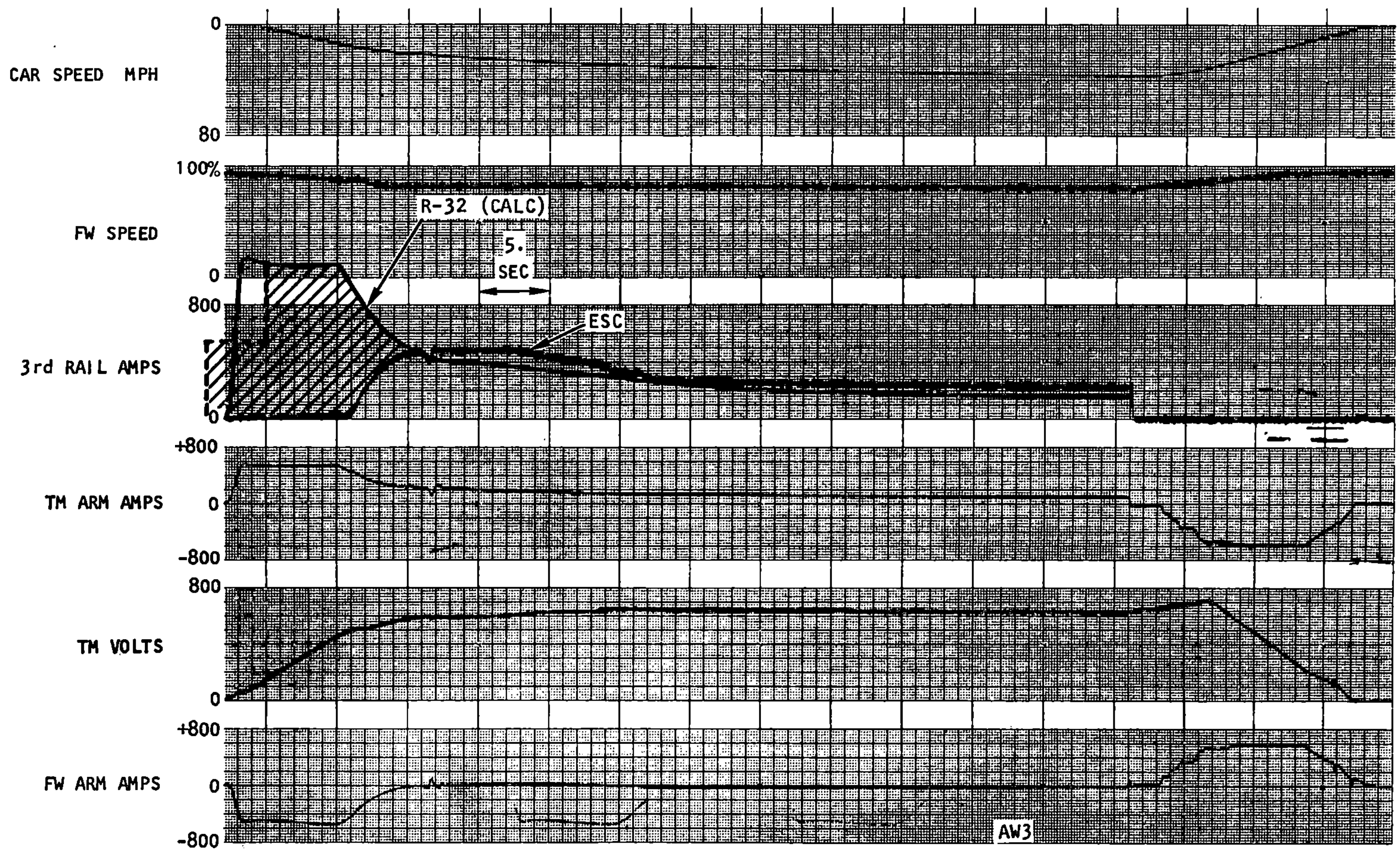


Figure 3-3. AWO Run 78/1317-3000 Foot Level Tangent Track

graphically shows the advantages referred to previously. Quantitatively the comparison is as follows for this 3000 foot run:

	ESC	R-32 (Calculated)
Peak line current	490 amps	1120 amps
RMS line current	257 amps	421 amps
Kw hrs/cm (approx)	4.7	6.9

The implied energy saving is slightly in excess of 31 percent. The above values are for AW3 weight and do not include any station stop time.

A summary of the power consumption tests is shown in Figure 3-4. The curves shown here are faired-in averages of the clockwise and anticlockwise laps made for constant station stop distances. Actual test data for the AW0, 2000 foot station stop runs was appreciably better than the faired curve; it averaged 3.7 kw hrs/cm as shown in the detailed results of Volume II.

The relationship between flywheel speed and vehicle speed is shown in Figure 3-5 for a representative 3000 foot station-to-station run. This figure is a machine plot of the data shown in Figure 3-3.

Refer to Volume II for details concerning the power consumption tests.

3.3 RADIO FREQUENCY INTERFERENCE TESTS

The interior and wayside electromagnetic interference was measured for the 0.15 to 400 MHz range and plots are shown in Volume II for the various conditions of propulsion equipment. The data shown in Figure 3-6 shows the maximum exterior emissions levels relative to ambient.

The reference goals for SOAC (state-of-the-art car) are superimposed on Figure 3-6 as a matter of interest. It should be noted that SOAC did meet the requirement, however, the test location was at the far side of the track (in the southwest corner) where the background noise was at a much lower level. The ESC tests were carried out at a location near the north end of track Section I.

Refer to Volume II for details concerning the radio frequency interference tests.

3.4 EXTERIOR NOISE TESTS

The wayside noise measured at platform level and 50 feet away from the side of the car indicates that the noise range is greater than the standard under-car rotating equipment. Summary plots of these data are shown in Figures 3-7 and 3-8.

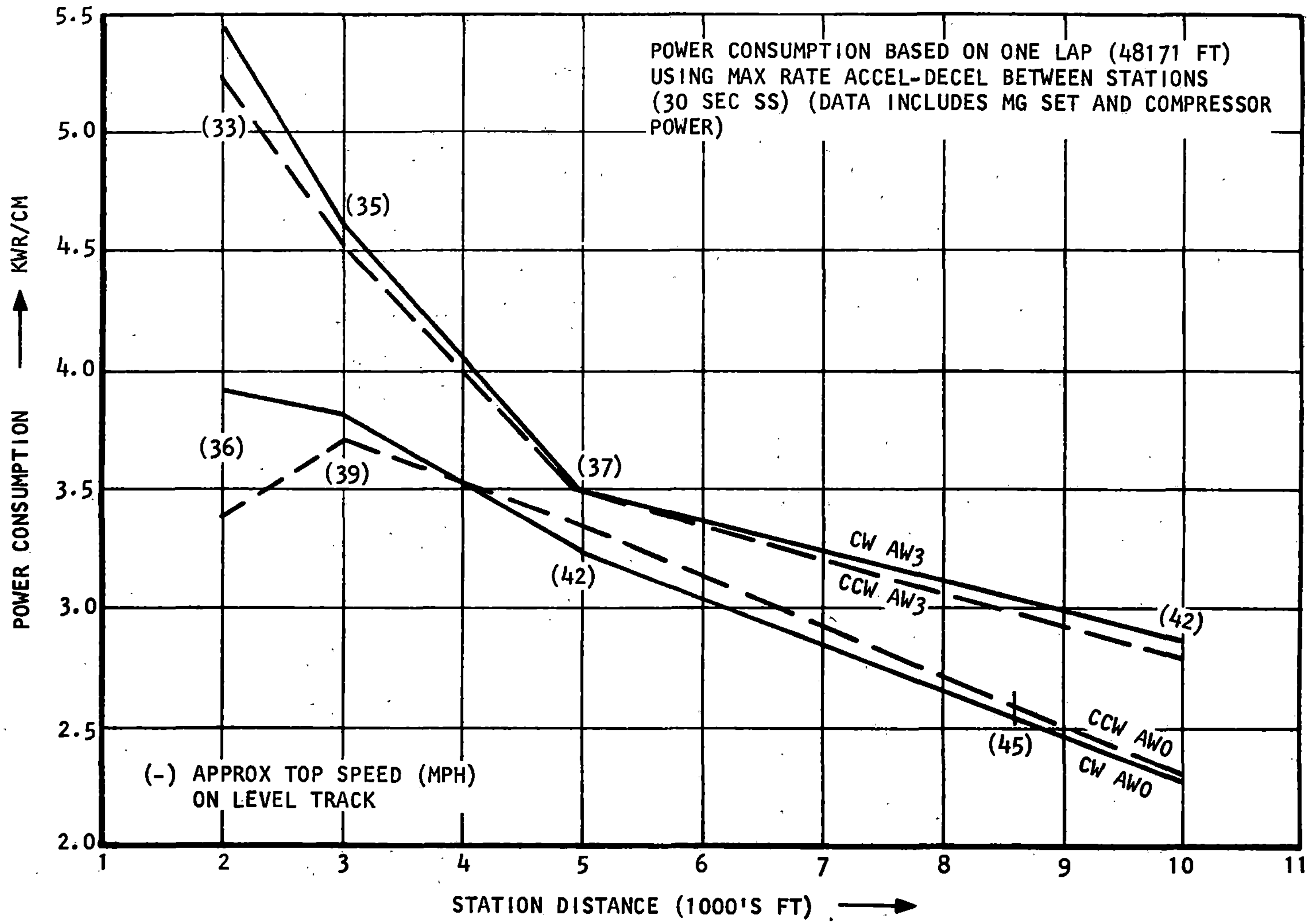


Figure 3-4. Power Consumption Test Summary

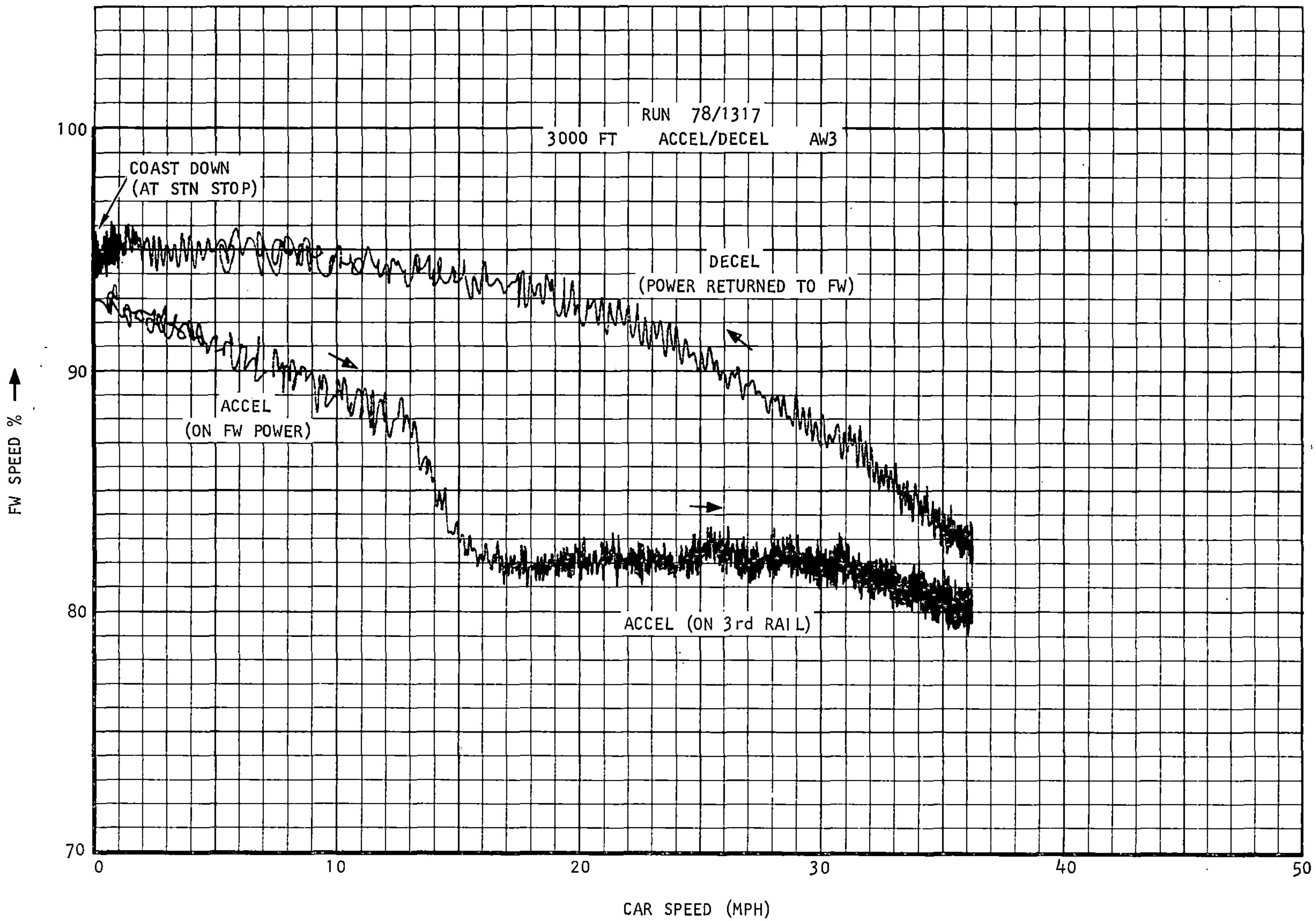


Figure 3-5. Flywheel Speed vs Car Speed

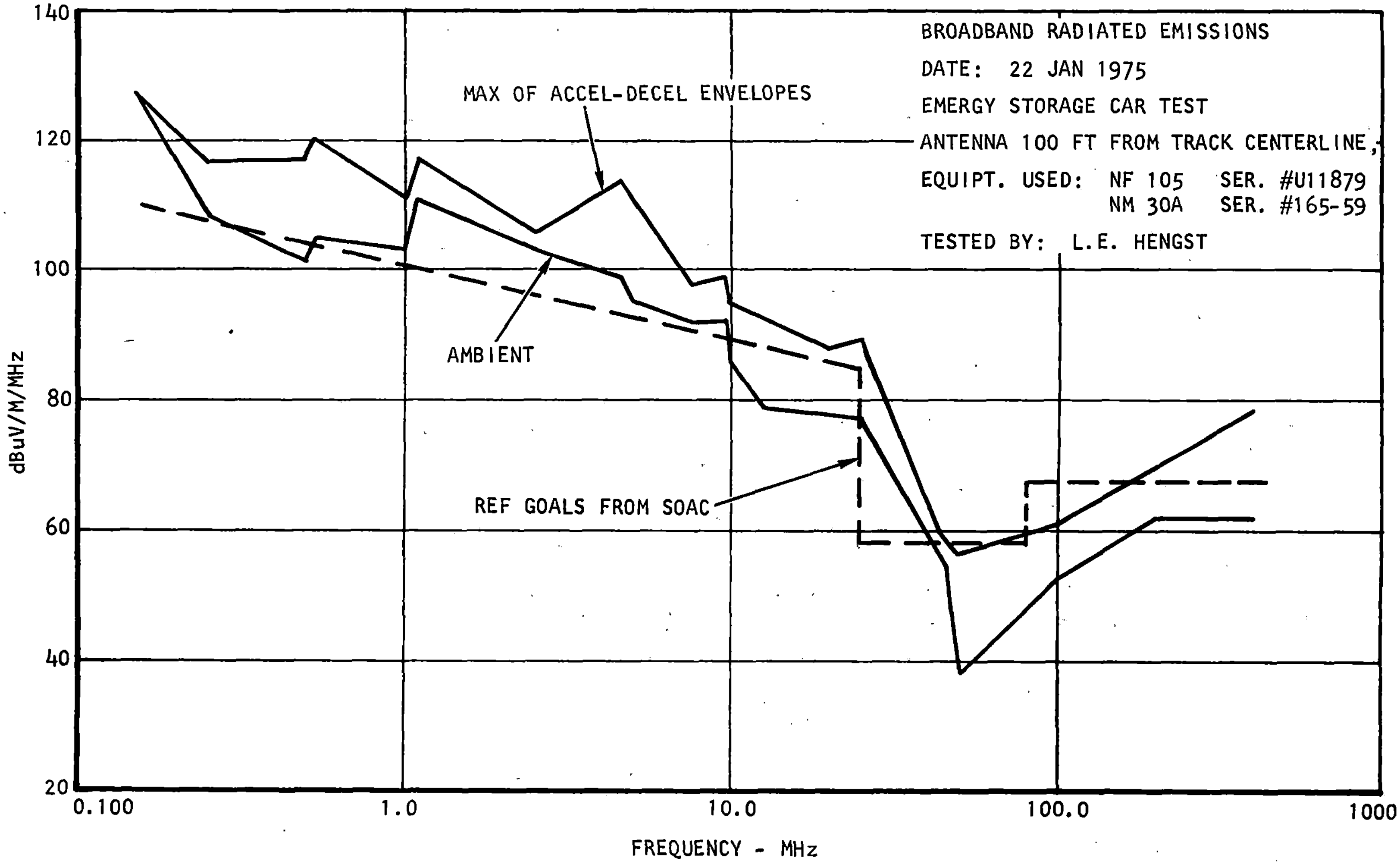


Figure 3-6. Broadband Radiated Emissions Tests-Exterior

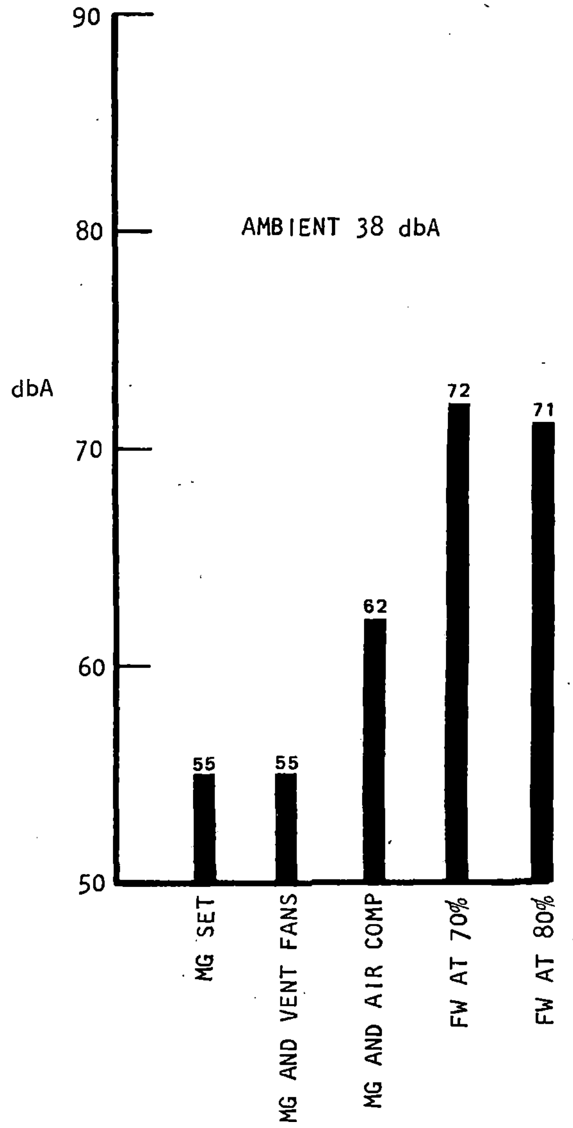


Figure 3-7. Exterior Noise Summary - Microphone 50 Feet From Track

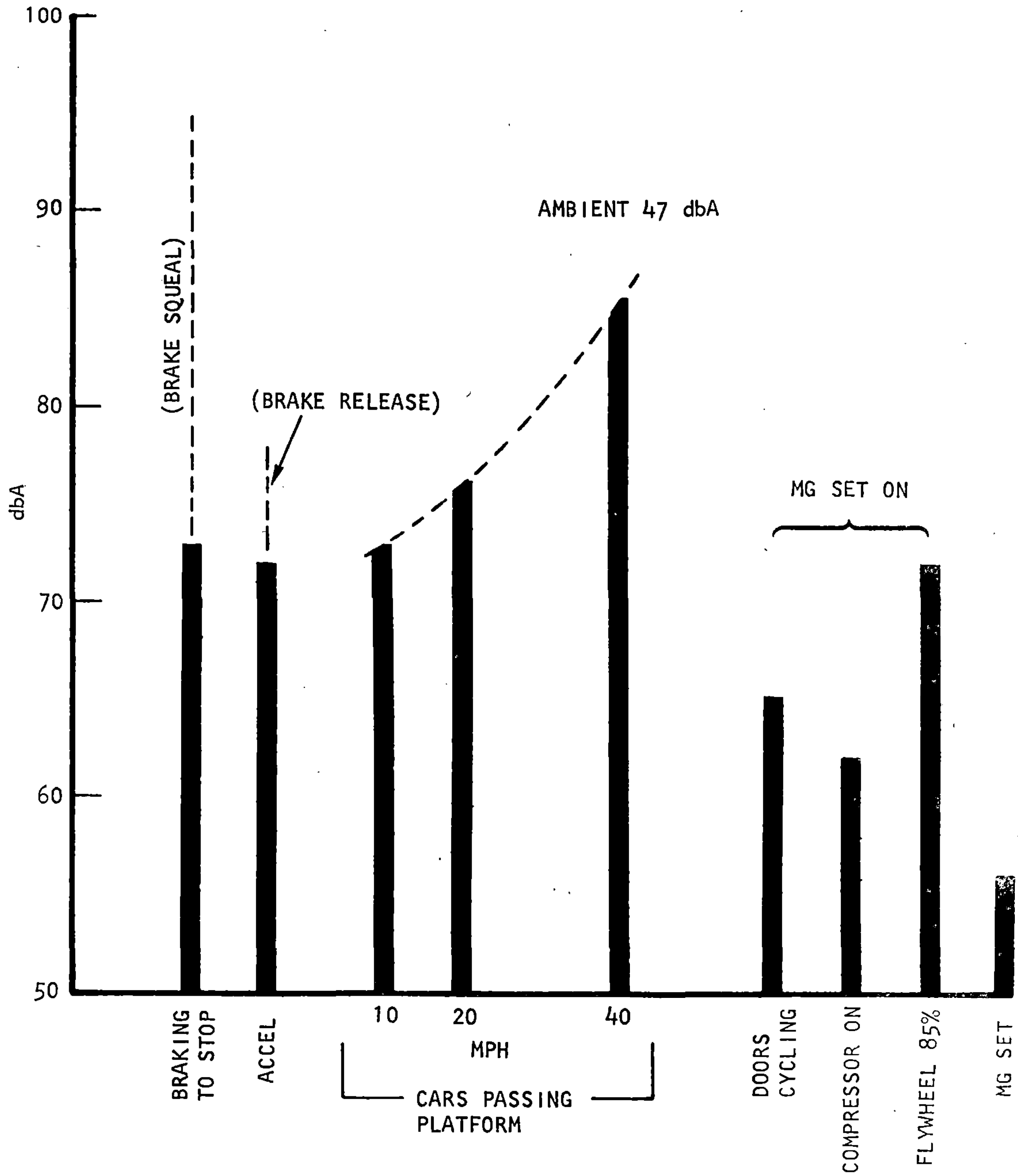


Figure 3-8. Exterior Noise Summary - Microphone on Platform

The under-car equipment noise, with car not moving, shows very little increase in level at the platform. Microphone perspective may account for this since only one platform location was used. Direct propagation from equipment on the far side and the ends of the train is partially blocked.

Moving vehicle data is shown at the center and left side of Figure 3-8. The momentary phenomena of brake squeal raching 95 dbA is the highest level. Generally the wheel rail noise at the platform is below 75 dbA except for fast moving cars.

At the time that these tests were conducted, the car wheels contained number of flats which would have some effect on the db levels recorded. A chart with the number and length of flats per wheel is shown in Figure 3-9.

Refer to Volume III for details concerning the exterior noise tests.

3.5 INTERIOR NOISE TESTS

Equipment interior noise contribution is summarized in Figure 3-10. The flywheel is the largest input with a slightly higher level at the low speed end of its operating range.

Noise levels in the moving train are shown in Figure 3-11 for different locations in the car at 40 mph. Higher levels toward the number two end are probably due to the adjacent car.

Runs were made over the six different track sections at constant speed. The noise level summary for these runs is shown in Figure 3-12 along with the configuration of each rail section.

The higher ambient noise levels for the interior tests is probably due to the proximity of the gas driven generator used to power the instrumentation equipment.

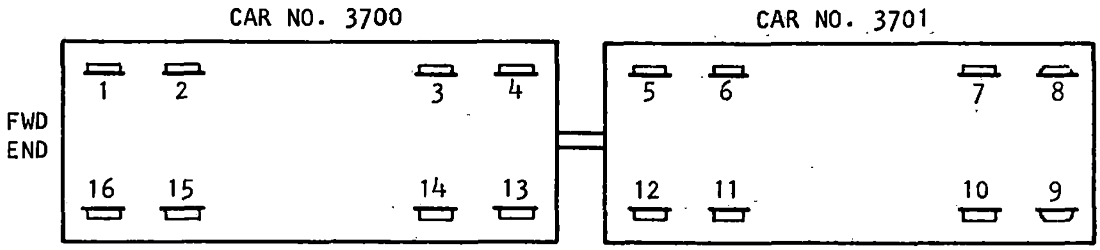
Refer to Volume III for details concerning the interior noise tests.

3.6 RIDE ROUGHNESS TESTS

The induced dynamic shake and vibration levels for ride roughness evaluation is presented for a wide range of conditions. The modification with the energy storage propulsion system was not expected to cause any significant changes from the standard R-32 car in these parameters and the test results did not uncover any unusual characteristics. The shake tests revealed that the first three car body bending modes (at AWO car weight) had natural frequencies of 7, 10.5 and 14.5 Hz. The results of the shake tests are shown in Figures 3-13 through 3-15.

Since there was no dominant worst speed condition the ride quality tests were run at a speed that could be controlled and maintained. Readings were taken at a carspeed of 35 mph, at two locations in the car for each track section as shown in the summary plots of Figures 3-16.

WHEEL LOCATION



Wheel No.	Number of Flats/Wheel		
	1-in.-Long	1.5-in.-Long	2-in.-Long
1	3	-	-
2	5	2	-
3	2	1	-
4	4	2	1
5	3	-	-
6	3	3	-
7	1	-	-
8	3	2	-
9	2	-	-
10	1	-	-
11	2	1	-
12	-	1	-
13	1	4	-
14	1	2	-
15	6	1	-
16	1	-	-

Figure 3-9. Wheel Flats Measurement

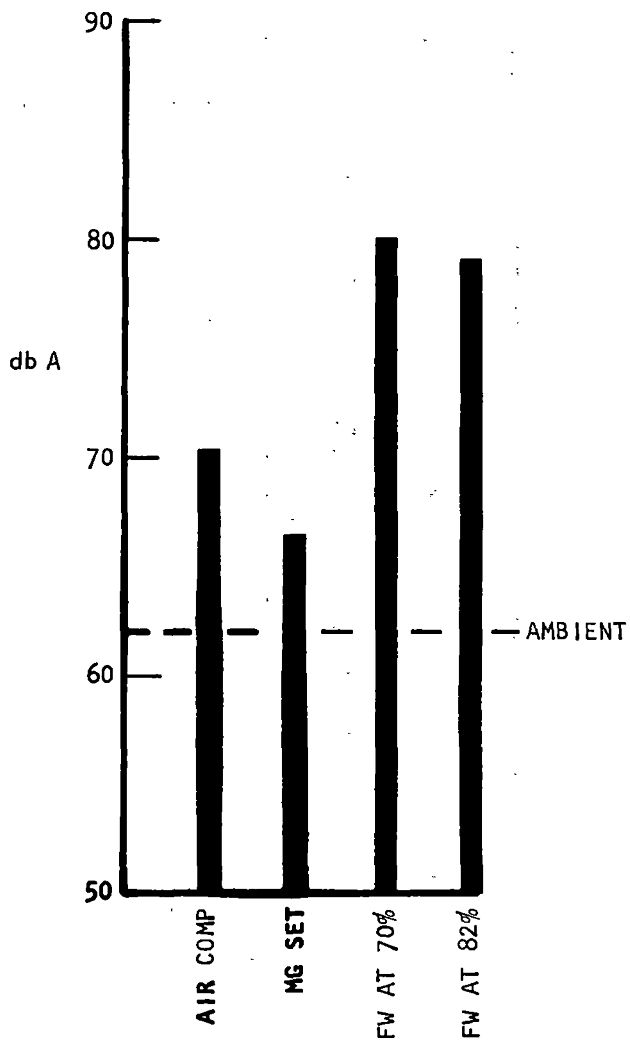


Figure 3-10. Interior Noise Summary - Equipment Noise Survey

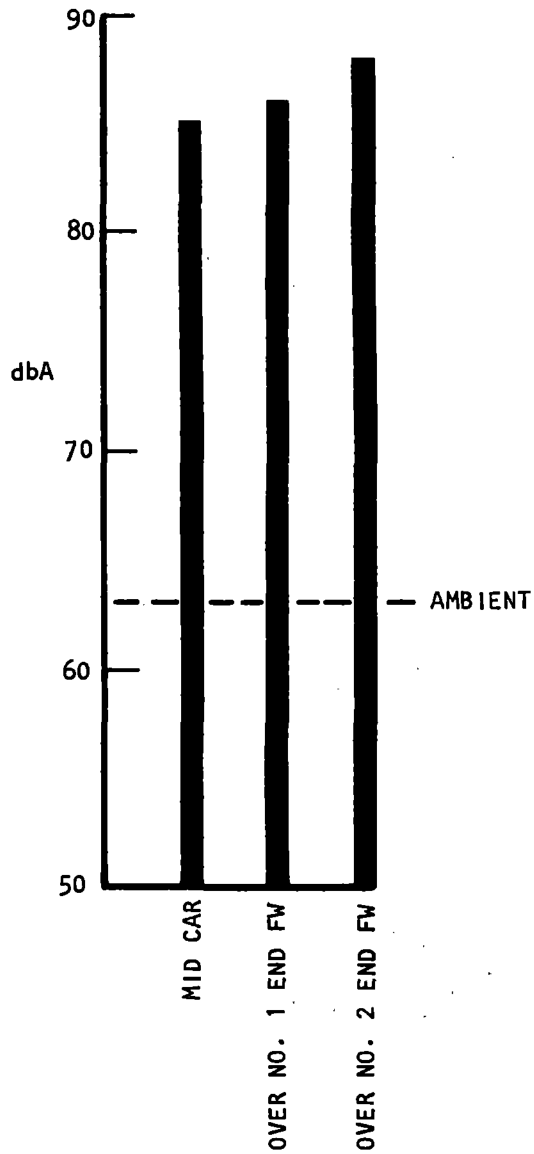


Figure 3-11. Interior Noise Summary - Constant Speed

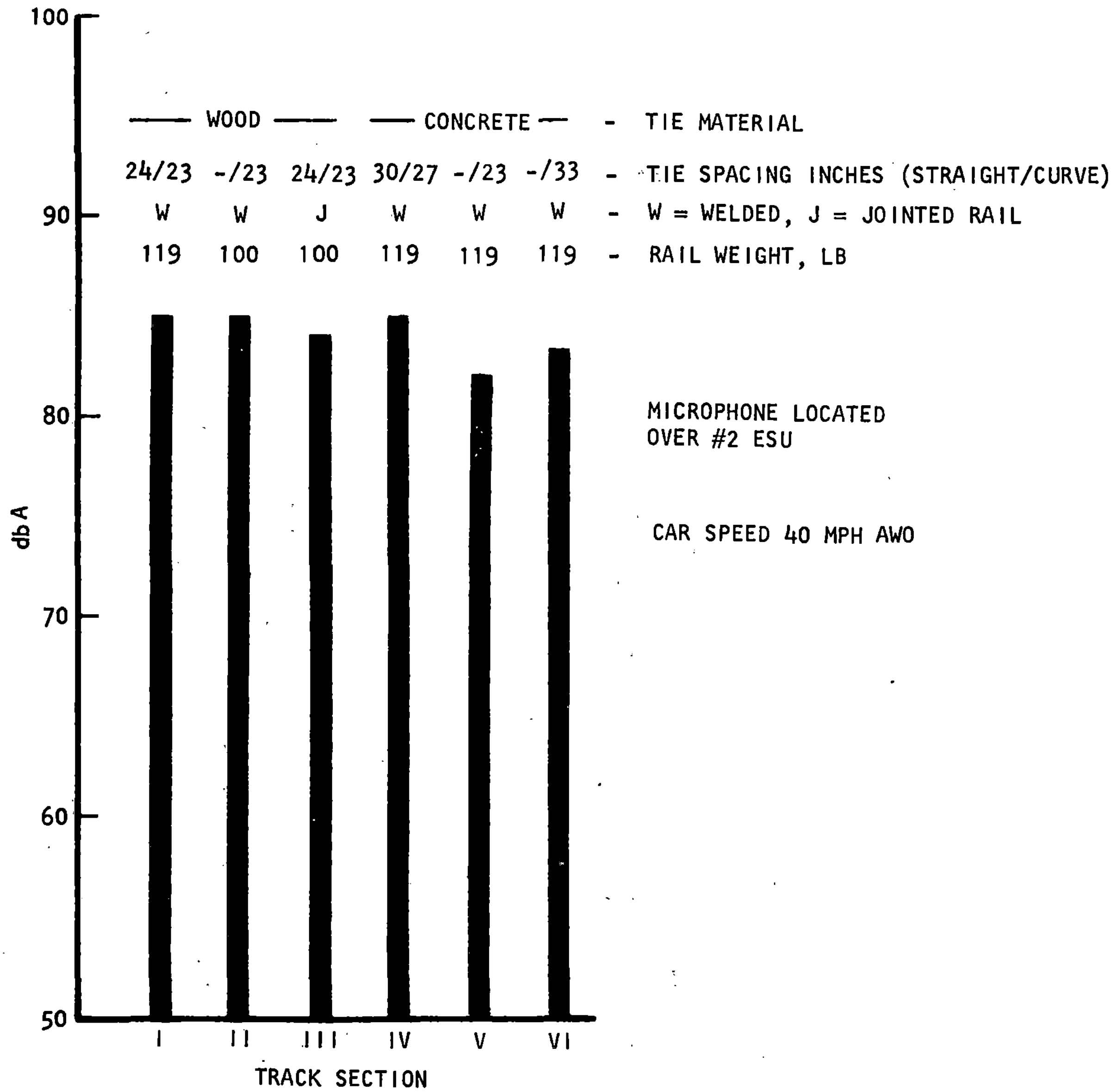


Figure 3-12. Interior Noise Summary-Track Configuration

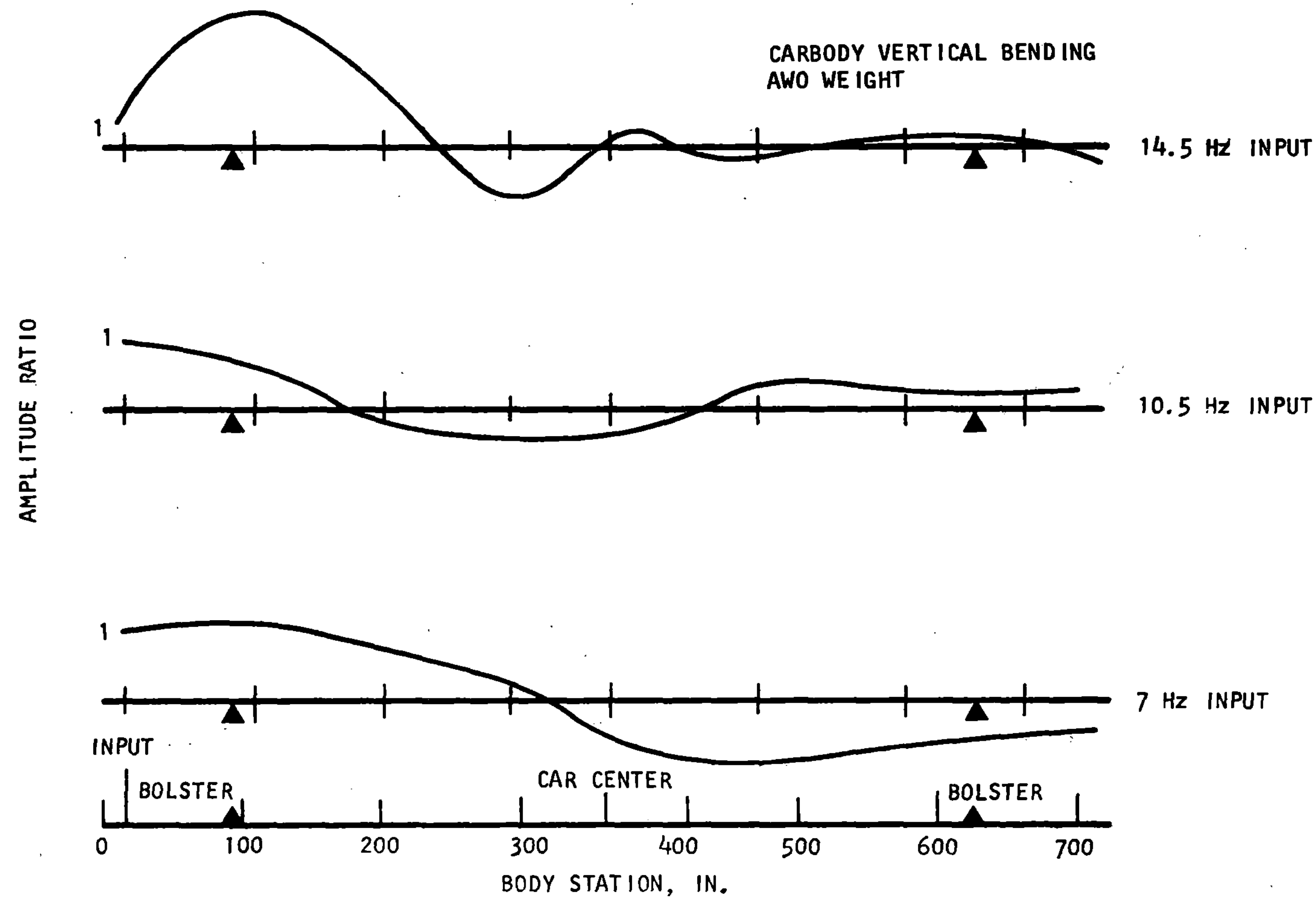


Figure 3-13. AWO Dynamic Shake Test - Vertical Mode

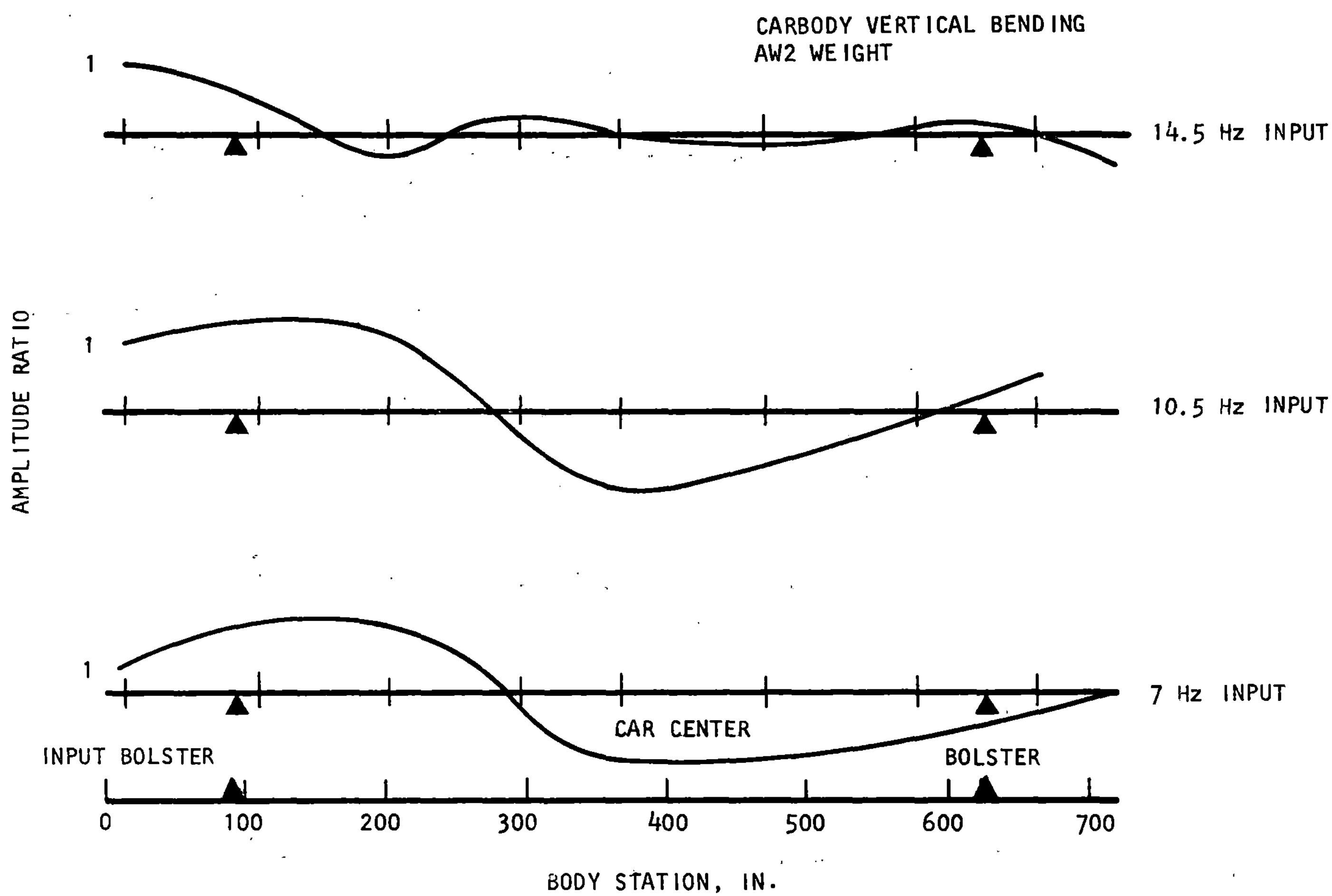


Figure 3-14. AW2 Dynamic Shake Test-Vertical Mode

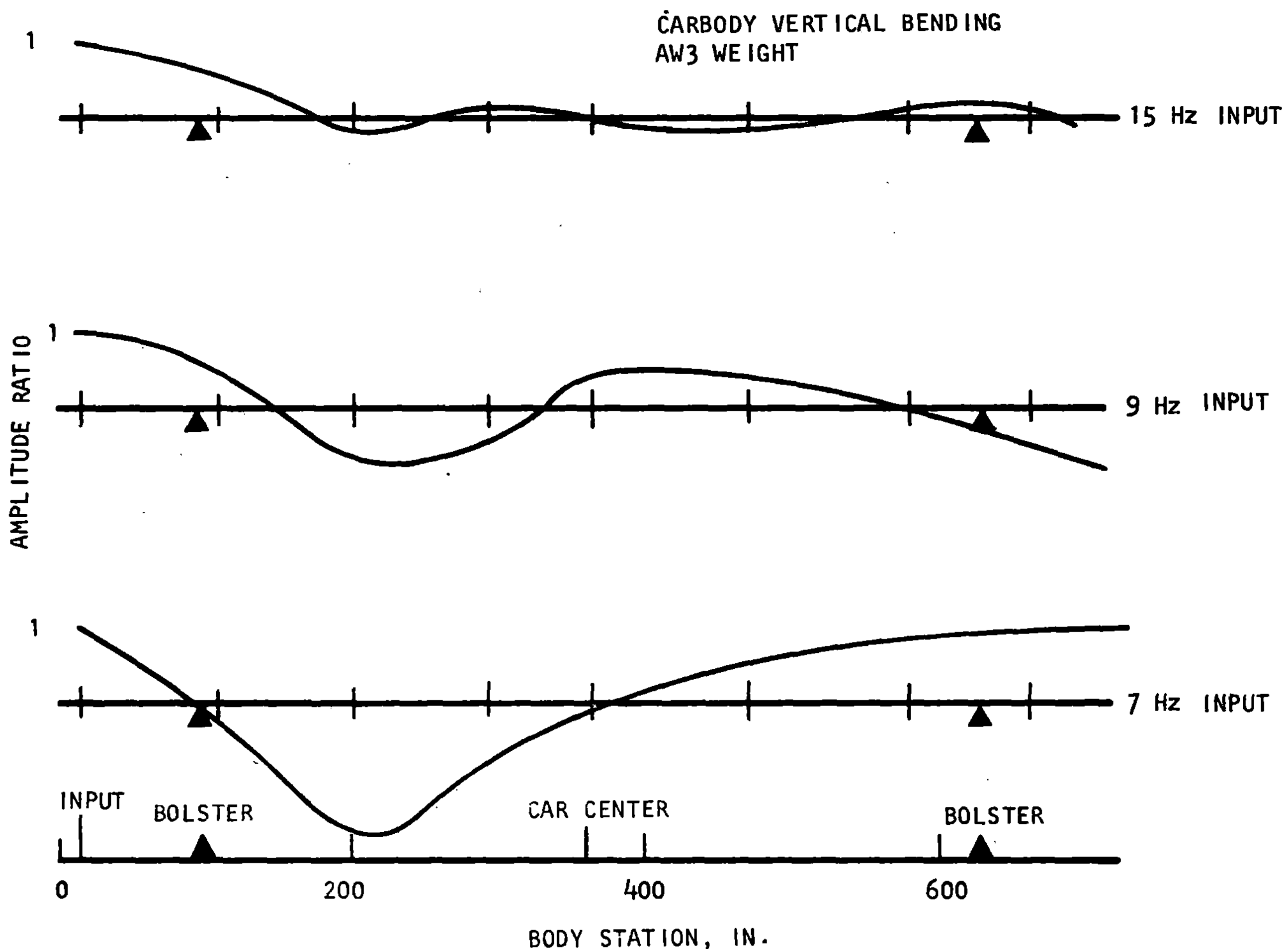
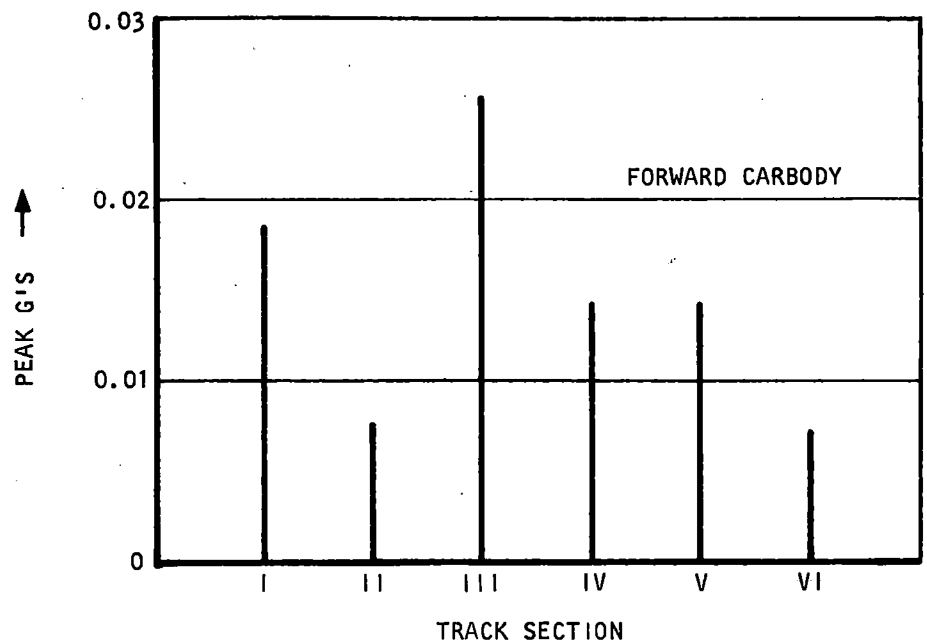


Figure 3-15. AW3 Dynamic Shake Test-Vertical Mode



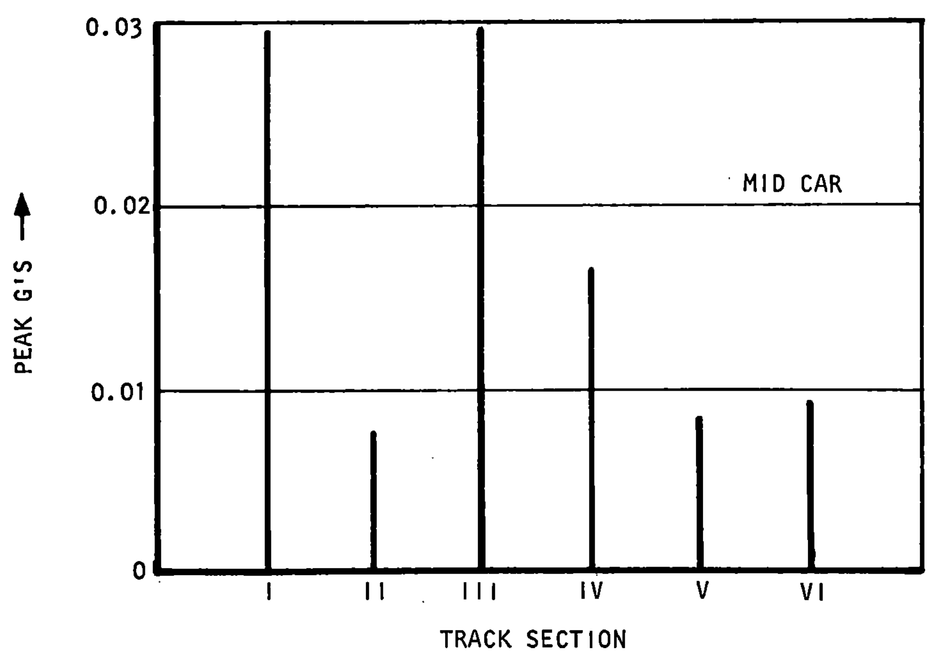


Figure 3-16. Ride Roughness Summary-Track Section Survey

Subjectively, track Section III seemed to provide the roughest ride and this was probably due to the ballast condition at the time of the test. High speed locomotive tests were being run on the track at night during this period.

Refer to Volume IV for details concerning the ride roughness tests.

APPENDIX A

REPORT OF INVENTIONS APPENDIX

The engineering tests conducted on the Energy Storage Cars utilized state-of-the-art testing technology and did not involve inventions or innovations. Development of the Energy Storage System being tested was carried out by Garrett AiResearch under a contract from the New York City Transit Authority. Inventions and innovations involved under that contract are not reported here.

APPENDIX B

TEST SET SUMMARY SHEETS

A GSP-064 Test Set summary sheet for each energy storage car test performed is provided here as a convenience for the reader. Each sheet covers the test objective, description, and status of a specific test.

TEST TITLE: ACCELERATION

TEST SET NUMBER: ESC-P-2001-TT

(Options 1 and 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 direct, 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	Half and full power
(6)	Line voltage	Min: 600: and max. volts
(5)	Car weights	AW0; AW2; AW3
(3)	Car direction	Forward and reverse
(7)	Train consists	Two car train

STATUS:

The energy storage cars successfully completed the acceleration tests as prescribed by the conditions specified in paragraph 2.1.2. Refer to test log runs 49 and 55 presented in Volume I, Appendix C of this report.

TEST TITLE: DECELERATION-BLENDED BRAKING

TEST SET NUMBER: ESC-P-3001-TT

(Options 1 through 3)

TEST OBJECTIVE:

To determine the overall deceleration characteristics of the test vehicle utilizing the blended braking system as affected by controller input level, line voltage, car weight (load weighing), car direction, and train consist. Regeneration capability will be tested at varying line "load".

TEST DESCRIPTION:

The test vehicle will be decelerated at the required controller command on level tangent track. The following (example) test combinations will be tested:

Procedure Option:	Prime Variable	Test Conditions
(5)	Controller Level	Half and full brake
(6)	Car weights	AW0; AW2; AW3
(7)	Line voltage	Min; 600; and max. volts
(8)	Train consists	Two car train
(4)	Car direction	Forward and reverse

STATUS:

The energy storage cars successfully completed the blended braking deceleration tests as prescribed by the conditions specified in paragraph 3.1.2 Refer to test log runs 55 and 76 presented in Volume I, Appendix C of this report.

TEST TITLE: DECELERATION - SERVICE FRICTION

TEST SET NUMBER: ESC-P-3002-TT

(Options 1 through 3)

TEST OBJECTIVE:

To determine the overall deceleration characteristics of the test vehicle utilizing the friction braking only system as affected by controller input level, car weight (load weighing), car direction, and train consist.

TEST DESCRIPTION:

The test vehicle will be decelerated at the required controller command on level tangent track. The following (example) test combinations will be tested:

Procedure Option	Prime Variable	Test Conditions
(5)	Controller level	Half and full brake
(6)	Car weights	AW0; AW2; AW3
(7)	Train consists	Two car train
(4)	Car direction	Forward and reverse

STATUS:

The energy storage cars successfully completed the service friction deceleration tests as prescribed by the conditions specified in paragraph 4.1.2. Refer to test log runs 54, 55, 67 and 76 presented in Volume I, Appendix C of this report.

TEST TITLE: TRACTION RESISTANCE (DRIFT)

TEST SET NUMBER: ESC-P-4001-TT

(Option 1)

TEST OBJECTIVE:

To determine the traction (train) resistance of the test vehicle for use in the analysis of adhesion test data, to check the coefficients used to calculate the design performance of the vehicle, and as a baseline for analysis of the vehicle tractive and braking effort values.

TEST DESCRIPTION:

During the drift tests the test consists will be allowed to coast from an initial speed on level tangent track. Both propulsion and friction brake systems will be disabled to attain a true coast. The speed-time-distance data will be the source of the final resistance values.

Procedure Option	Prime Variable	Test Conditions
(2)	Car weight	AW0 and AW2
(3)	Train consist	Two car train

STATUS:

The energy storage cars successfully completed the traction resistance tests as prescribed by the conditions specified in paragraph 5.1.2. Refer to test log runs 34, 71, 74 and 76 presented in Volume I, Appendix C of this report.

TEST TITLE: FRICTION BRAKE DUTY CYCLES

TEST SET NUMBER: ESP-P-5001-TT

TEST OBJECTIVE:

To determine the thermal capacity of the vehicle's friction braking system during a sample service run. The dynamic brake system will be inoperative during the tests with the friction brake providing all of the decelerating force, as applicable.

TEST DESCRIPTION:

The test vehicle will be accelerated to a target cruise speed, cruise for a defined time, and brake to a simulated station stop. Following a defined station dwell the cycle will be repeated.

Procedure Option	Prime Variable	Test Conditions
(1)	Cruise speed and time	35 mph for 45 sec. 50 mph for 55 sec.
(2)	Car weight	AW2 (or AW3)
(3)	Brake type	Solid and resilient wheels
(5)	Brake blending	Blended and frict. only

STATUS:

The energy storage cars successfully completed the friction brake duty cycle tests as prescribed by the conditions specified in paragraph 6.1.2. Refer to test log runs 77 and 81 presented in Volume I, Appendix C of this report.

TEST TITLE: POWER CONSUMPTION

TEST SET NUMBER: ESC-PC-5011-TT

TEST OBJECTIVE:

To determine the power consumption of the test vehicle while operating on a sample service route at a defined level of schedule performance. The tests will provide a measure of car schedule performance, power consumption and overall traction system efficiency.

TEST DESCRIPTION:

The car(s) will be operated over a simulated route with stops at specified stations. Normal service performance will be used. Power consumed by the traction and auxiliaries will be measured for each stop and the round-trip

Examples of test conditions

Procedure Options	Prime Variable	Test Conditions
(1)	Car weight	AW2
(2)	Line voltage	Min; 600; max. volts
(3)	Train consists	Two car train

STATUS:

The energy storage cars successfully completed the power consumption tests as prescribed by the conditions specified in paragraph 7.1.2. Refer to test log runs 35 through 48 presented in Volume I, Appendix C of this report.

TEST TITLE: RADIO FREQUENCY INTERFERENCE

TEST SET NUMBER: ESC-PSI-6001-TT

TEST OBJECTIVE:

To determine levels of broadband radiated electromagnetic emission from the test vehicle to the wayside.

TEST DESCRIPTION:

This test to be performed with test vehicle passing by a wayside station under each of the following conditions:

(a) Acceleration above and below base speed
(b) Constant speed
(c) Braking

STATUS:

The energy storage cars successfully completed the radio frequency interference tests as prescribed by the conditions specified in paragraph 8.1.2. Refer to test log runs 80 through 82 presented in Volume I, Appendix C of this report.

TEST TITLE: EQUIPMENT NOISE SURVEY - WAYSIDE

TEST SET NUMBER: ESC-CN-0001-TT

TEST OBJECTIVE:

To determine the contribution of equipment noise to total test vehicle signature.

TEST DESCRIPTION:

This test will be performed at a boarding platform area.

STATUS:

The energy storage cars successfully completed the equipment noise tests as prescribed by the conditions specified in paragraph 2.1.2. Refer to test log runs 51 through 54 presented in Volume I, Appendix C of this report.

TEST TITLE: EFFECT OF CAR SPEED - WAYSIDE

TEST SET NUMBER: ESC-CN-1001-TT

TEST OBJECTIVE:

Determine Wayside noise levels during vehicle passbys during constant speed conditions.

TEST DESCRIPTION:

This test will be performed at a wayside station 50 feet from the track for the following conditions:

(a) Vehicle weights of AW0 and AW3
(b) Single car and Multiple Units
(c) Five selected speeds

STATUS:

The energy storage cars successfully completed the exterior car speed tests as prescribed by the conditions specified in paragraph 3.1.2. Refer to test log runs 51 through 54 presented in Volume I, Appendix C of this report.

TEST TITLE: EFFECT OF CAR SPEED - ON CAR

TEST SET NUMBER: ESC-PN-1001-TT

TEST OBJECTIVE:

To determine noise levels inside the test vehicle while operating at various speeds.

TEST DESCRIPTION:

This test will be performed at the following conditions:

(a) Vehicle weights of AW0 and AW3
(b) Four car interior locations
(c) Five car speeds

STATUS:

The energy storage cars successfully completed the interior car speed tests as prescribed by the conditions specified in paragraph 4.1.2. Refer to test log run 72 presented in Volume I, Appendix C of this report.

TEST TITLE: EFFECT OF TRACK SECTION - ON CAR

TEST SET NUMBER: ESC-PN-1101-TT

TEST OBJECTIVE:

To determine the effect of track construction on interior noise levels.

TEST DESCRIPTION:

This test will be performed at one vehicle weight (AW0) and one speed on all sections of the UMTA test track.

STATUS:

The energy storage cars successfully completed the track section tests as prescribed by the conditions specified in paragraph 5.1.2. Refer to test log run 72 presented in Volume I, Appendix C of this report.

TEST TITLE: INTERIOR NOISE SURVEY

TEST SET NUMBER: ESC-PN-1301-TT

TEST OBJECTIVE:

To determine the noise characteristics of the test vehicle by a survey of various passenger locations.

TEST DESCRIPTION:

This test will be performed at one vehicle weight (AWO) while operating at a constant speed.

STATUS:

The energy storage cars successfully completed the interior noise tests as prescribed by the conditions specified in paragraph 6.1.2. Refer to test log runs 50, 71 and 72 presented in Volume I, Appendix C of this report.

TEST TITLE: ACCELERATION EFFECT - ON CAR

TEST SET NUMBER: ESC-PN-2001-TT

TEST OBJECTIVE:

To determine noise levels inside the test vehicle while accelerating.

TEST DESCRIPTION:

This test will be performed at selected interior test points for vehicle weights of AWO and AW3.

STATUS:

The energy storage cars successfully completed the acceleration effect tests as prescribed by the conditions specified in paragraph 7.1.2. Refer to test log runs 53, 67 and 72 presented in Volume I, Appendix C of this report.

TEST TITLE: DECELERATION EFFECT - ON CAR

TEST SET NUMBER: ESC-PN-3001-TT

TEST OBJECTIVE:

To determine noise levels inside the test vehicle while decelerating.

TEST DESCRIPTION:

This test will be performed at the following conditions:

(a) For selected interior test points
(b) For various braking configurations (depends upon modes available on test vehicle). The basic configuration will be the normal service system.
(c) Vehicle weights of AW0 and AW3.

STATUS:

The energy storage cars successfully completed the deceleration effect tests as prescribed by the conditions specified in paragraph 8.1.2. Refer to test log runs 53, 67 and 72 presented in Volume I, Appendix C of this report.

TEST TITLE: DYNAMIC SHAKE TEST - VERTICAL

TEST SET NUMBER: ESC-R-0001-XX

TEST OBJECTIVE:

To determine the vehicle vertical natural modes and frequencies.

TEST DESCRIPTION:

This test will include performing frequency sweeps of the vehicle by using a shaker to provide excitation forces. These sweeps will be generated for selected locations of the vehicle to determine the natural frequencies. At these natural frequencies detailed probes of the vehicle are necessary to determine the associated mode shapes. The test will be performed at vehicle weights of AW0, AW2 and AW3.

STATUS:

The energy storage cars successfully completed the vertical shake tests as prescribed by the conditions specified in paragraph 2.1.2. Refer to test log runs 83 through 86 presented in Volume I, Appendix C of this report.

TEST TITLE: DYNAMIC SHAKE TEST - LATERAL

TEST SET NUMBER: ESC-R-0002-XX

TEST OBJECTIVE:

To determine the vehicle lateral natural modes and frequencies.

TEST DESCRIPTION:

This test will include performing frequency sweeps of the vehicle by using a shaker to provide excitation forces. These sweeps will be generated for selected locations of the vehicle to determine the natural frequencies. At these natural frequencies detail probes of the vehicle are necessary to determine the associated mode shapes. The test will be performed at vehicle weights of AW0, AW2 and AW3.

STATUS:

The lateral shake tests could not be performed due to the lack of a mounting fixture. Refer to test log run 83 (Volume I, Appendix C).

TEST TITLE: DYNAMIC SHAKE TEST - LONGITUDINAL

TEST SET NUMBER: ESC-R-0003-XX

TEST OBJECTIVE:

To determine the vehicle longitudinal natural modes and freuqencies.

TEST DESCRIPTION:

This test will include performing frequency sweeps of the vehicle by using a shaker to provide excitation forces. These sweeps will be generated for selected locations of the vehicle to determine the natural frequencies. At these natural frequencies detailed probes of the vehicle are necessary to determine the associated mode shapes. The test will be performed at vehicle weights of AW0, AW2 and AW3.

STATUS:

No test data or results could be obtained for the longitudinal shake tests because the output of the shaker was not able to produce a measurable effect on the car body. Refer to test log runs 83 through 86 (Volume I, Appendix C).

TEST TITLE: COMPONENT INDUCED VIBRATION

TEST SET NUMBER: ESC-R-0010-TT

TEST OBJECTIVE:

To determine the vibration levels of the test vehicle components while stationary on the UMTA Test Track.

TEST DESCRIPTION:

This test will be performed on a stationary car at a known level section of track.

STATUS:

The energy storage cars successfully completed the component induced vibration tests as prescribed by the conditions specified in paragraph 5.1.2. Refer to test log run 73 presented in Volume I, Appendix C of this report.

TEST TITLE: RIDE ROUGHNESS - WORST SPEEDS

TEST SET NUMBER: ESC-R-1101-TT

TEST OBJECTIVE:

To determine worst steady vibration levels of the test vehicle on the UMTA test track.

TEST DESCRIPTION:

The following configurations will be tested:

(a) Vehicle weights of AW0, AW2, AW3.
(b) All track sections including grade crossings and switches as required to simulate revenue service.
(c) Select discrete vehicle speeds simulating revenue service and include V (max).
(d) Select other speeds as required to identify known or suspected acute vibration levels associated with carbody characteristics.

STATUS:

The energy storage cars successfully completed the worst speeds tests as prescribed by the conditions specified in paragraph 6.1.2. Refer to test log runs 73 through 75 presented in Volume I, Appendix C of this report.

TEST TITLE: RIDE ROUGHNESS - ACCELERATION

TEST SET NUMBER: ESC-R-2001-TT

TEST OBJECTIVE:

To determine the most severe vibration levels encountered during car acceleration

TEST DESCRIPTION:

This test is to be performed on track section I at vehicle weights of AW0, AW2 and AW3

STATUS:

The energy storage cars successfully completed the acceleration tests as prescribed by the conditions specified in paragraph 7.1.2 Refer to test log runs 73, 78 and 79 presented in Volume I, Appendix C of this report.

TEST TITLE: RIDE ROUGHNESS - DECELERATION

TEST SET NUMBER: ESC-R-3001-TT

TEST OBJECTIVE:

To determine the most severe vibration levels encountered during car deceleration.

TEST DESCRIPTION:

This test to be performed on track section I at vehicle weights of AW0, AW2, AW3

STATUS:

The energy storage cars successfully completed the deceleration tests as prescribed by the conditions specified in paragraph 8.1.2. Refer to test log runs 73, 78 and 79 presented in Volume I, Appendix C of this report.

APPENDIX C

TEST RUN LOG SHEETS

Log sheets for the energy storage car test runs are presented in numerical order and provide a brief description of the tests, conditions and results of the performance evaluation tests.

ESC TEST RUN NO. 32 DATE 5-14-74

RUN TIME: START 2:00 WEATHER CONDITION: WIND VEL

STOP 5:00 DIRECTION

MILES RECORDED 20, 3700 Fwd and Rev
20, R-42, Fwd and Rev

AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Sessions

REAR MONITOR As req'd

GROUND CONTROLLER As req'd

ADDITIONAL PERSONNEL Lewis, DeDee

TEST PROGRAM SPECIFICATION NO. 73-9373

TEST PROCEDURE NO. 4.3

TEST TITLE Performance verification - R-42 Trainline

VEHICLE CONFIGURATION 2 cars - empty wt.

TEST DESCRIPTION Functional checkout of ESC and R-42 cars in trainline. Record coupler displacement, accels, decel and drive from both end cabs.

COMMENTS Successfully demonstrated all trainline operations in TMB. Moved 4-car train to track - Successfully completed cond run in ccw dir driving from 3700. Ran through level tangent in Fwd (ccw) and Rev (cw) dir and recorded steady speed coupler displacement. Drawing ≈ 100 A more current above base speed on accel then drops to 200-300 steady state. No adverse personal reactions experienced bet R-32 and R-42 during accel. All running operations seemed satisfactory bet both sets of cars. Braking effort seemed smooth.

Driving from 3700, ccw, Fwd:+.56 (3700 pulling)
" " " , cw, Rev: +.32 (3700 pushing)
Performed decel test at 48 mph, F.S. Brake
Performed accel test in Fwd dir (ccw)
Performed Accel Test in rev Dir (cw)
Changed drive cabs from ESC to R-42 and repeated.

F.S. Decel
ccw, Rev Accel
cw, Fwd Accel

Ran start-stop cycle every 3000' for 1 lap, driving from R-42 car.
Trainline compatibility looks good. No problems experienced during test.
Ran 4 car T/L from both cabs, both direction.
Successfully demonstrated running through rail gaps (45') w/o any difficulty.
4-car T/L test is considered complete.
Disconnected R-42 to set up for R-32 tests in a.m.

ESC TEST RUN NO. 33 DATE 5-15-74

RUN TIME: START 9:15 WEATHER CONDITION: WIND VEL 0

STOP 2:00 DIRECTION 0

MILES RECORDED 42 AMBIENT AIR TEMPERATURE ____

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spon

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Sessions

REAR MONITOR As Req'd

GROUND CONTROLLER As Req'd

ADDITIONAL PERSONNEL Lewis, Nickel, Smits

TEST PROGRAM SPECIFICATION NO. 73-9373

TEST PROCEDURE NO. 4.3

TEST TITLE Performance Verification - Accel, Decel

VEHICLE CONFIGURATION 2 cars - Empty Wt.

TEST DESCRIPTION Perform Accels and Decels per Test Plan. Give demo ride to Under Secretary of DOT, John V. Barnum. Reel 2.

COMMENTS Successfully completed accel and decel tests per test plan. Began to set instr'n up for drift test. Gave demo tour ride at 1:30 p.m.

ESC TEST RUN NO. 34 DATE 5-16-74

RUN TIME: START 9:30 WEATHER CONDITION: WIND VEL 0 MPH

STOP 4:30 DIRECTION

MILES RECORDED 40 AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Sessions

REAR MONITOR As req'd

GROUND CONTROLLER As req'd

ADDITIONAL PERSONNEL Lewis, Nickel, Smits

TEST PROGRAM SPECIFICATION NO. 73-9373

TEST PROCEDURE NO. 4.3 ESC-P-4001-TT

TEST TITLE Performance verification - Drift, railgap and modes tests

VEHICLE CONFIGURATION 2 cars - empty wt.

TEST DESCRIPTION Perform drift test, railgap and dead rail test and mode change test per test plan. Reel 3.

COMMENTS Ran 2 sets of drift test due to longitudinal vib pickup cable defective - ran l set and then switched cables for 2nd set. Completed drift test. Ran Accel (max) Fwd and Rev driving from 3701. 2.53 mphps both dir. Successfully completed drift test, railgap and dead rail and mode change test per test plan. No problems experienced throughout day.

ESC TEST RUN NO. 35 DATE 5-17-74

RUN TIME: START 10:00 WEATHER CONDITION: WIND VEL

STOP 4:00 DIRECTION

MILES RECORDED 20 AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Sessions

REAR MONITOR As req'd

GROUND CONTROLLER As req'd

ADDITIONAL PERSONNEL Lewis, Smits, LaFranchi, Carroll

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Performance Verification - Power consumption test

VEHICLE CONFIGURATION 2 cars - empty wt.

TEST DESCRIPTION Run power consumption test per test plan - See Attachments.

COMMENTS On first brake initiation while driving from 3701, experienced T/L QSD on 3701 only. Experienced same in Rev dir. Switched driver's cab to 3700 - experienced same T/L QSD on 3700 but not 3701. Began investigating master controller for proper operation. Moved cars into barn to continue investigation on Saturday.

ESC TEST RUN NO. 36 DATE 5-20-74

RUN TIME: START 12:30

STOP 4:00

MILES RECORDED 30

WEATHER CONDITION: WIND VEL

DIRECTION

AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Jenkins

REAR MONITOR As required

GROUND CONTROLLER As required

ADDITIONAL PERSONNEL Lewis

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Performance Verification-Power Consumption Test

VEHICLE CONFIGURATION 2 Cars-Empty Wt.

TEST DESCRIPTION Perform Power consumption test per test plan; reel 4.

COMMENTS Initiated power consumption test per test plan. Completed Run Nos. 1 and 2. 3 to 1 OSD on current swapping. Shut down to investigate. Found F/W PDR volt trap had arced and under rated SCR's were damaged. Replaced SCR's with larger type as in T/m PDR's.

EST TEST RUN NO. 36 (Continued)

MONDAY A.M:

Found cause of Fridays QSD problem - under rated zener (1 watt) in LOM snubber network went out and caused short-to-gnd upon initial brake initiation.

Replace with temporary 1-watt zener. Will use 10 watt zeners when we receive them.

ESC TEST RUN NO. 37 DATE 5-21-74

RUN TIME: START 10:00 WEATHER CONDITION: WIND VEL

STOP 4:00 DIRECTION WSW

MILES RECORDED AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Jenkins

REAR MONITOR As required

GROUND CONTROLLER As required

ADDITIONAL PERSONNEL Lewis, Nickel, Raskin

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Perform verification-power cons test

VEHICLE CONFIGURATION 2 cars-empty wt.

TEST DESCRIPTION Continuation of power consumption test per test plan; reels 5 and 6.

COMMENTS Successfully completed cond run. Driving from 3701 in cw direction commenced Run No. 3. Must record power draw from lights, etc. to correct data for completed Runs 1, 2 and 3 in ccw direction. Experienced TMS on 3701 not opening during brake. Went to TMB to investigate, could not reproduce on simulated. Shorted out on 208 board. Resume testing in A.M.

ESC TEST RUN NO. 38 DATE 5-22-74

RUN TIME: START 10:00 WEATHER CONDITION: WIND VEL ______

STOP 5:00 DIRECTION ______

MILES RECORDED 25 AMBIENT AIR TEMPERATURE ______

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Jenkins

REAR MONITOR As required

GROUND CONTROLLER As required

ADDITIONAL PERSONNEL Lewis

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Performance Verification-Power Consumption Test

VEHICLE CONFIGURATION 2 cars-empty wt.

TEST DESCRIPTION Continuation of Power Consumption Test per test plan; reels 6 and 7.

COMMENTS TMS operating properly on 3701 with CR13 jumper in. Noticed that during P.S. test, when driving from 3701 cw (fwd notch) and 3700 ccw (fwd notch) the following occurred:

	cw 3701-fwd	ccw 3700-fwd
Run 2	80.7 Kwh/Lap	69
Run 3	85.1 Kwh/Lap	56

ECS TEST RUN NO. 38 (Continued)

Switched to driving from 3700 - fwd (ccw) Rev (cw)

Run 2 - 60 Kwh/Lap

Run 3 - 65.4 Kwh/Lap

Will run P.C. test from 3700 in both directions.

4:30 P.M: Smoke coming from outside of car - investigation revealed No. 2 F/W on 3700 was source. F/W alternator stator showed signs of burned windings. Moved cars to TMB. Further investigation showed flashed over volt trap in F/W PDR. Stator must be replaced and 800 V PDR SCR's replaced with 1200V SCR's. This was the only PDR assembly that was not updated with the higher rated SCR's due to their unavailability.

ESC TEST RUN NO. 39 DATE 5-29-74

RUN TIME: START 9:05 WEATHER CONDITION: WIND VEL ______

STOP 5:15 DIRECTION ______

MILES RECORDED 91 AMBIENT AIR

1,1,1,1,1,1,1,1,1,1 TEMPERATURE ______

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Jenkins

REAR MONITOR As required

GROUND CONTROLLER As required

ADDITIONAL PERSONNEL Lewis

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Performance Verification-Power Consumption Test

VEHICLE CONFIGURATION 2-cars-empty wt.

TEST DESCRIPTION Perform Power Consumption Test per Test Plan; reels 8 and 9.

COMMENTS Completed cond. Run. Re-ran Run No. 3 in ccw direction (Start = 9:40 stop =). Chopper inductor running at 90°F - New inductor. Scrubbed run - Track was sprayed for weeds and substance on track made it too slippery - Wheels slide. Entered Run No. 4-ccw and completed same. Ran No. 4 in ccw dir. (Start = 12:35, Stop =). Completed Run No. 4. Began Run No. 5. Completed Run 5.

ECS TEST RUN NO. 39 (Continued)

Completed Run No. 6

Run 7 - 58.8 (20) ccw
ccw
cw
cw

Upon second lap of Run 7, noticed instability in T/M currents - No. 2 truck drawing 800A, No. 1 truck drawing zero to - 300A. Shut down and went to TMB to investigate.

ESC TEST RUN NO. 40 DATE 6-17-74

RUN TIME: START 10:00 WEATHER CONDITION: WIND VEL ______

STOP 6:00 DIRECTION ______

MILES RECORDED 50 AMBIENT AIR TEMPERATURE ______

1,1,1,1,1

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Jenkins, Barnes

REAR MONITOR As required

GROUND CONTROLLER As required

ADDITIONAL PERSONNEL Lewis, Ebonbach

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Performance Verification-Power Consumption Test

VEHICLE CONFIGURATION 2 cars-empty wt.

TEST DESCRIPTION Perform Power Consumption Test per Test Plan and perform Strain Gauge test per test plan; reel 9.

COMMENTS Successfully completed conditioning run. Commenced stress level evaluation tests. Completed Steps A, B, C, D, and E in level tangent. Repeated steps B, C, and D in minimum curved radius track section (STA 180-300, Rad = (^{o}30):

Para	Sta Start	Sta Stop
B	300	290 (Lost sig #5)
C	300	265
D	300	280

ESC TEST RUN NO. 40 (Continued)

Completed step 'f' in following manner:

Entered Sta 300 at 35 mph and drove thru radius section at 45 mph from Sta 300-180 in ccw dir.

Spotcheck of 3000' P.C. Run at 45:

Kwh/Lap	Kwh/Mile/car
76.8	4.2

2000' P.C. Run @ 40:

Over 90 - run called due to wet track conditions.

ESC TEST RUN NO. 41 DATE 6-18-74

RUN TIME: START 09:00 WEATHER CONDITION: WIND VEL

STOP 12:00 DIRECTION

MILES RECORDED 0 AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER D. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR As required

GROUND CONTROLLER As required

ADDITIONAL PERSONNEL Lewis, McCormick

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Performance Verification-Power Consumption Test

VEHICLE CONFIGURATION 2 Cars-empty wt.

TEST DESCRIPTION Continue Power Consumption Test per Test Plan; reel 9.

COMMENTS Spent A.M. Calib. instructions.

ESC TEST RUN NO. 42 DATE 6-19-74

RUN TIME: START 9:00 WEATHER CONDITION: WIND VEL 0

STOP 6:00 DIRECTION

MILES RECORDED 128 AMBIENT AIR

1,1,1,1,1,1,1,1,1,1,1,1,1,1 TEMPERATURE 85-100

TEST PERSONNEL:

TEST CONTROLLER W. I. Thomas

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR As required

GROUND CONTROLLER As required

ADDITIONAL PERSONNEL Lewis, McCarty

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Performance Verification-Power Consumption Test

VEHICLE CONFIGURATION 2 Cars-empty wt.

TEST DESCRIPTION Test to be performed per Test Plan; reels 9 and 11.

COMMENTS Ran chopper ind. temp test - o to 80% in 10% increments. Completed cond. run. Commenced 2nd lap of Run #7, ccw dir. Successfully completed Run #7. Run #8 = Accel to 45 & Brake to 15, Accel to 30 & brake to 15, Accel to 45... Stop every 5000'. Successfully completed Run No. 8. Began Run 9. Successfully completed Run No. 9.

ESC TEST RUN NO. 42 (Continued)

Experienced TMS on 3701 not opening upon braking infrequently Will investigate tomorrow in Barn in A.M.

Began Run No. 10. 3701 QSD with Aux. gen lite - possible loss of SCR in PDR. Will Move to TMB to investigate. Scrub initial Run No. 10.

Need from Torr:

1 - Spare SCR's

2 - Spare volt traps

3 - PDR insulating stand - offs for 51 ohm resistors

4 - Qty = 4 - 51Ω resistors for PDR.

Investigation revealed that 3701 T/M and F/W PDR's were in good condition and not the source of problem. Simulator checkout showed problem to be in ECU. Intermittent occurrance in ECU on simulator - Looking at CARD #209. Prep cars for test continuation and 3701 ECU investigation.

ESC TEST RUN NO. 43 DATE 6-20-74

RUN TIME: START 3:20 WEATHER CONDITION: WIND VEL

STOP 5:30 DIRECTION

MILES RECORDED 20 AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL Lewis, McCarty

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-T

TEST TITLE Performance Verification-Power Consumption Test

VEHICLE CONFIGURATION 2 cars-empty wt.

TEST DESCRIPTION Continue Power consumption test per Test Plan; reel 11.

COMMENTS Continued investigation of TMS problem on 3701 revealed that FSR1 diode was shorted and caused R-13 relay to function improperly. R-13 relay finally burned 2 contacts. Replaced relay and diode.

Suspected Problem: Bad diode (0115) caused by previous loss of PDR and diodes D113 & D114 shorted which resulted in malfunction in 307 board and R-13 relay.

ESC TEST RUN NO. 43 (Continued)

Replaced all 3 diodes and relay and 307 board (found spare 307 had been running in 3701 for some time, it was board that failed).

ESC TEST RUN NO. 44 DATE 6-21-74

RUN TIME: START 08:45 WEATHER CONDITION: WIND VEL

STOP 8:00 DIRECTION

MILES RECORDED 91 AMBIENT AIR

1,1,1,1,1,1,1,1,1,1 TEMPERATURE 100+

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL Lewis, McCarty

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Performance Verification

VEHICLE CONFIGURATION 2 cars-empty wt.

TEST DESCRIPTION Complete Power Consumption Test and Run Drift Test; reels 11 and 12.

COMMENTS Successfully completed Run No. 10 of energy consum. test - empty wt. Performed re-run of Run No. 6 to further validate 3000' point. Completed Run No. 6. Gave demo to London Transit and Lockheed. Began re-run of Run No. 5. Completed Run No. 5. Postponed Drift test until later.

ESC TEST RUN NO. 45 DATE 6-24-74

RUN TIME: START 09:45 3rd rail

STOP 3:30

MILES RECORDED 20

WEATHER CONDITION: WIND VEL 5-10

DIRECTION West

AMBIENT AIR TEMPERATURE 70

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER H. Lewis

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL McCarty

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Performance Verification

VEHICLE CONFIGURATION 2 cars - 42,000 lbs Ballast each

TEST DESCRIPTION Commence max wt. power consumption test; reel 13.

COMMENTS Completed Run No. 1 of max. wt. Power Cons. Test. Experienced 3700 aux gen relay not functioning - Car would not regulate at 100% F/W speed. Went to barn to investigate. Found fuse F10 was blown which caused loss of 32 vdc output which kept F/W sys on batteries.

ESC TEST RUN NO. 46 DATE 6-25-74

RUN TIME: START 12:45 WEATHER CONDITION: WIND VEL ________

STOP 7:45 DIRECTION ________

MILES RECORDED 72.8 AMBIENT AIR TEMPERATURE ________

1,1,1,1,1,1,1,1

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR ________

GROUND CONTROLLER ________

ADDITIONAL PERSONNEL Lewis, McCarty

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Performance Verification-Power Consumption Test

VEHICLE CONFIGURATION 2 cars-max. wt.

TEST DESCRIPTION Perform test per test plan; reels 14 and 15

COMMENTS Successfully completed Run No. 1, 2, 3, & 4 ccw. Experienced FW/TL and aux. gen QSD on 3700 when shifting to coast during cw 15 mph run. ABRS "ON" ALB "OFF" on reset: AFWS "ON", AFWES "ON", ALB "ON" up to 40% - then trip and FW/TL "ON", ABRS "ON", ALB "OFF".

Attempted re-set in A.M. - No problem experienced with re-set-F/W's came up.

ESC TEST RUN NO. 47 DATE 6-26-74

RUN TIME: START 11:00 WEATHER CONDITION: WIND VEL

STOP 7:00 DIRECTION

MILES RECORDED 91 AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL Lewis, McCarty

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Performance Verification-Max wt. Power Consumption

VEHICLE CONFIGURATION 2 cars-max. wt.

TEST DESCRIPTION Perform tests per Test Plan; reels 16 and 17

COMMENTS Completed cw Run No. 4. During re-start, F10 fuse was blown on 3700-Replaced fuse and continued testing, completed Run No. 5 and 6. During Run 7, 3701 experienced QSD - found blown fuses F33, F34, and F35. Replaced fuses and continued testing. Experienced same QSD on 3700 and 3701 as experienced last nite. QSD becoming more frequent towards end of day.

ESC TEST RUN NO. 48 DATE 6-27-74

RUN TIME: START 9:40

STOP 9:00

MILES RECORDED 100

WEATHER CONDITION: WIND VEL

DIRECTION

AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL Lewis, McCarty

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PC-5011-TT

TEST TITLE Performance Verification-Power Consumption. Max. wt.

VEHICLE CONFIGURATION 2 cars-Max. Wt.

TEST DESCRIPTION Continue Power Consumption Test - Max. wt per Test Plan; reels 18 and 19.

COMMENTS Completed Run No's. 8 and 9 of Power Consumption Test. Plaqued by trips on 3700 (Aux gen, F10 fuse) and 3701 (Aux. gen, F33, 34 & 35). Also, 3701 has Fw overspeed trip (DB5 does not close at overspeed). 3701 problem seems associated with F/W overspeed during end of brake - Pops fuses. Completed Run No. 10 which completes max. wt. P.C. Changed 103 board in 3701. Did not experience flashing L/B lite. Must investigate aux. gen on 3700 & aux. gen and DBS on 3701.

ESC TEST RUN NO. 48 (Continued)

Investigation revealed in barn that entire Bank of 12 fuses on 3701 which included F-33, 34 & 35 were undersized: Should be 20A instead of 10A. Replaced with 20A fuses. F10 fuse on 3700 was also undersized: Should be 30A fuse instead of 20A. Replaced with 30A fuse.

ESC TEST RUN NO. 49 DATE 7-1-74

RUN TIME: START 09:40 WEATHER CONDITION: WIND VEL 15 mph

STOP 5:15 DIRECTION NNW

MILES RECORDED 33
1,1,1,1

AMBIENT AIR TEMPERATURE 99

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemle

INSTRUMENTATION Barnes

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL Lewis, McCarty

TEST PROGRAM SPECIFICATION NO. 73-9373

TEST PROCEDURE NO. 4.3 ESC-P-2001-TT

TEST TITLE Performance Verification-Max. wt. Accel, Decel Test

VEHICLE CONFIGURATION 2 cars-max wt.

TEST DESCRIPTION Perform Accel and Decel Tests per Test Plan; reel 20.

COMMENTS Gas generator set hard to start, rope broke, took 2 hrs to repair. Successfully completed conditioning run without any problems. Successfully completed accel test. max wt. Order of Runs listed on back side of paper-ref: Driving from 3701 max wt - max accel = 2.5 Fwd, 2.41 Rev. Ran decel test in same order (i.e: 1 Fwd, 1 Rev), Aux gen on 3701 QSD - Wait 5 min and reset O.K.

FSC TEST RUN NO. 49 (Continued)

Found breaker No. 5 in 3700 was tripped. Successfully completed accel tests. Secured for day.

Test 1 - Accel

Run 1	Switching accel - fwd (ccw)	
2	Switching accel - rev (cw)	
3	Switching accel - fwd	
4	Switching accel - rev	
5	Switching accel - fwd	
6	Switching accel - rev	
7	Series accel - fwd	
8	Series accel - rev	
9	" "	fwd
10	" "	rev
11	" "	fwd
12	" "	rev
13	Parallel accel	fwd
14	" "	rev
15	" "	fwd
16	" "	rev
17	" "	fwd
18	" "	rev

Test 2 - Decel

Run 1 20 psi sap fwd

2 rev

↓ ↓

Run 10 F.S. Brake Sap Rev.

NOTE: Found breaker No. 5 trip due to lead for LOM signal into O-graph had overheated. Removed lead from Lom card.

ESC TEST RUN NO. 50 DATE 7-2-74

RUN TIME: START 10:00 WEATHER CONDITION: WIND VEL 15+

STOP 4:30 DIRECTION

MILES RECORDED 30 AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL McCarty

TEST PROGRAM SPECIFICATION NO. 73-9373 GSP-064

TEST PROCEDURE NO. 4.3 ESC-PN-1301-TT

TEST TITLE Performance Verification - Noise Level Tests

VEHICLE CONFIGURATION 2 cars-max wt.

TEST DESCRIPTION Perform tests per Test Plan

COMMENTS Completed paras. A. B, and C of Interior Noise Test. Could not perform exterior test due to high wind effects. During Run D of Interior Noise Test, Aux. gen QSD - reset O.K. but noticed smell coming from underside of car. Investigation revealed T1 volt trap flashed and wires burned. Went to barn to investigate. Investigation revealed flashed VT1 volt trap caused by loss of diode D116. Replaced diode with higher rated - now have complete set of replacement diodes in 3701.

ESC TEST RUN NO. 51 DATE 7-11-74

RUN TIME: START 6:45 WEATHER CONDITION: WIND VEL

STOP 3:00 DIRECTION

MILES RECORDED 30 AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL McCarty, Luggett

TEST PROGRAM SPECIFICATION NO. 73-9373, GSP-064

TEST PROCEDURE NO. 4.3 ESC-CN-0001-TT

TEST TITLE Performance Verification-Noise Level

VEHICLE CONFIGURATION 2 cars-max. wt.

TEST DESCRIPTION Perform Noise Level Test per Test Plan

COMMENTS Completed Cond. run. Completed exterior noise test - 50' from rail. Experienced aux. gen. QSD's from 3701. Placed monitor on 3700 to check oper. integrity. B & K unit was on tripod in car and leg of tripod collapsed. Mike was broken. Borrowed TSC's. Will run exterior noise & interior noise in A.M. Gas gen set dropped power - Brush lead shorted.

ESC TEST RUN NO. 52 DATE 7-12-74

RUN TIME: START 09:30 WEATHER CONDITION: WIND VEL ____

STOP 2:00 DIRECTION ____

MILES RECORDED 30 AMBIENT AIR TEMPERATURE ____

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR ____

GROUND CONTROLLER ____

ADDITIONAL PERSONNEL McCarty, Luggett

TEST PROGRAM SPECIFICATION NO. 73-9373 & GSP-064

TEST PROCEDURE NO. Performance Verification-Noise Level ESC-CN-0001-TT

TEST TITLE Noise Level Tests - ext and int.

VEHICLE CONFIGURATION 2 cars - Max wt.

TEST DESCRIPTION Perform tests per above documents

COMMENTS Aux. gen. problem not in logic on 3701. Circuit is external & FAR and/or CFR is tripping out. Collin suggests that 32 vdc side of X-former be disconnected from logic since it is a signal only to ECD. Collin gave both cars clean bill of health for logic system. 3701 has only slight oscillation at brake - he will fix later.

ESC TEST RUN NO 52 (Continued)

3700 F/W No. 2 (SNA):

Noticed Thursday, 7-11-74, that noise from G/B area was becoming quite audible. Vibration was set up in floor. During 2 hr run, noise and vibration was becoming more apparent. Shut down to investigate. On Friday 7-12-74 ran spl on F/W (see attached sheet). Decided not to run car. Will remove F/W and send to Torr. for investigation. They are sending spare unit up.

ESC TEST RUN NO. 53 DATE 7-17-74

RUN TIME: START 08:48 WEATHER CONDITION: WIND VEL ______

STOP 3:00 DIRECTION ______

MILES RECORDED 30 AMBIENT AIR TEMPERATURE ______

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR ______

GROUND CONTROLLER ______

ADDITIONAL PERSONNEL McCarty

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-CN-0001-TT, ESC-PN-2001-TT, and ESC-PN-3001-TT

TEST TITLE Exterior Noise Level, Accel & Decel Effect on car

VEHICLE CONFIGURATION 2 cars - AW3

TEST DESCRIPTION Perform tests per test plan.

COMMENTS Successfully completed exterior noise test (1st half) and accel & decel effect on car. Experienced loss of fan power infrequently on 3701. Had disconnected 32 vdc from Xformer, but still have loss of fan. Will investigate regulator as a possible cause.

ESC TEST RUN NO. 54 DATE 7-18-74

RUN TIME: START 09:30 WEATHER CONDITION: WIND VEL ______

STOP 4:00 DIRECTION ______

MILES RECORDED 45 AMBIENT AIR TEMPERATURE ______

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR ______

GROUND CONTROLLER ______

ADDITIONAL PERSONNEL McCarty, Nickel, Raskin, Rabe, Bowler, Augiuado, Blakely

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-CN-0001, and ESC-P-3002-TT

TEST TITLE Exterior Noise test (Platform), Friction Brake Decel

VEHICLE CONFIGURATION 2 cars - AW3

TEST DESCRIPTION Perform tests per test plan. De-ballast cars to AW2 in P.M. Reel 21.

COMMENTS Successfully completed ext. noise test. Platform completed AW3 decel service friction at 45 psi and 25 psi set, 15, 30 and 40 mph. Experienced F/W T/L QSD on both cars in A.M. No QSD in P.M. Did not experience fan loss in 3701 all day. Gave demo. to Art Raabe and Dan Raskin- deballast to AW2 (30,800 lbs) in P.M.

ESC TEST RUN NO. 55 DATE 7-19-74

RUN TIME: START 10:00 WEATHER CONDITION: WIND VEL

STOP 12:00 DIRECTION

MILES RECORDED 20 AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Smith, Tate, Leaston, Beemler

INSTRUMENTATION Barnes

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL McCarty

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-P-3002-TT, ESC-P-3001-TT, and ESC-P-2001-TT

TEST TITLE Decel Service Friction (AW2), Decel B.B., Accel

VEHICLE CONFIGURATION 2 cars - AW2

TEST DESCRIPTION Perform tests per test plan; reel 21

COMMENTS Began AW2 decel service friction test. Completed Run #8. Initiated Run 9 when 3700 had aux. gen. QSD & much noise and vibration coming from F/W #1. Visual inspection on coastdown revealed noise (thrashing) coming from rear flange of F/W section. Vibration began to decrease from rear to fwd flange. Went to barn.

ESC TEST RUN NO. 67 DATE 12-18-74

RUN TIME: START 08:00 WEATHER CONDITION: WIND VEL

STOP 2:00 DIRECTION

MILES RECORDED 45 AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G.Spons

VEHICLE OPERATOR Smith, Tate

INSTRUMENTATION Mccommon

REAR MONITOR

GROUND CONTROLLER As required

ADDITIONAL PERSONNEL McCarty

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-P-3001-TT and ESC-P-3002-TT

TEST TITLE Decel blended braking, Decel service friction

VEHICLE CONFIGURATION 2 cars-AWO

TEST DESCRIPTION Perform tests per GSP-064

Reel 23

COMMENTS Successfully completed accel blended brake and decel service friction at AWO. No problems experienced during test day.

ESC TEST RUN NO. 71 DATE 1-7-75

RUN TIME: START 08:00 WEATHER CONDITION: WIND VEL 0

STOP 4:00 DIRECTION ______

MILES RECORDED 40 AMBIENT AIR TEMPERATURE ______

TEST PERSONNEL:

TEST CONTROLLER G. McClure

CHIEF TEST ENGINEER R. Begier

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR ______

INSTRUMENTATION Mccommon

REAR MONITOR Yes

GROUND CONTROLLER As required

ADDITIONAL PERSONNEL McCarty

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-P-4001-TT and ESC-PN-1301-TT

TEST TITLE Drift Test and Interior Noise Survey

VEHICLE CONFIGURATION 2 cars-AWO

TEST DESCRIPTION Perform per test plan; reel 23

COMMENTS Successfully completed drift test - AWO. Zero wind velocity. Changed R8 on 203 Brd from 75K to 150K - Both cars - no change in accel. Changed 3700 203, R8 from 100-150. Due to 3700 speed vs T/M curr higher than 3701. Noticed 1 mph dec in speed vs time. Changed R4 on 207 Brd from 75-100K. When R8 on 203 was increased to 150K, 3700 3rd rail fell off at 5 amp point with 3701- No longer stays on 3 to 5 sec more.

ESC TEST RUN NO. 72 DATE 1-8-75

RUN TIME: START 09:30 WEATHER CONDITION: WIND VEL 0

STOP 5:00 DIRECTION

MILES RECORDED 75 AMBIENT AIR TEMPERATURE 35

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR

INSTRUMENTATION Mccommon

REAR MONITOR Yes

GROUND CONTROLLER As required

ADDITIONAL PERSONNEL McCarty, Couvillon

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-PN-1301-TT

TEST TITLE Interior Noise Survey, Accel and Decel & effect, Effect of track on car

VEHICLE CONFIGURATION 2 cars -AWO

TEST DESCRIPTION Perform tests per test plan; reel 23

Reel 8, 9, and 10 - Small recorder

COMMENTS Successfully completed 73-9373 interior noise survey and GSP-064 interior noise survey. Also completed accel and decel effect on car and effect of track section on car, All at AWO. No problems experienced during test day.

ESC TEST RUN NO. 73 DATE 1-9-75

RUN TIME: START 09:00 WEATHER CONDITION: WIND VEL 15-25

STOP 4:00 DIRECTION N-S

MILES RECORDED 90 AMBIENT AIR TEMPERATURE 20

TEST PERSONNEL:

TEST CONTROLLER W. Myer

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR

INSTRUMENTATION Mccommon

REAR MONITOR as required

GROUND CONTROLLER as required

ADDITIONAL PERSONNEL McCarty, Convillion

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-R-0010; R-2001; R-3001; R-1101

TEST TITLE Ride Roughness - Component Induced Vibration, Accel & Decel, Worst speed

VEHICLE CONFIGURATION 2 cars - AWO

TEST DESCRIPTION Perform tests per test plan; reel 23

COMMENTS Successfully completed ride roughness tests of component induced vibration, worst speeds (Selected 20, 35 & 45 since no major indication of worst car speed) and accel & decel. No problems experienced during day. AWO complete except accel & power consumption. Weighed cars at end of day:

	No. 1 end	No. 2 end	Total
3701 =	42260	40560	82820
3700 =	43840	41200	85040
			A = 2220

ESC TEST RUN NO' 73 (Continued)

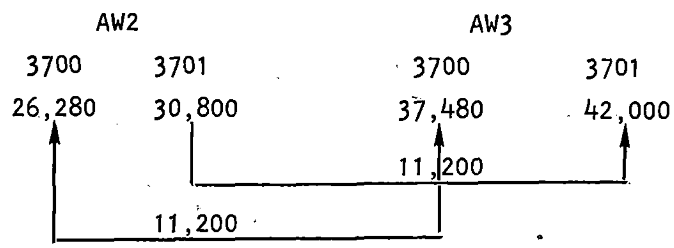
AWO			AW2	AW3
3701	=	82820	113620	124820
3700	=	82320	113120	124320

+1800 = people (9 @ 200 ea)

+2700 = Instr'n & equipment on car

86840

Ballast Req'd:



ESC TEST RUN NO. 74 DATE 1-13-75

RUN TIME: START 08:30 WEATHER CONDITION: WIND VEL ____

STOP 11:30 DIRECTION ____

MILES RECORDED 0 AMBIENT AIR TEMPERATURE ____

TEST PERSONNEL:

TEST CONTROLLER W. Myer

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR ____

INSTRUMENTATION Sessions

REAR MONITOR as required

GROUND CONTROLLER as required

ADDITIONAL PERSONNEL McCarty, Couvillion, Mcconnel

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-R-1101-TT

TEST TITLE Ride Roughness, Drift

VEHICLE CONFIGURATION 2 cars - AW2

TEST DESCRIPTION Perform tests per test plan. Weigh cars at AW2.

AW2 Wts:	Truck 1	Truck 2		Total
3701 =	59000	56360	=	115360
3700 =	56140	50900	=	107040

COMMENTS Correction:

1 - remove 1740 lbs from 3701, Truck 1

2 - Add 4280 lbs 3700, Truck 2

No test run today Pot 1 power supply wires shorted and need repair.

ESC TEST RUN NO. 75 DATE 1-14-75

RUN TIME: START 2:00 WEATHER CONDITION: WIND VEL ____

STOP 5:00 DIRECTION ____

MILES RECORDED 45 AMBIENT AIR TEMPERATURE ____

TEST PERSONNEL:

TEST CONTROLLER W. Myer

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR ____

INSTRUMENTATION Sessions

REAR MONITOR Yes

GROUND CONTROLLER as required

ADDITIONAL PERSONNEL McCarty, Couvillion, Mcconnel, Nickel Curran, Huggett

---

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-R-1101-TT

TEST TITLE Ride Roughness and Drift - AW2

VEHICLE CONFIGURATION 2 cars - AW2

TEST DESCRIPTION Perform tests per test plan; reel 24

COMMENTS Successfully completed ride roughness at AW2. Performed accel & decels in level tangent. Calibrated motor speed for car vs 9th wheel: Must rerun @ constant speeds. Investigation revealed that variable load reostat was set low for AW2; re-adjusted for proper output resistance at AW2.

ESC TEST RUN NO. 76 DATE 1-15-75

RUN TIME: START 08:30 WEATHER CONDITION: WIND VEL

STOP 5:00 DIRECTION

MILES RECORDED 70 AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER W. Myer

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR

INSTRUMENTATION Sessions

REAR MONITOR

GROUND CONTROLLER as required

ADDITIONAL PERSONNEL McCarty, Huggett, Couvillion, Nickel, Mcconnel, Curran

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-P-4001-TT

TEST TITLE Drift, decel service friction, Decel blended brake

VEHICLE CONFIGURATION 2 cars - AW2

TEST DESCRIPTION Perform tests per test plan; reel 24

COMMENTS Successfully completed drift test @ AW2, decel blended brake and decal service friction. Ran accel and decel in level tangent with and without friction brake. Ran 1 Lap of power consumption at AW2 = 88.2 Kwh/Lap. No problems experienced during test day.

ESC TEST RUN NO. 77 DATE 1-16-75

RUN TIME: START 08:30 WEATHER CONDITION: WIND VEL 0

STOP 3:30 DIRECTION ______

MILES RECORDED 70 AMBIENT AIR TEMPERATURE ______

TEST PERSONNEL:

TEST CONTROLLER W. Myer

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR Tate

INSTRUMENTATION Sessions

REAR MONITOR Lennesy

GROUND CONTROLLER ______

ADDITIONAL PERSONNEL Huggett, Nickel, Mcconnel, Curran

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-P-5001-TT

TEST TITLE Friction Brake Duty Cycle, Accel

VEHICLE CONFIGURATION 2 cars - AW2

TEST DESCRIPTION Perform tests per test plan; reel 24

COMMENTS Successfully completed friction brake duty cycle: Ran 1 lap at 30 mph, 45 sec cruise, 30 sec stop while recording temps @ stop. Ran in L. Tanjent fwd and rev for 1/2 hr at 45 mph, 55 sec cruise, etc. Completed accel, fwd and rev in L.T. Ran accels and decels for Bob, drift fwd and ran with and without inshot and 1 Lap of 10,000', 45 mph, 30 sec stop, CW. KwL/Lap = 67. Ballest cars to AW3.

ESC TEST RUN NO. 77 (Continued)

AW3

	3700		3701	
	Truck 1	Truck 2	Truck 1	Truck 2
	60,900	61,000	62,520	61,760
Total	121,900 lbs		Total = 124,280 lbs	
	+620		+600	

3701:

+600 Truck 1

3700:

Truck 1 = 310

Truck 2 = 310

ESC TEST RUN NO. 78 DATE 1-17-75

RUN TIME: START 08:30

STOP 5:00

MILES RECORDED 100

WEATHER CONDITION: WIND VEL ______

DIRECTION ______

AMBIENT AIR TEMPERATURE ______

TEST PERSONNEL:

TEST CONTROLLER W. Myer

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR ______

INSTRUMENTATION Sessions

REAR MONITOR ______

GROUND CONTROLLER ______

ADDITIONAL PERSONNEL Huggett

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-PC-5011-TT, ESC-R-2001-TT

TEST TITLE Accel, Decel, Power Cons., Ride Roughness

VEHICLE CONFIGURATION 2 cars - AW3

TEST DESCRIPTION Perform tests per test plan; reel 25

COMMENTS Successfully completed accel, decel, and power consumption at AW3. No problems experienced.

ESC TEST RUN NO. 79 DATE 1-20-75

RUN TIME: START 08:30 WEATHER CONDITION: WIND VEL

STOP 12:00 DIRECTION

MILES RECORDED 45 AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER W. Myer

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR

INSTRUMENTATION Sessions

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL McCarty, Huggett, Convillion, Henst

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-R-1101-TT

TEST TITLE Ride Roughness

VEHICLE CONFIGURATION 2 cars AW3

TEST DESCRIPTION Perform test per test plan; reel 26

COMMENTS Successfully completed ride roughness. Went in to barn to install T/M power cons. instr'n and hall effect current sensors.

ESC TEST RUN NO. 80 DATE 1-21-75

RUN TIME: START 9:00 WEATHER CONDITION: WIND VEL ____

STOP 5:00 DIRECTION ____

MILES RECORDED 64 AMBIENT AIR TEMPERATURE ____

TEST PERSONNEL:

TEST CONTROLLER R. Begier

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR ____

INSTRUMENTATION Sessions

REAR MONITOR ____

GROUND CONTROLLER ____

ADDITIONAL PERSONNEL Huggett, Wienstien

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-PSI-6001-TT

TEST TITLE EMI

VEHICLE CONFIGURATION 2 cars - AWO

TEST DESCRIPTION ____

COMMENTS Ran 1 lap fwd & Rev @ 3000 , 30 sec 45 mph with T/M and 3rd rail on Kwh meters at AWO. No change in Kwh/Lap however. T/M can = 24% higher with 10% added to reading for motor and chopper efficiency. Recal instr'n. and set up for shunts vs haul effects.

ESC TEST RUN NO. 81 DATE 1-22-75

RUN TIME: START 08:30 WEATHER CONDITION: WIND VEL ____

STOP 4:30 DIRECTION ____

MILES RECORDED 60 AMBIENT AIR TEMPERATURE ____

TEST PERSONNEL:

TEST CONTROLLER W. Myer

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR ____

INSTRUMENTATION Sessions

REAR MONITOR ____

GROUND CONTROLLER ____

ADDITIONAL PERSONNEL Henst, Wienstien

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-PSI-6001-TT

TEST TITLE Duty cycles and EMI

VEHICLE CONFIGURATION 2 cars - AWO

TEST DESCRIPTION ____

COMMENTS Ran duty cycles all day. Results: car 3701 runs at 3.92 Kwh/CM and T/M's are matched to within 2% of energy consumed. Car 3701 runs at 5.19 Kwh/CM and T/M's are matched to within 1% of energy consumed. Must run accel and reduce speed schedule for arm current reduction. Ran laps with and without inshot-NO appreciable difference.

ESC TEST RUN NO. 82 DATE 1-23-75

RUN TIME: START 09:00 WEATHER CONDITION: WIND VEL

STOP 1700 DIRECTION

MILES RECORDED 30 AMBIENT AIR TEMPERATURE

Reliability time = 3 hrs 30 min

TEST PERSONNEL:

TEST CONTROLLER W. Myer

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR

INSTRUMENTATION Sessions

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL Henst, Wienstien, Yutko

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-PSI-6001-TT

TEST TITLE EMI and Reliability, Accel and AWO

VEHICLE CONFIGURATION 2 cars - AWO

TEST DESCRIPTION ~~Run per test~~ plans; reel 26

COMMENTS Ran accel at AWO, FWD and REV. Gave accel and decel data to Charlie for AWO and AW3. Accel and decel schedule for both are low. Car 3700 pulling more T/M current than 3701 = 25A higher. Successfully completed constant speed runs at 45, 18 and 12 mph for EMI.

ESC TEST RUN NO. 83 DATE 1-24-75

RUN TIME: START ____ WEATHER CONDITION: WIND VEL ____

STOP ____ DIRECTION ____

MILES RECORDED ____ AMBIENT AIR TEMPERATURE ____

TEST PERSONNEL:

TEST CONTROLLER ____

CHIEF TEST ENGINEER McClure

SAFETY ENGINEER ____

VEHICLE OPERATOR ____

INSTRUMENTATION ____

REAR MONITOR ____

GROUND CONTROLLER ____

ADDITIONAL PERSONNEL ____

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-R-0001-XX

TEST TITLE Dynamic Shake Test and Pull Test at AWO

VEHICLE CONFIGURATION AWO Car 3700

TEST DESCRIPTION Perform test per test plan; reels 26 and 27

COMMENTS Performed Pull Test on cars

3701 - 300 @ No. 1 end and 280 No. 2 end.

3700 - 160 @ No. 1 end and 280 No. 2 end.

All data for Dyn. Shake Test is recorded on tape, O'graph and instruction Log Book. Performed vertical, longitudinal and vertical torsion @ AWO - Could not do lateral due to lack of mounting fixture. Test data follows test Log No. 86.

ESC TEST RUN NO. 84-85 DATE 1-25-75

RUN TIME: START

STOP

MILES RECORDED

WEATHER CONDITION: WIND VEL

DIRECTION

AMBIENT AIR TEMPERATURE

TEST PERSONNEL:

TEST CONTROLLER

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER

VEHICLE OPERATOR

INSTRUMENTATION Sessions, Mcconnon

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-R-0001-XX

TEST TITLE Dynamic Shake Test - AW2

VEHICLE CONFIGURATION

TEST DESCRIPTION Reel 27

COMMENTS Successfully completed Dynamic Shake Test vertical, longitudinal and vertical torsion at AW2 and began AW3. Test data follows test Log No. 86.

ESC TEST RUN NO. 86 DATE 1-26-75

RUN TIME: START________ WEATHER CONDITION: WIND VEL________

STOP________ DIRECTION________

MILES RECORDED________ AMBIENT AIR TEMPERATURE________

TEST PERSONNEL:

TEST CONTROLLER________

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER________

VEHICLE OPERATOR________

INSTRUMENTATION Sessions, Mcconnon

REAR MONITOR________

GROUND CONTROLLER________

ADDITIONAL PERSONNEL________

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-R-0001-XX

TEST TITLE Dynamic shake test at AW3

VEHICLE CONFIGURATION________

TEST DESCRIPTION Reel 27

COMMENTS Successfully completed vertical, longitudinal and vert. torsion (17" offset) at AW3. Calibrated suitcase for Monday.

ESC TEST RUN NO. 87 DATE 1-27-75

RUN TIME: START 10:00 WEATHER CONDITION: WIND VEL

STOP 5:00 DIRECTION

MILES RECORDED 50 AMBIENT AIR TEMPERATURE

Reliability Run Time = 4 hrs, 45 min.

TEST PERSONNEL:

TEST CONTROLLER W. Myer

CHIEF TEST ENGINEER G. McClure

SAFETY ENGINEER G. Spons

VEHICLE OPERATOR

INSTRUMENTATION Mcconnon

REAR MONITOR

GROUND CONTROLLER

ADDITIONAL PERSONNEL Yutko

TEST PROGRAM SPECIFICATION NO. GSP-064

TEST PROCEDURE NO. ESC-PSI-6001-TT

TEST TITLE EMI and Reliability

VEHICLE CONFIGURATION 2 cars, AW3

TEST DESCRIPTION

COMMENTS Successfully completed EMI testing. During below base speed accels, fuses blew in EMI equipment and only could record freq. above 25. Re-entered reliability running. Checked out both sides of suitcase by swapping 3rd rail from 3700 from right to left for same 2 runs = 0.2 KWH A. Completed 3700 T/M input and output test.

GLOSSARY

Ampl vs Freq plot	Log-log plot or semi-log plot of data
AW0	Vehicle empty weight
AW2	Vehicle empty weight plus full load
AW3	Vehicle empty weight plus crush load
CB	Carbody
DOT	Department of Transportation
ESC	Energy storage car
ESS	Energy storage system
FWD	Forward
F.S.	Full scale
F/W	Flywheel
H.P.	Hewlett Packard
MTA	Metropolitan Transportation Agency
NA	Not applicable
NYCTA	New York City Transit Authority
PAR	Parallel
QSD	Quick shutdown
REV	Reverse
RQD	Required
SER	Series
SW	Switch
TSC	Transportation Systems Center
TTC	Transportation Test Center
T/M	Traction motor
UMTA	Urban Mass Transportation Administration
X-Y Plot	Graphical data presentation obtained by running analog magnetic tape into an X-Y plotter with minimum filtering.

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VHF Communications Usage by U.S. Railroads

Federal Railroad Administration; E.L. Morrison, Jr; W.B. Grant; R.H. Espeland; T. H. Hemp

1/1/1977

FRA-RFA-78/02

FRA/RFA-78/02

VHF COMMUNICATIONS USAGE BY U.S. RAILROADS

E. L. Morrison, Jr.
W.B. Grant
R.H. Espeland
T.H. Hemp

U.S. DEPARTMENT OF COMMERCE
INSTITUTE FOR TELECOMMUNICATION SCIENCES
Boulder, Colorado 80302

FALL 1977
FINAL REPORT

This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

Prepared For

U.S. DEPARTMENT OF TRANSPORTATION
Federal Railroad Administration
Office of Federal Assistance
Washington, D.C. 20590

06 – Signals, Control and Communications

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15. Supplementary Notes

Carrier channel spectrum assignment data was provided by the rail transportation industry through the Radio Liaison Committee of the Communications and Signal Section of the Association of American Railroads.

16. Abstract

This document provides a comprehensive overview of radio communications and channel spectrum usage in the rail transportation industry. It reviews much of the data analyzed and methodologies/logic on which The Summary of Findings and Recommendations are based. Considerable focus is given to the growth of radio communication usage and associated safety and economic related achievements which resulted. Addressed are the impacts posed by a loss or reassignment of channel spectrum. The countermeasures available to preserve the achievements in safety and operating command control categories are also included in this research study effort.

The need to document through research study the importance of radio communications usage so as to provide a more clear understanding throughout Federal/State governmental agencies, industry carriers, communications community and railroad labor organizations was a key motivation to pursue the effort. The critical concern of the FRA was to scope the safety and economic impacting value contribution.

17. Key Words Enroute event flow, propagation, frequency stability, needlines, equipment inventory, operational capabilities, data working files, frequency usage, assignment plan, frequency/spectrum allocation, quality degradation	18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

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Unclassified	Unclassified	263	

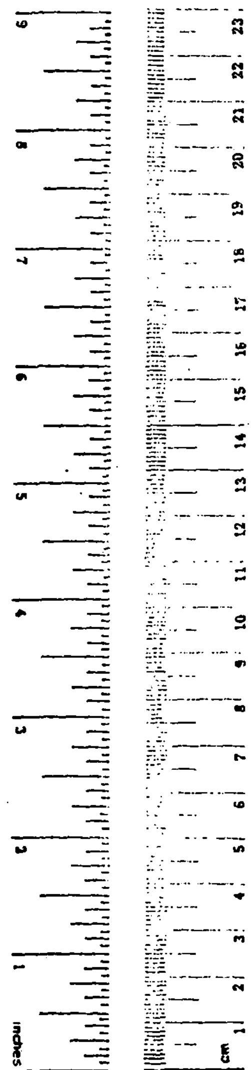
Form DOT F 1700.7 (8-69)

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

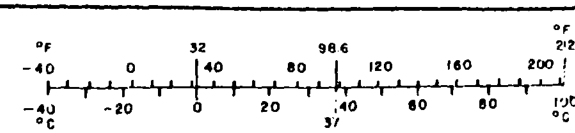
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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



VHF COMMUNICATIONS USAGE BY U. S. RAILROADS

E. L. Morrison, Jr., W. B. Grant, R. H. Espeland, and T. H. Hemp*

ABSTRACT

The U. S. railroad industry has implemented communications support services for various control and management applications. Communications services include microwave data systems, equipment control functions, and a wide range of VHF voice communications that are directly associated with resource management and movement control activities of the railroad.

With the increasing pressure from the maritime industry for additional channel allocations, particularly in consideration of the World Administrative Radio Conference (WARC) 1979, those existing VHF railroad allocations within the internationally allocated maritime channels (Footnote 287 frequencies) are being reconsidered as to the advisability of reallocating these railroad services with subsequent placement of all maritime allocations within the United States in accordance with international allocations. This report analyzes the impact of these proposed reallocation actions relative to cost and performance factors. Vacating this action would require railroad operations to implement a major exchange of equipment and procedures of operation over most of the continental U. S.

This investigation was initiated by the Federal Railroad Administration to examine the character of usage of VHF radio by the railroad industry, particularly relevant to the operational support required of these radio services; develop data regarding the current investment in VHF radio by the railroad industry; and examine various options and their consequences regarding reallocation of the railroad channels in conflict with the maritime channels or all the VHF radio services into other spectrum regions.

This railroad report describes the development of the operational and functional relationships that define the utility of the various VHF services, a detailed analysis of the impact of reducing current channel allocations or reallocation into UHF regions, the existing investment in equipment and support services, and the cost for proposed reallocation actions. The conclusions and recommendations of this report indicate the necessity of VHF radio to support the operational efficiency and safety of the U. S. railroad industry, and the major investment necessary by the industry over a period of almost a decade to transfer to another spectrum region. Current communications capabilities are fundamental to these operational considerations, and are not peripheral to other signaling or communications facilities. The conclusions on the basis of the data collected and the analyses developed favor the retention of all available VHF channels for the railroad industry because of the priority of operational support afforded by these communications and the indicated relationships to operational effectiveness and safety. The report presents detailed data summaries, operational and functional simulation and model exercises to demonstrate the communications usage in relation to operational requirements, and data regarding the time usage of the various communications channels.

* The authors are with the U. S. Department of Commerce, Office of Telecommunications, Institute for Telecommunication Sciences, Boulder, Colorado.

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1.0 INTRODUCTION

The radio frequency (rf) spectrum is recognized as a basic national resource, supportive to the national economy and defense, with priorities equal to those generally recognized material resources; energy sources, water, atmosphere, and natural physical material. One obvious difference in character is the non-consuming nature of the rf spectrum. The limitation in utility concerns the number of simultaneous operations within specific frequency channels and spatial regions that can be accommodated with satisfactory service. This usage is dependent on the modulation, unintentional emissions, spatial distribution of energy and receptor apertures, propagation modes, receiver discrimination and processing capabilities, and "channel" time statistics elements. The efficiency of channel usage or maximum support capability is dependent on signal and system technical characteristics, deployments and propagation mechanisms, and operational time factors.

With recognition of the rf spectrum as a prime national resource, the utilization relationship to national economy and security should be examined for all users to assure the maximum possible benefit to national goals. Renewal, reassignment or reallocation, and new authorization actions should have criteria that adequately consider the "national interest" support facets implicit with federal agency decisions. System technical parameters, employment and control procedures, and basic service support relationships should, therefore, be required as justification for proposals regarding spectrum usage.

During the previous three decades, one major element of the U.S. economy - the transportation industry - has developed extensive radio communications functions that are fundamental to control, management, security, and safety in relation to industry operations and public service. With the railroad industry, communications support roles have evolved that are in varying degrees functionally integrated with organizations and operations; also incorporated into the structure of operating rules and industry-union contracts. The operating rules for railroad and other elements of the transportation industry have been developed and modified over extended years between industry associations and the federal and individual state Departments of Transportation and Public Safety. Industry-union contracts have recognized the importance of radio communications to operational efficiency and safety. Efficiency considerations include equipment, operating personnel, and general citzenry located in the vicinity of industry traffic.

For railroad operations, radio communications affords extensive improvements in flexibility, reliability, and availability in comparison to manual signals (e.g., lanterns, flags), and the various telephone or telegraph line systems previously employed. These characteristics have allowed the large improvements in efficiency and safety for route and terminal transportation operations. Because of the extensive geographic coverage of railroads, the spectrum management problem is, however, significantly aggravated compared to other land mobile services.

Starting in 1944, the railroad industry initiated the utilization of radio for intratrain and train-wayside station communications, and local area security support. These uses, subsequently evolved into the existing large-scale integrated right-of-way, terminal, and yard systems for data and voice transmission, that are now fundamental to railroad facilities management, control, security, and safety. An explosive growth in radio applications occurred in the 1955-1970 period because of the demonstrated advantages in efficiency and safety and the acceptance by operating personnel.

Railroad communications can generally be categorized into the microwave data networks, and the VHF operations that are integrated into equipment coordination and control of nearly all right-of-way and yard functions. The microwave systems provide a multiplexed data and voice capability connecting terminals, and traffic and facility management elements to wayside stations that interface with VHF train communications and other remote track operations. The categories of VHF communications include intratrain (end-to-end); wayside station, train, or relay to train (point-to-train); and general service (yard operations, right-of-way maintenance and security, system supervision). The VHF categories in relation to railroad operations are discussed in subsequent sections of this report.

The current VHF radio communications functions will be extended in future years to incorporate increased data operations to improve the command/control effectiveness, and safety of yard and right-of-way operations. These modes will accommodate digital data displays for status and supervisory control information, and micro/mini processor interface for integration of track sensor (data with the command/control and alert or status information) transfer, intratrain and between trains, or moving equipment and supervisory or coordination elements. Voice will continue to be the primary mode for the command/

control functions provided by VHF systems, with the digital elements providing alerting, sensor assistance, and confirmation data for displays and local processor operations.

Frequencies for the Railroad Radio Service are contained in Part 93, Subpart H, of the Rules of the Federal Communications Commission (FCC). With a very few exceptions, all of these frequencies are at VHF in the 160.215 - 161.565 MHz band. The history of this allocation extends over some twenty or more years at which time this band was included as part of the Land Mobile Service. At a World Administrative Radio Conference (WARC) held in 1959, an agreement identified the 160.625 - 160.975 and 161.475 - 162.025 MHz regions for the exclusive worldwide use of maritime telecommunications as spelled out in Appendix 18 of the Radio Regulations of the International Telecommunications Union. However, a footnote (Footnote No. 287) was inserted in the Radio Regulations at the 1959 Conference to protect certain land mobile operations. (Without specifically stating, the footnote was intended to protect primarily railroad radio operations on those frequencies in the United States and Canada.) As of this time, the railroads of the United States still retained priority use of their VHF frequencies in the maritime band by virtue of Footnote 287.

The authorization of VHF for the Railroad Radio Service by the FCC actually consists of 91 channels, each fifteen kHz in bandwidth. The Railroad Radio Service, however, went through channel splitting three different times in arriving at the present fifteen kHz channels. While costly to the railroads each time, the channel splitting made possible continued use by the Railroad Radio Service of the VHF operations in the same contiguous spectrum.

Coordination of channel assignments within the railroad industry is effected through the Communications and Signals Section of the Association of American Railroads (AAR). This AAR group publishes annually a Frequency Assignment Plan which documents all industry licenses, and coordinates with the FCC all industry requests for new assignments or assignment modifications. The utility of the AAR Frequency Assignment Plan as one data source for the development of a Master Frequency File to support the reassignment analyses for this program is discussed in Section 3.2.2.

Commercial and government maritime operations have developed serious requirements for additional spectrum assignments during recent years for increasing voice, remote equipment control, and data transmission services.

The latter require bandwidths of at least double the standard channel. This maritime requirement and conflicting international interests in the elimination of the variation in Land Mobile band allocations represented by the present railroad assignments in the United States and Canada resulted in proposals by the maritime interests in both countries to phase the railroads and other land mobile operations from "Appendix 18" frequencies. The same maritime interests advocate strongly that Footnote 287 should be deleted from the Radio Regulations by the upcoming 1979 World Administrative Radio Conference. These proposals caused the Federal Railroad Administration of the U.S. Department of Transportation to initiate the study presented herein to determine the usage by the railroads of current assignments, and the impacts in cost and capability should the railroads be forced to either consolidate their VHF communications on the 58 channels remaining to them after vacating the maritime channels, or to relocate their operations to an entirely different band (presumably UHF).

The FRA recognized the national resource facets of this spectrum assignment problem and therefore organized an investigation that would address the requirements for VHF communications and provide the analyses of costs and capability penalties associated with any reduction in assignments or reallocation into other spectral regions. This program included the principal tasks listed:

a. Develop operational-communications connectivities to identify the specific utility of VHF communications relative to command/control and safety criteria. Right-of-way and yard areas were described separately. Communications availability and frequency usage were to be tracked through the operational descriptors.

b. Develop VHF communications investment data for U.S. railroads, with growth data for the previous two decades.

c. Examine the communications support capability impact, if the 33 channels (160.605 MHz to 160.980 MHz and 161.475 MHz to 161.565 MHz) were deleted from the railroad allocations. Determine the potential for reassignment of affected functions into the remaining 58 channels available to the railroad industry.

d. Determine costs for appropriate equipment modifications if reassignment of 33 channels into the remaining 58 VHF channels is functionally feasible.

e. Evaluate the operational capabilities and transition costs for reallocating the services supported by the 33 channels to the 450 MHz and 900 MHz regions.

f. Examine the potential for sharing of VHF assignments between railroad and maritime operations in major port areas.

g. Indicate the spectrum requirements implications of advanced support operations being planned by the railroad industry. These include track sensor and control data transfer, and mini/micro level processor interface.

Execution of these tasks required active participation by ITS, FRA, and the Communications and Signals Section of the Association of American Railroads. The AAR group participation was fundamental in assuring the necessary realism in the definition of right-of-way and yard operations and procedures, the communications events and the specific relationships to control and safety criteria, and interpretation of Frequency Assignment Plan listings relative to geography and types of service.

The general methodology employed for the analyses is indicated by the tasks listed:

a. Operations procedure specification and communication event definition to establish communication (and assigned frequency) support priorities. Flow diagrams indicating the right-of-way and yard operations involving communications support are presented in Sections 3.1.1 and 3.1.2.

b. Development of yard operations event models to derive ranges of operational penalties associated with reduced assignments. Delays in control of physical resources (switch and hump engine movement, inspection reporting and maintenance execution) and equipment and personnel safety (engine and materiel movement coordination) are derived in relation to frequency availability. The sets of most appropriate reassignments are examined; primarily reducing the available channels to serve operational functions. Impacts in communications availability because of the reductions in channels is subsequently interpreted in terms of control and safety criteria. The models are described in Section 3.2.2.3; the exercise results in Section 3.3.2.

c. Organize frequency usage data files with appropriate decision thresholds to evaluate the reassignment potential for the 33 VHF channels. Exemplary national and urban yard areas are tested with regard to interference and control utility. These fields are discussed in Section 3.2.2.1, and the reassignment tests in Section 3.2.2.2. Frequency usage summaries derived through selected retrieval exercises are presented in Appendix C.

d. Evaluate the utility of 450 MHz and 900 MHz spectrum region operations for yard and selected right-of-way communications, and derive transition costs and an implementation schedule for services indicating satisfactory usage. Technical and operational factors included in the analysis are summarized in Section 3.3.4.

e. Implement a measurements effort to validate the operations model task specifications and associated communications events with existing frequency assignments. This was accomplished at the Atchison, Topeka, and Santa Fe Railroad yard at Barstow, California. Records of individual communications channel usage were also used to update message character statistics. These measurements are discussed in Section 3.3.6.

f. Collect data from AAR and equipment manufacturers to indicate the existing investment and possible trends for VHF communications equipment and supporting services.

g. Review advanced usage and technology application planning by U. S. railroads that impacts the future VHF spectrum requirements. These include digital modes for control and sensor data, and mini/micro processor applications. Information to support this task was provided by AAR and industry sources. The applications and spectrum implication information is presented in Section 3.4.

Subsequent sections of this report detail the technical and data analysis tasks indicated, with Conclusions and Recommendations presented in Sections 5.0 and 6.0. These final sections relate specifically to VHF spectrum usage by the railroad industry and the expected impacts of any reductions in channel assignments or reallocation to the UHF spectral regions, and recommended actions by the railroad industry and AAR relative to spectrum management and planning functions.

2.0 PROGRAM BACKGROUND

2.1 Proposed Allocation Actions

As indicated previously, this program was initiated because of mounting pressure by the maritime interests on the FCC and on the Office of Telecommunications Policy to remove railroad operations from the "Appendix 18" frequencies and to reassign them for marine use in United States ports, waterways, and coastal confluences. Included in these pressures are proposals to delete Footnote 287 from the Radio Regulations when they come up for review at the 1979 WARC.

Specific actions that could result if the maritime proposals referenced above prevail are (1) the railroads could be required to vacate the spectrum concerned and to concentrate their operations on their remaining frequencies -- in short, accept a one-third reduction in spectrum; (2) the railroads could be offered replacements for the spectrum lost to the maritime interests in the UHF band -- result would be a split requiring two sets of equipment, one at VHF and one at UHF; (3) the railroads could be required to vacate all of their VHF spectrum and relocate their operations to UHF, i.e., to the 400 MHz region; or (4) the railroads could be required to vacate all their VHF spectrum and relocate to the 900 MHz band area. The simplest solution from the railroad standpoint would be, of course, to maintain the status quo.

The maritime services have been clear in statements to the FCC that requirements for short-range communications have grown substantially in recent years. Even if all of the railroad frequencies were turned over for maritime communications, the requirements of the latter would not come close to being satisfied. The additional maritime requirements include a large number of channels for public correspondence communications and spectrum to implement such functions as Vessel Traffic Systems (VTS) communications and various remote control operations.

For these services, the operations would be primarily in port areas, along the U. S. coastlines, and on inland lakes and large rivers. Sharing the allocations between railroads and maritime operators, therefore, has high potential for interference problems.

Interference is critical to both users because of the safety implications and the probable unacceptable degradation in efficiency of railroad and maritime commercial transportation operations. This consideration is additionally critical for railroads because of the usage rates for right-of-way and yard channels, as demonstrated by the data presented in this report. The potential for shared service in deep sea and river port areas is addressed in this investigation.

Subsequent sections of this report indicate the VHF communications utility by the railroads relative to operations and services and the impacts in performance and cost for any UHF reallocation.

2.2 Railroad Radio Communications History Summary

The U.S. railroad industry has, since World War II, evolved a substantial application for communications and other electronic systems that utilizes the electromagnetic spectrum. These systems are licensed primarily for operation in various VHF, UHF, and microwave bands.

Communications functions presently include voice and control signals relating to train movement in right-of-way and yard areas, a number of switching and train organization operations in humping and transfer yards, system maintenance and security, remote vehicle and functional control, and a range of system data and command/control requirements. Radar applications are currently confined to hump retarder control systems.

All modern yards have been designed with primary reliance on communications for control of the various inspection and checking, humping, and train movement operations. Procedures and physical organization are based on this communication mode availability. System management and control also are based on data transfer capabilities over microwave and VHF facilities. This includes numerous command, safety, and security functions.

The Railroad Radio Service was established by the FCC on December 31, 1945, following extensive general allocation hearings in 1944-1945. The principal allocation consisted of 60 channels, from 158.430 to 161.970 MHz inclusive, each with bandwidth of 60 kHz.

In 1949, the Land Transportation Radio Services were established with the Railroad Radio Service as a sub-service therein. In this service, the principal mobile allocation was thirty nine 60 kHz channels nation-wide, plus two additional channels for use in the Chicago area only.

The present VHF mobile radio allocation for railroad service is composed of 91 channels at 15 kHz separation between 160.215 and 161.565 MHz. This allocation consists of 45 frequencies at 30 kHz separation (called primary and secondary) which, under FCC rules, are intended for assignment in the same geographical area; and 46 frequencies interleaving the primary and secondary channels, presently assigned under conditions to not interfere with stations operating on the primary and secondary frequencies.

Early in the evolution of the Railroad Radio Service, it appeared that licensing of railroad employees to operate radio stations would involve a number of complications both for FCC and the railroads. Accordingly, the FCC issued an order providing that railroad employees would be qualified for the operation of railroad radio stations if they successfully completed an examination on radio rules given by the railroad's regular rules examiners. The material on which such an examination should be based was appended to the Commission order and entitled "Railroad Radio General and Operating Rules." Another provision of the order was that any railroad wishing to take advantage of this arrangement was required to adopt these rules. Practically all railroads have adopted these rules and a number have included them in the regular book of rules governing the operation of railroad trains.

The first use of radio by railroad was for communications between the conductor and the engineer (end-to-end) and between wayside stations and the train (point-to-train). Subsequent applications included communication between right-of-way crews and trains, and communication in support of nearly all yard and terminal activities. The use of radio has greatly enhanced the safety and efficiency of all operations. The radio communications nets utilized by the railroads permit a visual inspection of all trains by employees with an immediate and timely report of abnormal conditions and emergency situations. A closer coordination of track-side maintenance forces and normal rolling-stock traffic is accomplished through mobile radio links. Likewise, nearly all yard activities, such as car classification, inspection, switching, crew movements, servicing and repair, and general surveillance and security are accomplished more safely and efficiently with mobile radio.

Current applications include remote control of locomotives and extensive long-distance communication obtained via microwave systems. Future applications will include digital command/control microprocessor and miniprocessor data integration with track sensors and remote control facilities.

Present-day Radio Services

A partial list of the different radio operations now in service and several pictorial representations of these services are added to help the unfamiliar reader comprehend the need for and use of radio by the railroads:

A. End-to-End Radio -- Mobile radio provides essential communications from one end of a train to the other. On a freight train, for example, radio units are located in the locomotive and the caboose. On a long train, the distance between the two units may be one or two miles. Radio permits not only communications between the train crew in the caboose and the engine crew in the locomotive regarding the normal operation of their train, but is also a means of warning when an emergency or unusual condition occurs.

B. Train-to-Train Radio -- All trains on a given railroad use the same channel for end-to-end operation. Therefore, the crews of one train can talk to other crews of the same railroad when such trains are within radio range. The crews of all trains have standing orders to observe the condition of passing trains with special reference to potential hot boxes, shifted loads or dragging equipment.

C. Point-to-Train Radio -- Radio is used to provide communications between trains and telegraph offices (the traditional railroad term, which today might better be called wayside offices). On a number of railroads, this form of service also provides communication between the train dispatcher and moving trains. The dispatcher is the railroad employee who has the responsibility of seeing that trains move safely and efficiently over that area of the railroad he controls.

D. Automatic Wayside Equipment -- A number of railroads have devised systems whereby detector devices on the right-of-way transmit warnings to train crews immediately when a defect on the train is discovered. This system is used on the end-to-end frequency in connection with the operation of such devices as hot box detectors, dragging equipment detectors and wide load detectors.

E. Maintenance-of-Way Operation -- The maintenance of railroad tracks, roadbeds and rights-of-way requires numerous varieties of equipment, much of which is highly specialized. Examples are ballast cleaners, ballast tampers, spike drivers and tie renewers. Some of these machines operate off the track, but most of them employ the rails for movement, and some of them are extremely heavy. On some roads, equipment of this kind is furnished with radios that utilize the railroad's end-to-end frequency. On other roads, a separate frequency is required for maintenance vehicles. In the latter case, there is normally an additional radio or radio channel associated with this equipment to permit the maintenance-of-way gang to communicate with approaching trains on the end-to-end frequency. This is absolutely essential because the single greatest danger to be feared in maintenance-of-way work is that the work equipment will be struck by trains.

F. Use of Radio by Track-side Maintenance Forces -- Trackside maintenance forces, such as section forces, track supervisors, Communications Department maintenance personnel, Signal Department maintenance personnel and Engineering Department personnel operating along the railroad are provided with radios, usually in their vehicles, whether it is a station wagon, heavy truck, track motor car or, in some cases, packsets. Normally, the communications carried on by this group of people in their regular work are confined to the need to communicate with trains, or to communicate through the point-to-train radio system with either the telegraph operator or with their supervisors in order to report conditions along the railroad or to advise when abnormal conditions have been found and repaired.

G. Switching -- Switching operations are greatly assisted by radio. The frequency used may be either the end-to-end frequency, in cases where cars are picked up or set out in the course of over-the-road movements, or separate frequencies in terminal areas used solely for yard switching purposes.

H. Mobile Relay -- In yard and terminal areas on a number of railroads, mobile relay stations are used to increase the range of packsets so as to permit communication between them (when they are carried by men on the ground) for the entire length of the train. Such a train may extend from one end of the yard to the other. This service is ordinarily used to facilitate car inspection (for brake and other mechanical appliances associated with the work of assembling, disassembling and dispatching trains). Both inbound and outbound inspections for such mechanical matters are essential (many are required by law), and they require personnel to work around moving cars, thus making an instantly available channel of paramount importance to safety.

Figures 2.1 and 2.2 illustrate some of the uses described above. These figures and the use descriptions were edited from a report prepared by the Communications and Signal Section of the Association of American Railroads.

The Frequency Assignment Plan

A frequency assignment coordination procedure was initiated when the Railroad Radio Service was first established in 1945. As a first step, a questionnaire was sent to all railroads on the Association of American Railroads (AAR) roster. Each railroad was requested to submit maps with all lines marked in colors indicating what radio installations were being proposed. At that time, frequencies allocated to the Railroad Radio Service were primarily for train service; that is, communications between the front and rear of long trains, train-to-train, and from fixed point-to-train. The rules provided that, on a secondary basis, the frequencies might be used for radio communications in yard and terminal areas. Thus, in preparing the maps, the railroads were instructed to indicate in which yards and terminals frequencies were required and how many frequencies were desired.

With the questionnaire information on hand, work began on a national frequency assignment plan. Since Chicago was the largest terminal area in the United States and railroads fanned out from that point to all parts of the country, the assignment of frequencies was made with Chicago as the keystone of the plan. Upon completion of the assignment plan in the Chicago area, a meeting of communications officials of the Chicago railroads was held to achieve an approval of these tentative assignments. After the approval, a draft assignment plan was drawn up for the rest of the nation which was subsequently reviewed and approved.

Upon final completion and approval, the nationwide frequency assignment plan was submitted to the Federal Communications Commission by the President of the Association of American Railroads. The plan was filed with the FCC as a recommendation, subject to change as necessary to meet the requirements of the individual railroads. From the time the plan was originally submitted to the FCC, the Communications Engineer of the AAR has been available to coordinate frequency assignments between the various railroads. After obtaining agreement on changes in assignments, a recommendation is submitted to the FCC for a change in the national Frequency Assignment Plan. This practice has

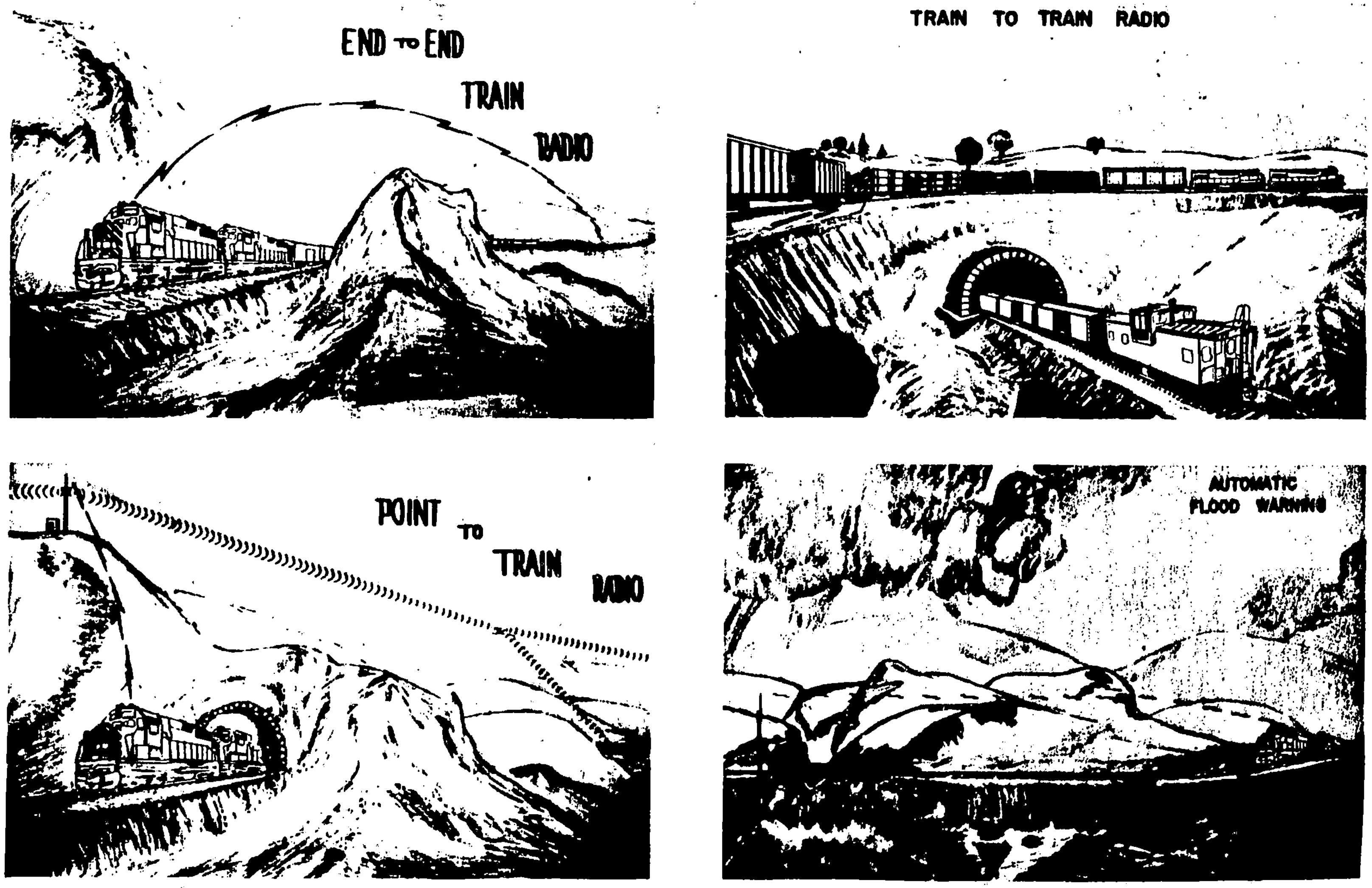


Figure 2.1. Illustrations of radio use by railroads.

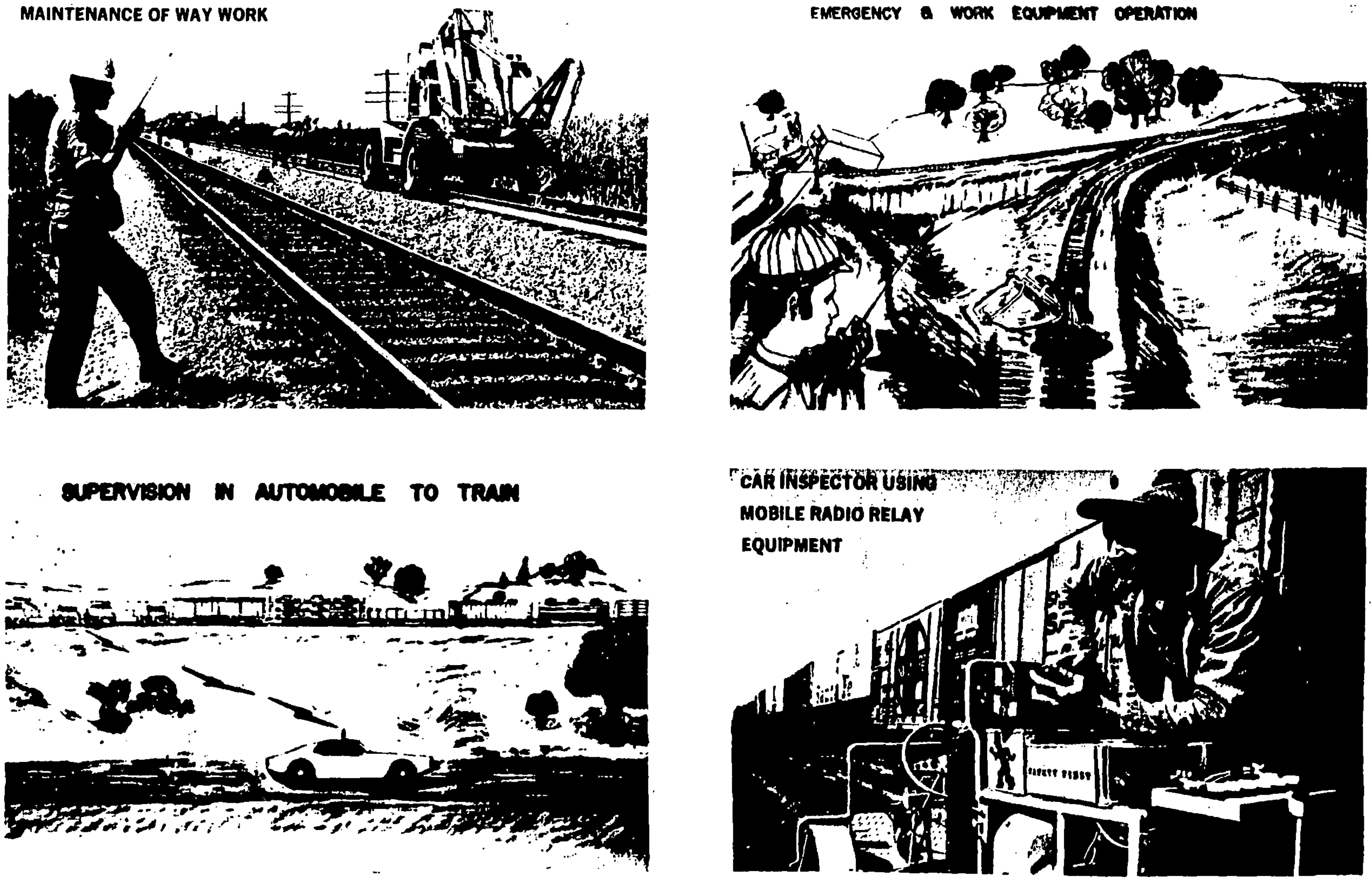


Figure 2.2. Illustrations of radio use of railroads.

continued to the present time. Between 100 and 150 changes, for example, are required each year.

The Canadian and United States railroads are assigned the same frequency band. Therefore, in the United States-Canadian border area coordination between assignments to U.S. railroads and Canadian railroads is necessary to avoid interference. By agreement with Canadian railroads, U.S. railroads in the border area have been assigned primary and secondary frequencies (Line A area). The Canadian railroads are assigned tertiary frequencies only, in this same area. Thus, a 15 kHz offset is provided between the frequencies used by U.S. and Canadian railroads, which, in most cases, is sufficient to eliminate interference.

No agreements currently exist for operations along the U. S.-Mexican border. Mexican railroads presently use no VHF radio operations, but are planning future applications. Frequency coordination is simplified because of the different spectrum areas that will probably be employed by Mexican railroads and because of the low Mexican railroad activity within about 100 miles of the U. S. border.

UHF Radio

In recent years, American railroads have had great success in the operation of remotely controlled auxiliary locomotives, through the use of radio. Slave locomotives are usually located somewhere between the rear and center of the train. They automatically perform all operations needed in starting, pulling, and stopping a train in response to controls from the lead locomotive. The several series of digital pulses used to transfer information between the controlling and controlled locomotives are issued in a coded and programmed format to provide fail-safe operation.

Three pairs of frequencies in the UHF band (450-460 MHz) have been allocated for railroad use. These are 452.900/457.900, 452.925/457.925, and 452.950/457.950 MHz. They are numbered, respectively, 47, 47m, 48, 48m, 49, and 49m. Channels 47 and 47m are authorized for general use and 48, 48m, 49, and 49m are authorized for remote control of slave and hump locomotives. The channels 47 and 47m are employed for locomotive-passenger terminal communications. Under the existing rules, these radio frequencies (452.925/457.925 and 452.950/457.950 MHz) cannot be used, even by railroads, for any other purpose.

Microwave Systems

A number of railroads have microwave systems along their rights-of-way to provide communications for railroad operations. In years past, the railroads' pole line provided for these communications needs. In recent years, the pole line has been supplemented or replaced by microwave to obtain the additional channels required for the extensive use of direct dialing telephone communications over the entire railroad, as well as to provide for the communications required for data and control of VHF point-to-train and point-to-mobile communications.

A railroad microwave system differs from the microwave systems of other users, primarily in the large number of drop-out points needed to serve local wayside communications and VHF control. Also, extensive branch operations feed off the main line right-of-way, all requiring communications. The microwave systems that are available for private users (railroad companies) have a maximum of 420 channels. Often, this entire baseband is allocated in segments to different parts of the railroad. In the process of providing service for the different branches, there may be only 50 percent loading of the total number of voice channels. Regardless of the link loading factor, the total bandwidth must be available and is used to provide the required system service.

3.0 TECHNICAL DISCUSSION

3.1 Communications Support to Railroad Operations

As indicated previously, one of the major emphases in this program concerns the priorities of supporting VHF communications in relation to railroad operations. These include equipment movement, facility maintenance coordination, and various inspection and status monitoring functions, with an identification with command/control and safety criteria.

This section presents discussions of sets of right-of-way and yard operations in the form of flow diagrams. The sequences of operational events particularly demonstrate the communications linkages; intratrain, train-to-track personnel for movement coordination, and the various control functions in yard operations.

These flow diagrams represent the basic form of operations for the specific functions indicated. Variations in procedures between railroads cause only minor differences in specific sequences, and have no effect on the support modes demonstrated.

As mentioned previously, these operations descriptors are the basis for the organization of the operations and communications resource utilization models described in Section 3.2.2.3. These models, with supporting communications channel activity measurements, define the typical usage and relationships to safety and command/control, with the current channel assignments, and various reduced channel availability situations.

3.1.1 Enroute operations

Enroute operations are those performed on the main run of track which interconnects the major switching yards and terminals. These include the actual operation of the train, including scheduling, set-out and pick-up operations, plus responding to all emergencies involving train malfunctions and track disorders. Similarly, all maintenance work performed on the track and right-of-way are enroute operations. Maintenance crews often use locomotive-powered equipment moving on the track and need to actually schedule reserve time for the operations. All crews traveling and working on the main lines have communications with each other and wayside stations in support of these operations.

3.1.1.1 Train movement functions

The flow diagram in Figure 3.1 displays typical sets of alternate events that generally occur during a train movement enroute. The diagram details actions required for each of several occurrences. The use of communications to enhance the efficiency and safety of these actions is implied. Nearly all such communications are by mobile radio or supplemented by radio.

The events start at the top of the flow diagram (Figure 3.1), with the train entering the departure block or an enroute block. Subsequent alternative actions are: routine, alert, and new train orders. If routine, the column on the left of the diagram shows typical following actions and communications. End-to-end movement includes (end-to-end) communications and actions to put the train underway or to continue movement. The actions that follow are primarily (point-to-train) communications between wayside stations, work crews or supervisors regarding status of the train and schedule. On most lines, all employees are required to make a visual inspection of passing trains to observe their functional status.

A second alternative would be train orders involving a change of schedule, emergency condition or instructions to "pick-up" or "set-out" cars. Such action requires (end-to-end) and (point-to-train) communications.

The third alternative, outlined in the diagram, starts with an alert. Such an alert can originate at any time enroute and at any location. The nature of the hazard or emergency may call for a stop or slow-down with subsequent movement to a siding. Either action would require a communications with a wayside station to advise supervisory personnel of this departure from schedule. An inspection by members of the train crew show that alternative actions (second page of Figure 3.1) could be a repair with subsequent resumption of schedule or a partial repair with a movement to clear the tracks. This might be followed with a car set-out and repair operation. Either alternative requires, again, communication (point-to-train) between the train and wayside stations, and (end-to-end) communications on the train.

Of course, other actions and communications possibilities exist. Those depicted in the diagram represent a major coverage of typical enroute train movement operations.

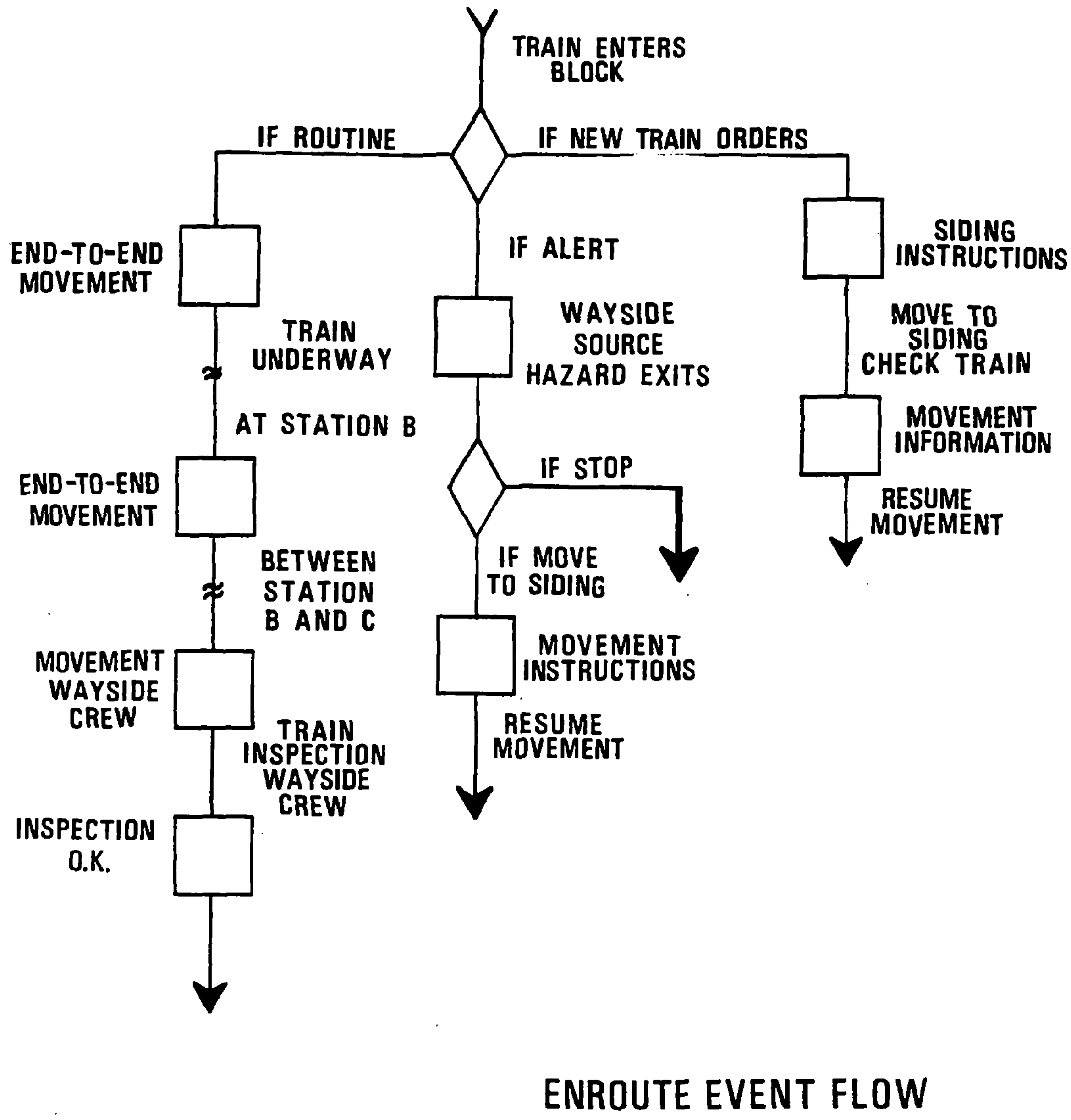
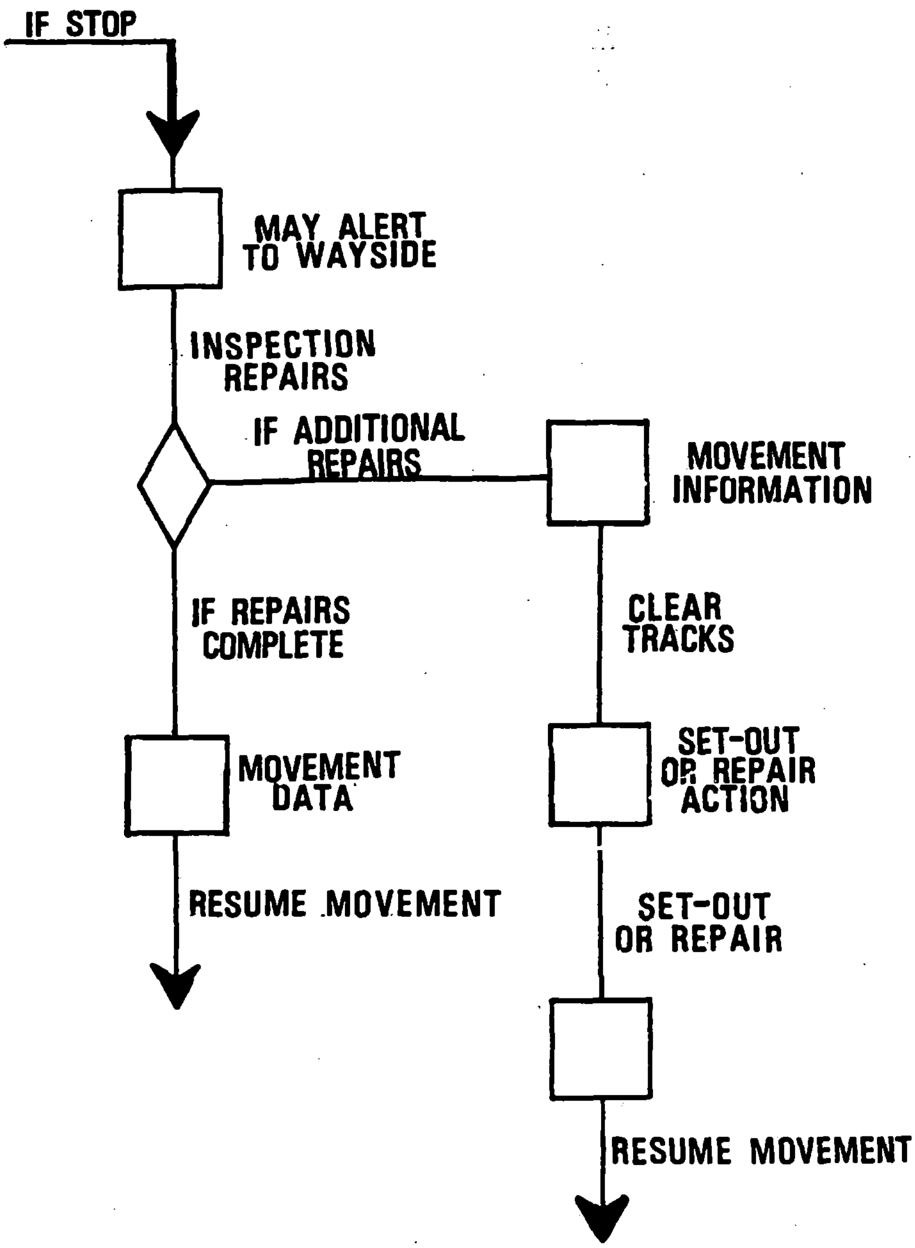


Figure 3.1. A flow diagram of enroute events.



ENROUTE EVENT FLOW

Figure 3.1. (cont'd) A flow diagram of enroute events.

3.1.1.2 Right-of-way maintenance

Right-of-way and track maintenance are not performed on a routine schedule, like the operation of trains. However, maintenance and repairs do involve the track and track side; therefore, scheduling and monitoring of the work is required. Routine maintenance would be scheduled at the most convenient time, in accordance with regular traffic. This scheduling includes the movement of equipment and personnel, often on the main tracks, to the work area. It may also require temporary clearing of the tracks to accommodate regularly scheduled trains. The availability of mobile radio affords a close scheduling capability without sacrifice of safety, and also provides a means for timely alerting of departure from planned schedules.

3.1.1.3 Supervision and security

These functions support right-of-way operations through the activities of various supervisory elements associated with facility maintenance, equipment control, and police surveillance and protection for railroad equipment.

Supervisory activities concern equipment movement coordination, maintenance crew movement, and various status monitoring responsibilities. These supervisory functions involve personnel located at operational control centers (e.g., Trainmaster and dispatcher offices), coordination responsibilities, particularly relative to train movement (movement to sidings for equipment repair and modified movement orders to other trains to assure safety, track or other facility emergencies), and supervision and coordination of right-of-way track and other fixed facility repair or modification.

These supervisory functions require communications support connecting supervisory offices and vehicles, right-of-way offices or way stations, and train and maintenance crews. Generally, the VHF and microwave systems are utilized for these requirements, depending on the communications organization within individual railroads. Emergency situations along the right-of-way, such as those examples cited, require extensive coordination between trains or other track site equipment, service crews, right-of-way offices, and Trainmasters and associated supervisors to assure safety and minimal impact in train services.

Security functions along right-of-way areas are primarily provided by railroad police having the responsibility for inspection and protection of trains on the right-of-way, equipment parked on sidings, and fixed facilities and temporary sites located on railroad property. The protection role frequently requires coordination and cooperation with municipal or state police agencies.

These activities are compounded in industrial or urban areas where, for example, right-of-way tracks pass through large cities or a continuum of cities and towns where speed may be restricted because of crossings or the density of railroad traffic. The Northeast corridor is one example of this type of environment. Damage to railroad equipment and property and pilferage of freight from parked or slowly moving trains have been serious problems in such regions. Railroad police accompany trains and use automobiles along sections of right-of-way, with communications to right-of-way offices and central supervisors.

3.1.2 Yard operations

3.1.2.1 Yard functions summary

- o classification yards used exclusively by a given railroad line for receiving trains, uncoupling, and regrouping cars into new trains, according to geographic destination.
- o classification yards with the same functions as above but shared by more than one railroad line which may also include piggyback handling facilities and freight unloading and pickup capability;
- o a third type would include shared or unshared facilities with passenger handling services as well as those functions listed above.

The two main types to be discussed here, and which make up the majority of modern railroad yards, are the freight train classification yards, shared and unshared.

The modern classification yard uses computer-aided control and uses a vast array of communications and data processing equipment to assure a smooth flow of cars through the yard. Most modern yards also include diesel and caboose servicing facilities, and freight car maintenance and repair which may or may not include refrigeration car servicing.

The main yard is composed of three major yard areas, as shown in Figure 3.2: the arrival or receiving yard, the classification or hump yard, and a departure yard.

Within the functional action elements in these yard areas, communications has a fundamental role in the efficiency and safety of execution of the individual tasks performed by various yard crews. Included are switch and hump

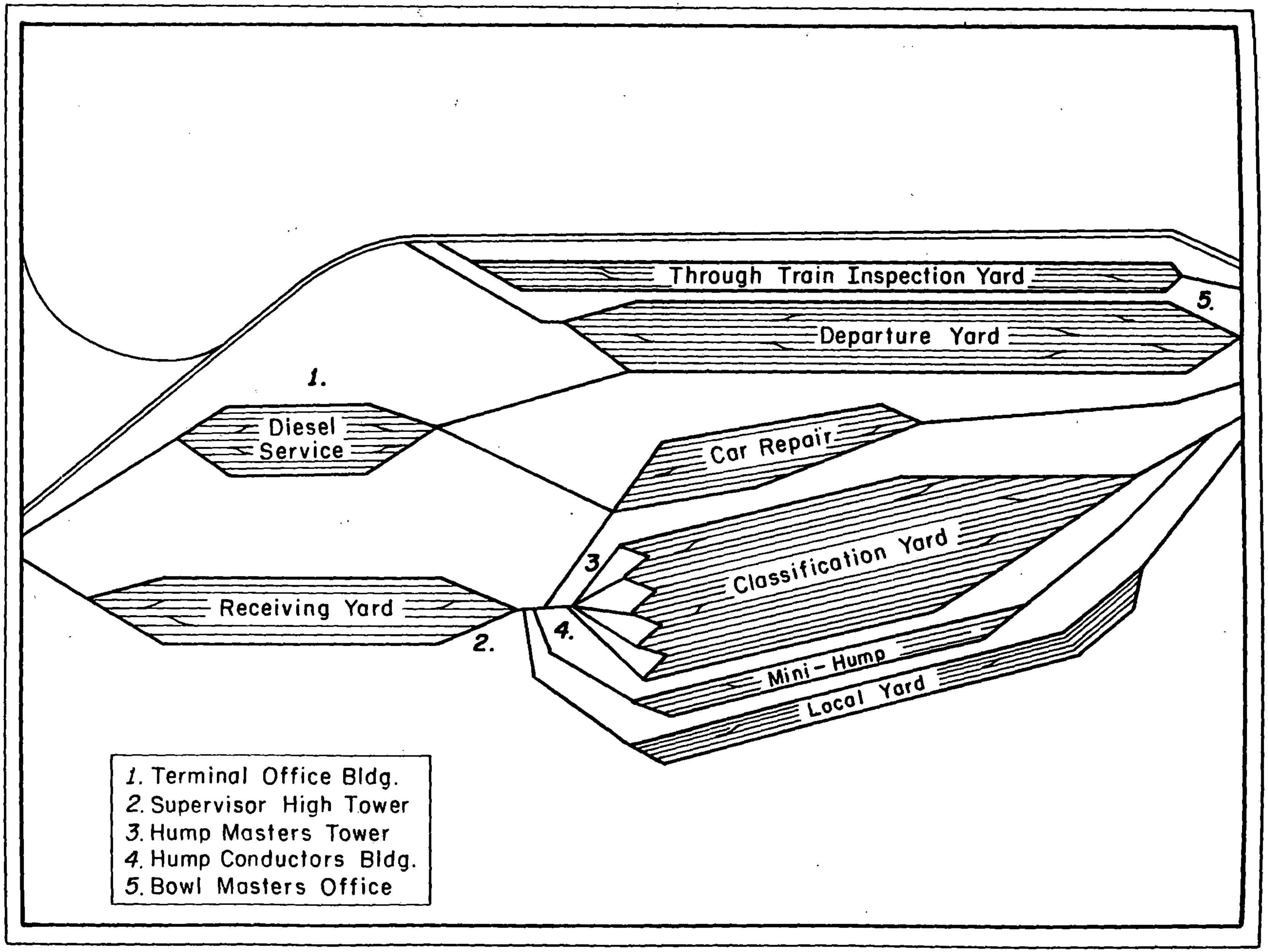


Figure 3.2. A modern railroad yard.

engine movement control and coordination, equipment inspection and repair, logistics control, administrative coordination, and security. These localized communications functions are all in the 91 channel VHF Land Mobile allocation, and interface with other right-of-way VHF operations (Train Service Modes), and microwave data services.

As indicated in the introductory section of this report, the analysis of railroad spectrum requirements and usage parameters must be based on operations support relationships. This procedure required the preparation of operational procedure definitions with communication users identified, thus allowing specification of the critical aspects of safety and control effectiveness.

A series of flow diagrams were prepared and closely coordinated with railroad operations and communications and signal personnel. These diagrams included primarily those yard operations requiring communications support; others were included only where clarity would be enhanced. The flow diagrams for the major yard operations are presented in Figures 3.3 through 3.10. Subsequent paragraphs summarize these operations descriptions, relating individual operations to the associated communications and user requirements. These descriptions also are the basis for the operations and communications event models as discussed in Section 3.2.2.2.3.

3.1.2.2 Incoming train communications functions

Information on trains due to arrive at a given yard, including associated car lineup and train movement status, is transmitted to the yard over railroad microwave communication links, or is transmitted via telephone. The information is presented to the train master from the computer on a cathode ray tube (CRT) display. This display contains details and status on all trains currently in the receiving yard and those due to arrive within the next 12 hours. This information is kept current by the computer which either updates automatically, or information can be entered manually as work progresses. This information is used by various supervisors to determine priority of trains to be worked.

Other computer outputs, either on printed paper and/or CRT display (depending on the yard), relate to the total number of cars in the various areas of the yard, the number of cars for given geographical destinations, a hump lineup, the moves necessary by switch engines to assemble outbound trains in the departure yard, and status of trains being assembled and planned.

These data-support operations indicate the basic character of communications utility for facility management and operational planning. In these contexts, the principals involved include the arriving train engineer or conductor, train masters, and yard master. Equipment status and identification are also provided to the hump master and yard area controllers, through similar communications and data processing systems, during the course of car processing and transfer within yard operations; this extends from the "breaking down" of a train in the receiving yard, to classification, and assembly actions for a departing train.

A train first arrives at the entry block, which is a point some miles away from the yard, designated by the respective line, as an area from which to report its arrival. The subsequent events are shown, starting with Figure 3.3. A call is made from the train to the yard on the assigned point-to-train radio frequency, notifying the yard of its arrival and, in return, getting a track assignment and routing instructions from the train master. The diamond shape nodes in the figures represent decision points. As seen in Figure 3.3, there are two possible assignments to be made for incoming trains; those trains to be broken down and classified, and through trains. Through trains are those designated for some other geographical area, but need enroute car inspection as required by law. If the train is a through train, the train master assigns it to an appropriate track in the receiving yard or to a special through-train receiving area which some yards have, as shown in Figure 3.2. The train master alerts the car inspector foreman of the incoming train on one of the yard frequencies assigned to car inspection functions. The car inspector foreman assigns the car inspectors to the train and inspection starts as soon as the train reports by radio that it is in position and ready. The car inspectors report, on the car inspector frequency, the extent and type of repairs needed. If no repairs are necessary, the train is radioed yard clearance on the point-to-train frequency. The train acknowledges and moves to the main track. The brakeman reports switch clearance to the engineer and to the train master on the assigned end-to-end frequency channel. The train master gives the order to "high ball"; the train confirms and proceeds on its way via the main track.

Returning to decision node number 2 (Figure 3.3), minor problems located by the car inspectors, such as brake shoes, hoses, etc., are radioed to the train master. The train master alerts the maintenance foreman on the frequency channel assigned to that function, and the maintenance foreman dispatches a

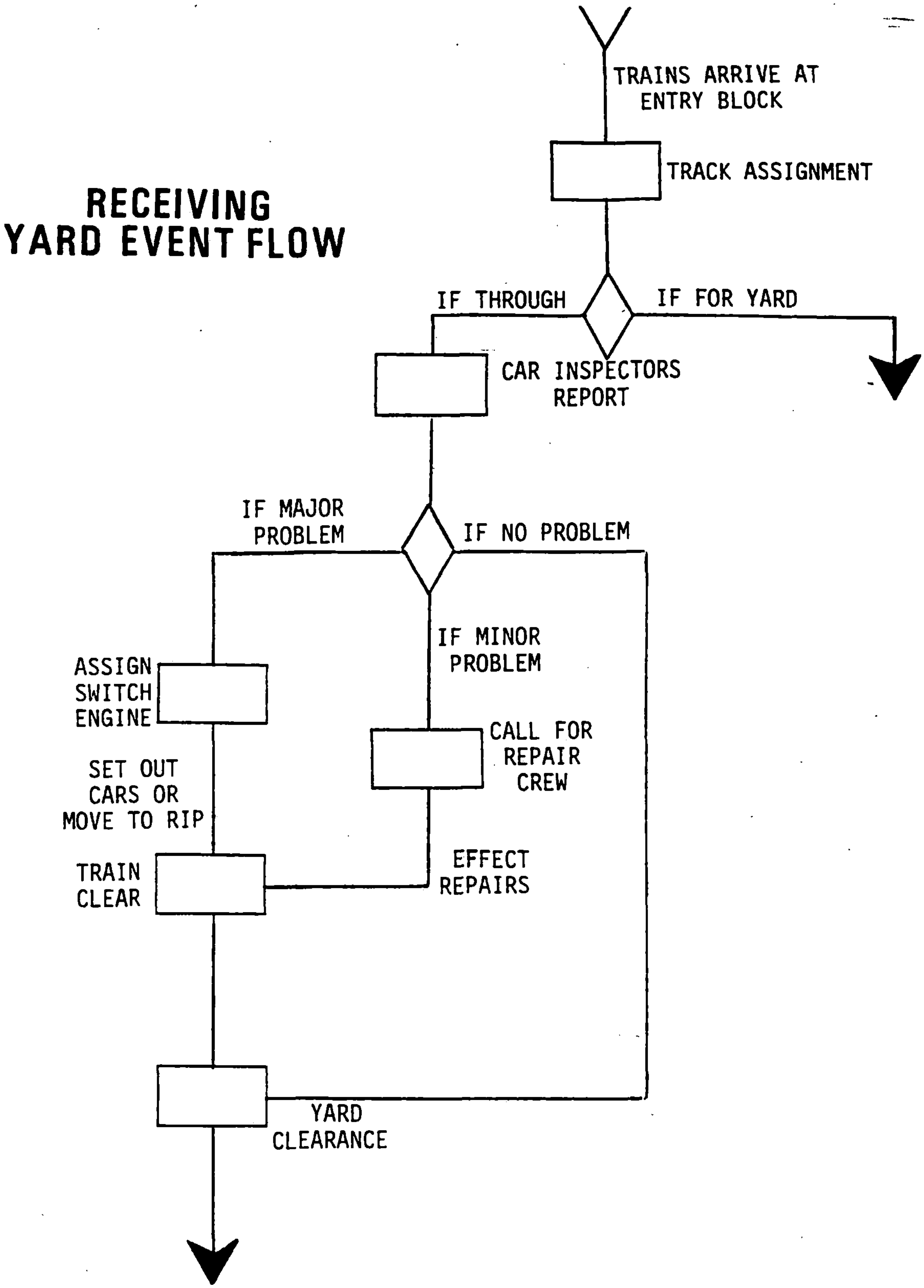


Figure 3.3. Receiving yard event diagram.

mobile repair crew to effect the repairs. The train master is notified by radio upon completion of repairs. The train requests yard clearance and proceeds as outlined above for the "no problem" situation. There are other communication events that support the repair operations while in progress. These may consist of communications between the brakeman, train engineer and repair crew for testing of brake action upon repair, air line pressure and coupling action when hoses have been changed, or any coordinated action necessary to complete and check out needed repairs.

The remaining branch from decision node 2 deals with major repairs. When major repairs are needed on a car (or cars), the car inspector radios this information to the train master. The train master calls for a switch engine to set out the car or cars which are in need of major repair, and the switch engine takes these cars to the appropriate car repair facility. The communication events needed to complete this "set out" consist of:

- assignment of switch engine,
- coordination of switch engine movement to the through-train receiving area,
- coordination between the train engineer, brakeman, and switch crew in uncoupling, setting out cars, and recoupling the train,
- the coordination of switch engine movement taking the cars to the car repair facility, and
- reassignment of the switch engine.

The frequency channels involved would be those assigned to the following communication functions: end-to-end, maintenance, switch engine, car inspection, and the various yard areas through which the switch engine passes to complete its assignment. Upon completion of "set out" and recoupling, the train requests yard clearance from the train master and exits as explained under the "no repair" condition.

Referring to Figure 3.4 and decision node number one, if the train has a yard assignment, it is assigned a track in the receiving yard. In some yards, such as the Santa Fe's Barstow, California, classification yard, the road power is removed as the train arrives in the receiving area. The road power units are given track assignment in the diesel service area by the diesel shop foreman and move to the appropriate tracks for engine inspection and

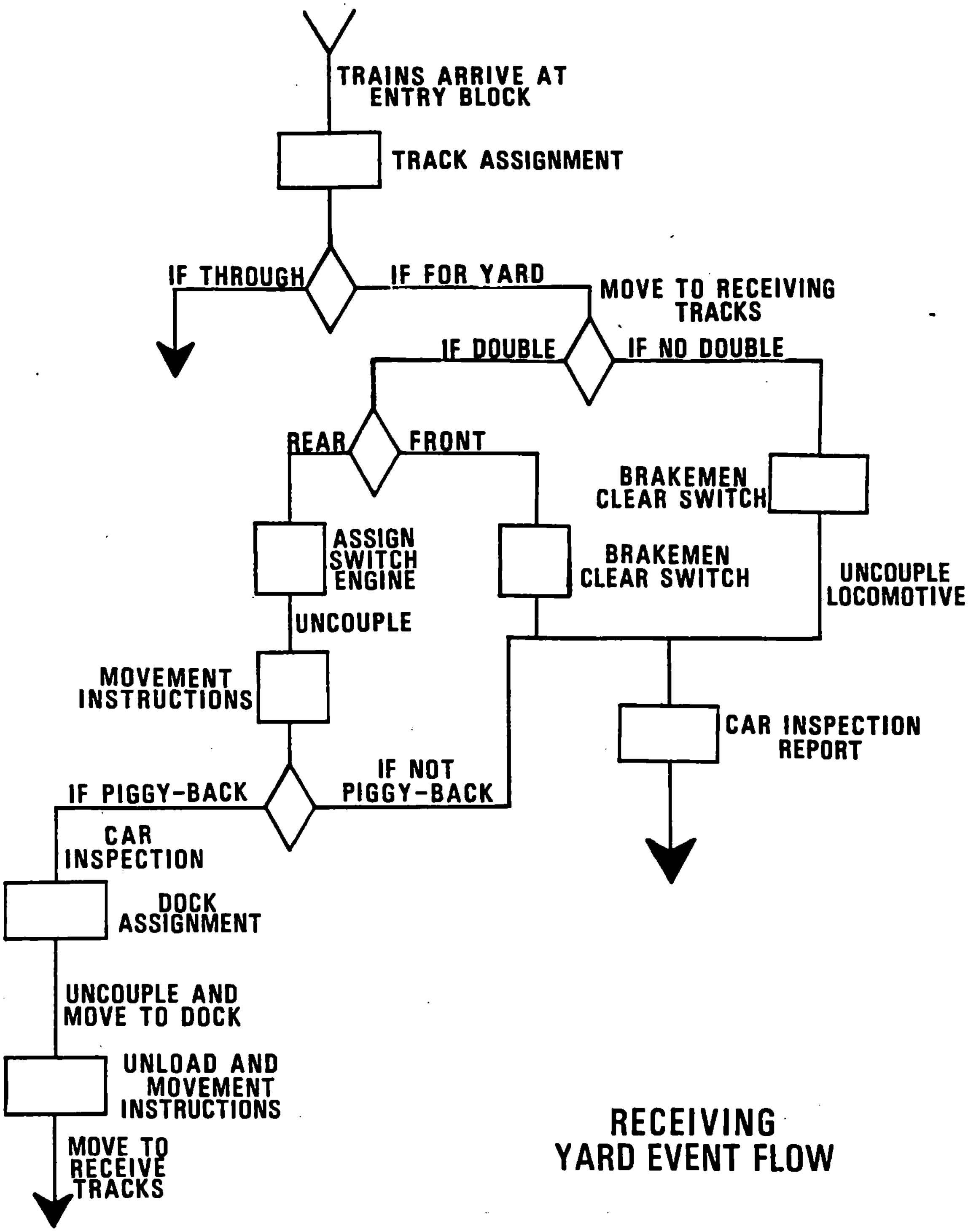


Figure 3.4. Receiving yard event diagram.

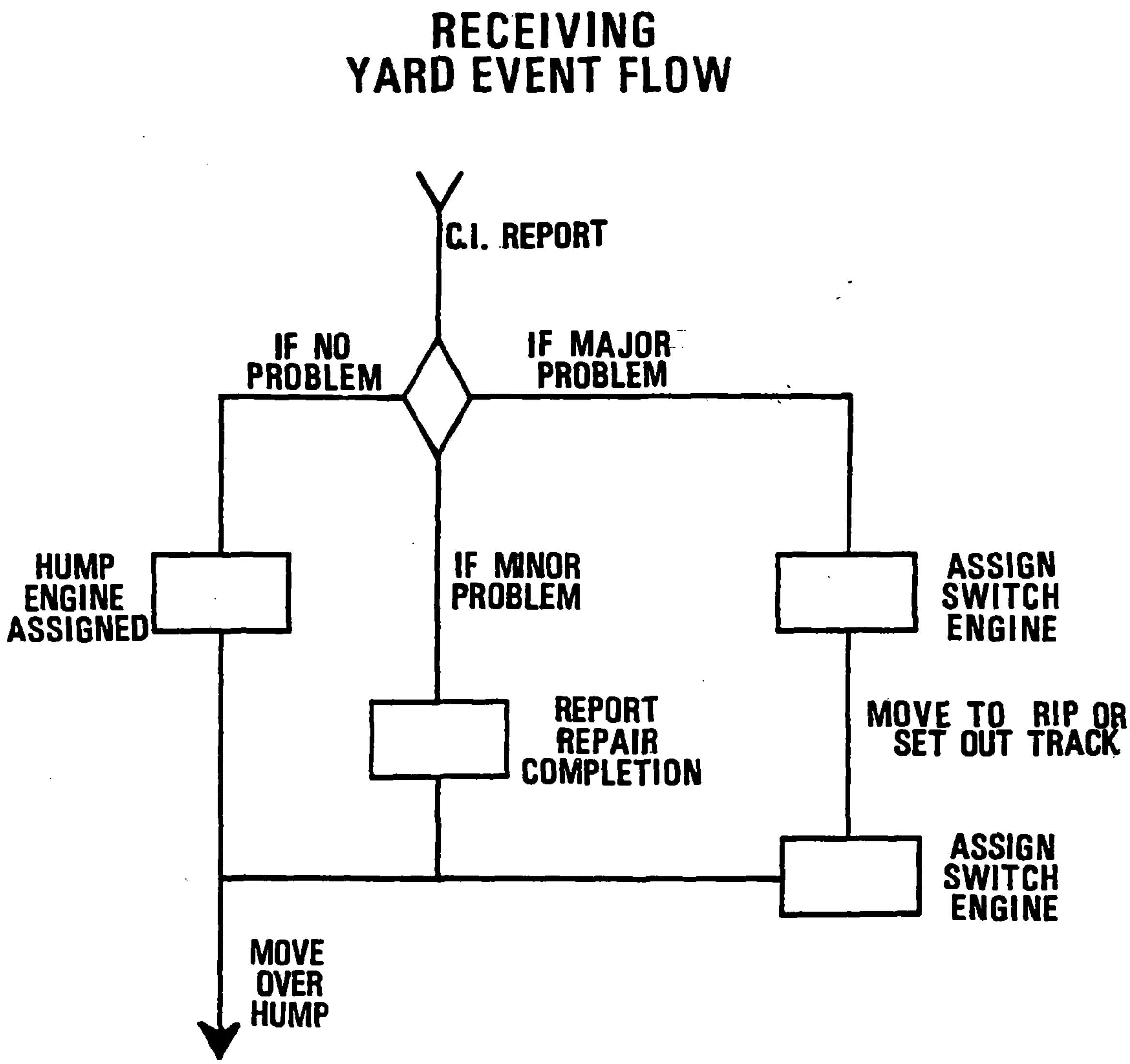


Figure 3.5. Receiving yard event diagram.

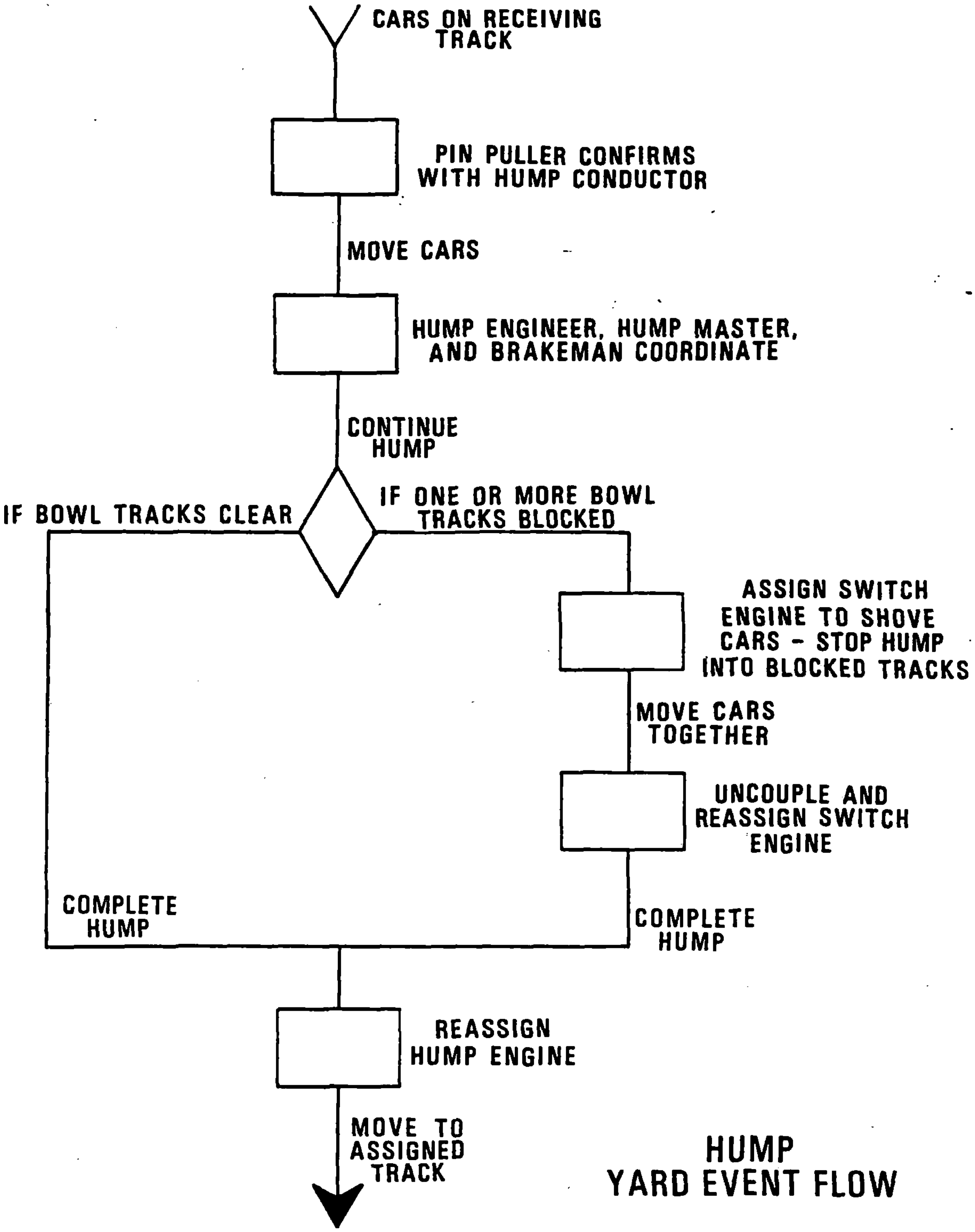


Figure 3.6. Hump yard event diagram.

service. The train master has alerted the crew caller foreman of the arriving train. The crew caller foreman assigns crews to each arriving train assigned for yard operation, thus the movement of trains in the yard is accomplished by yard personnel. A switch engine is assigned to pull the train onto the assigned track in the receiving yard. If the train is too long for the assigned track, a second switch engine may be assigned to uncouple the train in the middle and pull the rear section onto adjacent tracks. As the last car of each section clears the switch, the brakeman reports this event to the switch engine. When the train is in place, the train master is informed by radio and car inspection starts. The communications events that are needed to support the movement of a train into the receiving yard would consist of:

- announcement and confirmation of train arrival using the frequency channel assigned to the road or point-to-train;
- track assignment to the receiving yard and confirmation by the train using the same channel assignment as above;
- track assignment and confirmation for the movement of road power to the engine service area using a combination of road frequency and the diesel shop frequency;
- assignment of crews to the train by the train master via the crew caller foreman using the frequency channel assigned to the receiving yard for command and control;
- assignment of switch engines by the train master using either the individual channel assigned to each switch engine or the receiving yard channel;
- the assignment of car inspectors to the train via the car inspector foreman using the channel assigned to the car inspector function;
- coordination of the uncoupling of road power from the train using the end-to-end frequency;
- coordination in coupling the switch engine and uncoupling the train, coupling a second switch engine if a double is necessary. These actions would use the switch engine channels;
- movement coordination of switch engines, train movements, etc., using a combination of switch engine channels, receiving yard channel, and road channel.

If the train now in the receiving yard contains piggyback cars (flat cars carrying semi-trailers for trucking), the cars are assigned to a special dock designed for loading and unloading of these trailers. The piggyback cars are uncoupled, taken to the docks, unloaded, and the flat cars brought back to the receiving yard for humping. The communications support functions for the piggyback cars would be the coordination between the switch engine and crew for uncoupling and cutout of the cars, the movement coordination to the unloading docks, and the coordination upon return to the receiving yard.

The car inspectors inspect the train, checking car order and condition, then report any needed repairs to the train master as shown in Figure 3.5. A mobile repair crew is dispatched for minor repairs; cars needing major repair are cut out and taken to the car repair facility. This would be very similar to the car inspector function discussed for the through train situation and would use the same communications support. Upon completion of the car inspection and repair, the cars are ready for classification and are lined up for humping.

3.1.2.3 <u>Hump yard functions</u>

The event flow diagram for the hump activities is shown in Figure 3.6. The hump master is in charge of humping operations, issuing commands to begin operation, and supervises to assure everything in the humping process is functioning properly. The actual switching of cars into the appropriate tracks in the classification yard is an automatic operation under computer control. The humpmaster first reviews the inbound train lineup, either on his CRT or computer printout, and then, based on priority, determines the train identification and associated hump list number of the train to be classified. Based on this information, a switch crew is assigned and necessary switch alignment made to allow movement of the train from the receiving yard to the hump. During this movement, the humpmaster will enter the computer command identifying the hump list to be processed. Once the humping process has begun the humpmaster has the capability to override the computer and change signals, switches, or retard car speed manually from his console. He is in radio contact with the hump engine, hump conductor, and bowl master during the complete humping operations.

The train to be humped is pushed over a physical hump in the yard. As each car arrives at the top of the hump, a pinpuller uncouples it and the car coasts down the hump, through some speed-retarding section of track, and is switched into the appropriate track, under computer control. The tracks in the classification yard are graded so the cars will slowly coast down the track. The speed, as set by the computer operated retarding section, is such that the car is supposed to couple appropriately with any cars already on that track.

A hump conductor directs all actions involving the movement of cars over the hump while the hump master is concerned with the over-all classification of the cars. In this operation, a very tight coordination is required between the hump engine, the pinpuller, the hump conductor, and the humpmaster. For example, the cars moving over the hump in the Barstow, California, yard are traveling 2.4 miles per hour or at a rate of about 3 cars per minute. With this much activity, it is imperative that communication functions supporting these activities be dedicated frequencies not only for command and control but, particularly, for safety.

There are some classification yards such as the Barstow yard which have an automatic pause after some designated number of cars have gone over the hump (every eight cars at Barstow). After checking the status of the yard relating to the space availability, equipment status, and personnel operations, an appropriate command is entered to restart the operation, if all systems are "go." As the cars are switched into the classification tracks, the bowlmaster keeps alert of the status of cars in the bowl area.

Since the rolling friction is different for various cars, sometimes the tracks get blocked by cars which have not rolled the required distance down a given track. When this occurs, a "pull move" is required to shove the cars together and pull them to the end of the bowl track or into the departure yard. When pull moves are required or when cars are moved from the classification yard to the departure yard or minihump, the bowl master will take necessary steps to arrange for movements. This is shown in Figure 3.6, from the decision node to the right. The bowlmaster assigns switch engines for pull moves, as well as directing activities in the minihump for yards that have one. If there are cars that are mis-switched or some other problem occurs on the end of the classification yard closest to the hump master which causes a car to block a track, a "trim move" is made with a switch engine assigned by the hump master.

The communication activities in support of the hump events follow:

o coordination between the receiving yard car lineup and the hump master using a combination of the receiving yard, hump yard, and switch engine frequencies;

- assignment of switch engine to hump cars using the switch engine frequency;
- coordination of humping between the hump conductor, pinpuller, hump engine, brakeman, and hump master using the hump frequency and the hump engine frequency;
- uncoupling and reassignment of hump engine using the hump engine frequency;
- coordination between the hump master and bowl master using either the hump frequency or bowl frequency;
- assignment of switch engine to "pull" in the classification yard using the switch engine frequency.

These events, because of the many cars that move over the hump in a given day (at Barstow approximately 2,000 maximum in 24-hour period), demand dedicated frequency channels, particularly for safety of personnel and equipment, as well as command and control.

The ATSF Barstow yard uses a minihump to build smaller car blocks and put them in station order without tying up tracks in the main hump yard. For example, a train can be made up on the west coast, heading east, and the cars can be arranged in station order for ease in setting out as the train progresses from west to east. Cars for such a train are switched into the specified tracks in the main classification yard. When it is determined by the bowl master that these cars are ready for the minihump operations, a switch crew is called to pull the cars from the main classification tracks, in the appropriate order, to the minihump. The necessary moves to be made in the minihump are generated by the computer for the minihump conductor. The computer output helps to minimize the amount of classification switching as the blocks are put together.

When the blocks are in station order, the switch crew puts the train together by pulling the cars from the minihump tracks (in an order advised by the bowlmaster). The bowlmaster assigns the completed train a position in the departure yard. Of course, for those yards with a minihump facility, there are increased demands for communications since the amount of communications involved in these operations will be comparable to those in the main hump. The main difference in the minihump events compared to the main hump events would be the number of cars humped and the control person. Perhaps only one-third of the cars that are humped are minihumped; the minihump is under control of the bowl master and the minihump conductor. The frequencies used for this operation are the bowl frequency and the frequency channel assigned to the switch engine (assigned to minihump use).

3.1.2.4 Departure yard functions

Cars that have gone through classification are pulled from the classification tracks in the main hump yard, or from the minihump, to the departure yard. The bowl master arranges these pulls and assigns tracks in the departure yard. He also is responsible for the make-up of trains and, again, receives information from the computer on train makeup, order, cars involved, destination, priorities, and estimated time of departure.

When all cars making up a train are in the departure yard, the car inspectors are assigned to check the cars for damage and proper car assignment. In Figure 3.7, at decision node number 1, if the car inspectors find a problem, the bowl master is notified by radio and he, in turn, assigns a switch engine to set out the car or cars. The switch engine couples and moves the cars to the hold tracks, for minor repair, or to the car repair facility, upon assignment by the bowl master. If only minor repairs are needed, a mobile repair crew is assigned to make such repairs. If the repairs can be completed before the scheduled departure time of the train, the car is returned to the line up. If the repairs cannot be completed in time, the cars are held for the next train going to that geographical area. A switch engine will be assigned to bring cars from the hold area to the exit tracks for assignment to an outbound train.

If, in decision node 1 (Figure 3.7), the car inspectors find no problem, the train coupling and air hose status is reported to the bowl master. At decision node 2 (Figure 3.8), it is decided whether the train being made up is long enough to require make-up in two sections. If two sections are required, a switch engine is assigned to help couple the train together. The bowl master calls the diesel shop for road power, the caboose service area for a caboose, and the crew caller foreman for a road crew. The assigned engine calls the radio shop for radio check and, upon satisfactory completion, calls the bowl master for track assignment in the departure yard. After receiving track assignment, the road engine calls the train master or hump master (this varies for different yards) to coordinate movement in the various areas through

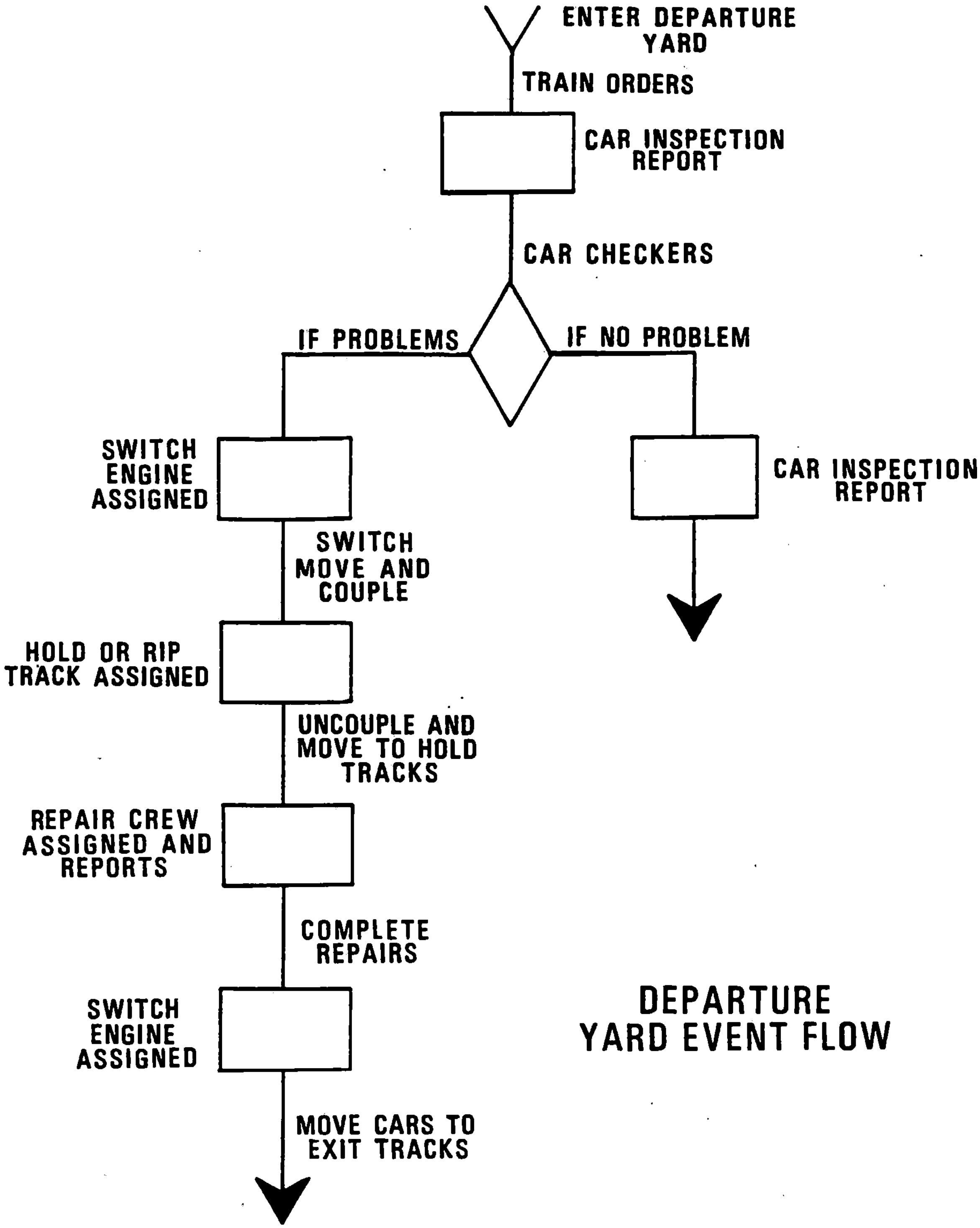


Figure 3.7. Departure yard event diagram.

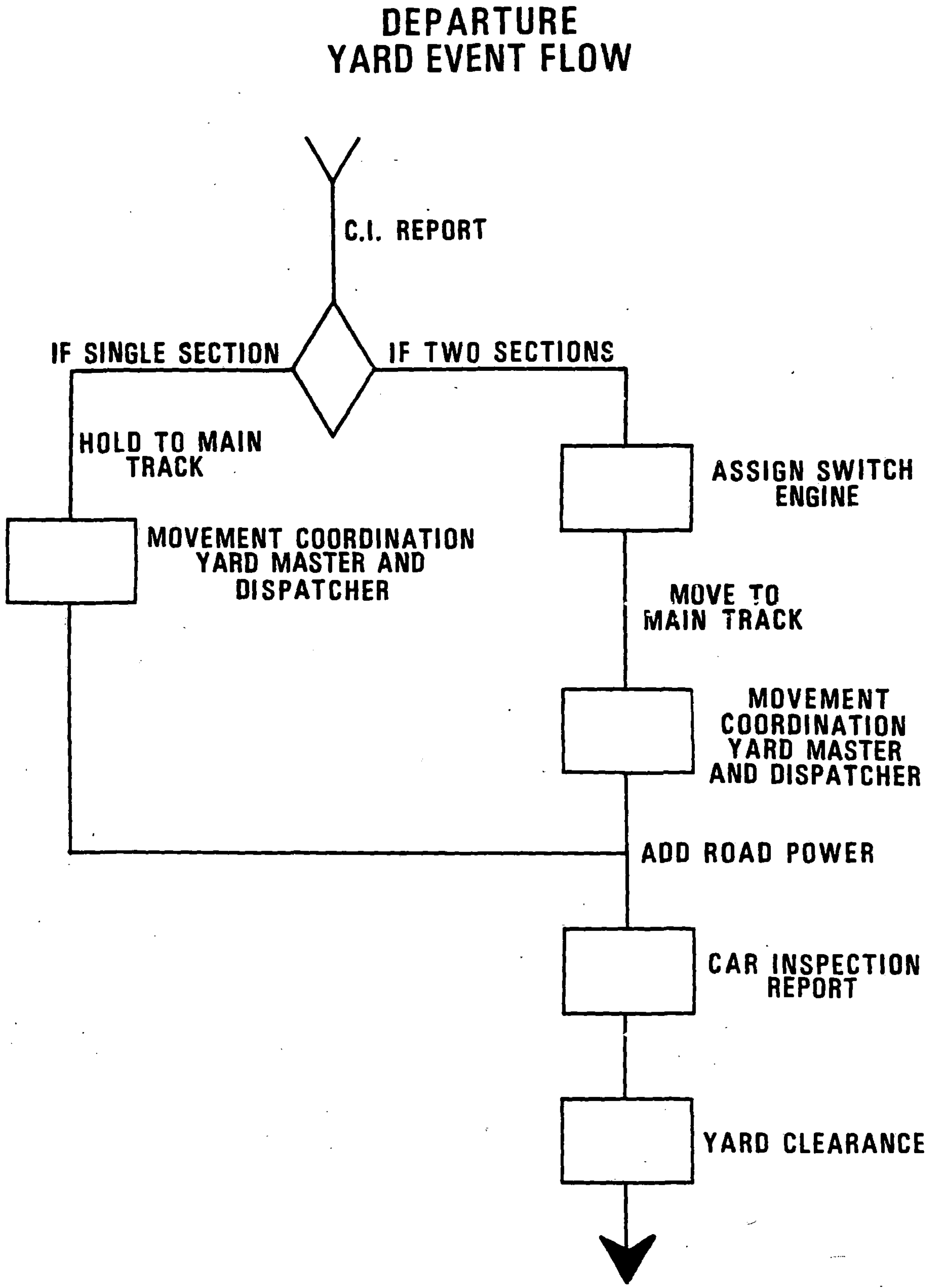


Figure 3.8. Departure yard event diagram.

which the engine must pass, to avoid potential collision with another moving vehicle or yard personnel who may be working along the route.

Upon arrival of the road power in the departure yard, the engine couples and checks out air and air coupling in coordination with the assigned train crew and the car inspectors. The front section is then pulled to the exit tracks. The rear section, with the caboose, is brought to the exit tracks by the assigned switch engine and coupled to the front section. The coupling and air are tested again and the car inspectors report ready for departure. The caboose calls the telegraph operator to report the caboose number, engine number, and departure time. The request for departure is radioed to the bowl master who gives the order to "high ball."

If there is only one section to be considered, the road power and caboose are added, air and coupling check made, and the exit made as explained for the two section case.

The communication activities to support a typical departure yard operation follow:

- o assignment of switch engine to pull cars from the classification yard to the departure yard using a switch engine frequency;
- o car inspection and reporting using the assigned channel for that function;
- o coordination of car set-out if car repair is necessary using the yard frequency and the associated switch engine frequency;
- o coordination of car movement from the holding yard or car repair facility to the departure yard using the associated switch engine frequency and the bowl master frequency;
- o the assignment and movement of road power and caboose to departing trains using the assigned road frequency;
- o coordination of train make-up between switch engine, road crew, car inspector, and road power, using road and switch engine frequencies;
- o train movement to exist track, subsequent reporting, and exit coordination using the road frequency.

Based on information from the Barstow yard, there are between 18 to 35 trains that are made up in the departure yard in a single day. At this rate, it can be seen that these yard functions are almost continuous, resulting in a very high utility of the frequencies involved.

3.1.2.5 Yard maintenance functions

Another function of major importance is yard maintenance. In the complex yards of today, there are miles of track, many automatic switches, retarder control and track sections, and other systems and areas too numerous to mention here. The general maintenance function covered here might be common to most yards and use communications backup to carry out the desired repairs.

Upon report of needed repairs, by the yard inspector or other yard personnel, the yard master assigns a crew to make the repairs (follow diagram in Figures 3.9 and 3.10). The crew chief takes his crew to the assigned area, isolates the track section, and reports the isolation to the yard master, who, in turn, informs the appropriate persons involved with train movement through the area. After the repairs are initiated, there is often train movement on adjacent tracks to those isolated. If this be the case, the yard master will advise the crew chief who, in turn, will clear the area until the train moves through. The yard master informs the crew chief when the track is clear and the crew returns to complete repairs. If the repair turns out to be more than the assigned crew can handle in good time, the crew chief requests additional crews and material through the yard master. The yard master then coordinates the movement of the new crews and material into the repair area and re-isolates it. The material may be large enough to require a switch engine and flat car. If so, this will also be coordinated by the yard master. This event is the path from the decision point represented in Figure 3.9 by the diamond shape, taking the flow to the right.

There are times when heavy-duty equipment, such as a crane, may be needed. This event flow is represented by the flow from the bottom of the decision diamond in Figure 3.10, wherein the crew chief requests the heavy equipment backup for the repair task at hand. The yard master assigns a switch crew to bring the desired equipment to the repair site. This will often mean movement from some remote storage area across the yard. This movement will be coordinated with the various yard area masters involved. Once on site, the yard master, crew chief, and switch crew will coordinate the placement of the equipment. After the equipment is in place, the switch engine is reassigned. Upon completion of the work involving the heavy equipment, the crew chief requests removal of the equipment through the yard master. The yard master again requests a switch crew to remove the equipment. When the heavy

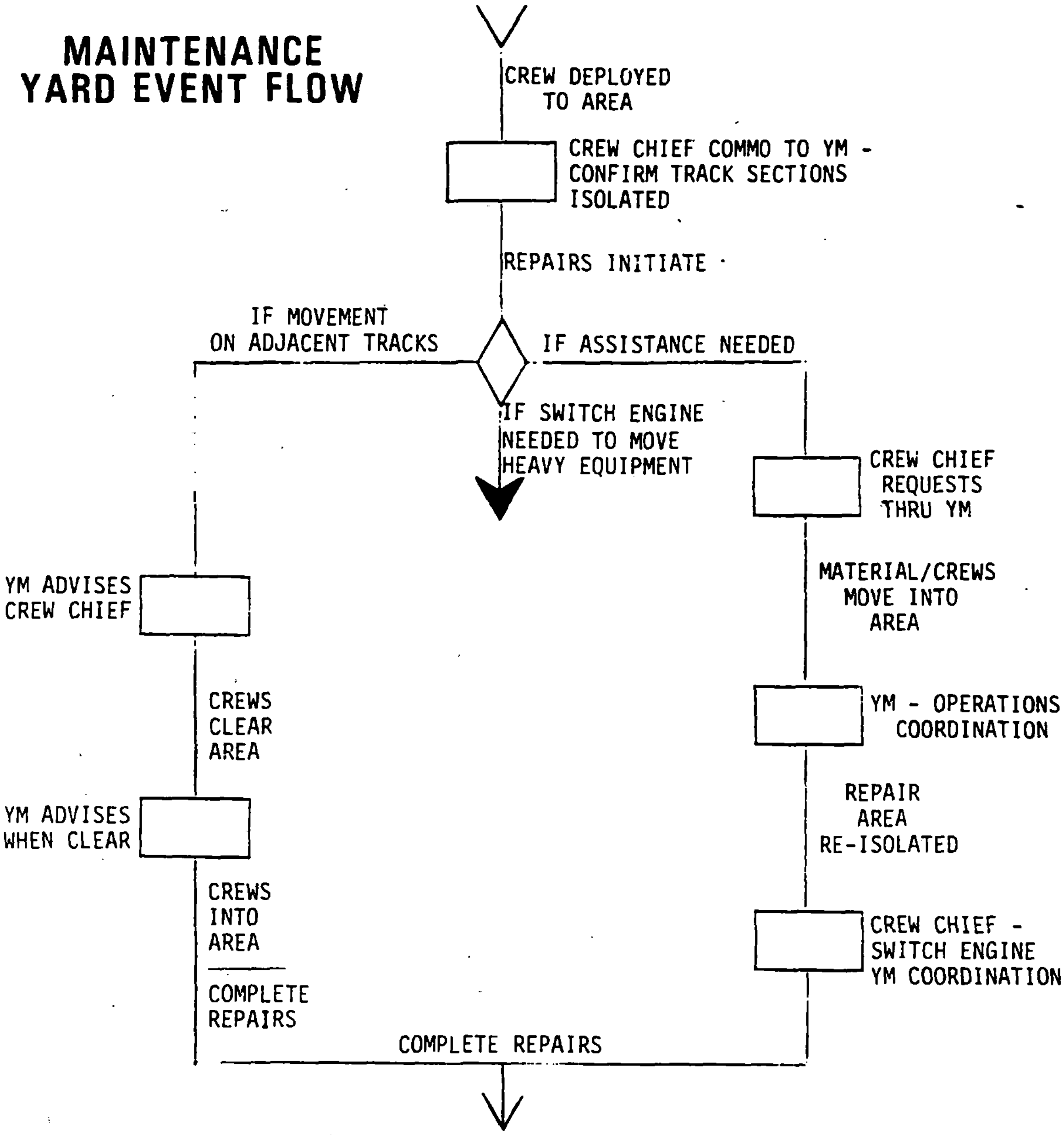
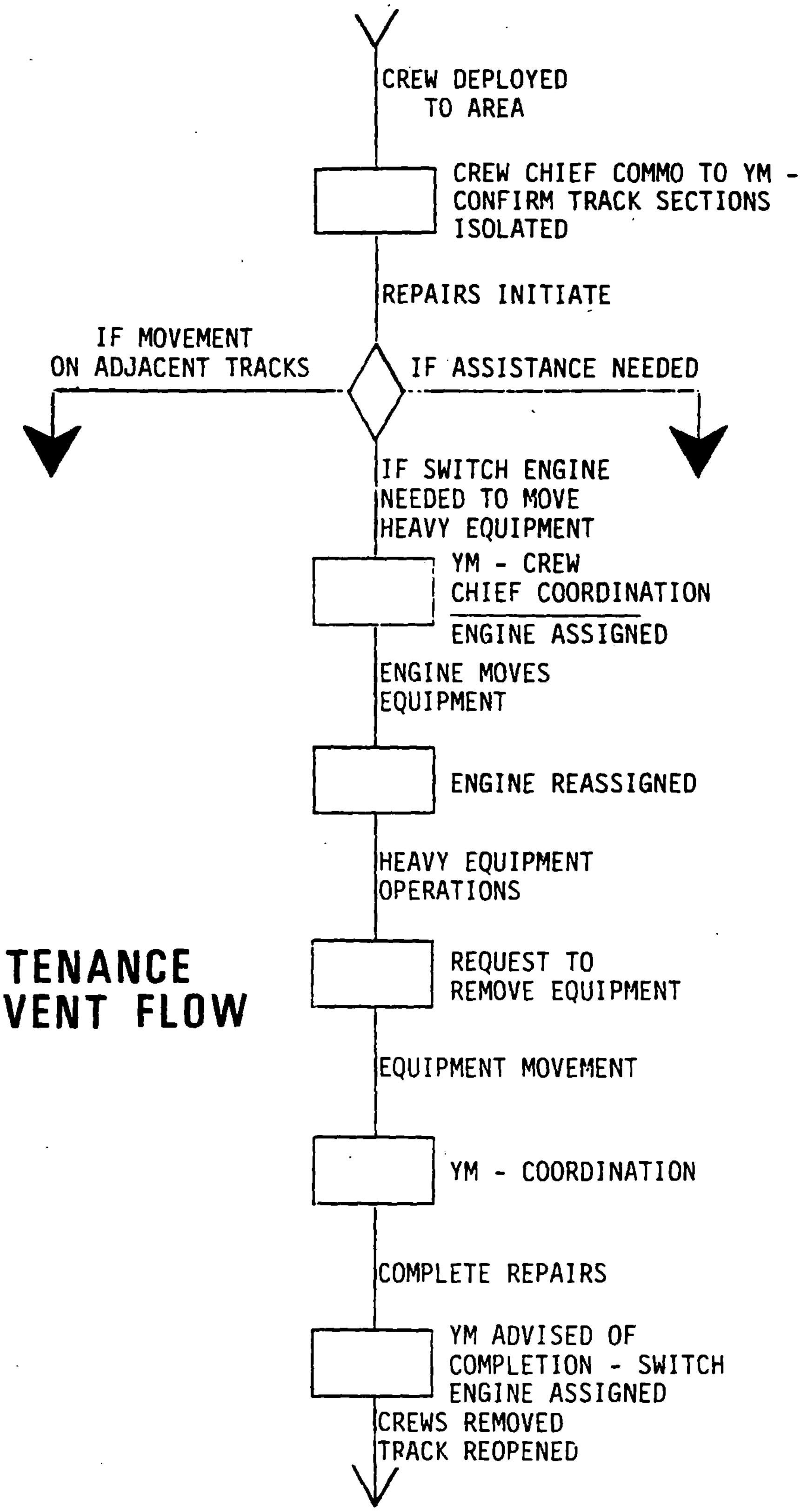


Figure 3.9. Maintenance yard event diagram.



MAINTENANCE YARD EVENT FLOW

Figure 3.10. Maintenance yard event diagram.

equipment has been removed and the final repairs and cleanup are completed, the crew chief reports the completion to the yard master. Arrangements are made for crew pickup and, upon crew clearance of the areas, the track is reopened.

The communications channel used in support of the yard maintenence functions are described as follows:

- o crew chief to yard master to confirm track sections isolated using the channel assigned to the yard maintenance function;
- o assignment and coordination of switch engines using switch engine frequencies and the frequencies assigned to the various yard areas that the switch engine must pass through;
- o alert to the yard areas of an isolated track using the various yard area frequencies.
- o requests to the shops for support using the shop frequency via the yard master;
- o clear crews from repair area when train moves on adjacent track using maintenance frequency;
- o coordination of repair effort and switch engine coupling, uncoupling, and equipment positioning using yard master, maintenance and switch engine frequencies.

These are only samples of the many yard maintenance functions that might take place in a yard. The kinds and descriptions of events would be exhaustive to write down in this report. These are explained here as examples of possible problems and the communications support required. A section of communication events for interconnections the yard maintenance functions is shown in Figure 3.11. This also points up the importance of radio communications in the operations of today's modern railroad yards.

3.1.2.6 Yard security and supervision

The supervisory elements of yard operations include the yardmaster, humpmaster, maintenance supervisors, and a general superintendent. Subordinate supervison includes various technical (car repair, track and physical facility maintenance, communications and signaling), security, and operations and scheduling functions. These activities require communications support within the general yard area that involves supervisor station, mobile operation (automobile, service vehicle), and handy-talkies. Generally, communications between fixed points (yardmaster and humpmaster stations, superintendent

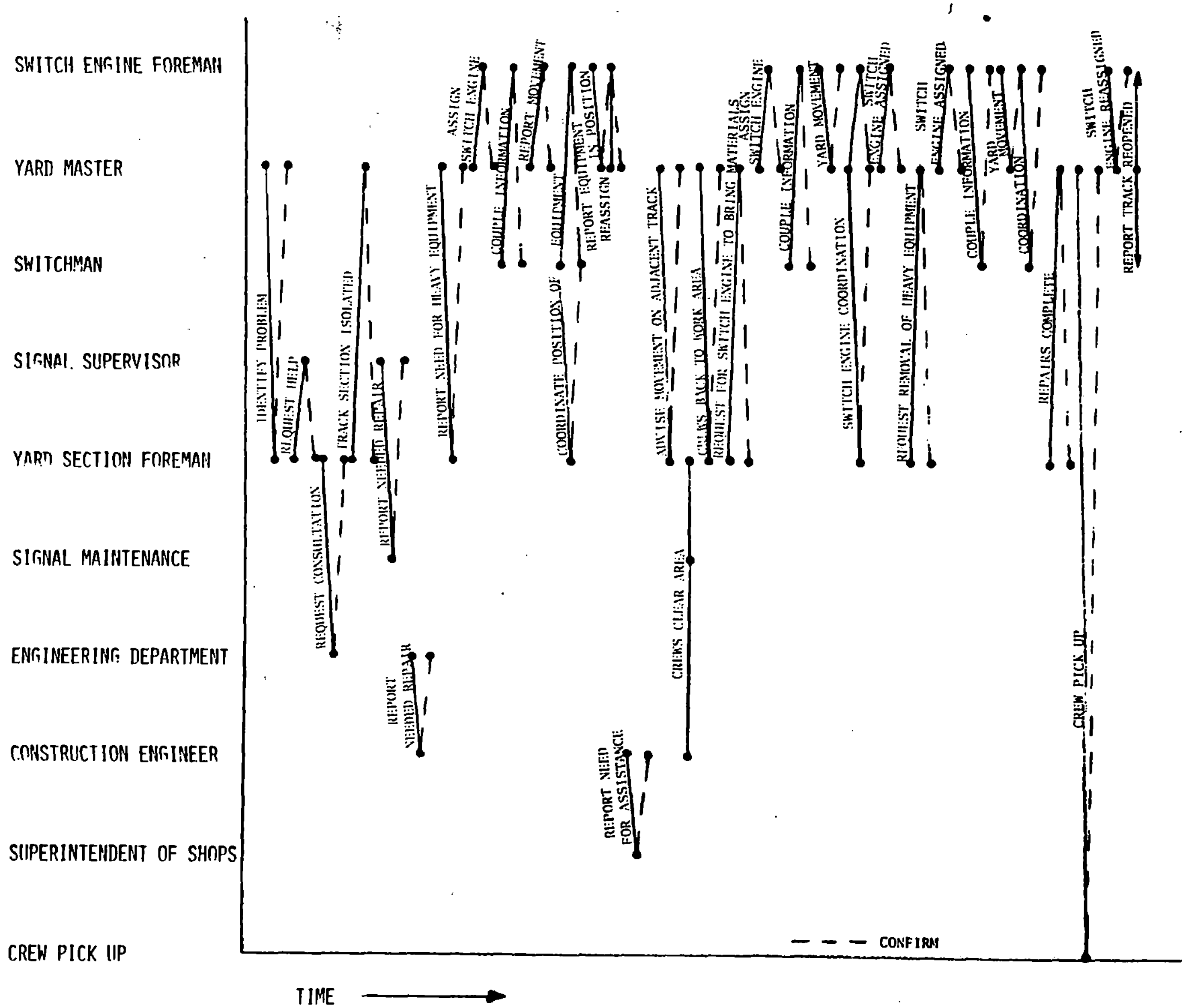


Figure 3.11. Communications event time-line.

and supervisor offices) is accommodated by telephone, with the mobile and remote activities supported through the VHF system. The single or dual channel pairs assigned to this service have a "more than occasional" usage because of equipment movement and scheduling coordination required to minimize train and load handling delays. During emergencies, these channels can be shared with security elements.

Yard security involves railroad police having patrol responsibilities within railroad property. Coordination with municipal or other governmental police agencies is effected where necessitated by common investigative or apprehension interests. Depending on the area and activity of a yard and proximity to other yard or connecting track facilities, one or two channel pairs would be assigned for communications support. The primary communication is between the security supervisor and patrols during emergencies; patrol unit to patrol unit also having heavy traffic. Relative to other communications links, the security traffic is of minimal density for normal patrol circumstances. In some urban situations, the municipal police dispatcher has access to the railroad security channel to facilitate joint operations.

Yard security includes more than patroling the perimeter of the yard to watch for vandalism, break-in, and theft, however important these may be. It is not a well-known fact that there is much cooperation between local and federal law enforcement agencies and railroad security people. There are times when fugitives from the local law will try to find either a place to hide among the cars in a railroad yard or secret themselves away in an empty car in hopes of escaping the area by train. Yard security personnel inspect all areas of the yard, including incoming cars and cars that have been held in the yard for repairs and reassignment. Along with the frequencies assigned to them by the railroad for yard use, they also use local law enforcement frequencies for aid in case of problems, as mentioned above. This helps in coordinating capture of fugitives who are either heading for the yards to escape from local police or have been routed out of a car by the yard security and are escaping toward a local community.

There is also an increasing problem with illegal aliens trying to smuggle into the country or be transported across the country by hiding in empty box cars. There are criminals fleeing from one part of the country to another who may gain entry into an open box car enroute and are discovered by yard security and turned over to local or federal authorities, whichever the case indicates.

The more intensive use of security is prevention of vandalism which represents increasing problems in metropolitan areas. This was highlighted in recent 1977 Congressional Hearings.

Any modern-day law enforcement agency depends upon communications for coordinated pursuit of alleged criminals, location of various units, and information gathering. Railroad security is dependent on communications for their activities within the yard and along railroad right-of-way as they carry out their assigned tasks, as well as coordinating with other law enforcement agencies in stopping criminal activity involving railroad domain.

3.2 Data support and analysis models

As indicated in Section 2, possible actions to be considered on the reduction of the existing VHF spectrum allocated to the Railroad Radio Service by one-third or a complete relocation in another frequency band. Either will require detailed information for evaluation in the manner in which existing communications channels are utilized. Such an evaluation required the implementation of a data file for railroad licenses, and the organization of resource utilization models for communication channel usage analysis. The data files were prepared by merging and purging FCC license files and the AAR Frequency Assignment Plan. Communications transmitter and receiver technical characteristics (power, emission bandwidth, receiver minimum detectable signal, and receiver selectivity) guided the selection of transmitter-receiver separation distance and adjacent channel utility criteria for the interference threshold in the reassignment analysis.

The models are organized to provide resource availability impact in relation to communications accessibility. These are operations event models based on the operations functions described in Section 3.1.2.

Subsequent paragraphs present discussions of communications equipment technical characteristics, the organization and usage of the master data file, and the organization of the yard operations and communications models.

3.2.1 Railroad communications equipment technical characteristics

In this section, curves of typical transmitter spectrum levels, receiver response, and signal propagation characteristics are presented. Two data sets are developed from this information that show the desired transmitter-to-receiver distance vs. adjacent channel transmitter distance for safe operation (Figure 3.16) and the minimum distance to an undesired adjacent channel transmitter to break squelch (Figure 3.17). These data and the railroad radio equipment specifications listed in Table 3.1 support the conclusions regarding performance penalties from operating with reduced VHF channel capacity, and the establishment of distance and frequency separations utilized for the reassignment analyses.

The Federal Communications Commission (FCC) sets rules and regulations and issues licenses to operate radio equipment for specific use and at designated locations. Rules and regulations for railroad radio services are contained in the Federal Communications Commission Rules and Regulations, Vol. V, Part 93 - Land Transportation Radio Service, Subpart H - Railroad Radio Services. Technical Standards for the Land Transportation Radio Services are described in Subpart C.

Provisions to license for several types of stations (base, mobile, fixed and mobile relay), within several frequency bands, and for various emissions are defined in the rules and regulations. Because the main emphasis of this study and report deals with the railroad radio service in the VHF band, it is primarily the regulations which govern operation in this band that are discussed here. Pertinent information includes frequencies and channels, type of emissions, and emission limitations, compiled from the cited FCC documents and typical FCC licenses. This material is supportive to the analysis and interpretation (in the next sections) of the frequency assignment constraints and potential interference programs, and contains a listing of performance specifications of various types of railroad radio equipment.

A recent ruling by the Federal Railroad Administration on Radio Standards and Procedures (Part 220) establishes operating procedures and regulates the specific utilization of radio transmissions in support of train movements. Included are terms of definitions consistent with railroad operations usage. This rule is published in the Federal Register, Volume 42, Number 18, January 27, 1977.

VHF Channels

Ninety-one frequencies are available for railroad radio service. These frequencies are between 160.215 MHz and 161.565 MHz, spaced at 15 kHz intervals. The FCC allocation of these frequencies is in paragraph 93.352 of Vol. V on page 264. It is reproduced here to provide a list of these frequencies:

"93.352 Frequencies below 952 MHz available for base and mobile stations.

(a) Base and mobile radio stations used for end-to-end, fixed point-to-train, or train-to-train communications in connection with the operation of railroad trains over a track or tracks extending through yards and between stations upon which trains are operated by timetable, train order, or both, or the use of which is governed by block signals, may use the following frequencies:

MHz	MHz	MHz	MHz
160.215	[4]160.560	[3]160.905	[3]161.250
160.230	[4]160.575	[3]160.920	[3]161.265
160.245	[4]160.590	[3]160.935	[3]161.280
160.260	[4]160.605	[3]160.590	[3]161.295
160.275	160.620	[3]160.965	[3]161.310
160.290	160.635	[3]160.980	[3]161.325
160.305	160.650	[3]160.995	[3]161.340
160.320	160.665	[3]161.010	[3]161.355
160.335	160.630	[2]161.025	[3]161.370
160.350	160.695	[3]161.040	[2]161.385
160.365	160.710	[3]161.055	[2]161.400
160.380	160.725	[3]161.070	[2]161.415
160.395	160.740	[3]161.035	[2]161.430
[4]160.410	160.755	[3]161.100	[2]161.445
[4]160.425	160.770	[3]161.115	[2]161.460
[4]160.440	160.785	[2]161.130	[2]161.475
[4]160.455	160.800	[2]161.145	[2]161.490
[4]160.470	160.815	[3]161.180	[2]161.505
[4]160.485	160.830	[3]161.175	[2]161.520
[4]160.500	160.845	[3]161.190	[2]161.535
[4]160.515	[3]160.860	[3]161.205	[2]161.550
[4]160.530	[3]160.875	[3]161.220	[3]161.565
[4]160.545	[3]160.890	[2]161.235	

[1] *(Reserved)*

[2] *In Puerto Rico and the Virgin islands only, these frequencies are not available to stations operating in the Railroad Radio Service.*

[3] *This frequency is available on a shared basis with remote pickup broadcast stations in Puerto Rico and the Virgin Islands.*

[4] *This frequency is shared with the Special Industrial Radio Service in Puerto Rico and the Virgin Islands. All applications for the assignment of a new frequency or to change existing facilities in such a manner as to require frequency coordination, as specified in paragraph 93.9 hereof, for stations in Puerto Rico or the Virgin Islands, shall be accompanied by evidence of interservice frequency coordination."*

Frequency Stability and Emissions

Regarding frequency and emissions, the rules cover several ranges of frequencies. For this report, however, only tolerances and limits applicable to the 160.215 to 161.565 MHz band are of interest. The following paragraphs define, in part, these regulations:

1) A licensee shall maintain the carrier frequency of each authorized transmitter within the following percentage of the assigned frequency in the 50 to 450 MHz band:

a)	all fixed and base stations	0.0005 percent
b)	all mobile stations	over 3W 0.0005 percent 3W or less 0.005 percent

2) Unless otherwise provided, stations will be authorized to use only A3 or F3 emission for radiotelephony. The authorization to use A3 or F3 emission will be construed to include the use of tone signals or signaling devices whose sole function is to establish and maintain communications between stations. An A3 designation indicates amplitude modulation (double sideband) and F3 indicates frequency (or phase) modulation. Emission limitations for these services are given below.

3) The maximum authorized bandwidth for all type A3 emissions is 8 kHz and the maximum authorized bandwidth and maximum authorized frequency deviation for type F3 in the 150 to 450 MHz band are 20 kHz and 5 kHz, respectively.

4) The power which may be used by a station in these services shall be no more than the minimum required for satisfactory technical operation commensurate with the size of the area to be served and local conditions which affect radio transmission and reception. Except where the maximum power that may be used on a particular frequency is specifically designated in connection with the use of such frequency, the maximum power that will be authorized for the 100 to 470 MHz band is 120 W maximum plate power input.

Many other specific and limiting statements are contained in the rules and regulations cited, but are not reproduced here.

3.2.1.1. Technical characteristics analysis

The consequences of a loss of one-third of its present spectrum would be either the "doubling-up" of railroad communications on the remaining VHF frequencies or the removal of all railroad operations to another band, presumably UHF. As an aid to studying and analyzing this impact, several graphs and figures are presented and discussed in regard to the emission and propagation characteristics of the VHF band.

Spectrum Level of Transmitters

The several curves in Figure 3.12 show relative emission levels as a function of frequency (referenced to the center frequency) for various modulations and transmitters. Curve (a) gives limitations of emissions as specified by the FCC. Curve (b) traces the average voice spectrum resulting from ± 5 kHz modulation bandwidth. Curve (c) shows the spectrum that results from tone modulation using a ± 3 kHz modulation bandwidth. A typical transmitter noise spectrum is shown by curve (d). Curves (e), (f), and (g) show, respectively, the upper limits of spurious and harmonic emissions for 2 W, 5 W, and 40 W transmitters. These levels are from manufacturer's specifications.

Receiver Response Curves

The response curves in Figure 3.13 give relative signal amplitude in dB as a function of frequency (offset from the center frequency) for various

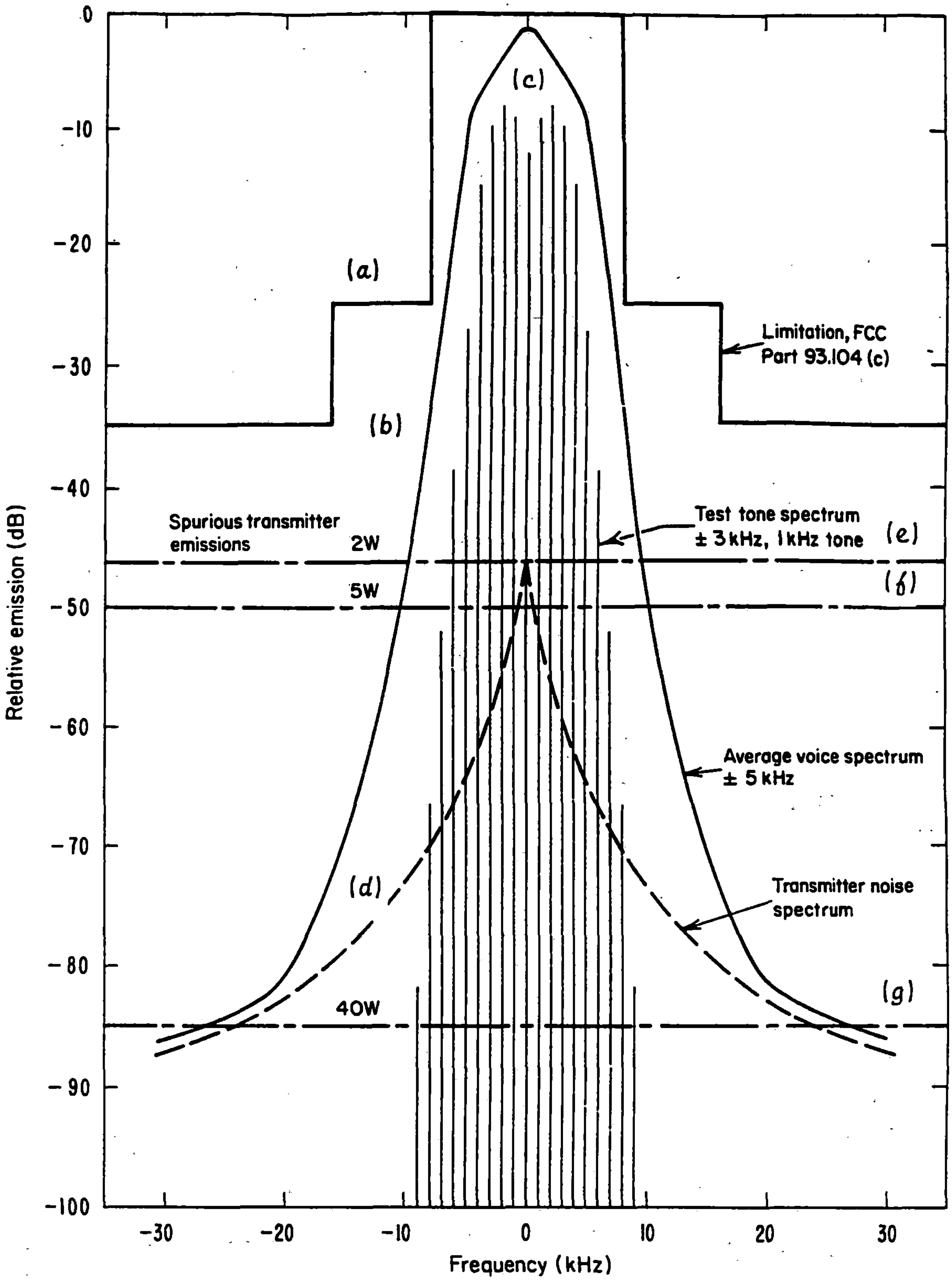


Figure 3.12. Spectrum levels for various modulations and transmitters.

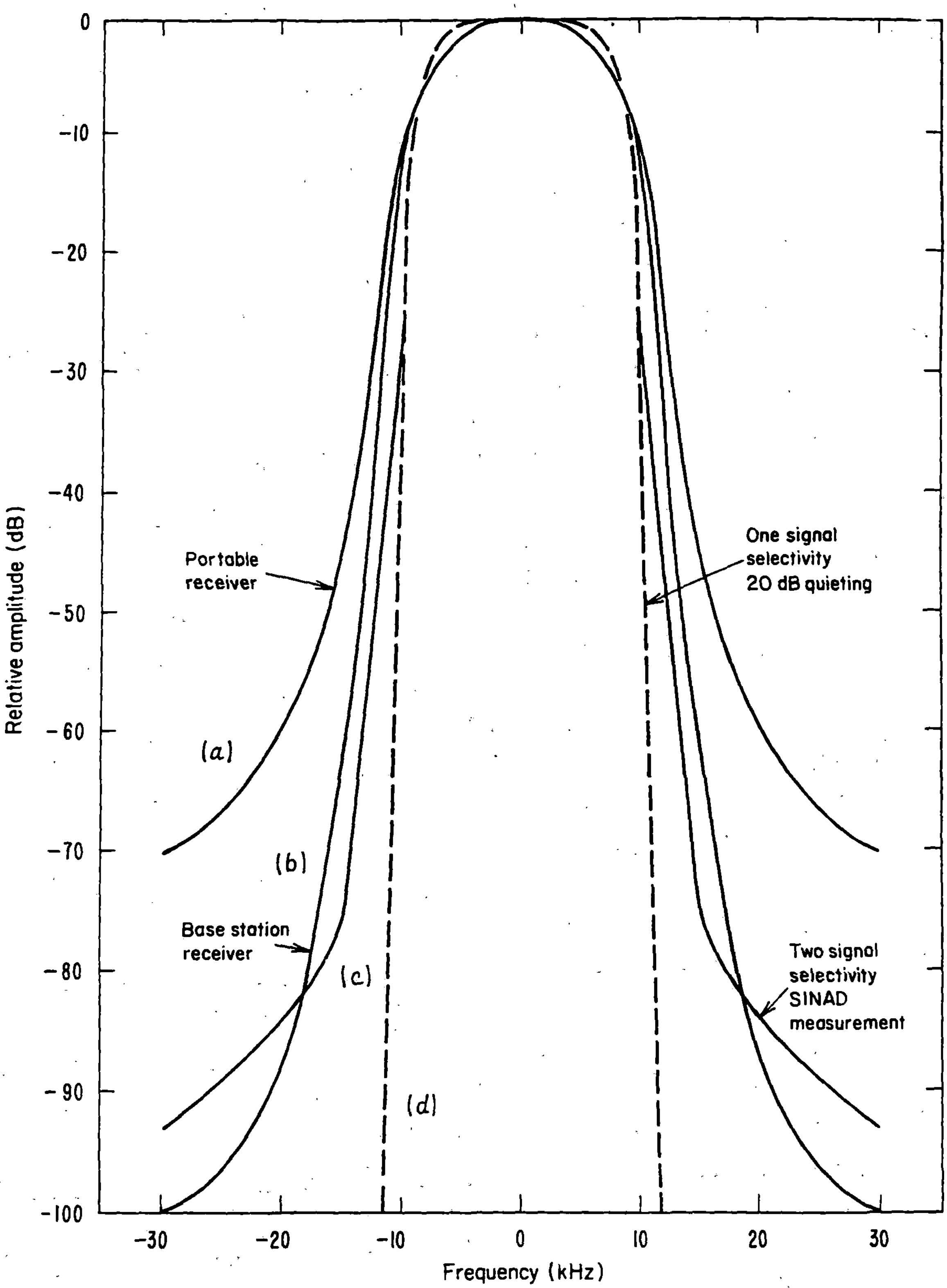


Figure 3.13. Response curves for various receivers and measurement methods.

receivers and measurement methods. Curve (a) defines the response curve for Westinghouse Air Brake Company (WABCO) portable equipment in the 2 or 5 W transmitter range and curve (b) defines a similar response for WABCO equipment in the 10-40 W transmitter range. Curves (c) and (d) show selectivity of a modern mobile FM receiver as determined by the one-signal selectivity 20 dB quieting method and the representative two-signal selectivity SINAD method. The two-signal selectivity SINAD measurement methods produced curve (c). SINAD (the ratio of audio signal + noise + distortion to noise + distortion) is measured using two signal generators. One signal generator operates at the desired signal frequency and the other signal generator produces interference effects. The procedure for producing the one-signal 20 dB quieting curve (d) is to first note the quiescent noise level and then increase the generator signal output level until a 20 dB audio output is measured.

Propagation Curves

The FCC Rules and Regulations contain a smooth-earth propagation curve which is adequate for calculation of general service area contours based on a receiving antenna height of 30 ft, for frequencies in the 156-162 MHz band and an effective radiated power of 1 kW. The propagation curves in Figures 3.14 and 3.15 are the FCC propagation curves modified and extended to represent 40 W radiated power and a 12.5 ft antenna, and to include the range 0.2 to 2 statute miles from the transmitter.

Figure 3.14 shows field strength as a function of distance for free space and various antenna heights. Data as shown are for the receiving antenna heights indicated, using a 30 ft transmitting antenna (the functions of the receiving and the transmitting antennas could be reversed and the results would be the same). The 30 ft antenna is typical of a yard installation and the 12.5 ft antenna height represents a short antenna mounted on a locomotive or caboose. The 100 ft and 200 ft antenna heights from the original (FCC graph), represent various coastal antenna elevations. They are equally useful for this study to represent antennas mounted on hills or tall buildings for railroad communications.

The data in Figure 3.15 are similar to those of Figure 3.14, covering the 2 to 100 mi range.

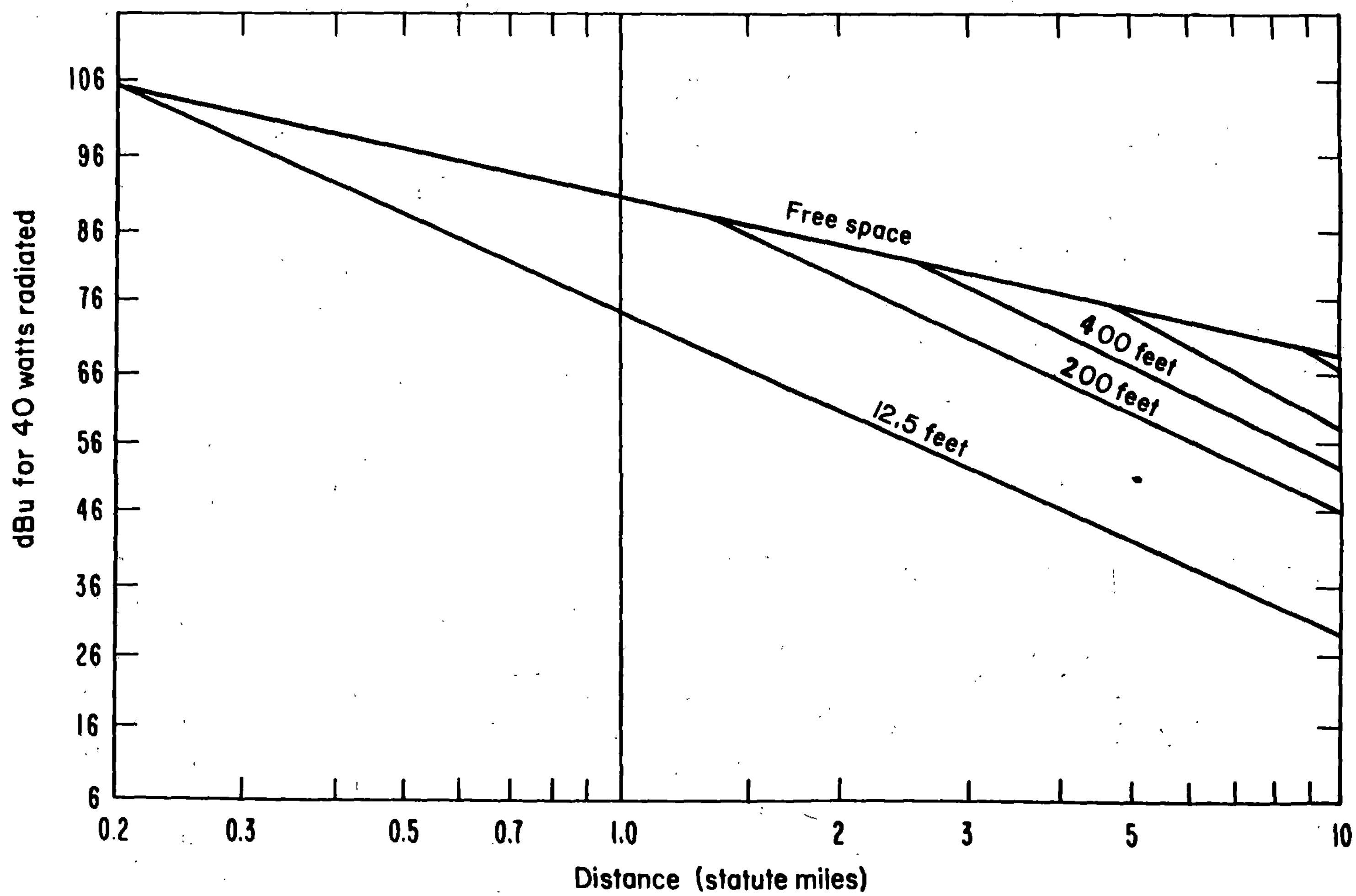


Figure 3.14. Propagation curves for VHF mobile radio service (0.2 to 10 miles).

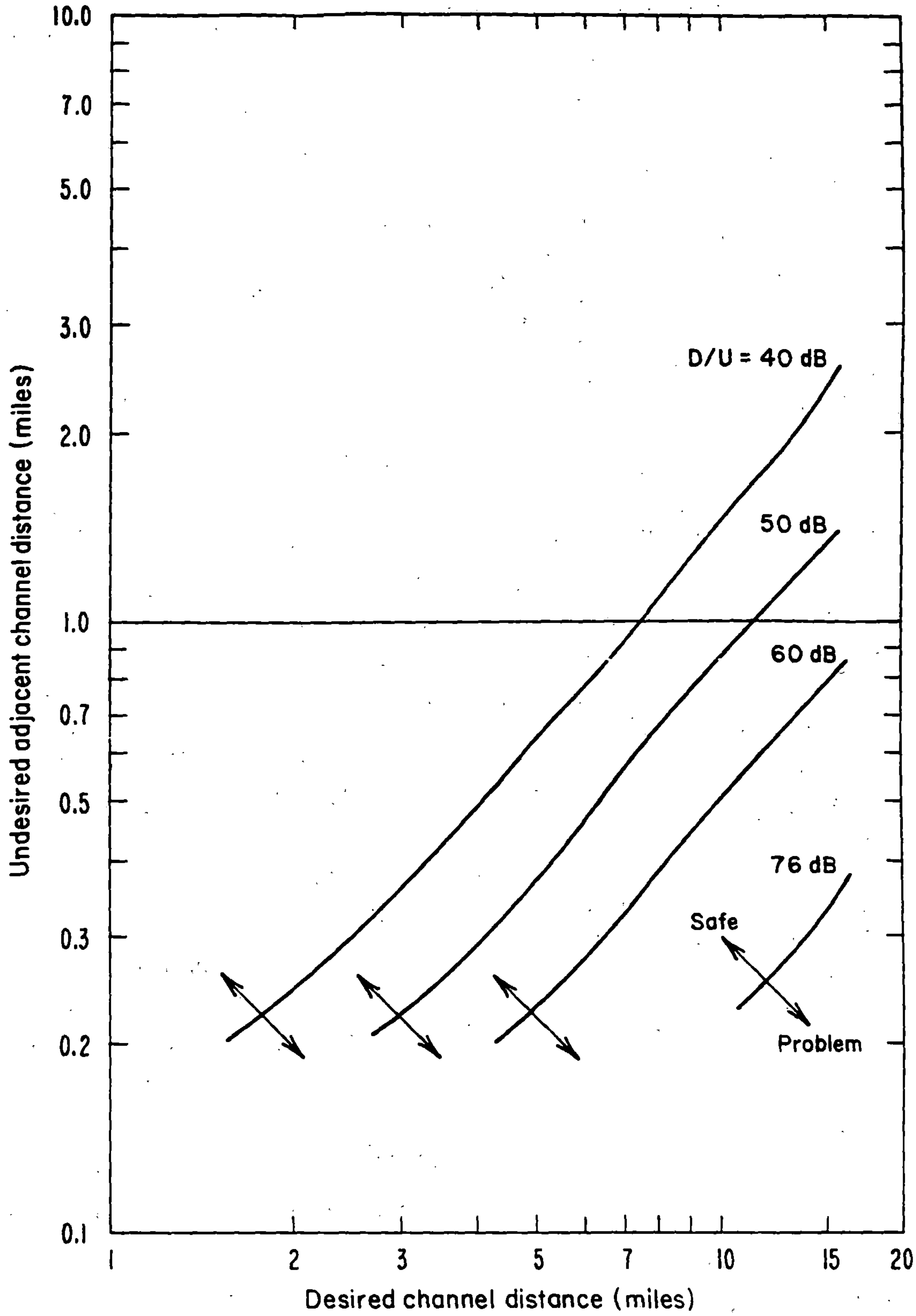


Figure 3.16. Desired transmitter-to-receiver distance vs. adjacent channel transmitter distance (safe operating region).

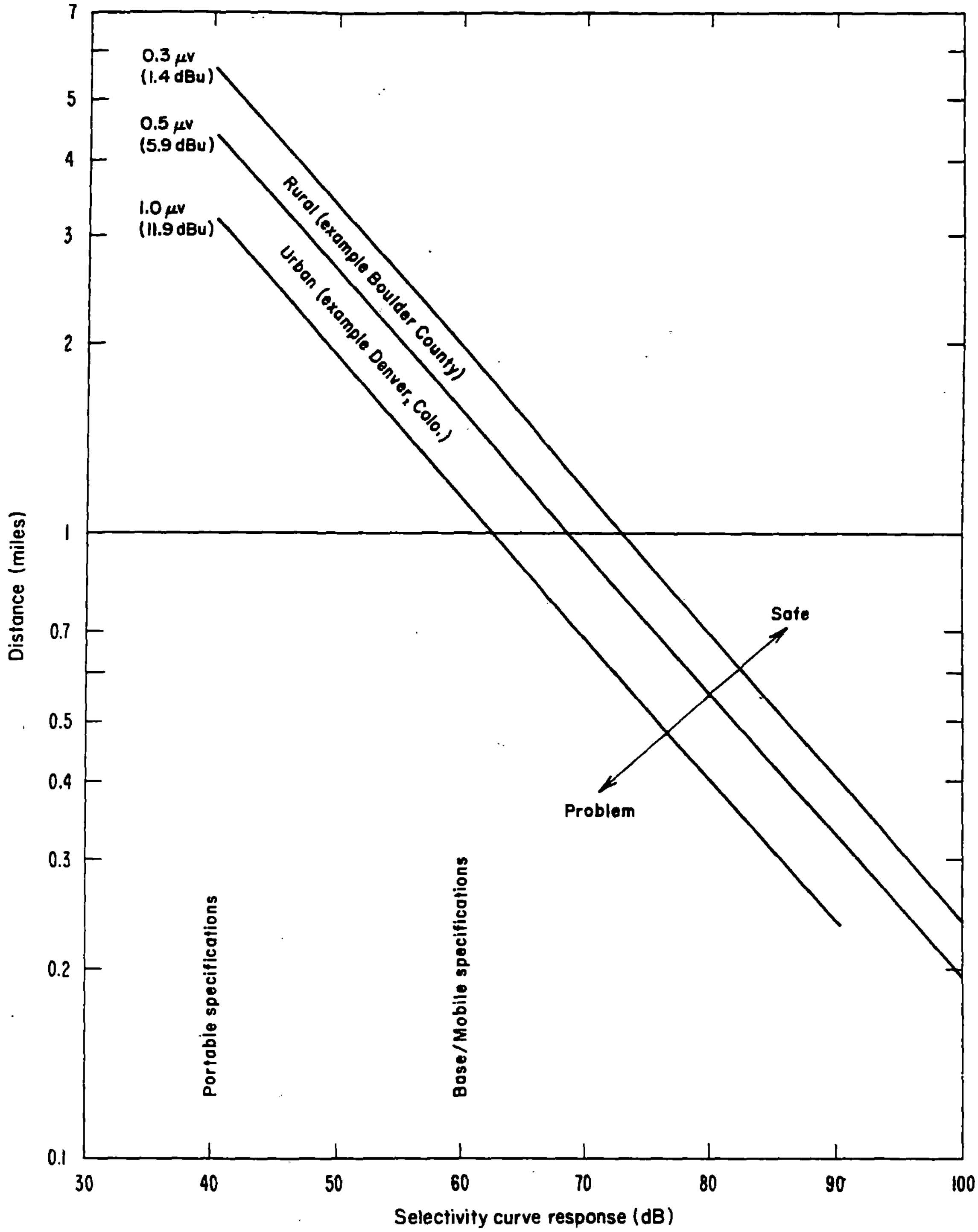


Figure 3.17. Minimum distance to an undesired transmitter to cause squelch to break (safe operating region).

Table 3.1. Railroad Radio Equipment Specifications.

	Hand-Held Portable	Mobile/Portable	Locomotives Cabooses	Cabooses Business Cars	Base Stations Business Cars	Cabooses Trucks Maintenance Equipment Automobiles
GENERAL						
Input Voltage	12.5 VDC	13.8 VDC/12.5 VDC	72/13.6 VDC	36/13.6 VDC	117 VAC/13.6 VDC	13.6 VDC
Standby Current	---	---	0.15A/0.33A	0.52A/0.33A	10 VA/0.33A	0.13A
Transmit Current	---	---	2.1A/7.8A	4.3A/7.8A	130VA/7.8A	7.6A
Battery Life	8 Hours	8 Hours	---	---	---	---
Weight	1 lbs 5 oz	7 lbs 2 oz	23 lbs	23 lbs	28 lbs	19 lbs
Dimensions	6.8"x2.58"x1.5"	1.87"x6.5"x8.9"	------ 10-5/8" x 16-1/8" x 3-11/16" ------			10-5/8" x 13-3/4" x 3-11/16"
No. of Frequencies	1 to 6	1 to 5	--------- 1 to 12 --------		1 to 4	1 to 12
Frequency Range	132-174 MHz	132-174 MHz	------------------------- 148 to 174 MHz ------------------------------			
TRANSMITTERS						
RF Power (Output)	2.0 or 5.0 W	25W (mobile) 8W (portable)	---------------------- 10 - 40 W (adjustable) ----------------------------			
Spurious & Harmonics	> 46 dB (2W) & > 50 dB (5W)	> 63 dB	----------------------------- - 85 dB -------------------------------------			
Frequency Stability	± 0.0005% - 30°C to + 60°C (+25°C ref)	0.0005% - 30°C to + 60°C (25°C ref)	-------------- ± 0.0005% - 30°C to + 65°C (28.5°C ref) ---------------------			
Modulation	± 5 kHz (16F3)	± 5 kHz duration @ 1 kHz	-------------- ± 5 kHz = 100% @ 1000 Hz -------------------------------------			
FM Noise & Hum	---	50 dB @ 2/3 system deviation	------------- 65 dB below 66% modulation ----------------------------------			
RECEIVER						
Sensitivity	20 dB quieting 0.50μV	20 dB quieting 0.35μV	------------- 20 dB quieting 0.50μV ---------------------------------			
	12 dB SINAD 0.35μV	12 dB SINAD 0.25μV	------------- EIA SINAD 0.35μV ------------------------------------			
Selectivity	EIA SINAD -70 dB	EIA (2 signal) -80 dB ± 30 kHz	------------- EIA SINAD -100 dB at ± 30 kHz -------------------------			
Intermodulation	≥ -60 dB	---	------------- EIA SINAD -80 dB -------------------------------------			
Spurious & Image Rejection	-60 dB	-85 dB	------------- -100 dB --			
Squelch Sensitivity	0.25μV	0.15μV	--------- Adjustable; 0.25μV at threshold ---------------------------			
Audio Output	0.6 W < 8% distortion	5 W < 10% distortion	---------- 10 W into 8Ω @ 1000 Hz with less that 5% distortion --------			
Modulation Acceptance	± 7.5 kHz	± 5 kHz	---------------------- ± 7 kHz -------------------------------------			

3.2.2 Environment data and models

3.2.2.1 Master file organization

Two major tasks in the study of radio communications for the railroad industry were 1) to identify and describe the current railroad use of land mobile communications in the 160.215-161.565 MHz band, and 2) to analyze the effect of the loss of all or part of 33 channels from the 160.215-161.565 MHz band. Because of the data structures, testing procedures, and analytical techniques used, this section is restricted to a discussion of the analysis of data obtained from the Federal Communications Commission's (FCC) listing of railroad service licenses, an FCC listing of maritime service licenses in the 150.250-162.0125 MHz band, the Association of American Railroads' (AAR) tables of frequency use assignments, and an inventory of mobile radio equipment in use by the industry as determined from the 1974 AAR survey. These analyses resulted in a definition of use and distribution of licenses and equipment, the establishment of a procedure for the reassignment evaluation and an assessment of that task. Similarly, an evaluation and assessment of the channel sharing with the maritime industry was made.

The FCC listing of railroad service and maritime service licenses contains authorizations issued through mid-year, 1975. The AAR frequency assignment plan used for this analysis was current for the same year. Although neither data file contained the most recent changes, the two files were compatible with each other and for the purposes of evaluating the effect of reassignment and frequency sharing, the files were very adequate. A similar confidence is placed on the data regarding distribution analyses. The approximate 100-500 changes processed per year represent about one percent of the more than 15,000 licenses contained in the working files. The distribution data presented in Appendix C is based on 1975 data.

The following paragraphs describe the data organization, the data retrieval processes, the evaluation criteria, and a discussion of the results obtained.

Data Resources

The data required for this study, as outlined above, came in different formats. The listing of licenses for railroad service and for maritime service was obtained from the FCC on magnetic tapes. The AAR frequency assignment plan and the equipment inventory data were obtained from the AAR Communications and Signal Office in printed handbook form.

Also, particularly in the FCC license listings, the records contained data that were not essential to the analyses to be performed and records not in the frequency bands of interest or geographic areas of interest. Thus, various data sorting and ordering routines were used to create working files pertinent to the study requirements. All the records were converted and stored on magnetic tape in a format compatible for reading and processing with the CDC-6600 computer at the Department of Commerce Computer Facilities at Boulder, Colorado. The methods and tasks undertaken to create the data files, to accomplish the testing and data displays and to perform the preliminary analyses are described. Detailed explanations of the file organization and format, and the test elements are given when considered helpful in the discussion of the task objectives and results.

The Railroad Mobile Radio Licenses

When an application for a mobile radio license by a member railroad (which is coordinated through the Communication and Signal Section of AAR) has been approved by the FCC, a license is issued to the railroad company as an authorization for that company to operate radio equipment in accordance with the general rules and regulations for Land Transportation Radio Services and in accordance with the specific items entered on the license. Further use designations are recorded in the Frequency Assignment Plan (FAP) through coordination with the AAR. Magnetic tape records of all issued licenses are maintained by the FCC.

The specific information contained on the licenses and stored on the FCC magnetic tape was read from a copy of the FCC magnetic tape and the data were converted to a format compatible with the CDC-6600 and some existing computer data processing programs. The format used was an IRAC standard format called the Non-Government Master File (NGMF). This format uses a control item in each record which identifies the contents of the record and character position of specific information in the record. This technique permits the use of variable record lengths, with a subsequent saving of tape or file space.

Typically, the information contained in a license record would include:

1. frequency of operation,
2. number of transmitters (mobile stations),
3. type of emission,
4. input power (watts),

5. name of licensee,
6. mailing address of licensee,
7. location of transmitters (fixed location),
    a) city
    b) state
    c) latitude
    d) longitude
8. area of operation (mobile or temporary locations),
9. name of radio service,
10. class of station,
11. antenna characteristic (if applicable),
    a) elevation of antenna site
    b) antenna height above ground
    c) elevation of support structure
12. special conditions (i.e., precautions regarding adjacent channel interference, etc.), and
13. date of issue and expiration.

All these items were retained in the VHF railroad radio service master files compiled for this study. However, only the frequency, railroad name, state name, latitude and longitude were recorded in the working files to be discussed later.

In the retrieval and conversion process, from the FCC magnetic tape to the CDC-6600 master file, only the licenses designated "LR" for railroad service were obtained. A total of 18,128 licenses were so designated, including licenses in all allowable bands (HF, VHF, UHF, and microwave). These licenses were further sorted by bands and a total of 15,071 were contained in the VHF band of interest to this study (14,895 licenses in the 160.215-161.565 MHz band and 176 licenses at 161.610 MHz). These were authorizations to operate as base stations, mobile stations or combinations of base and mobile stations.

<u>The Maritime Mobile Radio Licenses</u>

The FCC rules and regulations for the maritime radio service are contained in Volume IV, Part 81 - Stations on Land in the Maritime Services and Alaska - Public Fixed Stations, and Part 83 - Stations on Shipboard in the Maritime Services. The VHF frequency bands listed for maritime mobile services are as follows:

	Band (MHz)	Class of Station
1.	156.250-157.0375	Coast and Ship
2.	157.1875-157.450	Ship
3.	160.575-161.625	Coast
4.	161.775-162.0125	Coast

The initial search of the FCC tape* under the maritime (nature of service) symbols:

M = coastal group,

MA = marine auxiliary group,

MK = Alaska group,

MR = marine radiolocation land, and

MS = ship group,

produced a file containing 19,280 licenses. This file was later reduced via geographic and frequency band limitations to a file containing 16,550 licenses.

The information contained in each license record is very similar to the contents of the master file in the NGMF format. These data were used in the analysis to explore and evaluate a concept of frequency sharing between railroad and maritime users. The study and results are discussed later in the report.

Frequency Assignment Plan

The FAP is both the record and the reference for specific use assignments of railroad mobile radio, whereas the FCC licenses authorize operation in a particular territory. The FAP provides the details of use and limitations associated with that use. The two main classes of radio are train service and general. Radio for train services includes end-to-end communications, point-to-point communications, mobile relay service and right-of-way communications. The general service includes communications in such activities as switching, car inspection, police functions, etc. All of these communication functions are in support of safe and efficient train movements. Train service has priority over general service, and end-to-end and point-to-train communications have the highest priority within the train service. This priority is

*The tape is a record of the non-government file containing fixed-base and mobile authorizations for operations in specific states or in the United States. It does not include approximately 274,000 authorizations in this band for ship radio stations.

accomplished chiefly through frequency use assignments and through cooperative non-interference practices. The FAP, in its present form, does not readily facilitate spectrum utilization analysis. A computerized data bank affords much more flexibility for processing to determine distributions by railroad, use functions, number of licenses, etc.

The FAP is structured by territory. Specific assignments are given by state, groups of states, or areas within a state. A section of the handbook is maintained for each territory. All individual railroad use designations are listed for each of the 91 channels. Specific footnotes and comments regarding general use limitations are also listed. An example from one section of the handbook is shown in Figure 3.18.

To generate a computerized data file of the records in the FAP, a card was punched for each entry. Frequency, channel, railroad and use information plus all comments were transferred to the cards. This file was used in conjunction with the FCC license file to form working files for the train service and for general service.

The Radio Equipment Inventory

The 1974 AAR mobile radio equipment survey was conducted to develop inventory to determine the potential of spectrum use based on the number and type of equipment owned by the member railroads for each channel in which they were licensed to operate. The results of this study produced a handbook organized by channel, with listings of the railroads and the number of units owned for each type of equipment. The categories of equipment were multiple channel radio (extra crystals for a mobile radio), mobile radio stations, and base stations. An example page from this handbook is shown in Figure 3.19. These data were also computerized by entries from punched card. Each record contained frequency, channel, railroad, equipment type and quantity information. This data file was used in the analyses of usage and distribution of licenses and equipment.

The Railroad Radio Data Working Files

Among the requirements for the channel reassignment evaluation was a reordering and listing of the licenses into subgroups. For this study, the term "subgroup" is used to identify all the licenses issued to a given railroad at a given frequency for either train service or general service. Working

ILLINOIS
(Except Chicago and E. St. Louis Areas)

Channels No.	MHz	
1T	160.215	RI-MR, ES in Illinois except Chicago & E. St. Louis Areas* (1)
1	160.230	CO, BO & WM-EE
2T	160.245	SOU-PT (1)/ICG-G (1)
2	160.260	EJE-PT/ICG-G, Decatur area/ATSF-RW-MR, Dallas City
3T	160.275	ICG-G (1)
3	160.290	LN-G
4T	160.305	(1)/LN-RW, ES in ILL. (1)
4	160.320	RI-MR & G/CO, BO & WM-PT
5T	160.335	ICG-G (1)
5	160.350	EJE-EE/ITC-EE
6T	160.365	BN-G(1)
6	160.380	NW-G
7T	160.395	EJE-G (1)/LN-RW, ES(1) (3)
7	160.410	PC-G/PPU-G, ES/PC-EE in ILL. (8)/MI-EE/SSW, SP-EE (7-MP, TP, CEI)(8) MP, CEI-EE
8T	160.425	BN-G (1)
8	160.440	NW-EE/UP(7-NW) (8)
9T	160.455	CNW-RW, ES (1)
9	160.470	MP-PT/PPU-PT/PC-G/ /MI-PT, ES
10T	160.485	PC-G (1) (1) (12) (17)
10	160.500	SOU-PT/ICG-RW, Champaign Co.
11T	160.515	TPW-RW(1)
11	160.530	MILW-PT/GTW-PT/PPU-G CO, BO & WM-RW, ES
12T	160.545	
12	160.560	PC-G/ATSF-PT/ATSF RW-MR Lemont
13T	160.575	ITC-RW, ES (1)
13	160.590	ICG-RW, Bluford, Centralia, Decatur, Carbondale/GTW-EE
14T	160.605	RI-G (1)
14	160.620	NW-EE
15T	160.635	RI-G (1)
15	160.650	ATSF-EE/ICG-RW, Decatur/SOU-PT/PC-EE vicinity of Streator (7-ATSF) (8)/ TPW-EE, Lomax, Ill. to Fort Madison, Iowa (7-ATSF) (8)/AMTK-EE (7-ATSF) (8)
16T	160.665	
16	160.680	RI-G/PC-G (6-RI)
17T	160.695	ITC-RW, ES in Ill. (1)
17	160.710	PC-G, ES/DRI-G
18T	160.725	GMO-G (1)/CO & BO-G
18	160.740	NW-G (1) (6-GMO)
19T	160.755	PC-G (1)/RI-G (1)
19	160.770	MILW-EE/UP-EE on lines of MILW in Ill./AMTK-EE (7-MILW) (8)
20T	160.785	ICG (1)/CO & BO-G (1)
20	160.800	PC-PT/CNW-G/ATSF-EE, vicinity of Streator (7-PC) (8)/CO-PT, ES in ILL. (7-PC) AMTK-PT (7-PC) (8)
21T	160.815	ICG-G(1)
21	160.830	CIM-PT/SOU-PT
22T	160.845	GTW-RW, ES (1)
22	160.860	ICG-EE/PC-G (6-GMO)
23T	160.875	BO, CO-RW, ES (1)
23	160.890	CNW-EE/ITC-EE Madison and Macoupin Cos. (7-CNW) (8)
24T	160.905	LN-RW escept Chicago Area
24	160.920	ICG-EE/EJE-EE, ES in Ill. (6-MILW) (8)/IC-PT, Pulaski Co. (7-GMO) (9) AMTK-EE (7-ICG) (8)

All footnotes are listed in General Section of FAP.

*See "Areas" in General Section of FAP.

Figure 3.18. An example of the contents and structure of the frequency assignment plan.

CHANNEL 6 160.380

	*	Mobile	Base
Long Island Railroad Company	121	492	30
Belt Railway Company of Chicago	9	133	5
Western Maryland Railway CO.	8	2	
B&O Railway Company		10	
Western Pacific		360	36
Florida East Coast Railway Company	2	3	
Trona Railway Company		17	1
Apalachicola Northern		19	3
Burlington Northern		50	26
Louisville & Nashville Railroad Co.		318	18
Penn Central Transportation Co.		6	6
Cuyahoga Valley Railway Company	17		
Butte Anaconda Pacific Railway Co.	6		1
Norfolk & Western Rwy.	6	127	12
Chesapeake & Ohio Railway			1
Chicago, Rock Island Pacific Railroad			2
Seaboard Coastline Railroad			1
St. Louis-San Francisco Rwy.			1
Southern Pacific			10
Washington Metropolitan Area Transit Authority			2
*Multiple Channel Radio TOTAL	169	1,537	155

Figure 3.19. A sample page from the mobile radio equipment inventory handbook.

files for train service and general service were built to fulfill this requirement. The structuring procedures and data contents are discussed in the following paragraphs.

The information needed to test any given license for reassignment is contained in the frequency, railroad, state, use, and location coordinate information. Because all of these data existed in neither the FCC license files nor in the FAP, an interaction of the two data files was required to compile a file that uniquely grouped the licenses by frequency, railroad and use.

The data common to both files that is needed in the reassignment test are the frequency, railroad and state information. Consequently, it is necessary to match the FCC records to the FAP records and the composite of the two would produce a record of frequency, licensee, state, use and location of operation. A computer program was written to perform this task. The comparisons described above were made and each license grouped into either the train service working file or the general working file. The flow diagram of the computer program is shown in Figure 3.20. Of the 15,071 licenses processed, 11,177 were designated for train service and 3,894 for general service. All licenses authorizing operation on the same frequency are grouped together within each file. A second level of ordering within the frequency group is by railroad (licensee). Discussion of procedures and analysis for reassignment is in the next section. An example of a working file is the listing in Figure 3.21. This list is of the train service licenses for channel 14(160.620 MHz). This group of 46 licenses contains 8 subgroups. The contents of the listing are given at the top of each column - namely, frequency, state, railroad, latitude (degrees, minutes, seconds), longitude (degrees, minutes, seconds), call sign, service class, expiration date, the number of licenses in the subgroup and the home office (city).

The service class designations in Figure 3.21 are "FB", "MO", and "DM". The most common designations are "FB", indicating a base station, and "MO", indicating a mobile station. Each license issued for base station operation received location coordinates that define its point of operation and subsequent coverage area. Those licenses authorizing the operation of a mobile station received no location coordinates and are authorized for operation within a state, area, or other territory designation. These are generally issued for

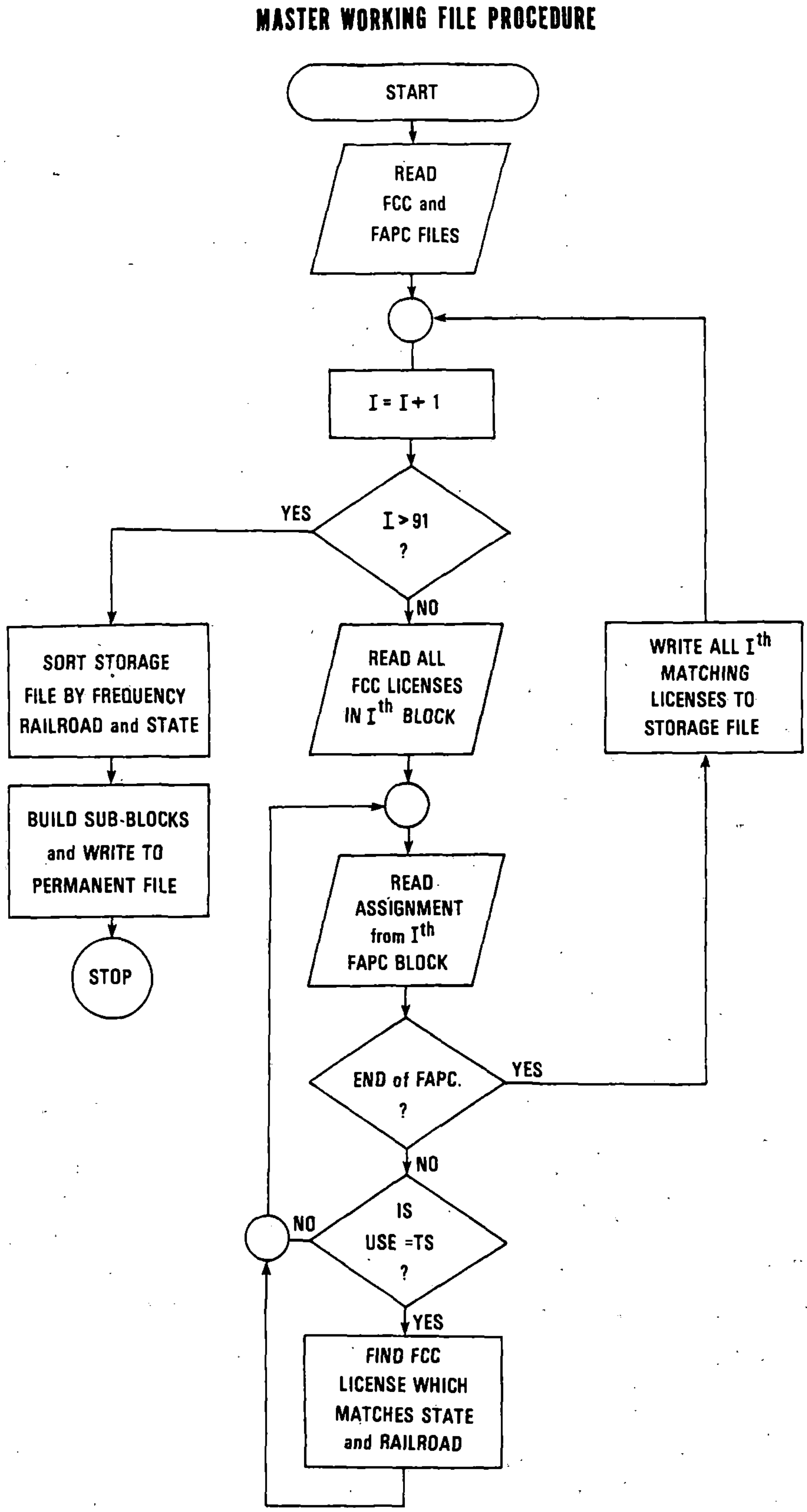


Figure 3.20. Flow diagram of the computer program to create railroad license working files.

```
Frequency
        State        Longitude
           Railroad                           Class          Size of Subgroup
             Latitude            Call Sign      Expiration   City
160.620GACIRR310950085055 2KDY857   FB780209   2CEDAR SPRINGS
160.620GACIRR                KDY857   MO780209    CEDAR SPRINGS
160.620COGWR 402536104535 7KCR597   FB770920   7DENVER
160.620COGWR 402009104535 2KCR602   FB770920    DENVER
160.620COGWR 400935105045 6KCR599   FB770920    DENVER
160.620COGWR 402351105032 1KCR598   FB770920    DENVER
160.620COGWR 402832104533 8KCR600   FB770920    DENVER
160.620COGWR                 KF6791   MO770920    DENVER
160.620COGWR 402408105034 1KSL893   FB751104    DENVER
160.620NJLV  404240074084 0KFZ538   FB751207   3BETHLEHEM
160.620USLV                  KH2916   MO790510    BETHLEHEM
160.620USLV                  KQ6194   MO780208    BETHLEHEM
160.620MEMEC 440506070113 5KCE546   FB800424   7PORTLAND
160.620MEMEC 441652069500 3KCE547   FB800424    PORTLAND
160.620MEMEC 435741069545 3KCE548   FB800424    PORTLAND
160.620MEMEC 434438070191 9KCE550   FB800424    PORTLAND
160.620MEMEC 444819068564 9KCE545   FB800424    PORTLAND
160.620MEMEC 443516069375 9KCE552   FB800424    PORTLAND
160.620USMEC                 KC3079   MO800424    PORTLAND
160.620MOSLSF365930091582 0KTG643   FB760825   8SPRINGFIELD
160.620MOSLSF380322091235 5KLW265   FB760816    SPRINGFIELD
160.620MOSLSF371342093185 5KW0493   FB800203    SPRINGFIELD
160.620MOSLSF371336093195 2KVI649   FB780710    SPRINGFIELD
160.620OKSLSF360743096400 0KUI626   FB770811    SPRINGFIELD
160.620OKSLSF360923095592 5KXD279   FB790826    SPRINGFIELD
160.620OKSLSF360923095592 5KXD279   FB790826    SPRINGFIELD
160.620USSLSF                KA8119   MO760224    SPRINGFIELD
160.620ILSOO                 KN5206   MO750617   3MINNEAPOLIS
160.620ILSOO 415000087400 0KN5206   DM
160.620USSOO                 KC9264   MO780416    MINNEAPOLIS
160.620PAURR 402232079512 1KGC768   FB760928   8PITTSBURGH
160.620PAURR 401801079521 3KGB375   FB800513    EAST PITTSBURGH
160.620PAURR 402450079532 0KGA849   FB760129    PITTSBURGH
160.620PAURR 402338079512 8KGF690 FB 800528    EAST PITTSBURGH
160.620PAURR 402231079501 8KDY781   FB790213    PITISBURGH
160.620PAURR 402028079540 5KJZ930   FB780503    EAST PITTSBURGH
160.620PAURR 402058079565 4KCY798   FB780503    EAST PITTSBURGH
160.620PAURR 402856079473 8KJZ931   FB780503    EAST PITTSBURGH
160.620NVWP  405850117442 2KOH408   FB780226   8SACRAMENTO
160.620NVWP  405018115450 6KOE264   FB790219    SACRAMENTO
160.620USWP                  KDD508   FB780226    SACRAMENTO
160.620USWP                  KA3503   MO770503    SACRAMENTO
160.620USWP                  KA3502   MO780226    SACRAMENTO
160.620UTWP  404119112272 6KQL802   FB790219    SACRAMENTO
160.620UTWP  404552111534 4KOH410   FB780226    SACRAMENTO
160.620UTWP  404346114020 4KOH409   FB780226    SACRAMENTO
```

Figure 3.21. A working file of train service licenses in channel 14.

operation on or near a railroad company's lines within a state or, if designated for "US" operation, for use over the entire line within the contiguous United States. The third service classification "DM" is not a formal service class as defined in the FCC rules. Rather, it is a convenient designation utilized only in these working files and serves to designate an area of operation for mobile licenses in the reassignment analysis. All licenses designated "DM" are artificial and are considered only in the area compatibility testing. They are not tallied for potential transfer or retained in any other data files.

Approximately 1,150 mobile licenses were reviewed to determine their dummy "DM" license requirements. The "DM" licenses were added to the working files only in those cases where inadequate area testing would result if they were not used.

3.2.2.2 Reassignment assessments

This section describes the analyses and presentation of the results of exercising the data files to reassign the challenged channels into the remaining 58 channels for comparable railroad operations, and the potential for maritime frequency sharing. The presentation on utilization of the railroad mobile VHF band is found in Appendix C.

Railroad License Reassignment Analysis

A primary objective of this project was to assess the feasibility and impact of channel reassignments that might be required if channel space in the operating band were lost. Specific ground rules were established for this evaluation. The channels designated as challenged were in the band from 160.620 through 160.980 MHz and from 161.460 through 161.565. These bands included channels 14 through 26 and 42 through 46T. An additional channel (here designated 46) is a grandfathered frequency assignment at 160.610 MHz, which, for this evaluation, is considered among the challenged channels. The remaining 58 channels in frequency bands 160.215 through 160.605 MHz and 160.995 through 161.445 MHz are all unchallenged and become candidates for additional assignments.

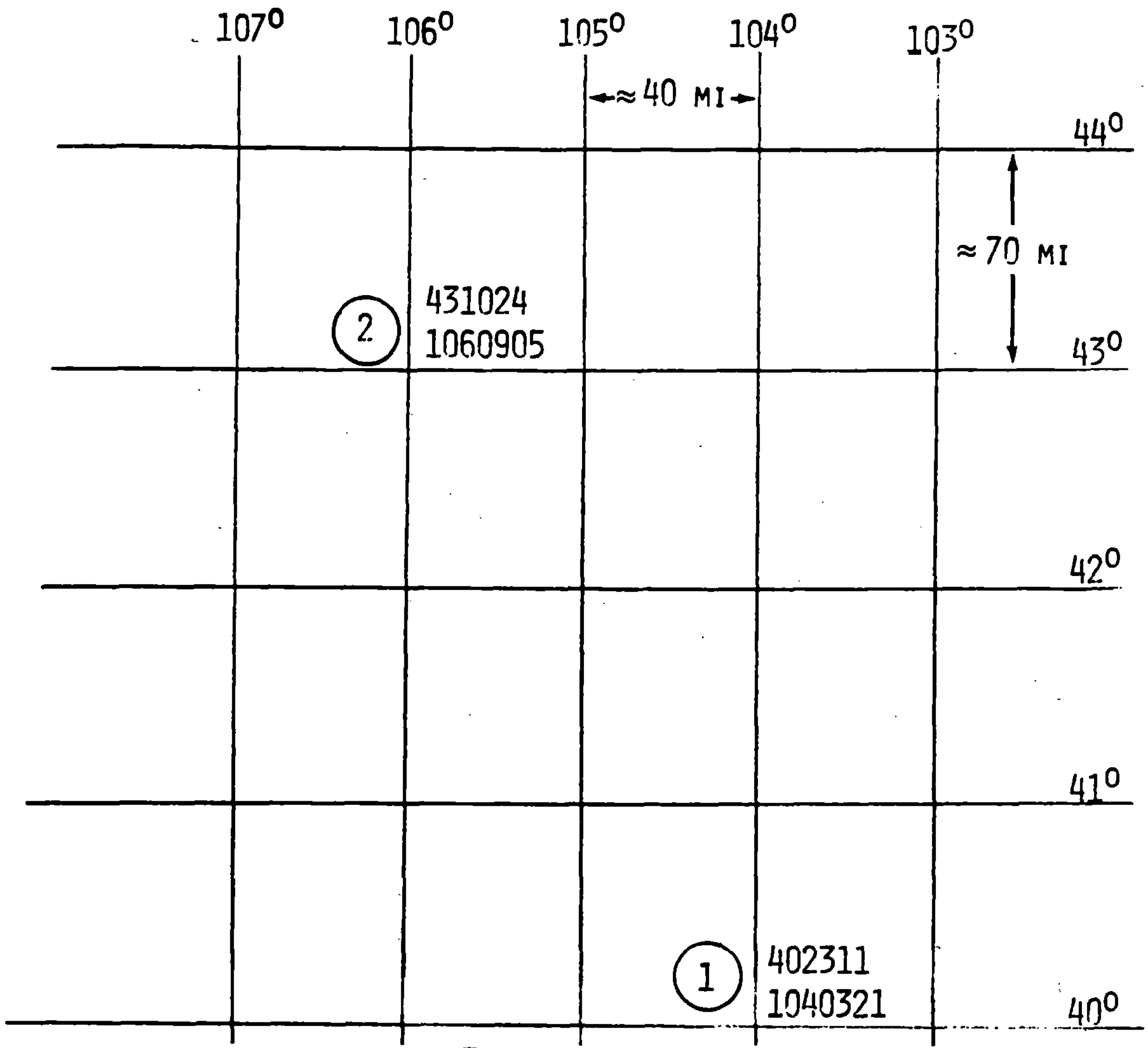
The conditions for reassignment eligibility are: 1) that all licenses in a frequency-railroad subgroup pass eligibility tests in order for the entire subgroup to be eligible, 2) that no challenged frequency can be reassigned within 50 miles of an existing assignment on the same frequency, and 3) that there must be a two-channel separation for reassignment of train service licenses. This means that all challenged licenses are tested in a cluster concept; the cluster being the candidate channel and both of its adjacent channels. The 50-mile separation criteria is evaluated using a great circle distance calculation or equivalent. The latitude and longitude values provide data for this calculation. The 50-mile separation affords non-interference for normal use and installations.

The drawing in Figure 3.22 illustrates the test for distance separation between a station operating on an existing frequency assignment in an area and a station in the same area which is being considered for reassignment to the same frequency. If the distance between the stations is 50 miles or greater, the two stations can be operated on the same frequency. It was not necessary to actually calculate the distance (by great circle distance equation) in all cases. An economy of computer process-time was realized by first comparing the respective latitudes and/or longitudes of the two stations. If the difference exceeded a given value (as shown in Figure 3.22), the 50-mile separation distance was assured.

The cluster-concept for testing in channel reassignment and sharing is illustrated in Figure 3.23. The data in the square on the left illustrates a candidate channel that may be challenged. The channel number, frequency and subgroups are identified. The number adjacent to the railroad abbreviation is the number of licenses assigned to that railroad. The numbers in the small square on the right represent the number of licenses respectively assigned to train service and general service in the designated unchallenged channels. These channels are identified by the numbering to the right. The rectangle formed by the broken line enclosing the small squares, identified "1T", "1", and "2T", defines the cluster to be processed in the test for eligibility of reassignment of a challenged channel, such as 15, to the new frequency occupied by channel 1. The computer process to evaluate the potential of reassignment of channel 15 licenses to the channel 1 frequency is shown in the flow-diagram of Figure 3.24.

In the process, each license in a challenged subgroup is tested in the order that it appears in the file against each license in the unchallenged cluster, (also in the order that they appear) until either a license fails or they all pass. The test is for 50 miles station separation. If they all (licenses in a subgroup) pass, the frequency of channel 1 is acceptable for

SEPARATION DISTANCE TEST



Given: Station locations (1) and (2)

*Tests: 1) The stations are compatible, if the latitude difference is greater than 1°.

2) The stations are compatible, if the longitude difference is greater than 1.5°.

3) The stations are compatible, if the greater circle distance is more than 50 miles.

*Only one test need be passed to permit reassignment.

Figure 3.22. An explanation of the separation distance test for two stations.

REASSIGNMENT TEST PROCEDURE

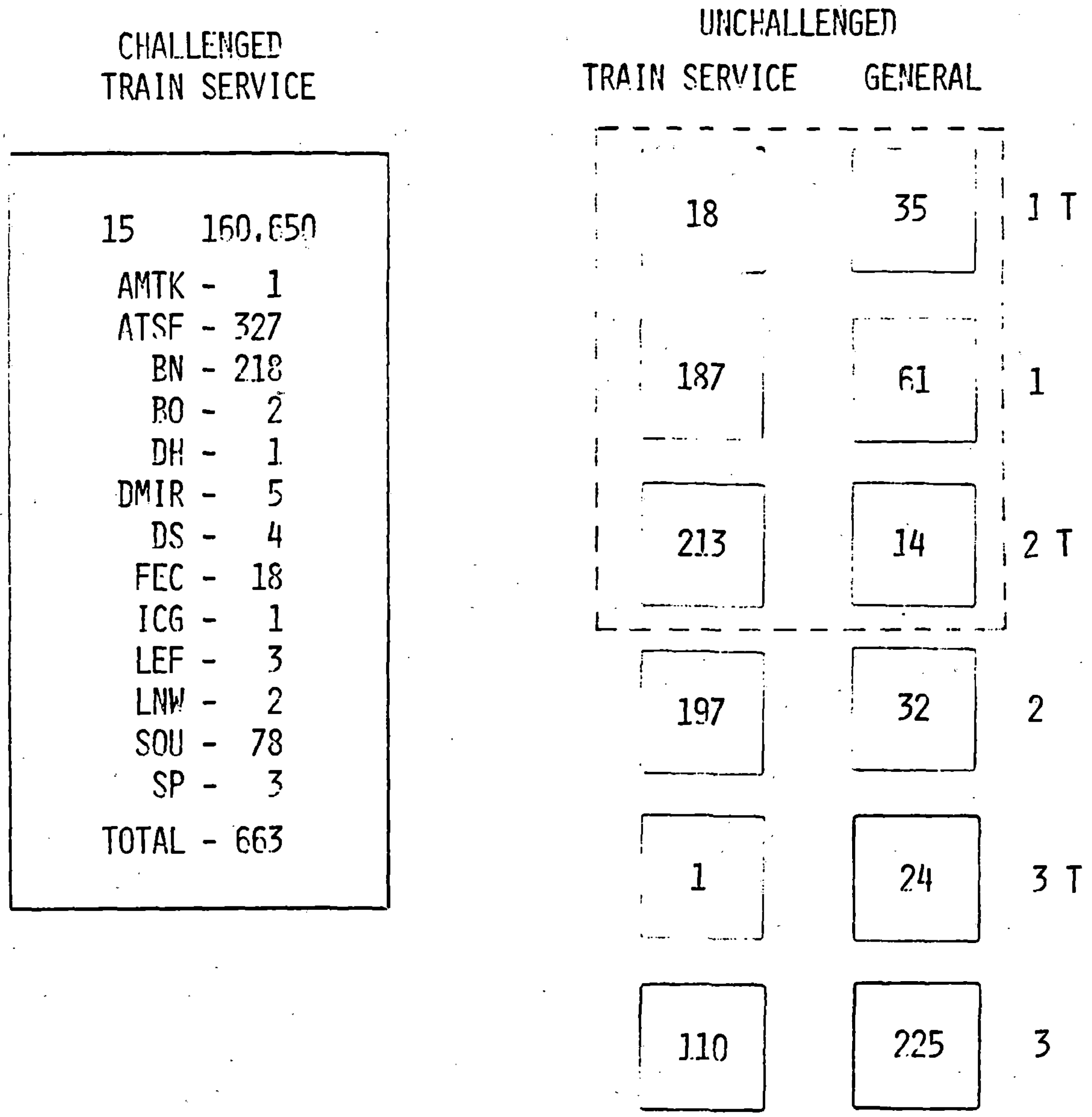


Figure 3.23. The cluster concept of testing for channel reassignment or channel sharing.

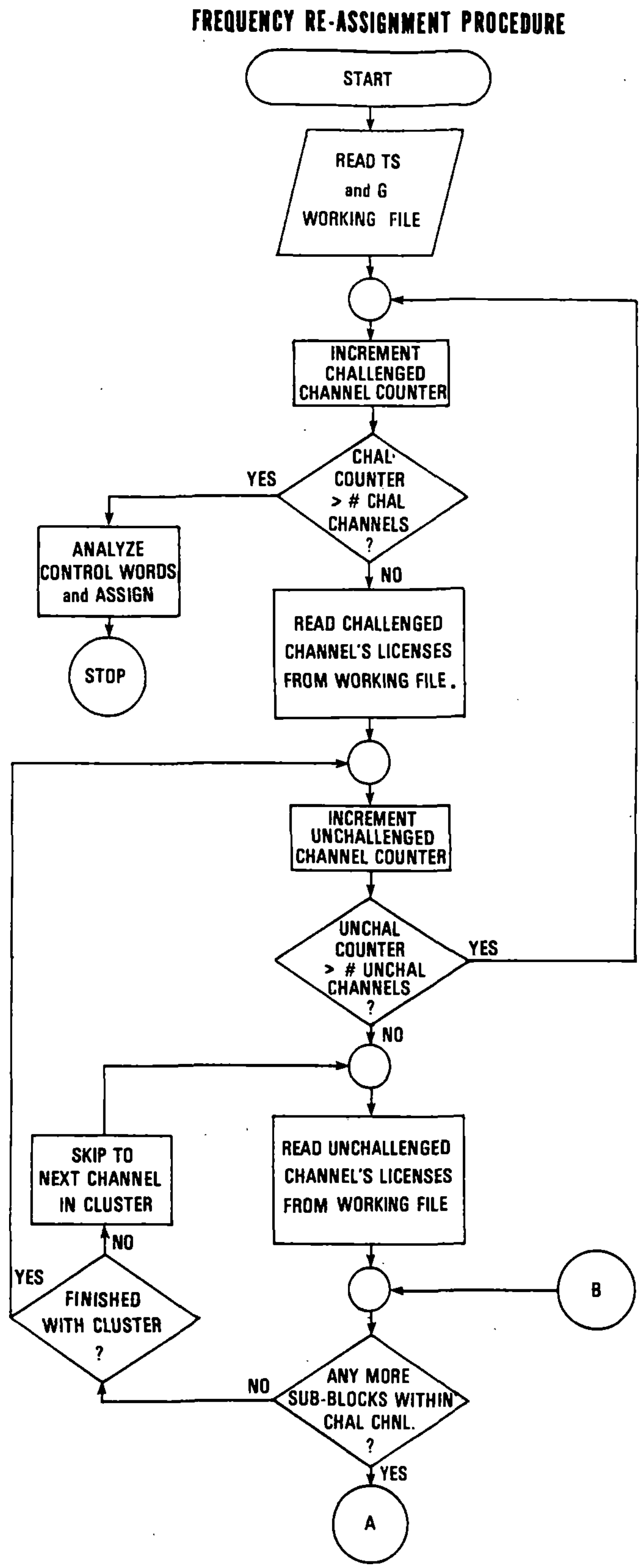


Figure 3.24. A flow diagram for channel reassignment evaluation (cont. on next page).

DISTANCE CHECK PROCEDURE

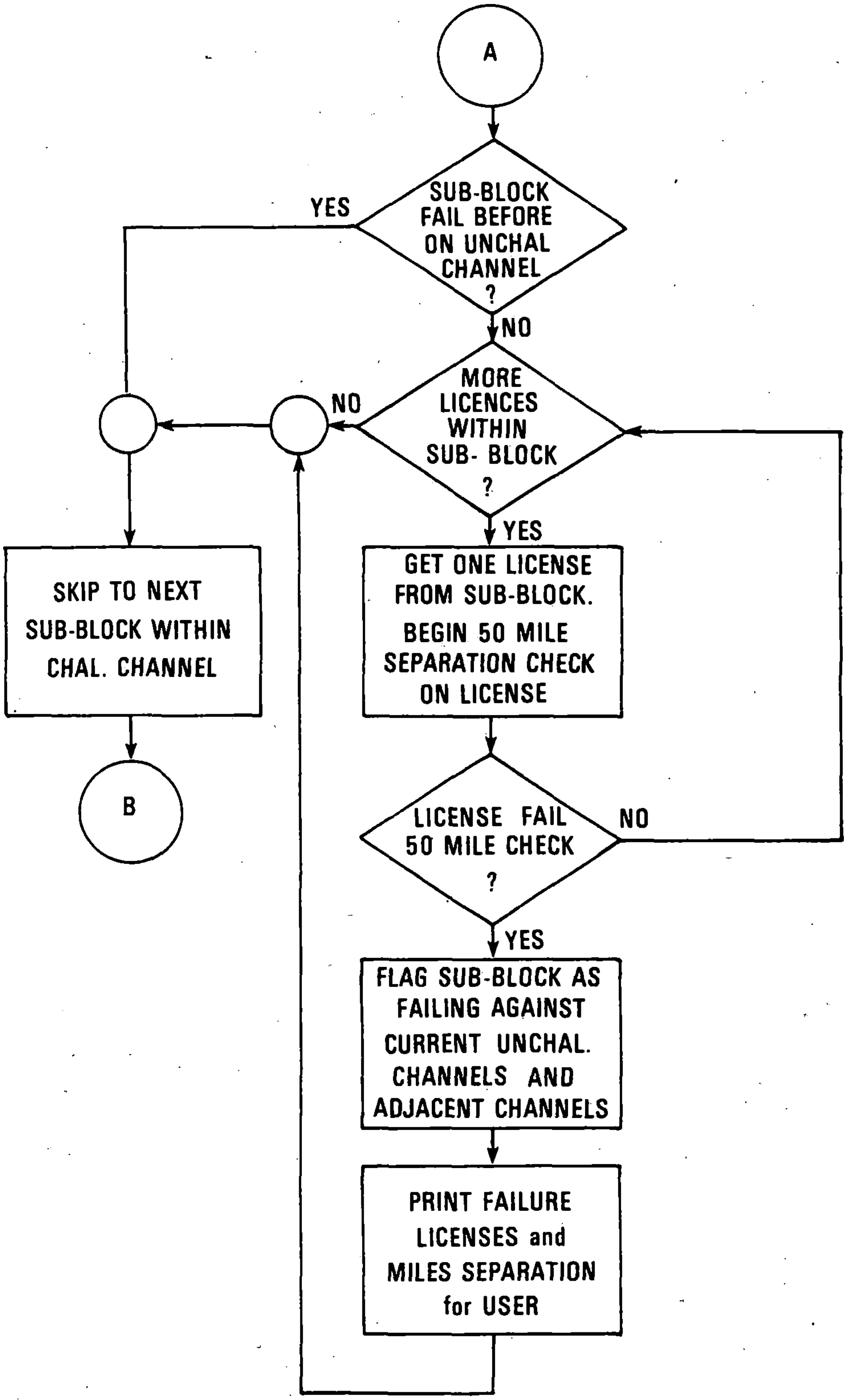


Figure 3.24.(cont.) A flow diagram for channel reassignment evaluation.

reassignment to those licenses. If one fails in the process, the testing is stopped, the channel 1 frequency is determined to be unacceptable in the reassignment process, and a new cluster is read in for testing. Again, a certain economy of process time and cost is achieved by only testing a cluster until a failure is detected. It efficiently accomplishes a first screening of all the challenged channels for potential reassignment within the unchallenged channels.

The results of this first screening of train service licenses (to determine the potential of transfer) of the 34 challenged channels is shown in Table B-1 (Appendix B). The individual lists (by channel) in the table are organized as a matrix (challenged subgroups vs. unchallenged channels). A number at a column-row intersection indicates that the frequency of the unchallenged channel (row) is suitable for replacement to the licenses in the challenged subgroup Because no licenses were assigned to channel 19T for train services, it was omitted from the table.

The number of unchallenged channel frequencies determined to be suitable as reassignment frequencies for the various challenged subgroups, varies from none (0) to all (58). A total of 40 subgroups were not eligible for reassignment to any of the unchallenged channels. Most of these contained a large number of licenses. The largest subgroup to pass the eligibility test was a subgroup of 69 licenses assigned to the DRGW on channel 24(160.920 MHz). Acceptable reassignment frequencies for channel 24 were determined to be 160.440 MHz - Channel 8, 160.560 MHZ - Channel 12, and 160.995 MHz - Channel 27T. This first screening test determines only eligibility. An actual attempt at creating a reassignment plan would require a series of assignment-retesting runs. Rather than proceed with such a plan, an analysis of the process and assessment of the magnitude and impact of such a process will be given.

A summary of the number of total licenses and subgroups, of the numbers of licenses and subgroups that passed, and of the number of licenses and subgroups that failed are shown in Table 3.2. This summary shows that the 33 channels tested contained 227 subgroups and 4,084 licenses. Of these, 187 subgroups passed (983 licenses) and 40 subgroups failed (3,101 licenses). This screening test indicates that nearly 75% of the train service licenses cannot be readily reassigned to any of the unchallenged frequencies, within the constraints of two-channel separation and a 50-mile distance between stations. A

Table 3.2. Summary of First Level Testing

(TRAIN SERVICE LICENSES)

		TOTAL		PASSED		FAILED	
CHANNEL	FREQUENCY	SUB GROUPS	NO. OF LICENSES	SUB GROUPS	NO. OF LICENSES	SUB GROUPS	NO. OF LICENSES
14	160.620	8	45	8	45	0	0
15 T	160.635	1	1	1	1	0	0
15	160.650	13	663	10	40	3	623
16 T	160.665	1	2	1	2	0	0
16	160.680	4	24	3	11	1	13
17 T	160.695	5	18	4	14	1	4
17	160.710	6	19	6	19	0	0
18 T	160.725	2	11	1	7	1	4
18	160.740	11	277	9	45	2	232
19	160.770	17	155	14	48	3	107
20 T	160.785	6	25	6	25	0	0
20	160.800	11	417	10	55	1	362
21 T	160.815	1	2	1	2	0	0
21	160.830	8	118	7	89	1	29
22 T	160.845	5	12	5	12	0	0
22	160.860	5	55	5	55	0	0
23 T	160.875	3	6	2	3	1	3
23	160.890	11	177	10	24	1	153
24 T	160.905	3	10	2	7	1	3
24	160.920	12	240	11	94	1	146
25 T	160.935	7	145	3	5	4	140
25	160.950	17	494	14	96	3	398
26 T	160.965	1	3	1	3	0	0
26	160.980	13	60	11	49	2	11
42	161.460	5	198	3	15	2	183
43 T	161.475	1	28	0	0	1	28
43	161.490	9	94	7	75	2	19
44 T	161.505	2	5	1	1	1	4
44	161.520	10	206	8	64	2	142
45 T	161.535	4	11	4	11	0	0
45	161.550	15	358	12	58	3	300
46 T	161.565	2	29	1	1	1	28
46	161.610	8	176	6	7	2	169
TOTAL		227	4084	187	983	40	3101

similar screening of challenged channel subgroups for general service was performed and the results are given in Table B-2 (Appendix B). A summary of these results are shown in Table 3.3.

The next step in the assessment process was to rank the train service subgroups by the number of potential frequencies available for reassignment. These results are shown in Table B-3 (Appendix B). The first 40 entries in this table are the subgroups that failed at all frequencies. These are followed by those that passed at only one frequency and so on. A review of this data suggests further analyses in the attempt at reassignment and also points to further barriers.

The only possibility for reassignment of the 40 subgroups (3101 licenses) that failed at all the unchallenged frequencies, is to relax or alter the conditions of reassignment. One consideration, which was tested on a sample basis, requires a second level of testing. The procedure is to test the subgroup against all licenses in a cluster instead of only until one license fails. If none of the failures occurred against train service licenses, and if some adjustment in the general service assignments of select unchallenged frequencies can be made, a possible assignment frequency could be found. Of course, any adjustments other than a few general licenses, would be a task such that a complete reassignment assessment should be considered. An evaluation of the potential of this process and the results of some select testing are discussed later.

A further look at Table B-3 shows that there are some unchallenged frequencies which seldom pass as candidates for reassignment and there are some which pass more often than average. This is not unexpected, but it does increase the potential for even more subgroups not passing the reassignment tests. As an example, the section in Table B-3, where a subgroup has only one potential frequency for reassignment, six subgroups passed on channel 10. If one of these subgroups is selected for reassignment (such as LI-21), then before any of the remaining five subgroups can be reassigned, those licenses must be tested against those that were previously reassigned. Thus, it is conceivable that several more subgroups would be added to the first 40 that did not pass, due to the initial reassignment attempt.

The block diagram in Figure 3.25 shows the steps in a progressive analysis of the frequency reassignment. The two upper blocks summarize the result of

Table 3.3. Summary of First Level Testing

(GENERAL LICENSES)

CHANNEL	FREQUENCY	TOTAL SUB GROUPS	TOTAL NO. OF LICENSES	PASSED SUB GROUPS	PASSED NO. OF LICENSES	FAILED SUB GROUPS	FAILED NO. OF LICENSES
14	160.620	17	67	15	55	2	12
15T	160.635	5	7	5	7	0	0
15	160.650	18	50	15	37	3	13
16T	160.665	6	9	6	9	0	0
16	160.680	16	98	14	33	2	65
17T	160.695	2	4	1	2	1	2
17	160.710	11	53	10	48	1	5
18T	160.725	3	10	2	4	1	6
18	160.740	14	91	12	86	2	5
19T	160.755	6	13	4	8	2	5
19	160.770	15	50	13	45	2	5
20T	160.785	4	8	4	8	0	0
20	160.800	12	45	11	32	1	13
21T	160.815	6	8	5	6	1	2
21	160.830	11	48	8	20	3	28
22T	160.845	5	17	4	15	1	2
22	160.860	13	60	10	25	3	35
23T	160.875	6	36	6	36	0	0
23	160.890	14	142	11	55	3	87
24T	160.905	4	6	4	6	0	0
24	160.920	16	43	13	32	3	11
25T	160.935	5	7	5	7	0	0
25	160.950	20	109	16	30	4	79
26T	160.965	6	17	4	5	2	12
26	160.980	15	69	13	34	2	35
42	161.460	9	113	7	34	2	79
43T	161.475	4	15	4	15	0	0
43	161.490	13	62	11	31	2	31
44T	161.505	5	27	5	27	0	0
44	161.520	14	43	13	35	1	8
45T	161.535	6	17	5	16	1	1
45	161.550	19	68	17	64	2	4
46T	161.565	9	30	8	29	1	1
TOTAL		329	1442	281	896	48	546

FREQUENCY REASSIGNMENT ANALYSIS

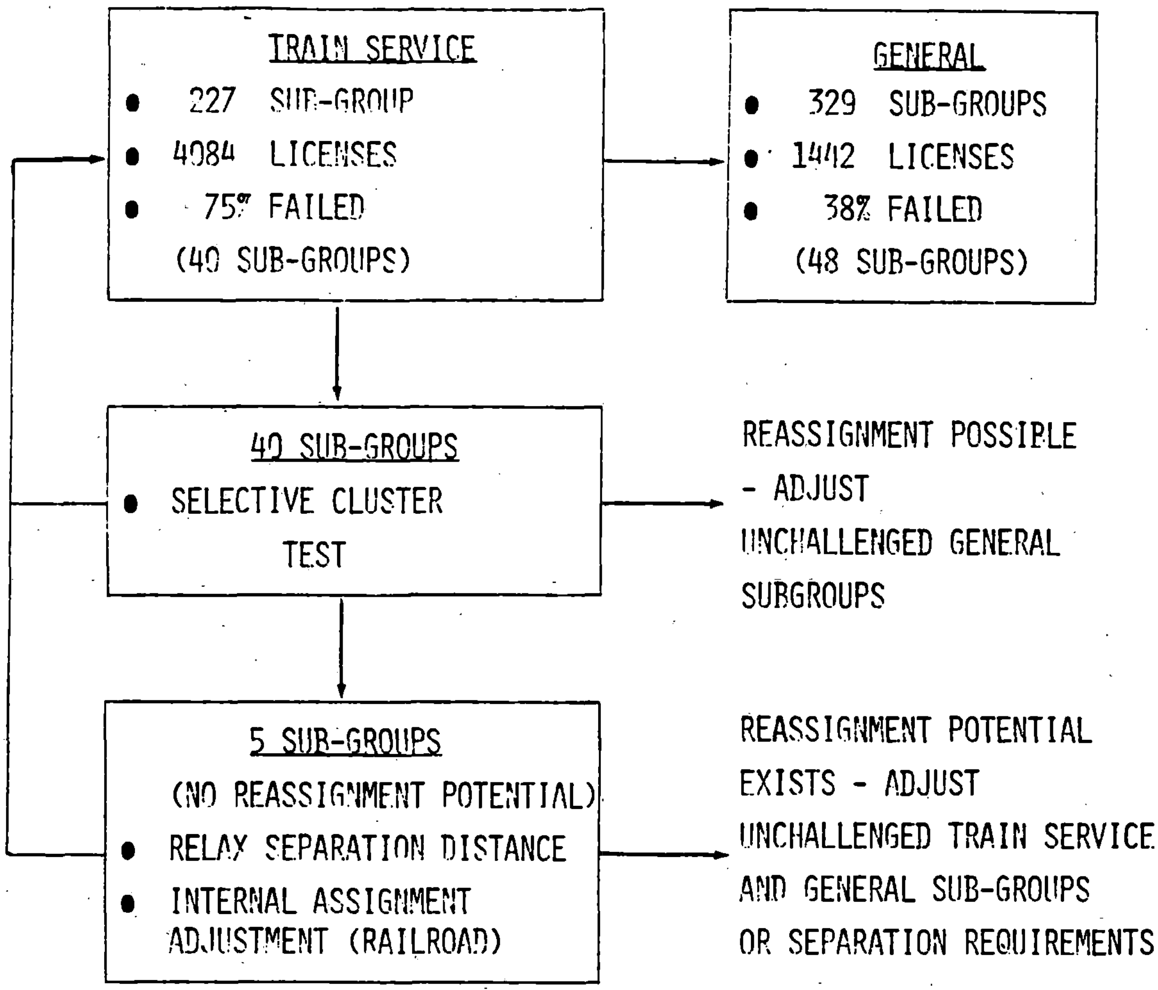


Figure 3.25. Frequency reassignment analysis.

the screening tests for both train service and general license groups. The middle block shows that, through selective cluster testing, possible reassignment frequencies may be located, but such a reassignment would entail additional testing and reassignment of unchallenged general subgroups. The lower block shows that there are at least five subgroups that exhibit no reassignment potential without even further concessions, such as a relaxation of separation distance or internal channel adjustment among licenses issued to the railroad company of the subgroup in question. Even these measures would only make possible further selective testing and not guarantee reassignment potential.

An example of the selective cluster testing is given using the results of the Channel 15 reassignment screen testing. The data in Figure 3.26 show that subgroups 2, 3, and 12 were unassignable to all 58 unchallenged channels. A diagnostic printout from the screening test shows which licenses in the unchallenged channel a subgroup failed and the separation distance of these stations. The tabulation of this information in Figure 3.27 readily shows where further testing (complete cluster test) is feasible. In this figure, a triangle identifies the unchallenged channel candidates for further testing for each of the three subgroups. At this stage, an exhaustive test of all candidates was not necessary since for each subgroup only one reassignment frequency need be identified. However, this reassignment process has built-in reiterative testing requirements and, as a result, any practical alternative reassignment options may be exercised.

Subsequent cluster testing disclosed potential reassignment frequencies for the three subgroups. The candidate channels and additional unchallenged frequency adjustments required to effect such reassignment are shown in the data of Figure 3.28. A reassignment of subgroup 2 ATSF(327) of Channel 15 would require an adjustment (reassignment) of the general service license KJN 910, issued to the Kansas City Terminal Railroad (KCT) on Channel 27T (161.010 MHz). The subgroup containing KJN 910 has two licenses. A similar action is required for the subgroup containing general service license KXM 782, issued to the Western Pacific Railroad (WP). A further interpretation of the chart indicates an adjustment in two general service subgroups of Channel 31 containing 12 licenses in order to reassign train service subgroup 3 of Channel 15 to Channel 31. If subgroup 12 of Channel 15 were to be reassigned to Channel 8, adjustments in two general subgroups of channel 8 and one subgroup

REASSIGNMENT TEST RESULTS

CHANNEL 15 (160.650)   663 LICENSE (TRAIN SERVICE)   13 SUB-GROUPS

		AMIK	ATSF	BN	BO	DH	DMIR	DS	FEC	ICG	LEF	LNW	SOU	SP
	*	1	327	218	2	1	5	4	18	1	3	2	78	3
01T	*	1	↑	↑						1		2	↑	3
01	*	1								1		2		3
02T	*	1								1				
02	*	1					5			1	3			
03T	*	1					5			1				
03	*	1					5			1				
04T	*	1								1				
04	*	1						4	18	1				3
05T	*	1								1				
05	*	1								1				
06T	*	1								1	3			
06	*	1				1	5			1	3	2		
07T	*	1				1	5			1	3			
07	*	1				1	5			1	3			
08T	*	1					5	4		1	3	2		3
08	*	1			2		5	4		1	3	2		3
09T	*	1					5	4		1	3			3
09	*	1					5	4	18	1	3			3
10T	*	1					5	4	18	1	3			
10	*	1					5	4	18	1	3	2		
11T	*	1					5			1				
11	*	1					5			1				
12T	*	1					5			1				
12	*	1				1	5	4		1	3	2		
13T	*	1								1	3	2		
13	*	1								1	3	2		
14T	*	1	FAILED							1	3	2	FAILED	
27T	*	1			2		5	4		1		2		3
27	*	1					5	4		1		2		3
28T	*	1					5			1		2		3

Figure 3.26. Reassignment testing for channel 15.

28	*	1			5			1	3	2	3
29T	*	1			5			1		2	3
29	*	1			5			1		2	3
30T	*	1						1		2	
30	*	1						1	3	1	
31T	*	1						1	3	2	
31	*	1			5	4	18	1	3	2	
32T	*	1						1		2	
32	*	1						1		2	3
33T	*	1						1		2	3
33	*	1	2					1	3	2	3
34T	*	1						1		2	3
34	*	1						1		2	3
35T	*	1			5			1			
35	*	1			5	4	18	1	3		
36T	*	1					18	1	3		
36	*	1		1			18	1	3		3
37T	*	1		1			18	1		2	
37	*	1	2	1	5	4	18	1		2	
38T	*	1	2					1		2	
38	*	1						1	3	2	3
39T	*	1						1	3	2	
39	*	1		1	5	4		1	3	2	
40T	*	1			5	4		1			
40	*	1						1			
41T	*	1						1			
41	*	1	2					1	3	2	
42T	*	1	2		5	4		1	3	2	

Figure 3.26.(cont.) Reassignment testing for channel 15.

REASSIGNMENT TEST RESULTS

CHANNEL 15 3 SUBGROUPS THAT FAILED
(160.650)

		ATSF-327 TS	G	BN-218 TS	G	SOU-78 TS	G
01T	*	BN-44.0				SCL-45.1	
01	*			DMIR-38.5			
02T•	*	ATSF- 6.5				CG-43.5	
02	*			S00-35.3			
03T	*						
03	*	UP-20.7		UP- 6.6		BS-31.6	
04T	*						
04	*	SP-43.9		RI-38.0		LN-38.2	
05T	*						
05	*	KCS-34.1		DMIR-49.5		MB-23.8	
06T	*						
06	*	WP-17.3		◀	BN-37.0	◀	
07T	*			◀		◀	SCL-31.3
07	*	MP-46.7		◀	BN-31.8	◀	
08T	*			◀		◀	
08	*	MW- 9.3				◀	LN-30.1
09T	*			CNW-35.7		◀	
09	*	MP-46.7				◀	
10T	*			◀		◀	SLSF-32.1
10	*	SN-40.9		◀	BN-31.3	◀	
11T	*			◀			
11	*	BO-12.7		◀	BN- 6.2	SLSF-32.1	
12T	*						
12	*	ATSF-41.1		SI-31.3			
13T	*					AAW-19.8	
13	*	SERA-46.8		BN- 0.0			LN-39.4
14T	*					◀	
27T	*	◀					

Figure 3.27. Reassignment test diagnostics for subgroups 2 (ATSF-327), 3 (BN-218), and 12 (SOU-85).

27 *	◀	KCT-37.1	BN-31.1		ICG-46.3	
28T *						
28 *	CNW-19.3		◀	BN-22.5		
29T *					SCL-34.6	
29 *	ATSF- 0.0		VSL-25.6			
30T *						
30 *	ATSF- 6.5		BN-40.6		SCL-48.9	
31T *						
31 *	DRGW-41.1		◀	BN-31.5	SLSF-43.2	
32T *			◀			
32 *	CS-27.7		◀	BN- 0.0	SLSF-48.6	
33T *						
33 *	ICG-31.8		ICG-19.0		ICG-32.4	
34T *						
34 *	RI-11.0		◀			
35T *			◀	CSP-18.1	SLSF-32.1	
35 *	CW-42.3		◀			
36T *						
36 *	ICG-31.8		ICG-19.0		CHU-49.6	
37T *						
37 *	SP- 5.0		◀	BN-42.3	WA- 0.7	
38T *						
38 *	RI-13.7		DMIR-33.9		◀	
39T *					◀	SOO-0.0
39 *	ATSF- 0.0		SOO-29.7			
40T *					WA-40.5	
40 *	SP- 3.0		MNS-31.6			
41T *					SCL-37.6	
41 *	MILW-14.7		MILW-45.6			
42T *					◀	BS-31.3

Figure 3.27.(cont.) Reassignment test diagnostics for subgroups 2 (ATSF-327), 3 (BN-218), and 12 (SOU-85).

RE-ASSIGNMENT TEST RESULTS

CHANNEL 15 (160.650 MHz)	UNCHALLENGED GENERAL SUB-GROUP ADJUSTMENTS
1. SUB-GROUP 2 ATSF (327) - 4540 MOBILE - 290 BASE	27T A. CHANNEL 27 (161.010) o KCT KJN 910 SUB-GROUP - 2 LICENSES (15 MOBILE UNITS) B. CHANNEL 27T (160.995) o WP KXM 782 SUB-GROUP - 2 LICENSES
2. SUB-GROUP 3 BN (218) - 198 MOBILE	31 A. CHANNEL 31 (161.130) o BN KYF 398 SUB-GROUP - 5 LICENSES (22 MOBILE, 2 BASE) o SP KOK 728 SUB-GROUP - 7 LICENSES (46 MOBILE - 2 BASE)
3. SUB-GROUP 12 SOU (78) - 9 MOBILE - 61 BASE	8 A) CHANNEL 8 (160.440) o LN - (13 LICENSES) SUB-GROUP - 21 LICENSES (402 MOBILE, 18 BASE) o SCL - (6 LICENSES) SUB-GROUP - 16 LICENSES (1 MOBILE, 5 BASE) B) CHANNEL 8T (160.425) o BS - KA 2688 SUB-GROUP - 2 LICENSES (3 MOBILE, 1 BASE)

Figure 3.28. Unchallenged frequency adjustments required to assign channel 15 subgroups 2, 3, and 12.

of Channel 8T are required. A total of 39 licenses could be involved in this adjustment. This reassignment philosophy is to make adjustments in general service subgroups in order to find a channel for potential reassignment of challenged train service subgroups.

Even so, this approach can only be carried so far. The diagnostic displays of the five subgroups in Figure 3.29 exhibit no channels where further cluster testing is feasible. This means that either the process stops or further concessions are required. Concessions suggested were to reduce the separation distance and/or consider adjustments of channel use among the several channel subgroup licenses issued to a railroad company. To illustrate this concept, those channels in Figure 3.29 where the fail distance was within 5% of the 50-mile requirement are highlighted with a circle, and those channels in the same figure where both the challenged license and the unchallenged license which caused the subgroup to fail are issued to the same railroad company are highlighted by a square. These symbols readily identify channels where further testing is feasible. No actual testing was pursued because positive results would require adjustments similar to those displayed in Figure 3.28.

Prior to attempting analyses of the types described for reassignment of the challenged train service and general license subgroups contained in Tables 3.2 and 3.3 additional display of data such as contained in Figures 3.27 and 3.29 would be useful in establishing an order for analysis. These processes are not readily adaptable to optimization routines, thus a manual procedure is suggested. The best chances of success might come from starting with the most difficult subgroups and working toward the least difficult, performing all iterative testing as required.

The analyses conducted in this section consisted of a screening test (results in Appendix B, with summaries in Tables 3.2 and 3.3) and a second-level testing to assess the potential of train service subgroup reassignment at the expense of general service subgroup realignment. Some cursory analysis was conducted to identify procedures leading to reassignment as a result of relaxed operating conditions. Although the only exhaustive testing was for screening, the overall indication has been that to attempt a reassignment of this magnitude, with reduced constraints, would be an immense exercise with little chance of a successful completion. This conclusion is based on the outcome of the screening

		Channel 20 PC-362		Channel 23 CNW-153		Channel 25 SOU-376
		TS	G	TS	G	TS
01T	*	ITC- 4.1		RI-48.1		SCL-38.7
01	*					
02T	*	SOU- 1.7		SOU-41.0		AGS-41.9
02	*					
03T	*					
03	*	BO-35.9		UP-22.1		BS-27.3
04T	*					
04	*	BO- 4.7		RI-49.9		LN-38.9
05T	*					
05	*	RDG- 3.0		ITC-14.1		MB-30.7
06T	*					
06	*	LI-40.0		BRC-22.6		FEC-40.1
07T	*					
07	*	BO- 4.7		CEI-27.2		BO- 5.5
08T	*					
08	*	RDG-46.7		NW-32.8		NW-47.9
09T	*					
09	*	BO-34.8		MP-44.5		BO-34.6
10T	*					
10	*	SOU-26.1		CIC-29.6		SOU-32.5
11T	*					
11	*	BO- 4.7		MILW-36.5		SLSF-27.5
12T	*					
12	*	PC-24.5		ALS-38.7		ALS- 0.7
13T	*					
13	*	DH-37.8		BN-16.0		SCL-29.4
14T	*					
27T	*					
27	*	ICG- 5.3		ICG-38.9		ICG-12.7
28T	*					
28	*	GTW-35.4		CNW-43.0		
29T	*					SCL- 0.2
29	*	PC-25.6		PC-35.1		
30T	*					ICG- 8.6
30	*	BN-48.6		BN-32.2		
31T	*					PBR-37.6
31	*	PC-25.6		SLSF-42.9		
32T	*					
32	*	BO-34.7		BN-42.3		SLSF-33.6
33T	*					
33	*	PRS-12.2		ICG-14.5		SLSF-27.5
34T	*					
34	*	PC-37.9		RI-42.6		MSE-42.6
35T	*					
35	*	CNJ-26.5		NW-49.5		ICG-38.1
36T	*					
36	*	PC-40.7		ICG-14.5		ICG-17.0
37T	*					
37	*	CNJ-26.5		TRRA-36.9		WA- 0.8
38T	*					
38	*	ICG-37.8		KI-12.6		ICG-44.0
39T	*					
39	*	LN- 9.4		SOU-49.6		LN- 8.8
40T	*					
40	*	DH-37.8		BN-24.2		CCR-49.6
41T	*					
41	*	PC-24.7		MILW-34.5		WA-40.3
42T	*					

Figure 3.29. Reassignment screen test diagnostic displays of subgroups CH 20-PC(362), CH 23-CNW(153) and CH 25-SOW(78).

		Channel 42 ICG-161 TS	G	Channel 46 RI-167 TS	G
01T	*	ITC-49.5		BN-39.4	
01	*				
02T	*	SOU-17.0		SOU-45.5	
02	*				
03T	*				
03	*	ICG-42.2		ICG-41.0	
04T	*				
04	*	LN- 0.8		RI-40.1	
05T	*				
05	*	ITC-48.7		KCS-33.4	
06T	*				
06	*	BRC-12.8		BRC-12.1	
07T	*				
07	*	CEI-12.8		MP-42.8	
08T	*				
08	*	NW-49.1		ALM-40.9	
09T	*				
09	*	MI-38.4		MP-22.2	
10T	*				
10	*	SOU-33.3		BXN-23.3	
11T	*				
11	*	BO-47.1		SLSF-43.0	
12T	*				
12	*	ALS-45.4		ATSF- 1.7	
13T	*				
13	*	BN-19.1		ICG-40.0	
14T	*				
27T	*				
27	*	ICG-29.7		ICG-38.5	
28T	*				
28	*	CNW-24.0		MP-42.7	
29T	*				
29	*	PC-45.9		CNW-15.5	
30T	*				
30	*	BN-23.3		ICG-40.5	
31T	*				
31	*	SLSF- 0.7		SLSF-40.6	
32T	*				
32	*	SLSF- 0.7		CS-16.4	
33T	*				
33	*	ICG- 0.6		ICG- 5.4	
34T	*				
34	*	MSE-35.4		RI- 5.1	
35T	*				
35	*	LA-36.1		ICG-38.5	
36T	*				
36	*	ICG- 0.0		ICG-47.5	
37T	*				
37	*	TRRA-45.8		SLSF-43.0	
38T	*				
38	*	ICG-31.7		RI- 1.9	
39T	*				
39	*	LN-18.3		LN-46.9	
40T	*				
40	*	BN-49.2		SSW-42.6	
41T	*				
41	*	SLSF-30.8		SLSF-43.0	
42T	*				

Figure 3.29.(cont.) Reassignment screen test diagnostic displays of subgroups CH 20-PC(362), CH 23-CNW(153) and CH 25-SOW(78).

tests and the fact that the process of reassignment is iterative. Seventy-five percent of the train service licenses and thirty-eight percent of the general service licenses failed the screen test, meaning that the only potential for reassignment lies in the realignment of unchallenged general and/or train service licenses. The iterative processing aspect means that each tentative assignment leads to additional testing (increased potential for failure) as further reassignment is attempted to a given channel. Convergence to a satisfactory situation is not indicated.

3.2.2.3 Communications models

3.2.2.3.1 Model applications

In order to assess accurately the use of radio frequencies for railroad communications, computer models simulating events that take place in a railroad yard were built. The following paragraphs discuss in detail the application, experiences, and results of modelling and of exercising those models.

The operations events relate to equipment movement and facility control. For this requirement, the only functional element of interest is the associated usage of the VHF channel resources. As indicated earlier, the organization of the models must allow link identification for operational event with safety and command/control impact criteria. The operations model includes primarily only those events having identifiable linkages to frequency resources obtained from the assignment tables.

Event modeling and computer simulation has wide application and can give desired information on system management, operations, control and design. An event model of a modern railroad yard could be accomplished showing communication support activities with given resource allocations, allowing these resource allocations to be manipulated in the computer and the resultant effect on yard operations could be evaluated. Once the model was completed, any number of frequency allocation schemes could be excercised and studied to show yard impact. In the yard model, frequency channel allocation would not have to be the only yard resources that could be studied. For example, switch engines could be resources, yard crews, or freight car unloading schemes could be studied. This type of modeling and computer simulation readily provides detailed analysis of yard management, command and control, yard safety, crew efficiency, car movement efficiency, yard design criteria, and yard operations priorities.

3.2.2.3.2 Yard models

As discussed previously, the various models were organized to demonstrate the connectivity and priorities between operations and the VHF communications resource. An important factor in building an event model is experience with, and knowledge of, the system to be modeled. Expert advice must come from those most familiar with the system. ITS personnel met with experts from various railroad lines to develop the event flow diagrams of Section 3.1.2 of this report. These event flow diagrams detail the connecting of operations of a railroad yard with supporting communications activities. This allows frequency assignments to be examined with regard to operations event priorities, e.g., management, command and control, yard safety, etc.

The Santa Fe's new Barstow, California, Classification Yard was chosen as the yard to evaluate. This facility represents one of the most integrated communications-operations capabilities having full operational status. Operational compromises in older facilities, because of reduced communications capability, should be greater than indicated by these model exercises. Personnel from the Santa Fe line assisted in procedure definition as required for development of the typical operations-communications time-line event diagram, part of which is shown in Figure 3.30. From that and the flow diagrams of Section 3.1.2, an event model was developed. The event model describes the communications support events in network terms using a given symbol set. This network model identifies each task to be performed, the resources required to perform the tasks, states variables and the conditions that initiate interactions between variables and task performance. Once the model is developed, the simulation program will automatically generate system performance estimates. The modeling problem considered was to determine what the impact of reducing the number of channels assigned to the Barstow Yard and the effect on the various operations, and to examine the possible frequency sharing schemes among the remaining communications channels.

The system description of the yard included the characteristics of the resources required, the tasks performed by the resources, the precedence relations among tasks, the flow of information through the system, and the effects of environmental stressors on task performance.

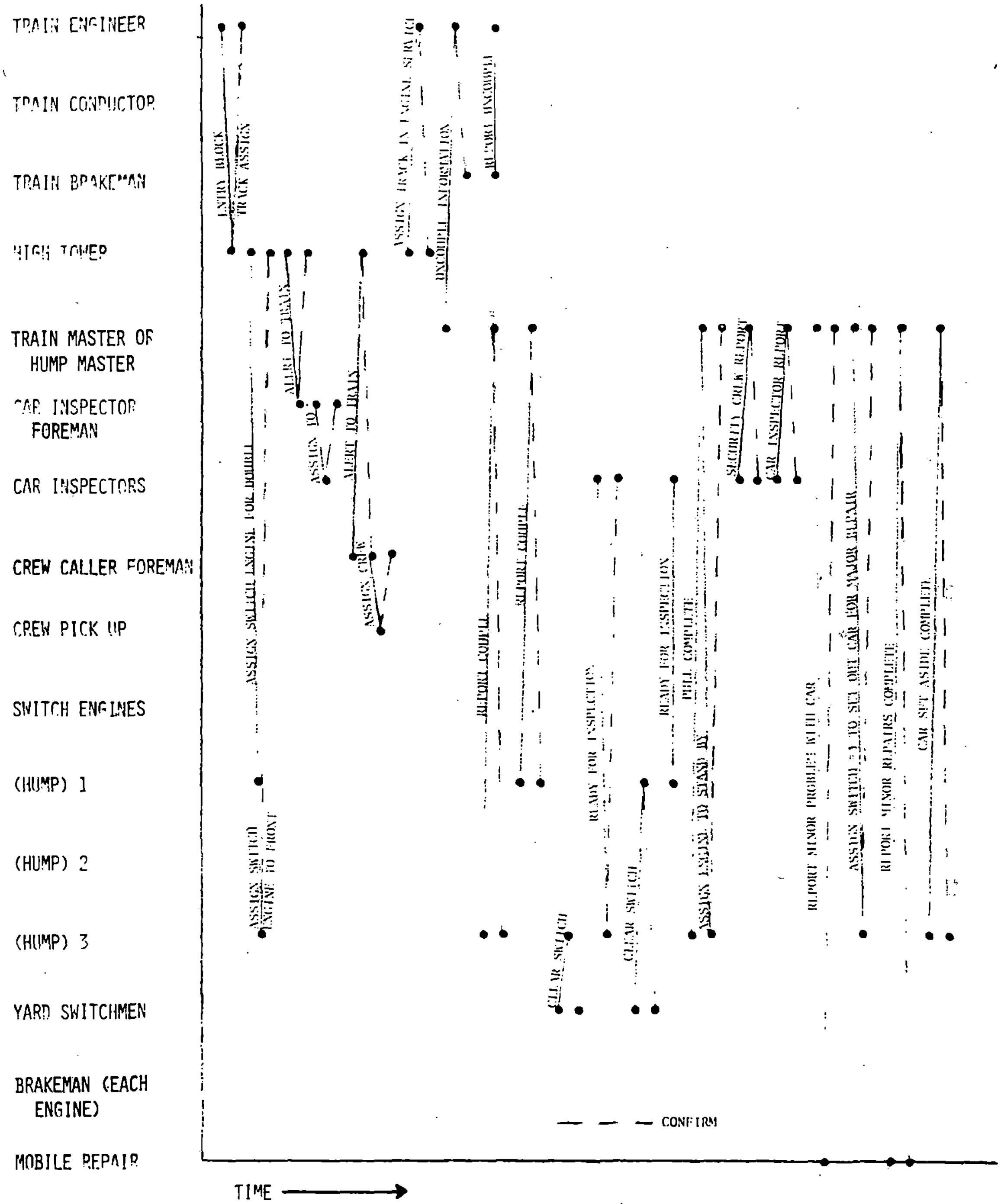


Figure 3.30. Operations communications event time-line diagram.

The SAINT Simulation Program was used to analyze the system model. This is a queuing type program which shows what resources are being used, what tasks they are performing and which tasks are waiting for resources to complete their job. The basic element of the network model is a task. The graphical symbol used to portray tasks in this model is shown in Figure 3.31. Three basic functions are associated with each task:

1) release of the task (satisfying all predecessor requirements);
2) performance of the task and associated operations, and
3) identification of potential successor tasks.

These functions are described by an input side, a task description, and an output side. The task of Figure 3.31 is assigning a switch engine to work in the departure yard. The time assigned to accomplish this task is given by decision set 60 which is assigned to task 60. The time assigned to the decision sets may be some constant value or may be represented by probability distribution. There are eleven distribution types available in SAINT; some of which are normal, uniform, triangular, Poisson, lognormal, etc.

The resources (RESR) available to this task are frequency channels 8, 9, 10, and 18 which are assigned to switch engines 4, 5, 6, and 7, respectively. The frequencies of switch engines are selected in order as they are freed by the simulation program. This task is assigned one of the idle channels or waits until one of the channels is freed. The code STAT on the task description, sets the statistics that will be kept at this node. In this instance, it tells the program to mark the time of release of this task and sets internal statistics on time as assigned by decision set 60. The output of this task is deterministic and all output arcs are released. The task output characteristics can be deterministic, conditional, or probabilistic. For any task in a SAINT network that is defined as a statistics task, the program obtains estimates of the mean, standard deviation, minimum and maximum value of time that resources are busy, and prints a histogram associated with the statistical quantity to be observed.

A portion of the network in SAINT symbol set, showing some of the activities in the receiving yard, is displayed in Figure 3.32. This represents only 16 tasks of the 144 tasks that make up the total network model. The type of statistics desired from the program give the time delays that trains will experi-

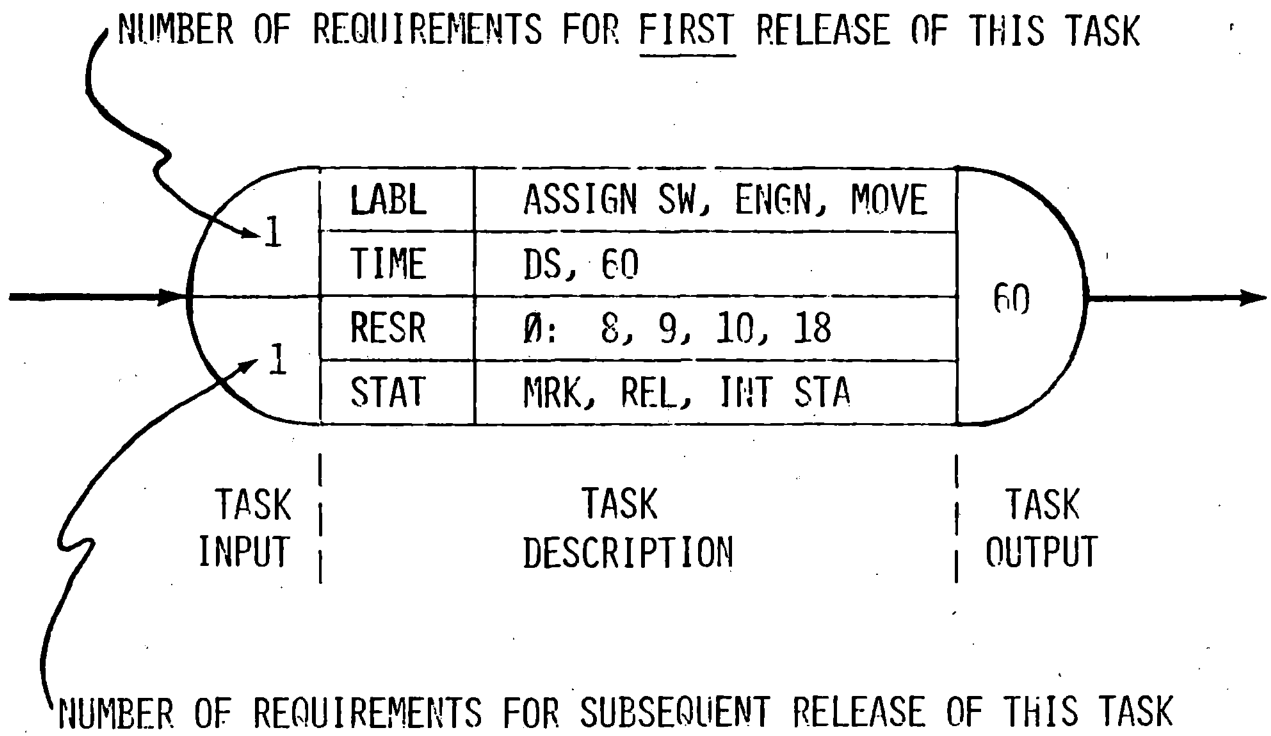


Figure 3.31. Graphic symbol for network model.

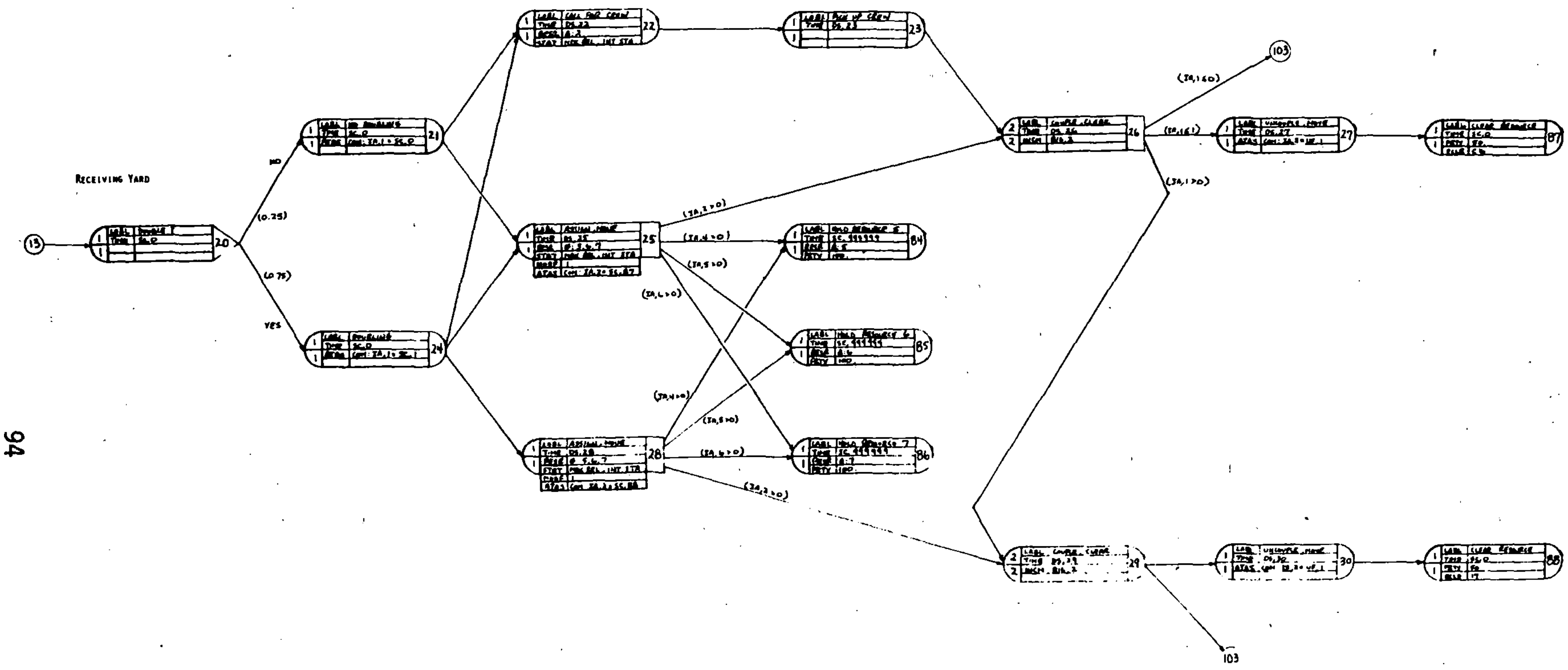


Figure 3.32. A portion of a network using SAINT symbols.

ence in various areas in the yard as fewer frequency channels are available to assist in the flow of cars through the yard.

The actual exercises of the model and output will be discussed in Section 3.3.2.

3.3 Communications Capability Evaluation

3.3.1 Yard model exercises

The yard model, as described in Section 3.2, was designed to give statistics to show the effect of frequency channel reduction on the flow of cars through a modern railroad yard. The network model was built around Santa Fe's Barstow, California, Classification Yard. A form of time-line diagram of communication events was completed to help understand the timing and occurrence of communications activity within the yard, a portion of which was shown in Figure 3.30. This helped to establish the "decision set" for tasks and communication channel resources described in the yard model section, as they relate to yard operations. Once the decision sets were completed and resources assigned, the yard model was exercised.

There are 18 frequency channels allocated to the Barstow yard. The yard assignments of these frequencies are shown in Figure 3.33. The yard model was exercised under six different frequency allocation schemes as follows:

1. The original resource allocation given in Figure 3.33.

2. Resource reallocation #1 - all car inspector communication events to be carried out on the Diesel Shop channels (Channels 11 and 12 to Channels 13, 14).

3. Resource reallocation #2 - in addition to the car inspector functions, all maintenance communication events to be carried by the Diesel Shop channels (Channels 11, 12, 15 to Channels 13 and 14).

4. Resource reallocation #3 - in addition to above, removal of Channel #9 assigned to switch engine #5. Switch engine #5 must share frequencies Channels 8, 10, and 18.

5. Resource reallocation #4 - In addition to all above, removal of Channel #7 assigned to switch engine #3. Switch engine #3 must share frequency Channels 5 and 6.

6. Resource reallocation #5 - In addition to all above, removal of Channels #6 and #18 assigned to switch engines #2 and #7, respectively. Switch engines 1, 2, and 3 must share frequency Channel #5. Switch engines 4, 5, 6, and 7 must share frequency channels #8 and #10.

CHAN	FREQ	ASSIGNMENT
F1	160.650	ROAD
F2	161.370	WEST YARD
F3	160.560	EAST YARD
F4	161.145	MAIN HUMP
F5	161.250	SWITCH ENGINE #1 WEST
F6	161.280	SWITCH ENGINE #2 WEST
F7	161.340	SWITCH ENGINE #3 WEST
F8	160.530	SWITCH ENGINE #4 EAST
F9	160.770	SWITCH ENGINE #5 EAST
F10	160.275	SWITCH ENGINE #6 EAST
F11	161.565	CAR INSP BASE REC
F12	160.440	CAR INSP BASE XMT
F13	161.190	DIESEL SHOP RPTR XMT
F14	160.215	DIESEL SHOP RPTR REC
F15	160.980	MAINT 8 SUPVY
UHF	457.925	HUMP ENG CONT
F16	160.260T	PBX 3 RPTR (161490R)
F17	160.335T	PBX 4 RPTR (161460R)
F18	160.605	SWITCH ENGINE #7 EAST

VEHICLE MOBILE ASSMT	FREQ EQPTD
TERM SUPT	1-2-16-17
TRAINMASTER	1-2-16-17
SIG SUPVR	1-15-16-17
ROADMASTER	1-15-16-17
SECTION FRMN	1-15-
SIGNAL MAINT	1-15-
COMM DEPT TRK #1	1-15-16-17
COMM DEPT TRK #2	1-15-16-17
MESSGR VAN	1-2-3
ENGR DEPT	1-15-16-17
CONST ENG	1-15-16-17
CREW CALLER	1-3-2-
COMM ASSTENG	1-15-16-17
COMM ASST ENGR	1-15-16-17
COMM DIV LINEMAN	1-15-
SUPT OF SHOPS	1-15-16-17
ASST SUPT OF SHOP	1-15-16-17
ASST ROADMASTER	1-15-16-17
SIG INSPECTOR	1-15-

Figure 3.33. Channel allocation to Barstow yards.

The results of the model exercises are shown in Figures 3.34 through 3.39. In Figure 3.34 are shown receiving yard tasks which have to do with movement of trains into the receiving yard. These particular tasks use the road frequency and mainly include communications with the road power as the train arrives. Actual task descriptions are given in Figures 3.41 through 3.54. The delay time "τ" is shown in minutes at the left. The trains are programmed to arrive at the yard in the following fashion:

- From 6:00 a.m. to 9:00 a.m., one train every 20 minutes.
- From 9:00 a.m. to 5:00 p.m., one train every 40 minutes.
- From 5:00 p.m. to 8:00 p.m., one train every 20 minutes.
- From 8:00 p.m. to 6:00 p.m., one train every 2 hours.

This arrival rate produced 35 trains per day into the yard which is the average for Barstow. The highest arrival rates are between 6:00 a.m. to 9:00 a.m. and 5:00 p.m. to 8:00 p.m., which is based on actual peak arrival times at Barstow. The program is set up to run the 35 trains per day through the yard for 30 days.

It can be seen in Figure 3.34 that there is little effect on delay times in these entry tasks caused by the frequency sharing. Only resource reallocation #5 seems to have any large effect and this causes waiting time to drop. This was expected from the model since it is not designed to tally the number of trains waiting for track assignment on the main line for entry into the yard. As the number of communication channels decreases, the remaining resources are so busy with tasks in other areas of the yard that the actual number of trains that could get track assignment in the receiving yard drops and, consequently, the entry tasks are not as busy.

In Figure 3.35, the tasks are those that require the car inspector channel for communications. Here, the removal of the car inspector channel and subsequent use of the diesel shop channel for car inspector functions shows a significant jump in average waiting time. There is some random change in "τ" as the other resource reallocations are made. In the case of CI tasks 31, 32, and 33, the trend is toward increased waiting time until the reduced number of resources are tied up doing tasks in other parts of the yard and trains are not coming into the yard in a normal flow. At this point, the delay for car inspector function drops simply because there are fewer trains getting into the yard to inspect.

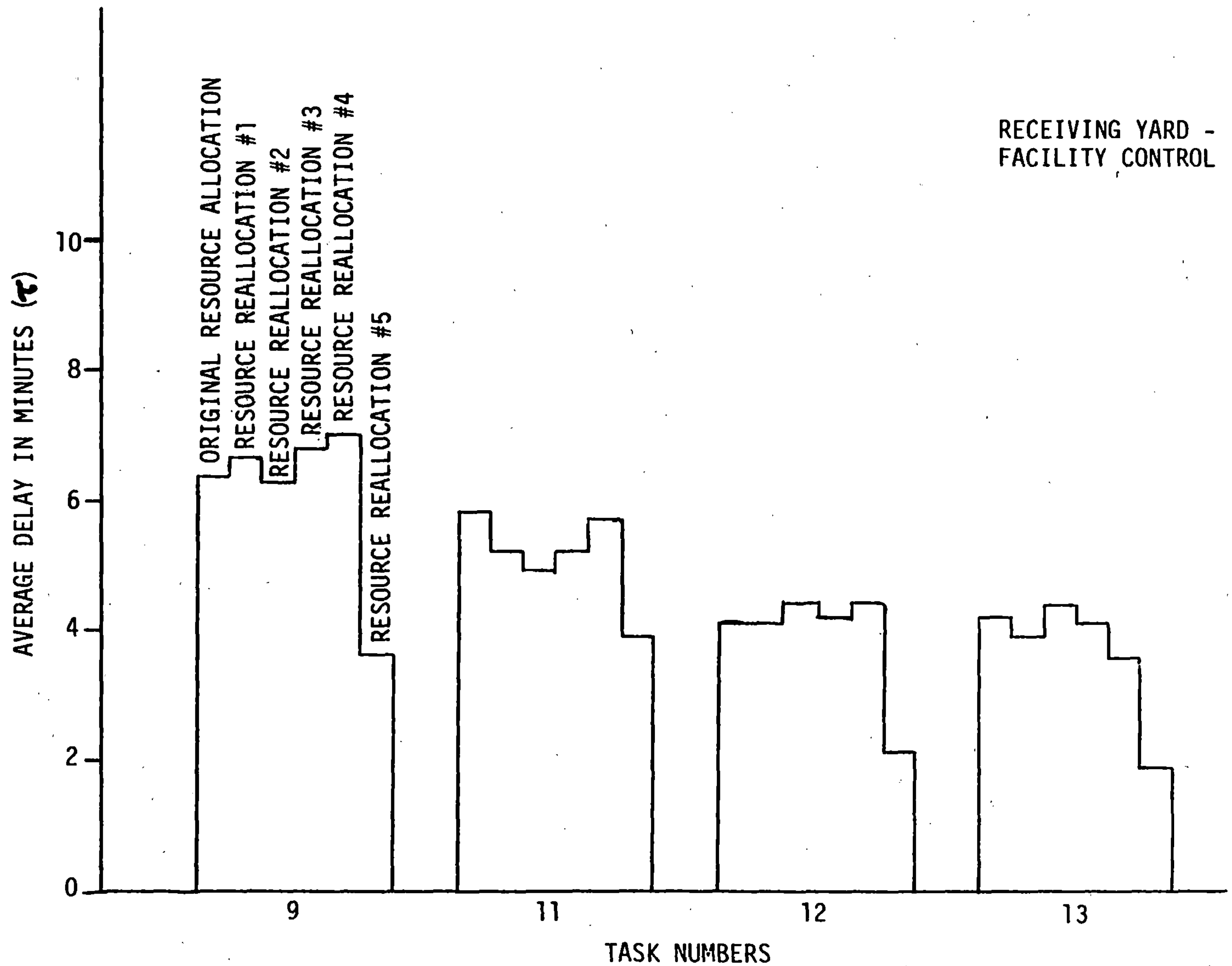


Figure 3.34. Model results - delay in receiving yard (facility control).

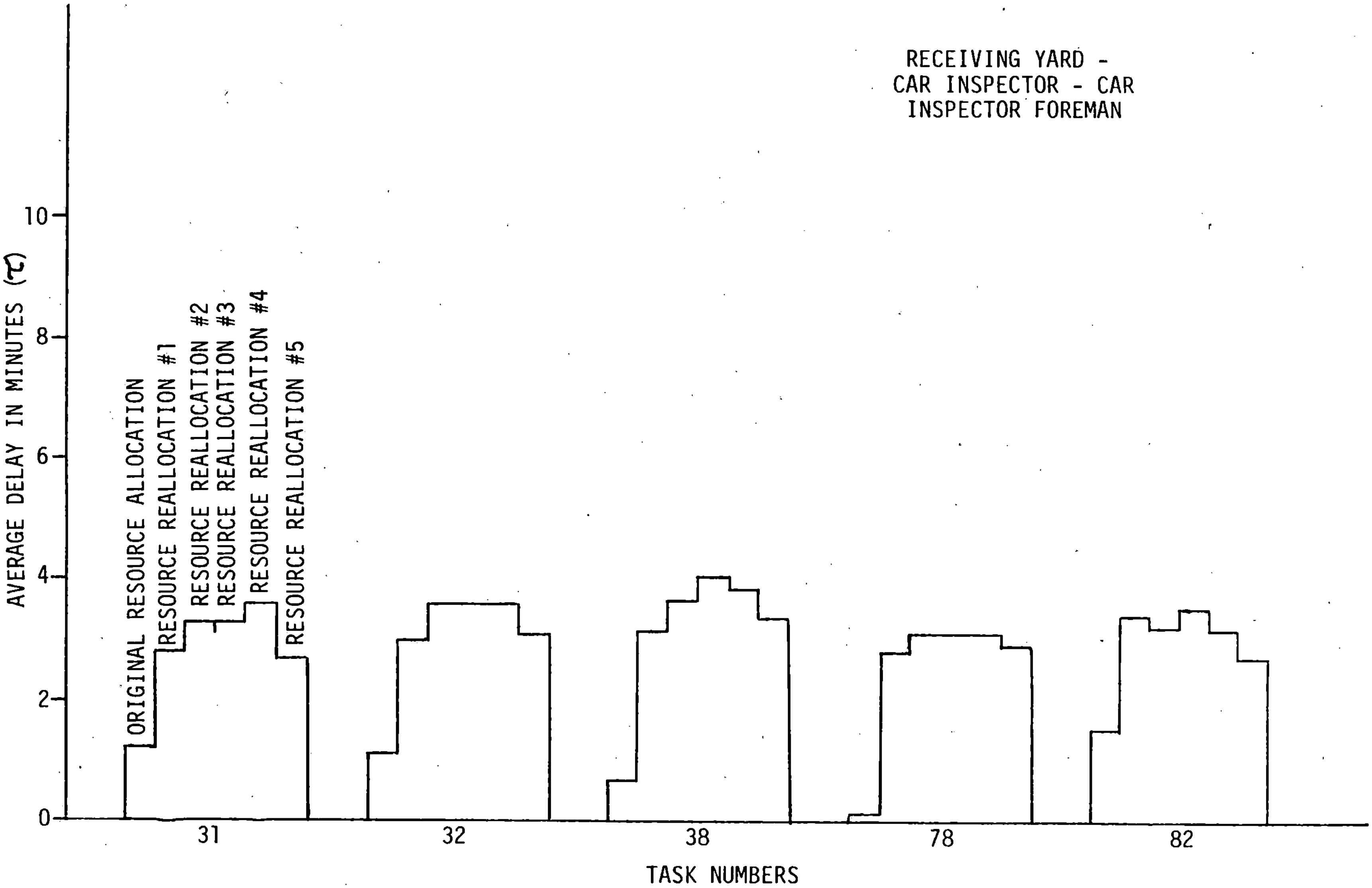


Figure 3.35. Model results - delay in receiving yard (car inspector-car inspector foreman).

Figure 3.36 shows most dramatically how those functions in the receiving yard are affected by reduced allocation for tasks which involve switch engine assignment and movement coordination. The waiting time for resource availability is almost negligible for the original resource allocation. It was felt that the average delay "τ" should increase exponentially as these tasks were required to share fewer and fewer channels. As can be seen in the bar graphs, the increase in "τ" does indeed follow what appears to be an exponential function. The greatest "τ" occurs in task 28, which is assignment of a switch engine to pull the rear section of a train being doubled into the receiving yard. This varies from an average waiting time at 3 minutes for the original allocation to 63 minutes waiting time for resource reallocation #5.

Humpyard activities are shown in Figure 3.37. It shows the activities that are tied to those communications functions supporting hump engine and switch engine movement coordination in the humping process. Again, the shape is that of a somewhat modified exponential curve. Tasks 45, 48, and 50 have to do with those communication activities that support the actual humping of trains, such as communications between the humpmaster, hump engine, hump conductor, pinpuller, etc. Tasks 47 and 49 are the communication support activities involving switch engine "pull moves" in the hump and mini-hump, and are not as busy for the equivalent times as the actual hump activity. It can be seen that the real significant delays come with those channel allocation reductions that support switch engine movement as would be expected.

Figure 3.38 shows tasks that support facility control and car inspector functions in the departure yard. Tasks 63, 64, and 80 are car inspector support communications and show significant increase in waiting time as they share the Diesel Shop channel. An additional delay in ability to access the shared channel is noticed with the addition of maintenance support sharing. Again, as in the receiving yard, a reduced delay for reallocations 4 and 5 is seen, caused by reduced ability of trains to move freely through the yard as command and control functions become paralyzed by lack of communication capability. There are simply fewer trains entering the departure yard for car inspection.

Tasks 57, 60, and 69 in Figure 3.39 are those tasks which represent communication support to switch engine movement in the departure yard. Here, again the basic shape of the average delay, as the frequency channels are removed, is

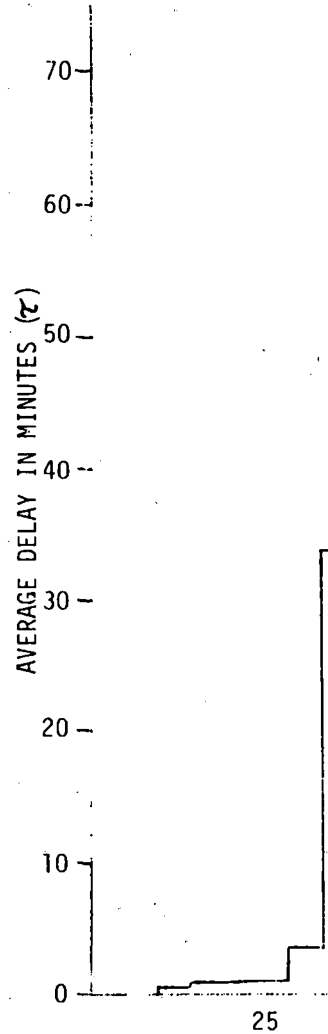
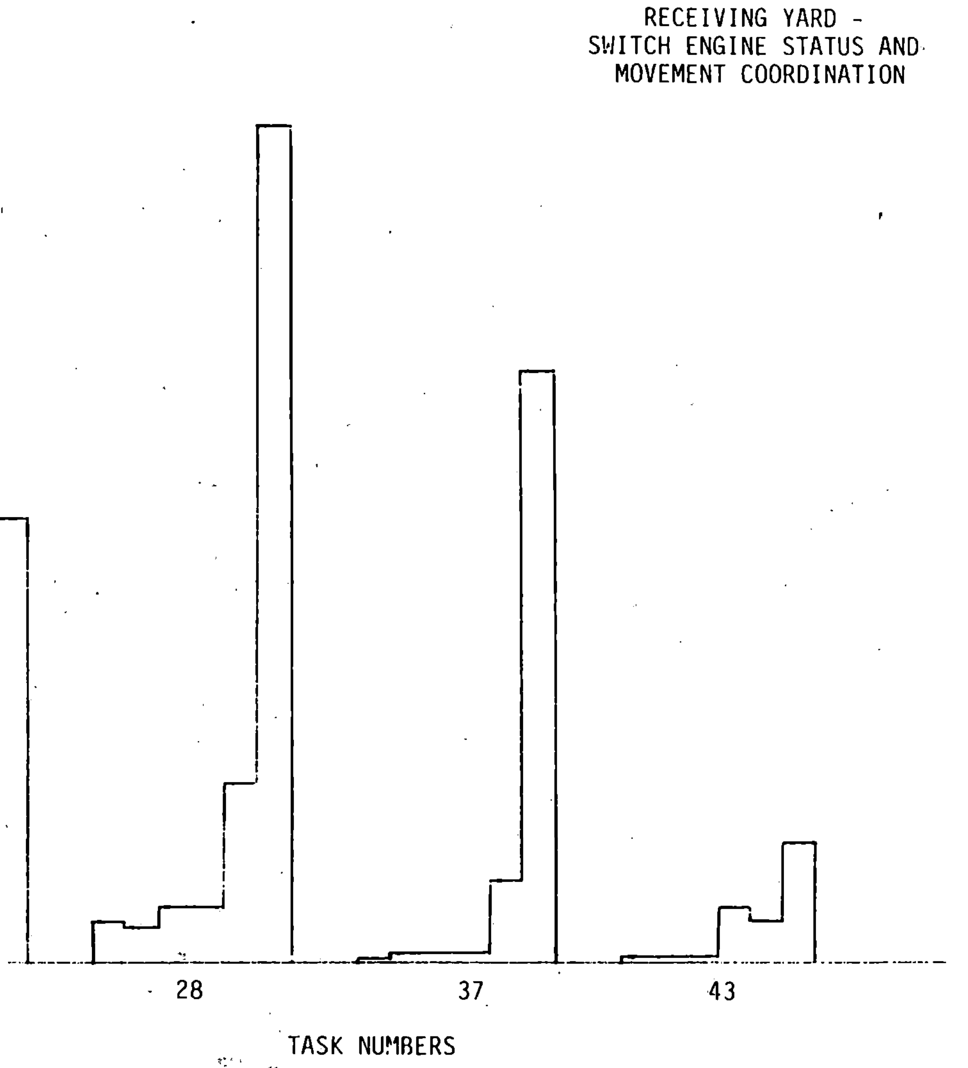


Figure 3.36.



Model results - delay in receiving yard (switch engine status and movement coordination).

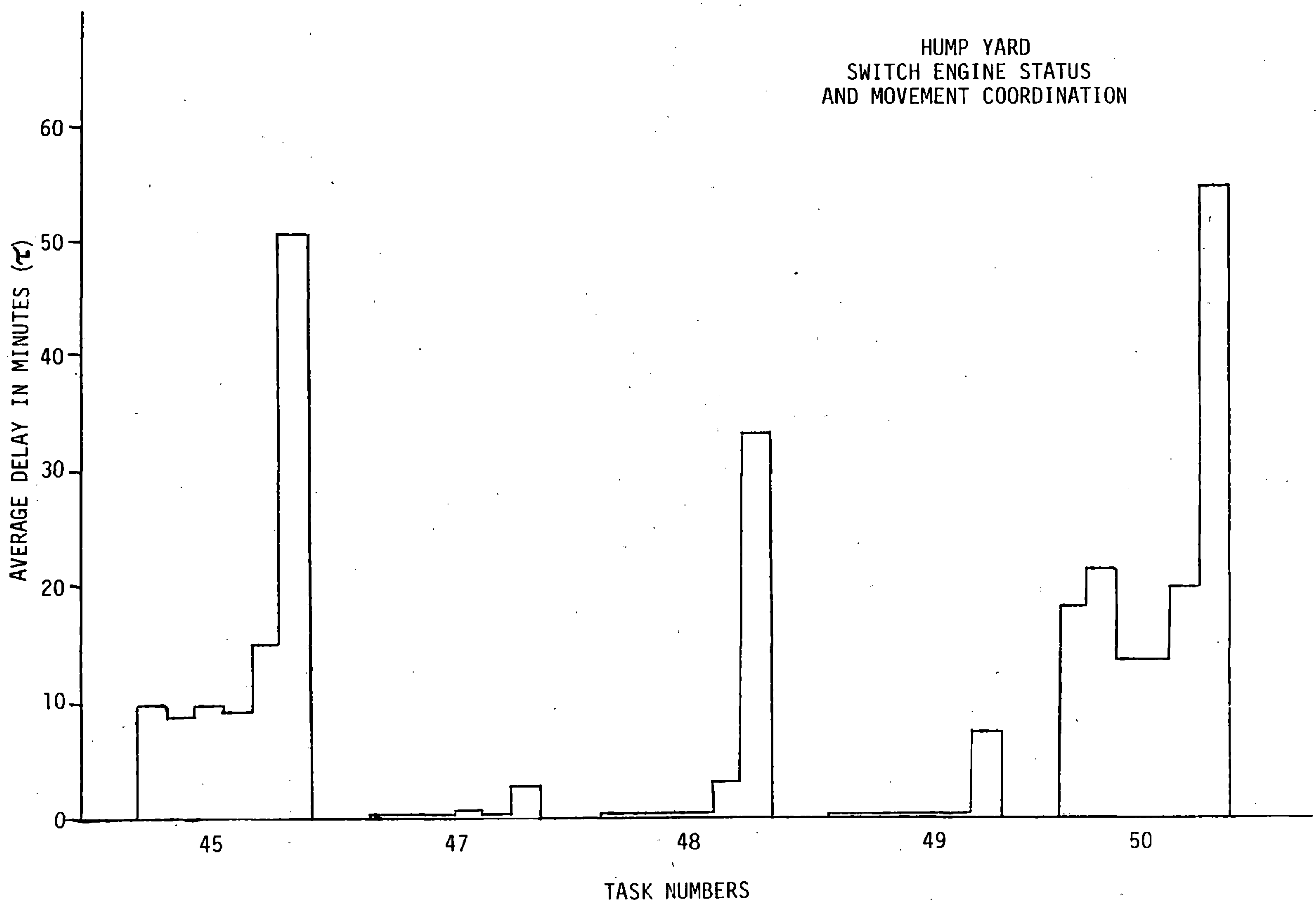


Figure 3.37. Model results - delay in hump yard (switch engine status and movement coordination).

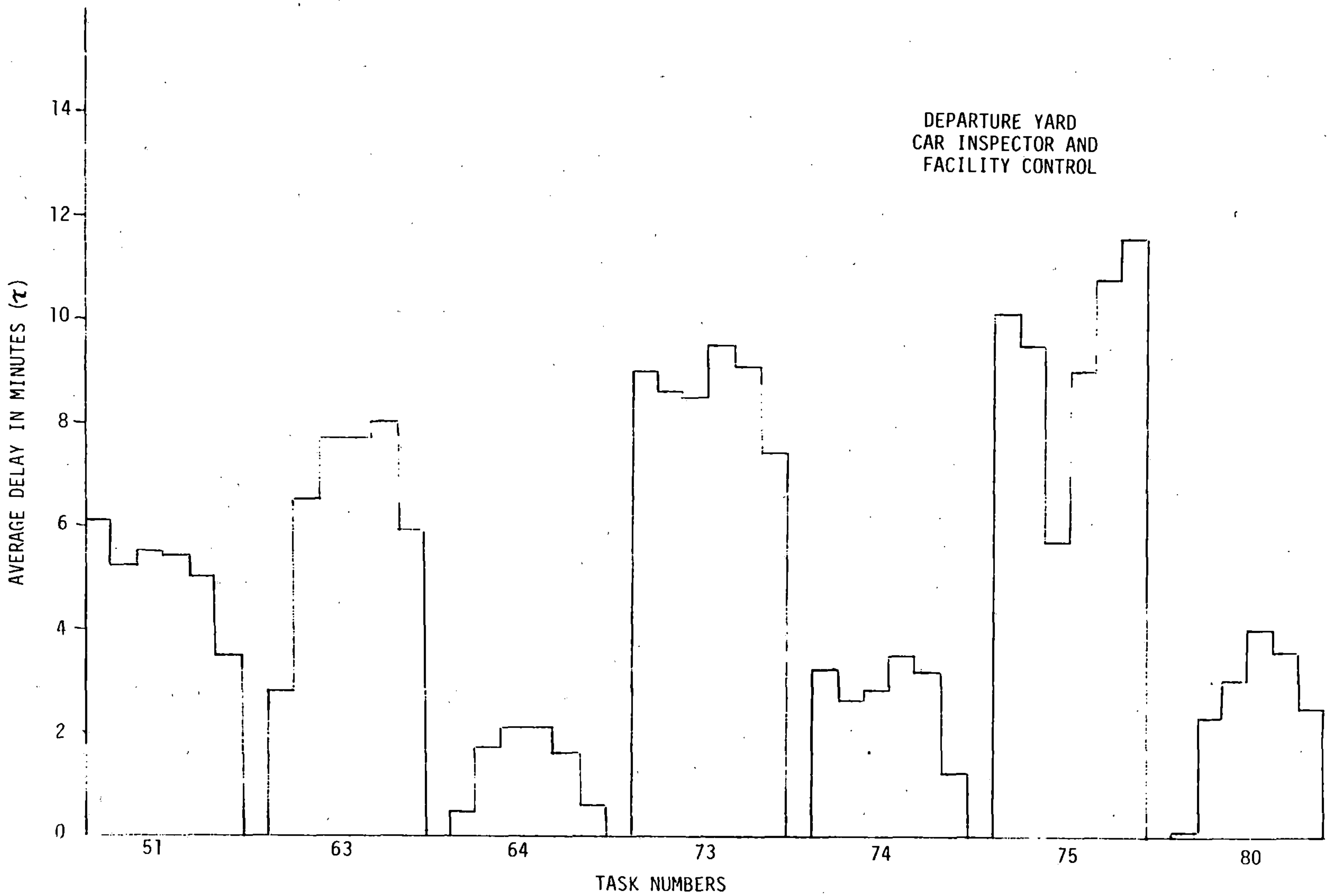


Figure 3.38. Model results - delay in departure yard (car inspector and facility control).

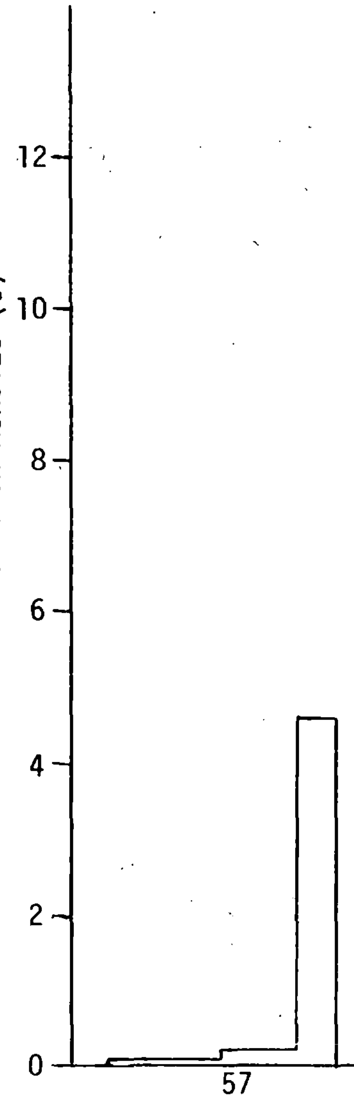
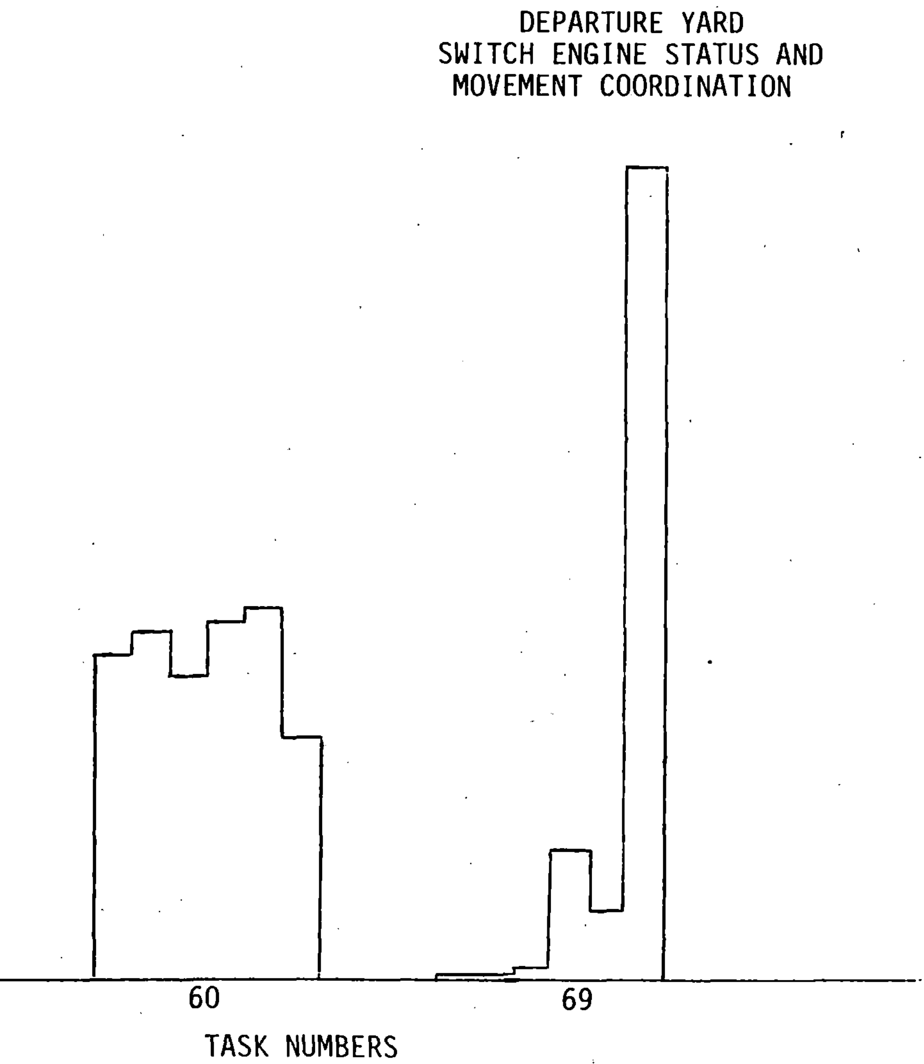


Figure 3.39.



Model results - delay in departure yard (switch engine status and movement coordination.

that of an exponential. Task 60 is only used 10% of the time so does not have the statistical base that tasks 57 and 69 have where each train entering the departure yard gets communication support.

As will be explained later, under Section 3.3.3, the model, as dimensioned here, will not show every use of communications in the yard. There are some 140 network nodes in the existing model. This constitutes a very complex network and will adequately show the trends which the average delay time will take as communication resources are removed. It has been shown that modern railroad yards use and need communications for efficient operations. For those tasks involved with communications support to switch engine movement, full channel availability is critical. Again, one must keep in mind that this model is patterned after what could soon be the most modern and efficient yard in the country. If a comparison were made to a yard where there is no hump and all car movement must be powered by switch engines, it is not hard to imagine delays building up to intolerable levels much sooner than at Barstow.

The network tasks giving the communication function they perform are listed in Figures 3.41 through 3.54. These tasks, when compared to the event flow diagrams of Section 3.1.2, will show almost parallel actions. There are some events that are unique to Barstow, but this model could easily be modified to match almost any modern classification yard. Other statistics or variations of resources could be used to give further detail as to the operation of the yard. The results given here are those that give information on the effects of frequency channel impact on yard operations. A copy of a portion of computer output from SAINT is presented in Figure 3.40, which shows the type of data (average value) used to produce the bar graphs given in this section.

3.3.2 Shared service evaluation

An alternate to channel reassignment of railroad license subgroups, as discussed in a previous section, might be a sharing of frequency channels between members of the railroad industry and the maritime industry. This could be a utilization of railroad channels by the maritime users, or utilization of maritime channels by railroad users, or a combination of both on an assignment schedule that precluded interference.

The techniques for determining the feasibility of frequency sharing between these two industries can be the same as described and used in the previous sections. The procedure would be to create a working file of maritime frequen-

TASK NUMBER	TASK LABEL
[illegible]	ENTY [illegible]
11	A [illegible] TRK
13	UNCP [illegible]
15	[illegible]
17	ASN MOVE
22	CALL GRW
23	ASN MOVE
2[illegible]	ASN MOVE
31	ALRT [illegible]
32	COORD
3[illegible]	CALL MSL
35	RPP COMP
36	ALRT [illegible]
37	ASN MOVT
38	REPORT
[illegible]	CALL MSL
41	RPP COMP
42	ALRT [illegible]
43	ASN MOV
44	[illegible]
4[illegible]	CAPT [illegible]
4[illegible]	CAPT [illegible]
47	CAPT [illegible]
[illegible]	CAPT [illegible]
[illegible]	CAPT [illegible]
5[illegible]	CAPT [illegible]
51	[illegible]
[illegible]	CALL [illegible]
57	ASN MOVE
5[illegible]	ASN MOV
6[illegible]	ALRT [illegible]
[illegible]	COORD
6[illegible]	CALL MSL
67	RPP COMP
[illegible]	ALRT [illegible]
[illegible]	ASN MOV
[illegible]	[illegible]
71	[illegible]
73	GOUP [illegible]
74	ASGN [illegible]
75	RDY [illegible]
7[illegible]	REPORT
8[illegible]	REPORT
82	ALRT [illegible]
1[illegible]	CAPT [illegible]
10[illegible]	CAPT MAP
10[illegible]	CAPT [illegible]
113	CALL [illegible]
114	ISOLATE
115	ISOLATE
117	TRAK [illegible]
11[illegible]	TRAK [illegible]
11[illegible]	COORD
12[illegible]	ASN MOVE
121	ASN MOVE
122	POS UNCP
12[illegible]	ADJ [illegible]

Figure 3.40.

STATISTICS TASK SUMMARY FOR ITERATION 1

ITERATION LENGTH = .6640E+05 TIME UNITS

STAT TYPE	COLCT POINT	AVERAGE VALUE	STANDARD DEVIATION	NUMBER OF OBSERVATIONS	MINIMUM VALUE	MAXIMUM VALUE
INT	STA	[illegible]	.1936E+01	600	0.	.9034E+01
INT	STA	.1923E+00	.1013E+01	478	0.	.9506E+01
INT	STA	.2782E+00	.1315E+01	475	0.	.9120E+01
INT	STA	.1433E+00	.8200E+00	476	0.	.1447E+02
INT	STA	.1325E+01	.4314E+01	35	0.	.2575E+02
INT	STA	.1037E-01	.2267E+00	478	0.	.4356E+01
INT	STA	.6733E-01	.1136E+01	475	0.	.2508E+02
INT	STA	.1177E+01	.4626E+01	338	0.	.3953E+02
INT	STA	.1081E+00	.7369E+00	476	0.	.1102E+02
INT	STA	.2672E+00	.1125E+01	478	0.	.1340E+02
INT	STA	.2381E+00	.8238E+00	189	0.	.5913E+01
INT	STA	.2012E+00	.9177E+00	188	0.	.9922E+01
INT	STA	.2621E+00	.7725E+00	94	0.	.3531E+01
INT	STA	.2405E+00	.1643E+01	94	0.	.1511E+02
INT	STA	.1572E+00	.9911E+00	122	0.	.9366E+01
INT	STA	.2263E+00	.7270E+00	55	0.	.2967E+01
INT	STA	.4243E-01	.2754E+00	55	0.	.2342E+01
INT	STA	.2149E+00	.6172E+00	25	0.	.3935E+01
INT	STA	0.	0.	25	0.	0.
INT	STA	.2141E+00	.1113E+01	122	0.	.8750E+01
INT	STA	.3277E+01	.8730E+01	477	0.	.5252E+02
INT	STA	0.	0.	477	0.	0.
INT	STA	.3153E+00	.2162E+01	477	0.	.2239E+02
INT	STA	.2149E+00	.1900E+01	477	0.	.2481E+02
INT	STA	.6509E-01	.1121E+01	477	0.	[illegible]
INT	STA	.4593E+00	.2634E+01	477	0.	.2465E+02
INT	STA	.4193E-01	.7672E+00	477	0.	.1670E+02
INT	STA	.7339E-02	.6169E-01	477	0.	.1000E+01
INT	STA	.3092E-01	.6754E+00	477	0.	.1475E+02
INT	STA	.9597E+00	.4556E+01	307	0.	.3099E+02
INT	STA	.1134E+00	.7959E+00	477	0.	.1514E+02
INT	STA	.1059E+00	.8200E+00	477	0.	.1577E+02
INT	STA	.2025E+00	.6956E+00	233	0.	.5000E+01
INT	STA	.2093E+00	.7759E+00	233	0.	.4696E+01
INT	STA	.9403E-01	.4529E+00	65	0.	.3493E+01
INT	STA	0.	0.	65	0.	0.
INT	STA	.5426E-01	.6270E+00	477	0.	.1000E+02
INT	STA	.2411E-01	.4596E+00	477	0.	.1300E+02
INT	STA	.1533E-01	.1692E+00	477	0.	.2676E+01
INT	STA	.5167E+00	.2955E+01	477	0.	.2524E+02
INT	STA	.6413E-01	.3440E+00	477	0.	.5000E+01
INT	STA	.2169E+00	.1349E+01	478	0.	.2644E+02
INT	STA	.1147E+00	.6261E+00	477	0.	.1374E+02
INT	STA	.1944E+00	.5031E+00	122	0.	.2998E+01
INT	STA	.2237E+01	.4321E+01	478	0.	.2376E+02
INT	STA	.3266E+02	.4573E+02	477	0.	.1990E+03
INT	STA	.3624E+00	.2174E+01	477	0.	.1750E+02
INT	STA	.2414E+00	.9435E+00	23	0.	.4214E+01
INT	STA	0.	0.	9	0.	0.
INT	STA	.5609E+00	.6766E+00	11	0.	.2635E+01
INT	STA	0.	0.	9	0.	0.
INT	STA	0.	0.	11	0.	0.
INT	STA	.7010E+00	.1402E+01	4	0.	.2804E+01
INT	STA	0.	0.	1	0.	0.
INT	STA	0.	0.	3	0.	0.
INT	STA	0.	0.	4	0.	0.
INT	STA	.3774E+00	.7547E+00	4	0.	.1509E+01

A portion of the computer output from the SAINT model.

TASK DESCRIPTIONS

SIMULATION CONTROL

Task No.	Description
1	Begin simulation. Started automatically by SAINT.
2	When completed, simulation will end and final statistics reports will be printed.
3	When completed, arrival of trains to Barstow will be changed to the low rate (DS,8). Started automatically by SAINT.
4	When completed, arrival of trains to Barstow will be changed to the high rate (DS,7).
5	When completed, arrival of trains to Barstow will be changed to the low rate (DS,1).
6	When completed, arrival of trains to Barstow will be changed to the high rate (DS,7).

Figure 3.41. Task descriptions of simulation control.

ARRIVALS AT BARSTOW

Task No.	Description
7	Begins the arrival process of trains to Barstow.
8	Generates all arrivals of trains at Barstow based on the current arrival rate (DS,7; DS,8; or DS,1) as determined by tasks 3, 4, 5, and 6.
9	Train arrives at entry block. Receiving yard track is assigned.
10	Train moves to receiving yard.
11	Train arrives at receiving yard. Engine service track is assigned.
12	Road power is uncoupled.
13	Road power has been uncoupled. Uncoupling is reported.
31	Car inspector foreman is alerted to incoming train. He alerts CI and security crew.
101	Train is being taken into receiving yard. No other trains may enter until train is in position.
102	Receiving yard is kept busy until train is in position.

Figure 3.42. Task descriptions of arrivals at Barstow.

THROUGH TRAIN INSPECTION YARD

Task No.	Description
38	CI and security crew make inspection report.
39	Mobile repair crew is called for minor repairs.
40	Mobile repair crew moves to train and affects repairs.
41	Mobile repair crew reports that repairs are complete.
42	Repair crew is alerted to major repair requirements.
43	Switch engine is assigned, moves to train, and sets cars requiring major repairs aside.
44	Through train is ready for departure.
76	Through train moves to through train inspection yard.
82	Car inspector foreman is alerted to incoming train. He coordinates inspection by CI and security crew.
83	CI and security crew inspect train.

Figure 3.43. Task descriptions of through train inspection yard.

DIESEL SERVICING

Task No.	Description
14	Road power is moved to diesel service area, checked, and serviced.
15	Road power service report is made.
16	Road power is moved to ready yard.
17	Switch engine is assigned and moves to ready yard. Engine requiring major repairs is removed and taken to diesel shop by switch engine.
18	Road power is moved to ready yard.
19	Road power is moved to ready yard. Minor repairs are made.
144	Call repaired unit from diesel repair yard.
145	Road power unit is moved to ready yard after major repair.

Figure 3.44. Task descriptions of diesel servicing.

RECEIVING YARD

Task No.	Description
20	Determines if train requires doubling.
21	Doubling is not required.
22	Crew pickup is called for.
23	Crew is picked up and taken to receiving yard.
24	Doubling is required.
25	Switch engine is assigned and moves to receiving yard for bringing train into receiving yard. If doubling is required, this switch engine will bring only first half of train into receiving yard.
26	Switch engine is coupled to train and brings it into the receiving yard, clearing the switch.
27	Switch engine is uncoupled from train and moves to standby area to await reassignment.
28	Switch engine is assigned and moves to receiving yard if doubling is required. This switch engine will bring second half of train into receiving yard.
29	Switch engine is coupled to second half of train and brings it into the receiving yard, clearing the switch, after first half of train has cleared the switch.
30	Switch engine is uncoupled from second half of train and moves to standby area to await reassignment.

Figure 3.45. Task descriptions of receiving yard.

RECEIVING YARD

Task No.	Description
84	Switch engine frequency 5 is kept busy until it is no longer needed.
85	Switch engine frequency 6 is kept busy until it is no longer needed.
86	Switch engine frequency 7 is kept busy until it is no longer needed.
87	Switch engine is no longer needed and may be reassigned.
88	Switch engine is no longer needed and may be reassigned.
103	Train is in position in the receiving yard. Another train may now enter receiving yard.

Figure 3.45.(cont.) Task descriptions of receiving yard.

CAR REPAIR

Task No.	Description
32	Car inspector foreman coordinates inspection by CI and security crew.
33	Mobile repair crew is called for minor repairs.
34	Mobile repair crew moves to train and affects repairs.
35	Mobile repair crew reports that repairs are complete.
36	Repair crew is alerted to major repair requirements.
37	Switch engine is assigned, mvoes to train, and sets cars requiring major repairs aside.
77	CI and security crew inspect train.
78	CI and security crew make inspection report.

Figure 3.46. Task descriptions of car repair.

CLASSIFICATION YARD

Task No.	Description
45	Train is ready to be humped. No other train may be humped until this train has been humped.
46	Hump master is assigned to hump this train.
47	Switch engine is assigned to hump.
48	Switch engine is assigned to hump.
49	Switch engine is assigned to mini-hump.
50	Switch engine is assigned to mini-hump.
84	See receiving yard task descriptions.
85	See receiving yard task descriptions.
86	See receiving yard task descriptions.
89	Hump master frequency is kept busy until humping operation has been completed.
90	Train is humped.
91	Switch engines and hump master are no longer needed and may be reassigned. Another train may now be humped.

Figure 3.47. Task descriptions of classification yard.

CLASSIFICATION YARD

Task No.	Description
92	Train is mini-humped.
93	Switch engines and mini-hump are no longer needed and may be reassigned. Another train may now be mini-humped.
94	Humping operation has been completed. Prepare to free resources.
95	Mini-hump operation has been completed. Prepare to free resources.
96	See classification yard to departure yard descriptions.
97	See classification yard to departure yard descriptions.
98	See classification yard to departure yard descriptions.
99	See classification yard to departure yard descriptions.
104	Hump is kept busy until humping operation is completed.
105	Train is ready to be mini-humped. No other train may be mini-humped until this train has been mini-humped.
106	Mini-hump is kept busy until train is in position in departure yard.

Figure 3.48. Task descriptions of classification yard.

CLASSIFICATION YARD TO DEPARTURE YARD

Task No.	Description
51	Classification has been completed. Departure track is assigned.
52	Determines if train requires doubling.
53	Doubling is not required.
54	Crew pickup is called for.
55	Crew is picked up and taken to classification yard.
56	Doubling is required.
57	Switch engine is assigned and moves to classification yard for taking train to departure yard.
58	Switch engine is coupled to train and takes it to the departure yard.
59	Switch engine is uncoupled from train and moves to standby area to await reassignment.
60	Switch engine is assigned and moves to classification yard if doubling is required. This switch engine will take second half of train to departure yard.

Figure 3.49. Task description of classification yard to departure yard.

CLASSIFICATION YARD TO DEPARTURE YARD

Task No.	Description
61	Switch engine is coupled to second half of train and takes it to the departure yard after first half of train has been moved.
62	Switch engine is uncoupled from second half of train and moves to standby area to await reassignment.
63	Car inspector foreman is alerted to outbound train. He alerts CI.
81	Switch engine is no longer needed and may be reassigned.
96	Switch engine frequency 8 is kept busy until it is no longer needed.
97	Switch engine frequency 9 is kept busy until it is no longer needed.
98	Switch engine freuqency 10 is kept busy until it is no longer needed.
99	Switch engine frequency 18 is kept busy until it is no longer needed.
100	Switch engine is no longer needed and may be reassigned.

Figure 3.50. Task description of classification yard to departure yard.

DEPARTURE YARD

Task No.	Description
64	Car inspector foreman coordinates inspection by CI.
65	Mobile repair crew is called for minor repairs.
66	Mobile repair crew moves to train and affects repairs.
67	Mobile repair crew reports that repairs are complete.
68	Repair crew is alerted to major repair requirements.
69	Switch engine is assigned, moves to train, and sets cars requiring major repairs aside.
70	Cars are ready for departure.
71	Crew pickup is called for. Road power is assigned.
72	Crew is picked up and taken to road power.
73	Road power moves to train and couples.
74	Switch engine is assigned and moves caboose from waycar service area to train.
75	Train is ready for departure.
79	CI inspects train.
80	CI makes inspection report.
108	Train is ready to enter departure yard. No other train may enter until this train has left.
109	Departure yard is kept busy until train has left.
110	Train is in position in departure yard. Another train may now enter.

Figure 3.51. Task descriptions of departure yard.

YARD MAINTENANCE: MINOR PROBLEMS

Task No.	Description
112	Generates occurrences of minor problems.
113	Mobile repair crew is called.
114	Problem is in west yard. Mobile repair crew moves to area. Track section is isolated.
115	Problem is in east yard. Mobile repair crew moves to area. Track section is isolated.
116	Mobile repair crew affects repairs.
117	Problem was in west yard. Track is reported as ready.
118	Problem was in east yard. Track is reported as ready.

Figure 3.52. Task descriptions of yard maintenance: minor problems.

YARD MAINTENANCE: MAJOR PROBLEMS

Task No.	Description
84	See receiving yard task descriptions.
85	See receiving yard task descriptions.
86	See receiving yard task descriptions.
96	See classification yard to departure yard task descriptions.
97	See classification yard to departure yard task descriptions.
98	See classification yard to departure yard task descriptions.
99	See classification yard to departure yard task descriptions.
111	Generates occurrences of major problems.
119	Major problem is reported to supervisor. Engineering department is notified. Track section is isolated. Need for heavy equipment is reported.

Figure 3.53. Task descriptions of yard maintenance: major problems.

YARD MAINTENANCE: MAJOR PROBLEMS

Task No.	Description
120	Problem is in west yard. Switch engine is assigned and moves to equipment storage area.
121	Problem is in east yard. Switch engine is assigned and moves to equipment storage area.
122	Switch engine moves equipment to problem area. Equipment is put in position. Switch engine is uncoupled.
123	Equipment is reported as in position.
124	Switch engine is no longer needed and may be reassigned.
125	Crew effects repairs.
126	Train is moving on adjacent track. Crew leaves area. Train on adjacent track is now in position. Crew returns to work.
127	Switch engine is requested to bring additional materials.

Figure 3.53.(cont.) Task descriptions of yard maintenance: major problems.

YARD MAINTENANCE: MAJOR PROBLEMS

Task No.	Description
128	Problem is in west yard. Switch engine is assigned.
129	Problem is in east yard. Switch engine is assigned.
130	Switch engine moves to material storage area, obtains required materials, and takes them to problem area.
131	Switch engine positions materials and uncouples.
132	Switch engine is no longer needed and may be reassigned.
133	Crew completes repairs.
134	Repairs are reported as complete. Switch engine is requested to remove heavy equipment.
135	Problem was in west yard. Switch engine is assigned and moves to area.
136	Problem was in east yard. Switch engine is assigned and moves to area.
137	Switch engine moves heavy equipment to equipment storage area.
138	Track is reported as clear.
139	Problem was in west yard. Crew pickup is called for.
140	Problem was in east yard. Crew pickup is called for.
141	Switch engine is no longer needed and may be reassigned.
142	Track is reported as reopened.
143	Need for additional materials is reported to superintendent of shops.

Figure 3.54. Task descriptions of yard maintenance: major problems.

cies which is designated as a challenged frequency complete with subgroups. Then any or all of the current challenged railroad channels could become the unchallenged frequencies. Selected reassignment testing could be performed resulting in preliminary analysis tables (such as 3.2 and 3.3 above) that could be used for an initial evaluation and assessment of this plan.

Maritime mobile working files

The frequency band definitions of the maritime mobile service and the contents of the FCC tape are discussed in Section 3.2.2.1. This tape is a record of the non-government licenses containing fixed-base and mobile authorizations for operations in specific states or the entire United States. This does not include approximately 274,000 ship radio station licenses in this band. These additional ship radio station licenses are contained in the Marine Master File, including both required and voluntary licenses.* The initial search of the tape produced 19280 licenses issued to maritime service. When the Alaska group had been removed, 16550 licenses remained in the file. Further listings of these data show that licenses have been issued at 1200 different frequencies to maritime users in the range from 1 MHz to 997.6 MHz. In the maritime mobile service bands (see Section 3.2.2.1) between 156.250 and 162.0125 MHz, 60 channels are indicated for a total of 8211 licenses issued. A listing of the number of licenses in each of the 60 channels is given in Table 3.4. The frequencies are listed by file number because the formal channel designations, if they exist, are not known. The number of licenses per channel range from one to 3274. The channel frequency at 156.800 MHz with the 3274 licenses is designated for distress, safety and calling, indicating a utility frequency for emergency use. As explained above, this file does not contain approximately 274,000 licenses to ocean-going vessels in this frequency band. Even with this omission, the file is adequate to demonstrate techniques of testing and the application of the cross-services sharing.

These 8211 licenses were converted to a working file similar in form to the train service and general service files of the railroad. These files contain frequency, state, user abbreviation, latitude and longitude, call sign,

*This information was obtained from Mr. R. E. Miehley of the FCC Aviation and Marine Division, Safety and Special Radio Service Bureau.

Table 3.4. Maritime Mobile Service

File	Frequency (MHz)	Number	File	Frequency (MHz)	Number
1	156.275	21	31	157.050	3
2	156.300	102	32	157.100	10
3	156.325	6	33	157.150	3
4	156.340	1	34	157.200	7
5	156.350	399	35	157.225	5
6	156.375	1	36	157.250	9
7	156.400	3	37	157.275	2
8	156.425	344	38	157.300	22
9	156.450	772	39	157.325	3
10	156.475	38	40	157.350	8
11	156.500	627	41	157.375	2
12	156.525	1	42	157.400	17
13	156.550	247	43	157.425	1
14	156.575	31	44	158.000	4
15	156.600	368	45	158.800	1
16	156.625	1	46	159.400	1
17	156.650	166	47	159.900	1
18	156.675	30	48	160.800	1
19	156.700	190	49	161.500	1
20	156.725	50	50	161.600	7
21	156.750	2	51	161.800	20
22	156.800	3274	52	161.825	6
23	156.850	13	53	161.850	18
24	156.875	2	54	161.875	10
25	156.900	533	55	161.900	97
26	156.925	27	56	161.925	6
27	156.950	240	57	161.950	30
28	156.975	177	58	161.975	2
29	157.000	2	59	162.-00	2
30	157.025	171	60	162.000	3
				TOTAL	8211

class, expiration date, and subgroup information. A listing of file 26 is shown in Figure 3.55. The user abbreviation is a letter-number combination. The letter is the first letter in the user name and the three-digit number distinguishes that user from others with the same first letter. This procedure was used to properly identify a user with different names on more than one license.

The approximate locations of the licensees in this file are indicated on the map in Figure 3.56. This appears to be a typical distribution of licensees. The number of licensees in a subgroup in the maritime files is generally much smaller than for the railroad users. The subgroup size seldom exceeds 20 in number and is,most often 1, 2, or 3 licenses in a group. The small subgroup numbers are not unexpected, realizing that there are approximately 3200 licensees using the maritime mobile service. Again, recall that this file is of fixed-base and U. S. or state designated mobile, only.

Data analysis

An analysis suggested in the introduction of this section was to determine the compatibility of licenses in a maritime mobile channel for reassignment and consequent sharing with one of the challenged railroad channels. Five channels from the 60 in the working file were tested in a manner similar to the railroad reassignment tests. These five were:

1. File 10 - 156.475 MHz - 38 licenses
2. File 14 - 156.575 MHz - 31 licenses
3. File 18 - 156.675 MHz - 30 licenses
4. File 23 - 156.850 MHz - 13 licenses
5. File 26 - 156.925 MHz - 27 licenses

These five were selected partly on the basis of size (number of licenses), being neither trivial nor enormous, and partly because they consist predominantly of fixed-base licenses. There is no information available at this time with which to generate area limits to evaluate mobile assignments. Also, this is only an exercise to demonstrate the feasibility of the sharing assignment process and to briefly assess the contents of these files and their distribution. It is highly unlikely that transfers of licenses as demonstrated here would take place. However, new licenses of distributions similar to those

Frequency (MHz)	State	Abbr	Latitude	Longitude
156.925	WA	A142	474834	1222323
156.925	CA	B023	333619	1175307
156.925	PR	C186	182742	0660508
156.925	FL	C223	280300	0824712
156.925	MA	C267	422159	0705859
156.925	MD	G055	390504	0762522
156.925	CT	G074	411319	0730249
156.925	ME	H074	435909	0690432
156.925	CA	H134	334259	1180259
156.925	LA	J003	302429	0903329
156.925	CA	J069	404413	1221331
156.925	LA	L002	295016	0900050
156.925	CT	L031	411429	0730353
156.925	MA	M025	423359	0704639
156.925	IN	M182	414326	0865425
156.925	PR	M197	182739	0660509
156.925	UP	P048	000000	0000000
156.925	NH	P180	430421	0704305
156.925	WI	P190	444434	0924739
156.925	FL	R027	294954	0851844
156.925	WI	R062	464559	0905359
156.925	ME	R092	000000	0000000
156.925	CA	S091	333714	1175519
156.925	MA	V051	422659	0705759
156.925	CT	W013	411054	0731234
156.925	CA	W126	335947	1182635
156.925	MA	W140	413235	0703617

Figure 3.55.

Call Sign	Class	Date	Sub-Group	Company Name
KQU487	FC	791107	1	Anchor Boat Charters Sales
KSK249	FC	760318	1	Bahia Corinthian Yacht Club
KXE246	FC	791030	1	Club Nautico De San Juan
KTR834	FCL	800708	1	Commodores Intl Yacht Club
KSK273	FC	760125	1	Cottage Park Yacht Club
KSK352	FC	760416	1	Gibson Island Yacht Squadron
KQU442	FC	791211	1	Godfrey, John F.
KXS249	FC	800509	1	Hewetts Island Corp.
KTA417	FC	760602	1	Huntington Harbour Yacht Club
KTD509	FC	771207	1	J.D. Hair, Inc.
KVF862	FC	780725	1	Jones Valley Resort
KUF814	FC	780302	1	L.L. Oil Co., Inc.
KUF603	FC	770803	1	Land Sea Enterprises
KVL931	FC	781003	1	Manchester Yacht Club
KTR977	FC	771107	1	Michigan, City of
KWS619	FC	790620	1	Mike Benitez Marina, Inc.
MSP551	TP		1	Part 83, Vol. IV, FCC RR
KQU637	FC	750527	1	Portsmouth Yacht Club, Inc.
KTA448	FC	760622	1	Prescott Marina, Inc.
KTR898	FC	770314	1	Raffield Fisheries, Inc.
KLG311	FC	760709	1	Reeds, Inc.
KQ9022	FC	790301	1	Rings Marine Service, Inc.
KUR855	FC	780523	1	Sea Air Systems Co., Inc.
KUF795	FC	770331	1	Volunteer Yacht Club
KUF598	FC	770803	1	Waldhaus Electronics
KUF742	FC	771106	1	Windjammers Yacht Club
KSK255	FC	800505	1	Woods Hole Boat Sales, Inc.

Maritime mobile licenses - file 26.

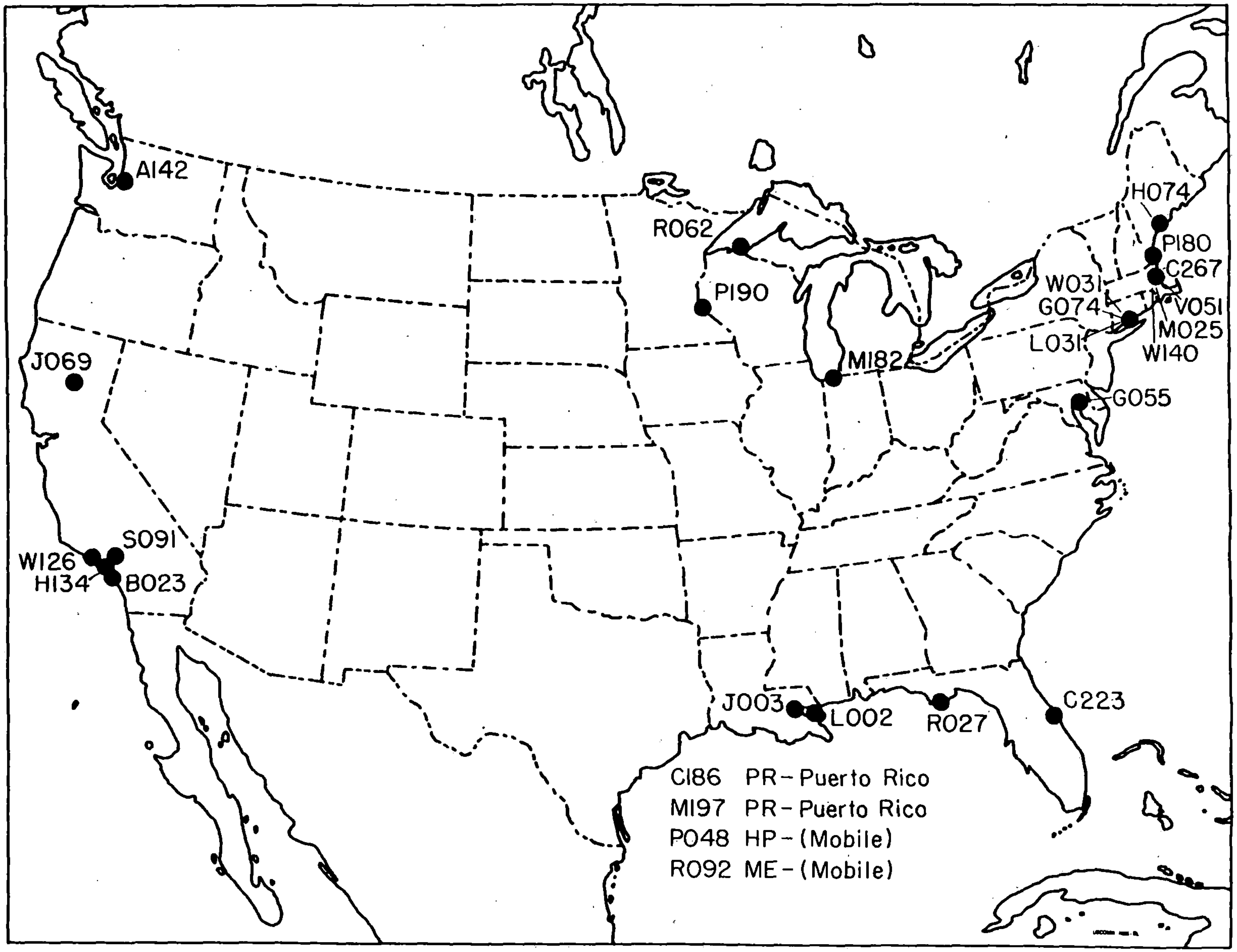


Figure 3.56. Maritime mobile file 26 (156.925 MHz) geographic distribution.

contained in these files could be placed among the railroad channels and operated without interference. This would put additional loading on the existing railroad channel capacity.

The results of the frequency sharing analysis for file 26-156.925 MHz are shown in Figure 3.57. This file contained 27 licenses, each as a single subgroup. All of the subgroups passed one or more of the frequency tests. The only subgroups to pass on all channels were the two mobile assignments (which were not properly tested) and the two Puerto Rico assignments (which understandably would pass).

The composite results of the five channels tested are:

1. A total of 139 licenses were tested against the 33 railroad channels.
2. All but <u>one</u> passed at one or more frequencies.
3. Nine of the 139 licenses are mobile and have no coordinates assigned.
4. Three of the 139 licenses are in Puerto Rico.
5. The largest subgroup contained 5 licenses.
6. A total of 124 subgroups were tested.

Any or all of the remaining channels could be tested and scored. Such an exercise is not planned at this time. The reason for not testing further is that, for the state and U. S. assigned maritime mobile licenses, no area use information is immediately available. This information would be in a form similar to the frequency assignment plan maintained by the railroads.

Conclusions to be drawn from this limited exercise are that the process developed for reassignment evaluation of railroad licenses would work very well for a shared service evaluation of railroad and maritime frequency channels. However, in order to make such an evaluation, considerable work would be required to properly define the use areas of the mobile licenses in the maritime mobile file and to properly define the use areas of any ship radio station licenses that could work in any given test area.

3.3.3 UHF reallocation analysis

The possibilities of relocating all current VHF functions into the 450 MHz or 900 MHz spectral regions are herein discussed relative to implications in communications support capabilities and the probable costs for transition. Conversion of train service and yard systems are considered.

							I		15		16		17		18		19		20		21		22		23		24		25		26			43		44		45		46
								14		15		16		17		18		19		20		21		22		23		24		25		26	42		43		44		45	
156.925	WA	A142	474834	1222323	KQU487	FC	791107																			1	1				1								
156.925	CA	B023	333619	1175307	KSK249	FC	760318											1								1				1		1	1	1	1	1	1			
156.925	PR	C186	182742	0660508	KXE246	FC	791030	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
156.925	FL	C223	280300	0824712	KTR834	FCL	800708	1	1	1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1
156.925	MA	C267	422159	0705859	KSK273	FC	760125	1				1	1	1	1	1	1	1				1	1	1				1	1	1			1	1	1				1	1
156.925	MD	G055	390504	0762522	KSK352	FC	760416	1																																
156.925	CT	G074	411319	0730249	KQU442	FC	791211	1	1	1	1	1	1				1	1								1	1	1	1	1				1	1	1	1	1	1	1
156.925	ME	H074	435909	0690432	KXS249	FC	800509			1	1	1				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
156.925	CA	H134	334259	1180259	KTA417	FC	760702											1								1				1			1	1	1	1	1			
156.925	LA	J003	302429	0903329	KTD509	FC	771207	1	1	1												1	1	1													1			
156.925	CA	J069	404413	1221331	KVF862	FC	780725	1	1	1	1				1	1	1	1	1	1	1	1	1	1				1				1	1	1	1	1	1			
156.925	LA	L002	295016	0900050	KUF814	FC	780302	1	1	1												1	1	1													1			
156.925	CT	L031	411429	0730353	KUF603	FC	770803	1	1	1	1	1	1				1	1								1	1	1	1	1				1	1	1	1	1	1	1
156.925	MA	M025	423359	0704639	KVL931	FC	781003	1	1	1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1	1	1	1	1	1				1	1
156.925	IN	M182	414326	0865425	KTR977	FC	771107								1	1	1					1					1													
156.925	PR	M197	182739	0660509	KWS619	FC	790620	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
156.925	UP	P048	000000	0000000	MSP551	TP		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
156.925	NH	P180	430421	0704305	KQU637	FC	750527			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1	1
156.925	WI	P190	444434	0924739	KTA448	FC	760622	1					1	1						1				1						1			1	1	1					
156.925	FL	R027	294954	0851844	KTR898	FC	770314	1	1	1	1	1	1	1	1	1	1	1				1	1	1				1	1	1	1	1	1	1	1	1	1	1	1	1
156.925	WI	R062	464559	0905359	KLG311	FC	760709	1	1	1	1	1	1	1	1	1	1	1				1	1	1				1	1	1	1	1	1	1	1	1	1	1	1	1
156.925	ME	R092	000000	0000000	KQ9022	FC	790301	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
156.925	CA	S091	333714	1175519	KUF855	FC	780523											1							1					1			1	1	1	1	1			
156.925	MA	V051	422659	0705759	KUF795	FC	770831	1				1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1			1	1	1				1	1
156.925	CT	W013	411054	0731234	KUF598	FC	770803	1	1	1	1	1	1													1				1				1	1					
156.925	CA	W126	335947	1182635	KUF742	FC	771106																										1	1	1	1	1			
156.925	MA	W140	413235	0703617	KSK255	FC	800505	1				1	1	1	1	1	1	1				1	1	1				1	1	1			1	1	1	1	1	1	1	1

Figure 3.57. Compatibility test results for maritime mobile file 26.

Relocation of services to the UHF region cannot be considered selectively within any railroad, since equipment must be usable over the geographic extent of the railroad lines. Transition of equipment between VHF and UHF channels, for example, as a train moves geographically, presents unacceptable safety and control problems.

3.3.3.1 Train service communications

This application involves the intra-train, inter-train, train-to-relay or way-station, and train-to-track facilities communications. Particular effects associated with any UHF transition include signal fading and attenuation caused by the various propagation modes and equipment characteristics required to maintain the existing capabilities.

Propagation considerations include the frequency dependent line-of-sight and reflection attenuation, and resultant mixed mode fading. The reflection geometry involves the tops of freight cars (primarily of concern for end-to-end communications) and terrain in the general vicinity of the track route. With a moving train, the comparison between VHF and UHF capabilities concerns the average attenuation and fading rates for the end-to-end and train-to-wayside station links. The extent of trackage in the Appalachian and Rocky Mountain regions indicates the importance of examining typical sets of mountain geography with regard to these propagation effects.

Difference in conductivity and the secondary factor of vegetation cover between the mountain and rolling hill areas of eastern and western U.S. must be considered in determining UHF utility. For a moving train in hilly or mountainous regions, these elements affect the magnitude of the reflected signal component and the fading rates. The latter will be particularly more serious at the UHF bands than encountered with present VHF operations.

These propagation effects are herein tabulated for the frequencies and geometries listed to demonstrate the range of variations:

- o frequency - 160 MHz, 450 MHz, 900 MHz,
- o train length - 1 mile with hardwood car tops,
- o track - curve with 1 mile radius,
- o terrain - open prairie, shallow canyon with smooth stone walls and a width of 1000 ft.
- o train antennas - 160 MHz - monopole mounted on top of locomotive and caboose,
  450 MHz and 900 MHz-topload monopole with center phasing element.

The propagation effects for these geometries and frequencies are summarized in Tables 3.5 and 3.6. These characteristics are usable for voice and FSK transmissions, but would require additional parameter definition if any future operation would involve signal tracking functions with frequency multiplexed formats.

Table 3.5 Propagation Effects (Terrain - Open Prairie)

	160 MHz	450 MHz	900 MHz
Mean Attenuation	81	92	98
Avg. Fluctuation Frequency	---	3 Hz	5 Hz
Fade Depth	2 dB	5-9 dB	12-16 dB
Fraction of Time Signal to Threshold	0.96	0.76	0.68

Table 3.6 Propagation Effects (Terrain - Shallow Canyon)

	160 MHz	450 MHz	900 MHz
Mean Attenuation	82	94	101
Avg. Fluctuation Frequency	6 Hz	11 Hz	13 Hz
Fade Depth	6-9 dB	11-13 dB	18-24 dB
Fraction of Time Signal to Threshold	0.87	0.65	0.53

These data demonstrate the range of differences in propagation effects for the three land mobile bands with the indicated terrain situations. The characteristics presented indicate the expected direct relationships of attenuation and fluctuation magnitudes and rates with frequency. The relation of these characteristics to communications availability (assuming a receiver minimum-usable-signal of -105 dBm) is indicated by the fraction of time the signal is above threshold for the three frequencies and two terrain situations. Mountainous or hilly terrain causes the larger reduction in signal availability for the end-to-end mode. The reductions in channel availability are generally unacceptable because of the access requirements dictated by safety and command/

control factors. Safety elements include end-to-end, train-to-relay or train-wayside station, and train-relay-track crew or train-track crew modes.

3.3.3.2 Yard service communications

Transition of yard communications to the UHF regions involves similar propagation and associated access or availability considerations. Efficiency and safety are potentially severely compromised.

The primary considerations for yard operations concern switch engine-brakeman-yard master, and car inspector-car inspector foreman communications. For these modes, the reflective multipath environment caused by cars in the receiving and departure yards, fixed structures in the yard, and buildings on the periphery of the yard causes very erratic spatial coverage. The shadowing problem primarily concerns communications "outages" for brakemen and car inspectors that do not have line-of-sight geometry to locomotives and tower areas. A significant safety and control problem is evident because of the sensitivities with channel availability (ref. Section 3.3.2). These problems can be resolved with additional repeaters in yards, with the cost penalties and the requirements for additional channels.

The geometry problems cited obviously predominate with urban yards. With increased repeater operations, the interference problems also escalate because of the close proximity of yards, and connecting tracks for different railroads converging into terminals and port areas.

To illustrate typical problems, the ATSF, EJE, and CNW Chicago yards were utilized to determine the probable propagation impact and the requirements for additional intra-yard repeaters to provide acceptable service levels. For these Chicago yards, the receiving and departure yard areas were assumed to have 50% of maximum car capacity, and the tower, shops, and nearby industrial buildings. The effects of these situations are summarized in Table 3.7.

For these data, a switch engine is assumed to be moving longitudinally on a central track in either receiving or departure yard areas, and car inspectors were moving the full length of the same receiving and departure yard tracks. Line-of-sight and reflective signal components were included, and shadow areas beyond any diffraction zones were used for drop-out tabulation. The channel availability data represents an unacceptable compromise with respect to car inspection and equipment control, and the safety aspects of movement coordination. With present yard operations, the accident potential for equipment and personnel is not acceptable.

Table 3.7 Propagation Impact (Chicago Yards)

	450 MHz	900 MHz
Attenuation Increase	12 dB	19 dB
Fraction of Time Switch Engine Channel Signal to Threshold	0.76	0.68
Fraction of Time Brakeman Receiver Signal to Threshold	0.64	0.52
Fraction of Time Car Inspector Foreman Receiver Signal to Threshold	0.55	0.46

The small number of yards in open areas such as the ATSF Barstow facility would have a reduced reflective problem, but similar shadowing and intra-yard multipath effects.

3.3.3.3 UHF capability extension

The previously indicated problems for UHF operations can be eliminated with the deployment of repeaters in yard areas, and additional repeaters along the right-of-way. This requires additional channels and a serious cost penalty. In urban areas where a number of railroads are in close proximity, a severe interference problem is also probable.

The additional relay complement required to achieve service comparable to the existing VHF systems are indicated in Table 3.8. The Chicago yards cited were also used for reference geometry and relative facility separations.

Table 3.8 Additional Relay Requirements

- o 3-5 additional yard relays - fixed and mobile operations.
- o 60% additional wayside relay complement.
- o Approximately 80% increase in total UHF channel requirements.

3.3.3.4 UHF conversion time and cost

For conversion of current yard, train, and wayside facilities to UHF operation, the times listed in Table 3.9 are necessary. These allow for engineering and development, installation, and test and evaluation phases.

Table 3.9 Facility Implementation and Conversion Times (VHF-to-UHF)

o	frequency assignment planning		
	urban areas	-	9 months
	enroute facilities	-	6 months
o	site and facility engineering	-	1 year
o	test and evaluation		
	urban yards	-	1 year
o	enroute facilities	-	18 months
o	phased transition period	-	5 years
o	total conversion time	-	8 years

These transition times assume a scheduling so as to minimize the degree of dual VHF and UHF services in enroute trains and yard locomotives. For the major railroads having more than one yard, operation in urban areas (New York and Northeast Corridor, Chicago, St. Louis, New Orleans, San Francisco, Los Angeles, Houston), restricted locomotive services between yards may extend to a 6-9 month period. This represents a significant operational expense for the railroad industry, in addition to the costs of equipment purchases with associated engineering and installation costs. Since about 60% of existing equipment was procured before 1965, salvage or resale credits will not reduce the transition expenses.

The anticipated transition cost for the major railroads is about $288,000,000. This includes direct mobile and fixed site equipment exchange, the additional relays for yards and right-of-way areas; and engineering, installation, test, and site preparation expenses. Siting costs include the relocation of existing right-of-way relays and control equipments, and the necessary measurements to assure coverage and isolation which are particularly important in hilly and mountain regions. The approximately 80% increase in channel availability is required to provide a level of service comparable to the existing VHF operations. In addition to the conversion times and costs cited, the industry would be subjected to hampered operations and jeopardized safety during the transition to new frequencies, equipment, and engineering designs.

3.3.4 Yard measurement requirements

In the development of a model, the statistics that set the timing of events are important for a credible analysis of the system. For the Barstow yard, for example, the shortest trains into the yard have about 15 cars, the longest have approximately 190 cars with a normal distribution between these limits. The timing assigned to most communication events which support train movement and processing are tied to the length of trains. There are 135 time distribution sets for communication support events in the Barstow model. The mean and variances of each of these sets must be as accurate as possible to assure the desired confidence level in the information from the network simulation.

The yard measurement of frequency channel usage was an important part of the model validation. The methodology applied to the making of radio transmission measurements in a railroad yard is important. Factors such as geometry, equipment characteristics, and operational procedures are involved in determining the placement of the receiving system for proper reception of the greatest number of transmissions for a given period of time. Most yards will be on flat land, but tall structures, particularly those that are basically steel construction, may interfere with certain transmissions or cause reflections and multipath reception. The layout of tracks and subsequent transmission problems encountered when many sets of parallel tracks are full of cars must be considered. Low power pack sets may use repeater transmitters placed appropriately in the yard to transmit from an area close to the ground between cars to other areas of the yard. Potential multipath problems often occur either in conjunction with atmospheric phenomena, certain car line-ups in a particular area of the yard, terrain effects, power line placement, or a combination of all of these. In the Barstow yard, for example, "radio holes" are experienced in some areas of the yard under certain conditions of car line-up in the departure area. The responsible radio communication personnel at a given yard can relate actual experiences encountered with such phenomena and such problem areas can be avoided when placing the monitor receiver antenna.

If the monitoring antenna is placed close to a high-powered base station transmitting antenna, the sensitivity of receiving unit may have to be reduced to such a level in overcoming saturation that low-power pack set transmissions will not always be received. The ideal location for the monitoring antenna would be at both ends of a long yard such as Barstow. This would allow the best line-of-sight paths between the various transmitting units and the antenna since the transmissions would propagate along corridors between parallel trains. This would require two measurement systems if all transmissions in a yard were to be monitored at the same time. If only one measurement system is available, the best location would probably be central in the yard with the antenna as high as possible above the ground. The height of the antenna is important in getting the most line-of-sight paths which allow best reception for measurement. If the measuring equipment is portable, sample measurements around the yard can alleviate detection uncertainties caused by propagation characteristics depending on terrain features, transmitter antenna placement and power, buildings, yard and track layout, etc., which are peculiar to that yard. The suggestions made here are general, but should help to locate the monitoring antenna for best results.

The instrumentation employed for measuring all channel activity simultaneously included a spectrum analyzer, an oscilloscope and a continuously moving photograph film. Figure 3.58 shows interconnection of three instruments. The scan width of the spectrum analyzer was set so that the grid on the face of the CRT display was 2 MHz full scale. The 2 MHz bandwidth was sufficient to display all of the channels at Barstow in the range from 160.215 MHz to 161.565 MHz. Transmissions are displayed as pulses or spikes on the CRT display as shown in the upper diagram in Figure 3.59. The "SCAN OUT" from the analyzer drives the horizontal sweep of the oscilloscope. The "VERTICAL OUTPUT" signal from the analyzer is coupled to the z-axis input on the oscilliscope. This causes the beam intensity modulation where the transmission spikes occur. This is shown in the middle diagram of Figure 3.59 where the brightness of the spot is proportional to the magnitude of the corresponding pulse on the CRT or received signal amplitude. A 35 mm moving film oscilloscope camera was utilized for the data recording. The film speed was set at 2" per minute and as the film was exposed by the CRT display, lines were traced corresponding to the intensity spots. These traces on the film lasted only the duration of the

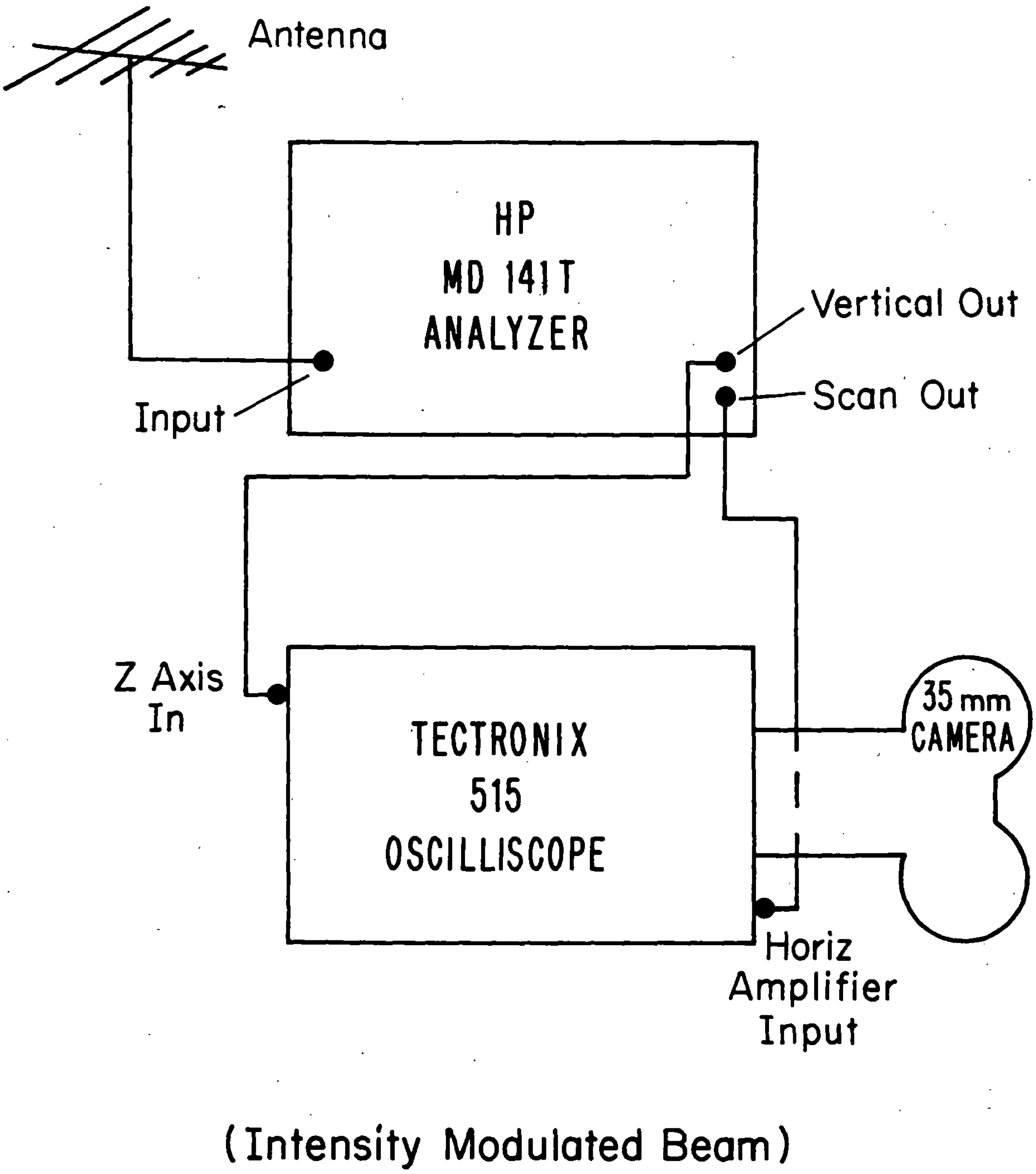


Figure 3.58. Pictorial diagram of channel usage measurements equipment.

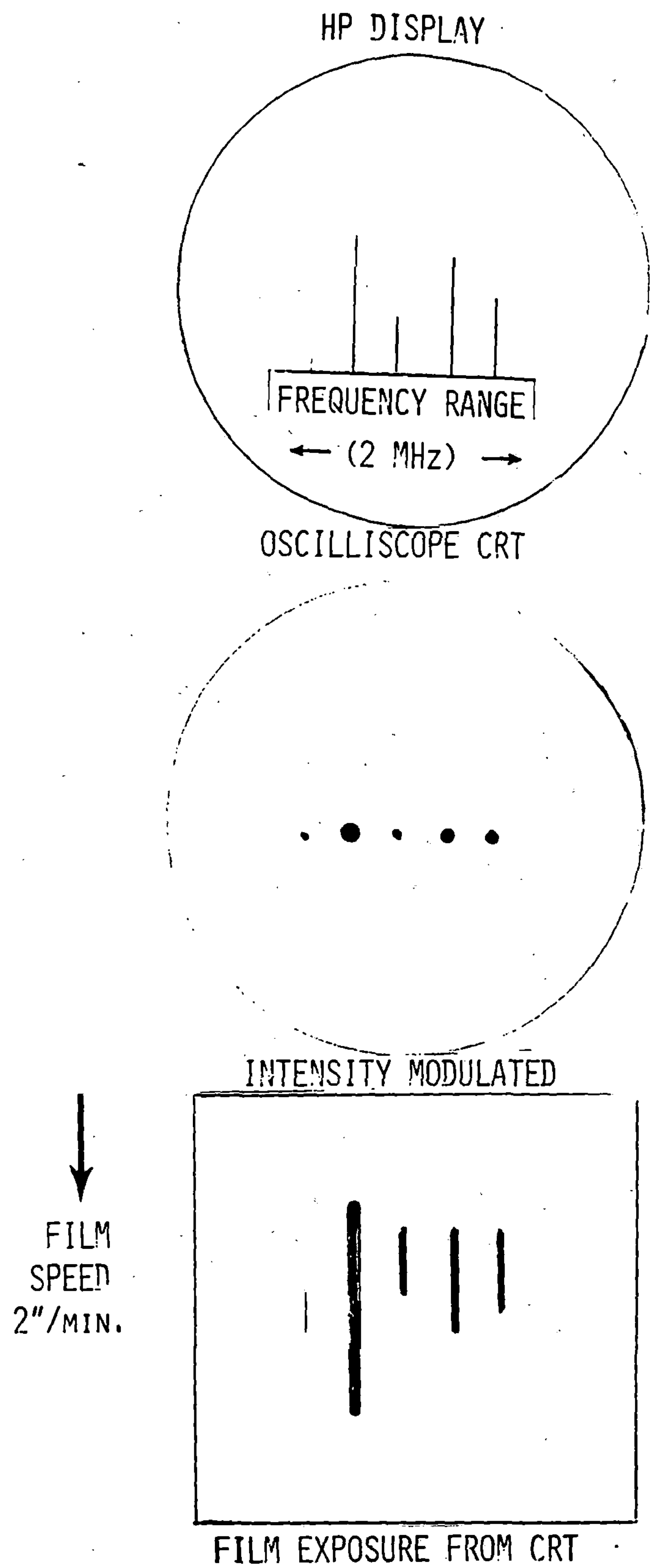


Figure 3.59. Representative oscilloscope display diagrams from the usage measurement equipment.

actual transmissions as shown in the bottom diagram of Figure 3.59. In this diagram, the horizontal axis scale represents the frequency band, and the vertical axis represents time. A typical section of film is shown in Figure 3.60.

To calibrate the measurement system, signals at the lowest (160.215 MHz) and highest (161.565 MHz) frequencies were injected into the analyzer and recorded on the film. This was repeated at 6 hour intervals. A clock in the camera provided day and time information which was recorded at the edge of the film. This was done each hour to provide a time record and as a check to verify film speed.

For convenience of operation and in cooperation with the Barstow communications personnel, the system, as described, was set up in the communication test lab in the terminal building at the west end of the Barstow yard. Receiving antennas on top of the terminal building were used during this measurement program, which lasted 48 hours. The only problem encountered was the anticipated occasional missed measurements of packset transmissions when the operators were between cars at the extreme ends of the yard. The input sensitivity of the analyzer was adjusted to allow reception of the low-level signals and not saturate on the local high-level signals. The few missed transmissions could have been recorded if the receiving antenna could have been placed more centrally in the yard.

Planning for a validation measurement program where signal sources are mobile and have a high probability of obstructed transmission paths should include a detailed examination of source magnitudes, propagation variations, and operational modes to guide monitor location and equipment technical characteristic specifications. For this exercise at Barstow, the facility near the tower was the best location available (minimum compromise in detection of packset signals from the yard extreme locations and large signal non-linear responses in the monitor receiver). An examination of typical train arrival and departure data, and the flow of communications related activities within the yard provides guidance in the anticipated channel density patterns. For this program, the initial operations model exercises provided this baseline activity reference. This experiment design problem for a railroad yard is greatly simplified because ofthe use of separate frequency assignments for different operational functions; contrasted with similar measurements of time multiplexed communications.

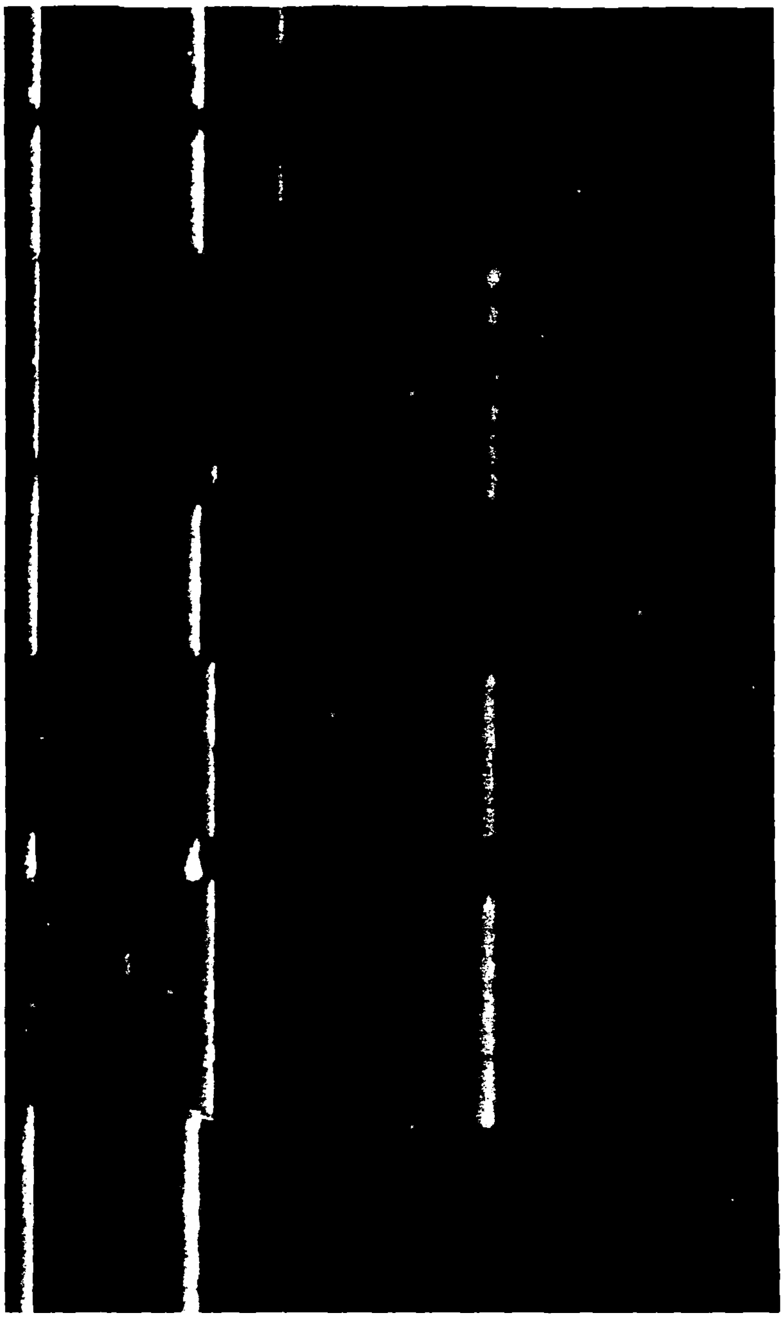


Figure 3.60. A section of film showing the output formed from the usage measurements.

A summary of yard measurements is discussed in the following section.

3.3.5 Measurements summary

The 35 mm film containing the recorded data discussed in the previous section was developed and the data scaled. A 35 mm film viewer with a calibrated scale provided good accuracy, for determining the frequency and duration of each transmission.

Curves produced from the scaled data (Figures 3.61 and 3.62) indicate the duty cycle of communication events identified over a 24-hour period. The duty cycle represents the percent activity for 10-minute segments, from midnight through noon to midnight the following night. These curves represent the average of two days of collected data. The top curve of Figure 3.61 represents those communication events which back up train service such as car inspection, car repair, etc., throughout the total yard. The lower curve represents those communication events that support switch engine status and movement in the departure and bowl area. In Figure 3.62, the upper curve represents communications events that support switch engine movement in the receiving yard. The lower curve represents those communications events that support humping activities. These curves show that the frequency utilization was lowest in the departure area. This is due to the sensitivity of the receiving system not being adequate to detect all the communcitions events in the departure area. Some degree of correlation within the model outputs was attempted after adjustment for train throughput. The correlation with train services between the model and the measurements was poor for functions associated with movement coordination and assignments for switch engines in the receiving and departure yard. The cause for discrepancy was due to the use of road engines for switch engine support in these two areas of the yard. This was, of course, unique to the Barstow operation.

Figures 3.63, 3.64, and 3.65 present the number of messages per 4-minute interval for movement coordination and administrative support activities as indicated on each curve averaged over two 24-hour periods. For example, in Figure 3.63, the curve for train services shows that 54 messages/4-minute interval were recorded at noon. These curves support the previous duty cycle curves of Figures 3.61 and 3.62 by indicating the channel utilization of the

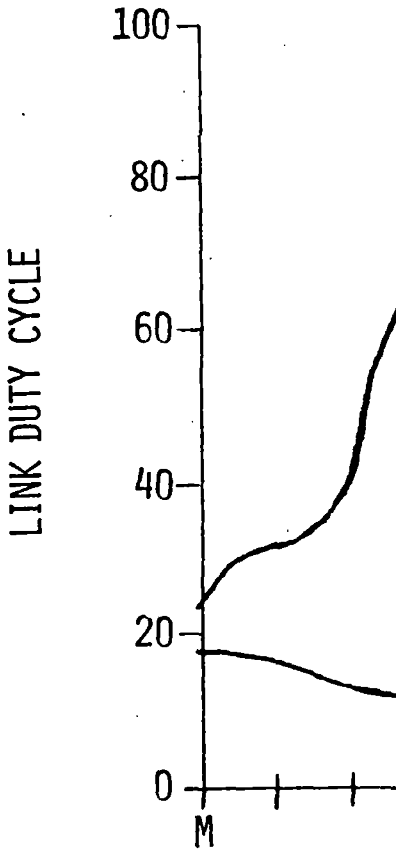
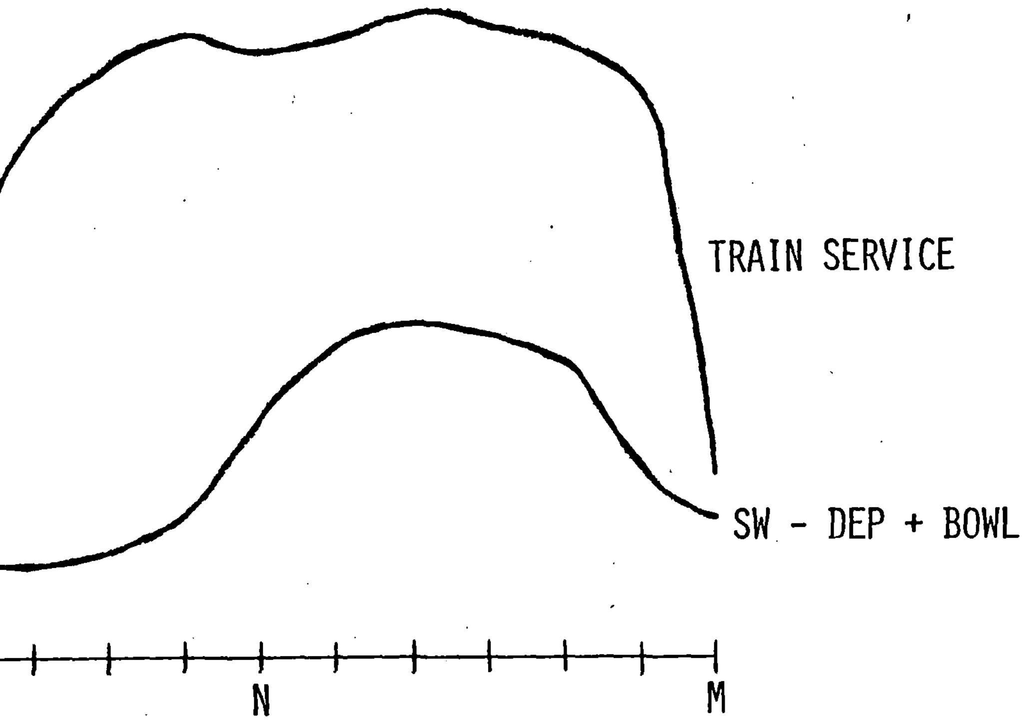


Figure 3.61.



Duty cycle of communications events (train service and switch engine channels at departure yard and bowl).

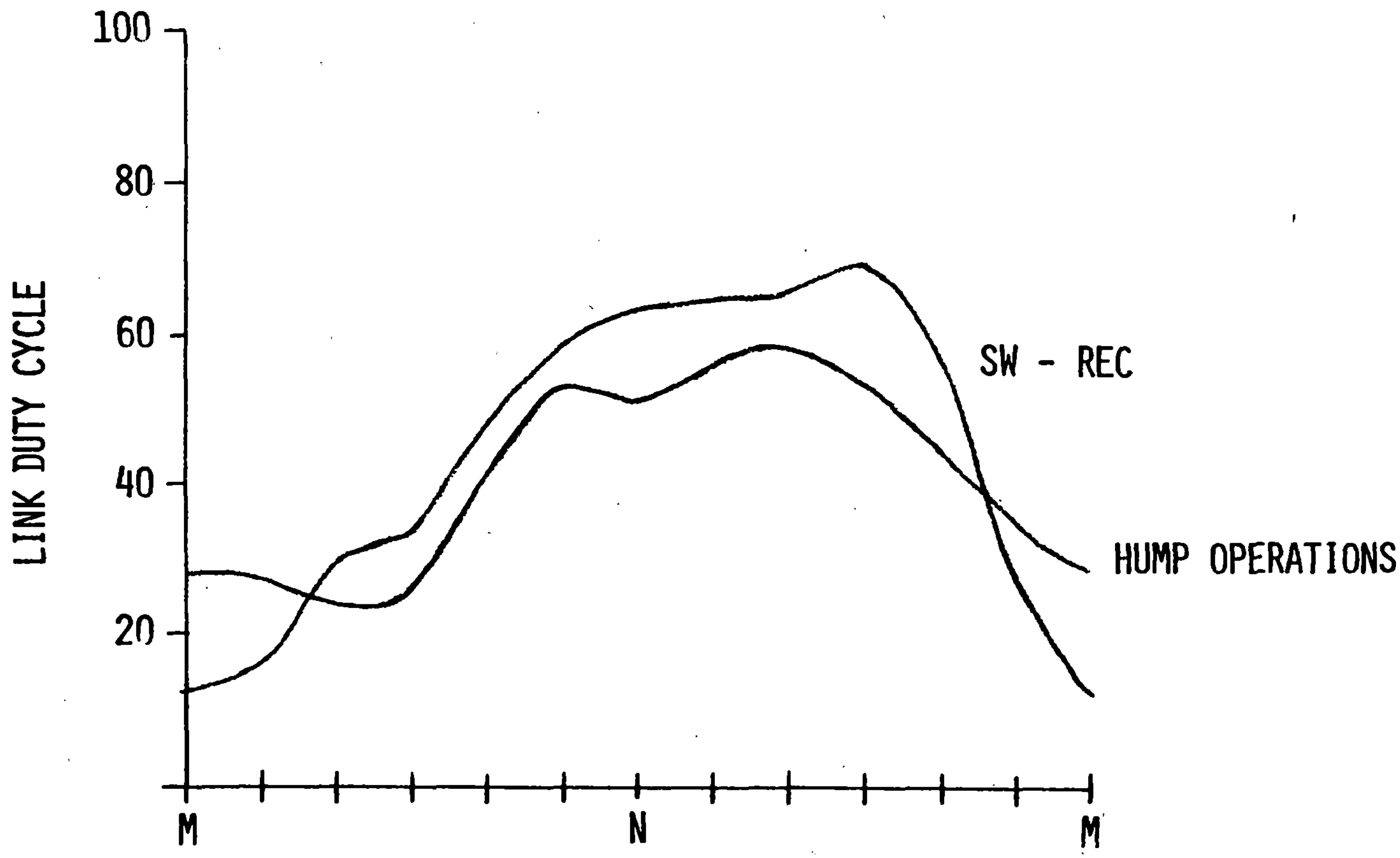


Figure 3.62. Duty cycle of communications events (switch engine channels at receiving yard and hump yard).

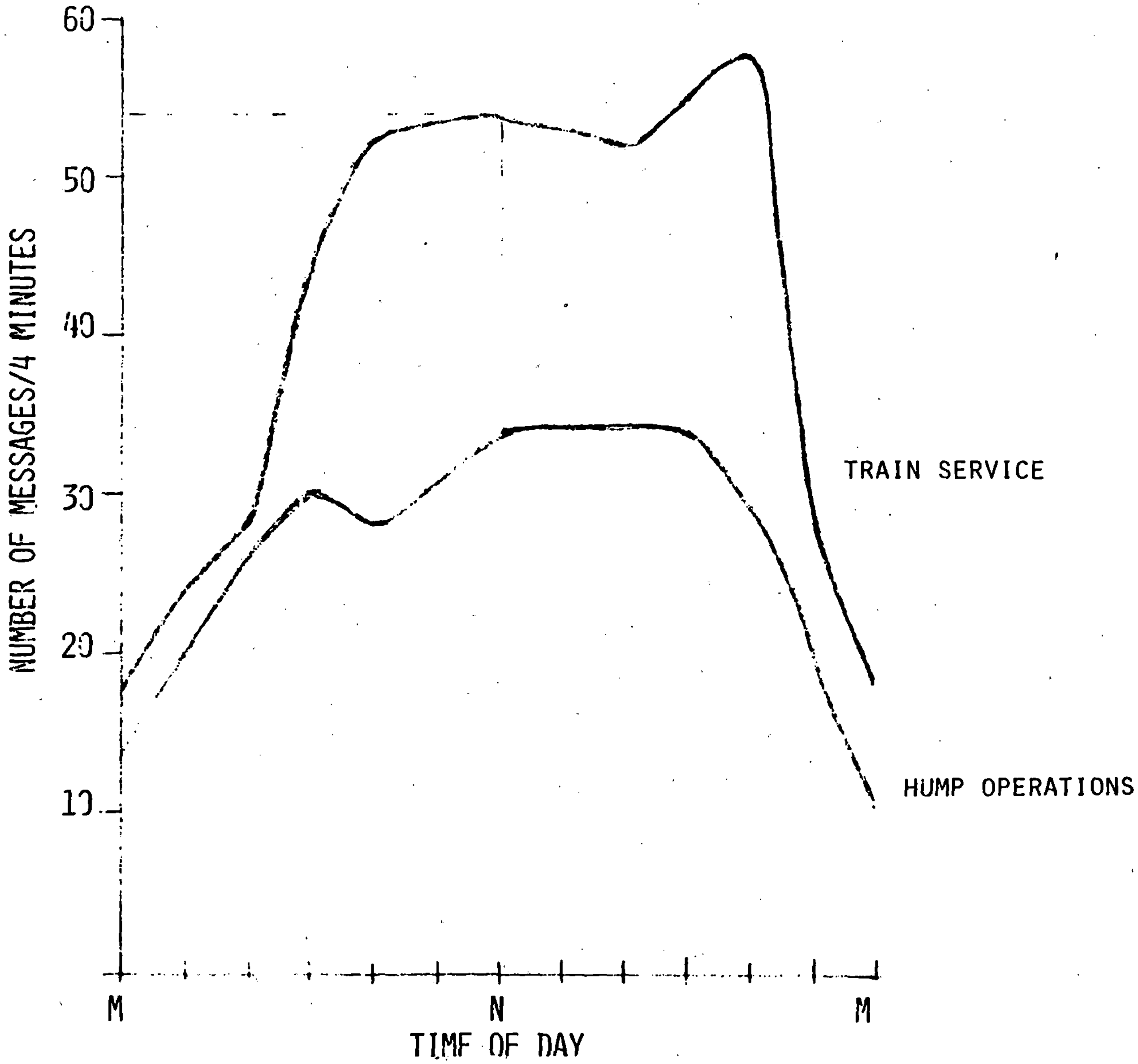


Figure 3.63. Number of messages per four minute intervals (train service and hump operations).

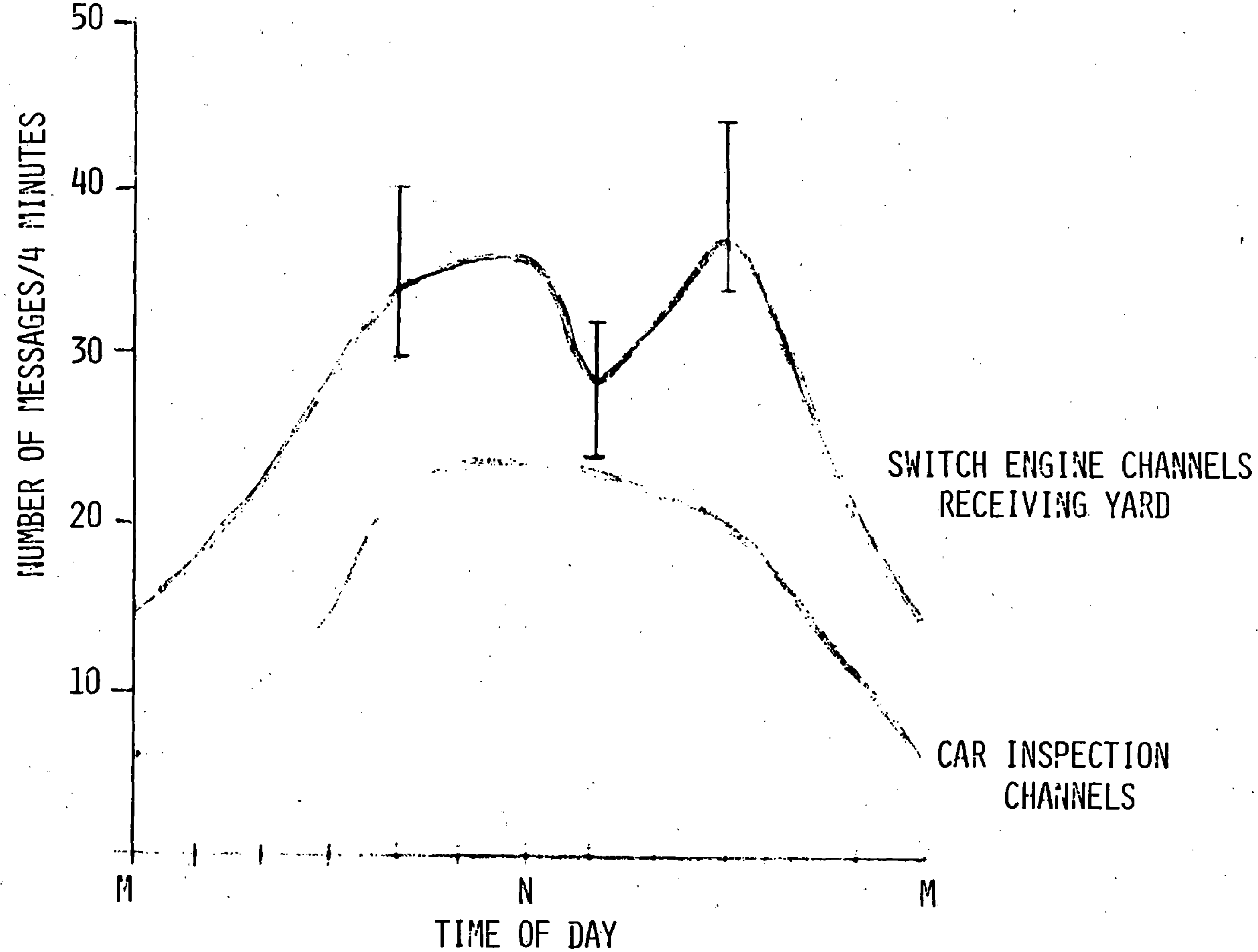


Figure 3.64. Number of messages per four minute interval (switch engine channels at receiving yard and car inspector channels).

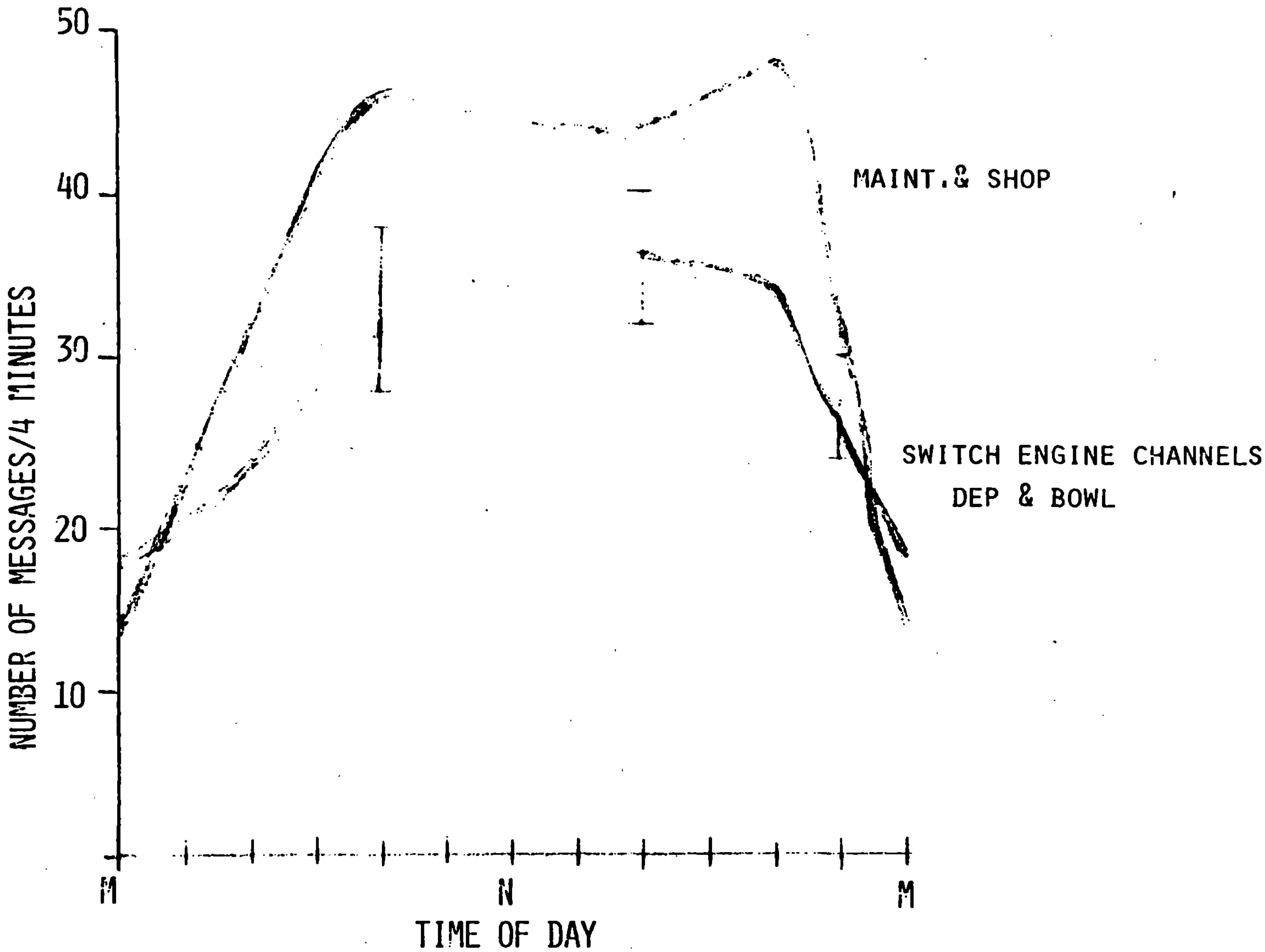


Figure 3.65. Number of messages per four minute interval (maintenance shop and switch engine channels at departure yard and bowl).

24-hour periods. The error bars on the switch engine curves in Figures 3.64 and 3.65 represent the maximum and minimum recorded values for those events.

Figure 3.66 indicates message length for the switch engine channels operating in the departure yard and bowl. These curves indicate the probability of a transmitted message taking less time than the value assigned to each curve. These curves represent a two-hour period from noon to 2:00 p.m. during the busy part of a day. For example, if one chooses 1300 on the time scale, the probability of a message taking less than 3 seconds is 0.15. However, there is a high probability, approximately 0.85, that a message will be less than 10 seconds for that same time. These curves also indicate the efficiency of message utilization since the average message duration was approximately 5 seconds.

Figure 3.67 shows the effects of combining communication functions. The curves of this figure represent the probability that a tried communication activity will have to attempt a retransmission based on channel unavailability. There are 3 reallocation combinations shown:

- The lower curve is the result of combining the yard master-maintenance functions with the diesel shop channel.
- The middle curve shows the additional combination of the car inspector functions with the diesel shop channel.
- The upper curve shows the reduction of frequency channels assigned to switch engine functions from 7 to 3 channels.

These curves are results of averaging data taken at Barstow for two periods from noon to 2:00 p.m. An example of information these curves give is at 1300, the probability of channel unavailability (communication already in progress) for the upper curve is approximately 0.6. So, there is a fairly high probability that a person would have some delay time in making his transmission. This is assuming no priority consideration, but that a first call, first serve procedure governed communications on the individual lines. From these plots, the yard activity (trains processed per 24-hour period) measured at Barstow became input to the model data to adjust to frequency usage outputs.

3.3.6 <u>Communications capability modifications</u>

The measurements at Barstow introduced some modifications in the original yard event model. As mentioned in Section 3.3.4, the yard model consistently showed very long delays in availability of switch engines. This suggested

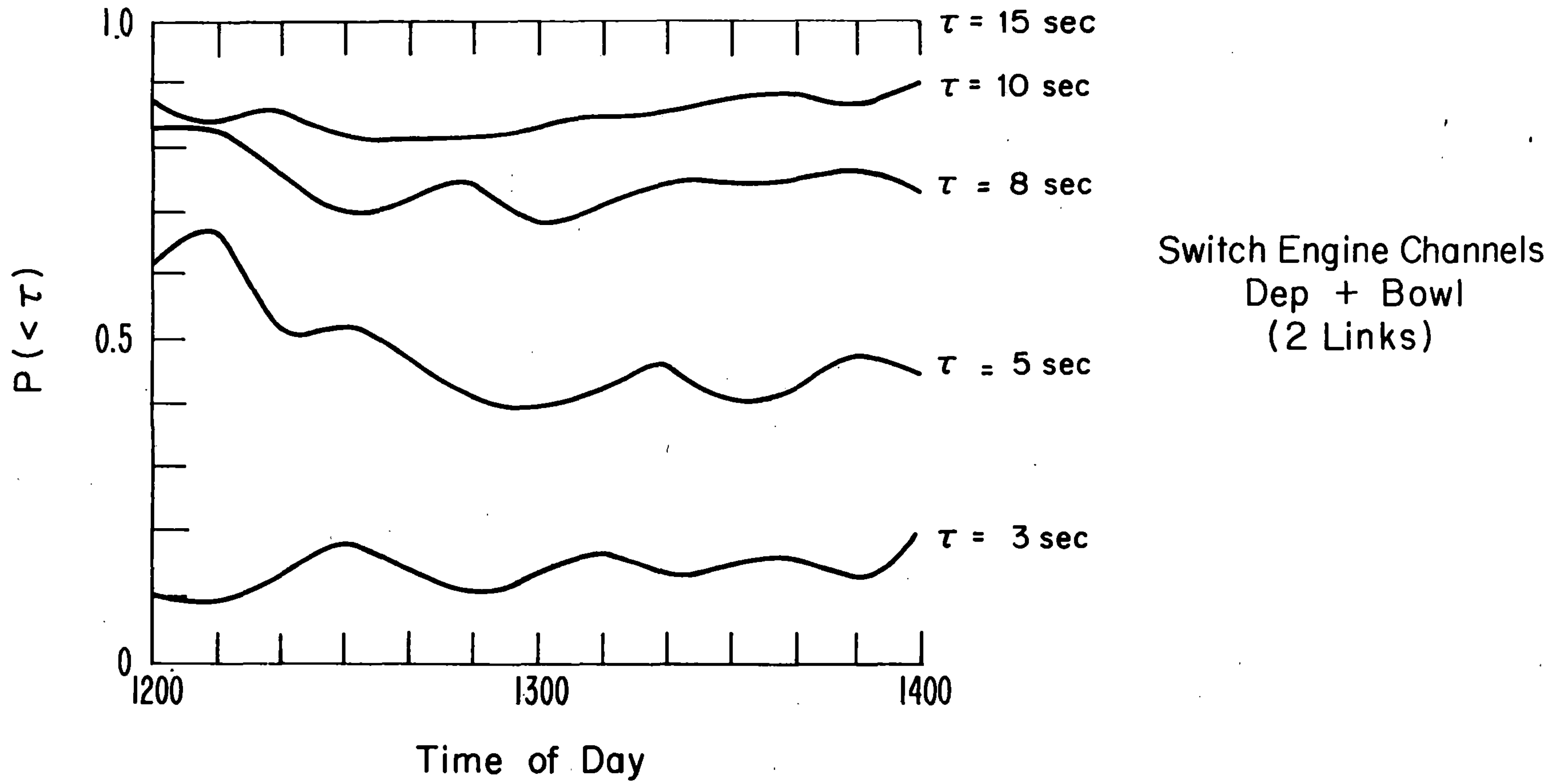


Figure 3.66. Message length statistics (probabilities).

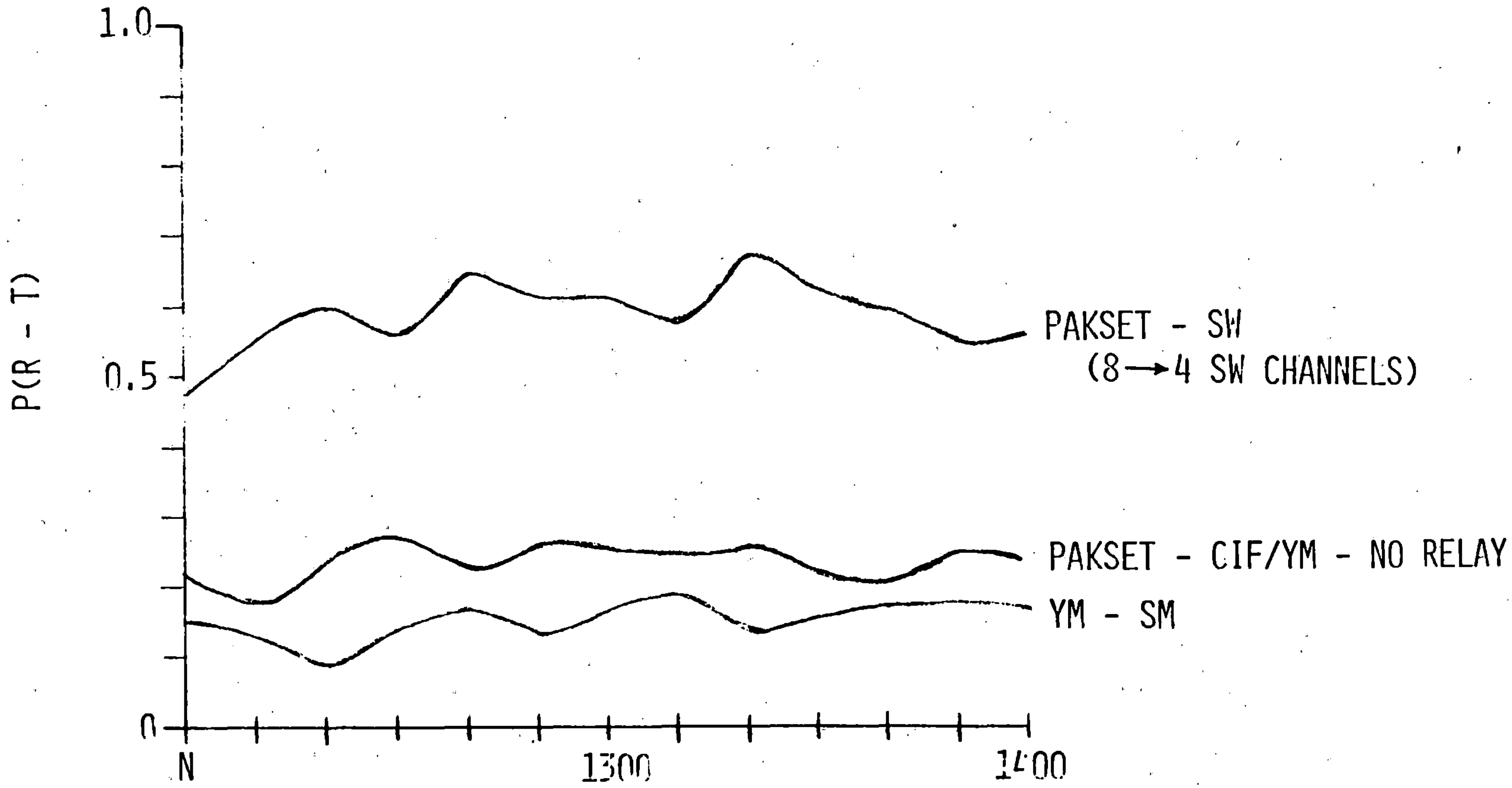


Figure 3.67. Message length statistics (probabilities).

that either information was missing or some information which went into the designing of the model concerning switch engine task timing was not correct. The yard measurements showed that indeed there was a shortage of switch engine capability at peak operation times in the yard and that road power was used to help make up trains in the departure yard.

Another model change had to be made regarding the number of trains that arrived at Barstow in a given 24-hour period. The model had been designed to handle 15 to 20 trains in a 24-hour period. Actual arrivals and departures turned out to average 35 trains with a maximum of 45. Other changes in the task timing concerned car inspector functions which were either lengthened or shortened appropriately.

According to the original model exercises, the diesel shop frequency was not heavily utilized in the yard. Based upon this premise and the fact that the diesel shop used repeater aid to communicate from pack sets between cars and for communications originating from the old east Barstow yard, car inspector and maintenance channel activities shared these diesel shop frequencies. The actual measurements in the yard showed that the diesel shop frequency was one of the busiest communication channels in the yard. Since the car inspector communications also used a repeater for pack set operation between rows of cars, the diesel shop channels still seemed to be the logical choice for sharing. However, the task timing had to be changed to show the appropriate diesel shop use.

The main communication activities within the yard are well represented by the model. However, there were many communications activities such as the diesel-ready yard transmissions to the major diesel repair shop in east Barstow to bring parts for a minor repair, or yard personnel who carry on many pack set communications in support of yard work activity that could not be represented in the model. A network which has 145 tasks is already quite complex and takes considerable time to run on the computer. The addition of every possible pack set communication would have made the network unmanageable and cost of computer runs would have been exorbitant.

There were many timing adjustments made in the model based on yard measurements. These changes were mainly in yard operations such as the length of time to hump trains (the number of cars per minute on the average), the length of time it takes a car inspector to inspect a car, the distribution of train sizes (the number of cars that make up the smallest trains, the number of cars in the longest trains, and the number of cars in the average train that enters Barstow), and other information that helped set the distributions used to generate statistics in the model.

With the feedback generated by the yard measurements, the model in its new modified form is a good facsimile of the actual Barstow operation. With appropriate modifications, it could easily represent many classification yards throughout the country. The information that can be extracted from this type of event model is helpful in learning much about the intricate operations of a railroad yard and can be designed to give information on almost any facet of yard function capability.

3.4 Advanced Technology Applications

The importance of the current VHF communications capabilities to safety and operational efficiency of various railroad functions has been discussed. Present procedures utilize almost exclusively voice modes. The VHF communications links can with the integration of data transmission and processing technology allow utilization of digital display and limited control functions, and accommodate interface with track and wayside sensor and "status" advisory systems. The applications discussed herein represent the general consensus of railroad communications management as reflected by the AAR Communications and Signals Group's movement or action signaling and coordination through digital data displays, status monitors and alerting, and situation status interrogation through remote computer facilities. Additional summaries are also included regarding the general problems in utilizing directional antennas and "net control" techniques to improve spectrum usage efficiency.

Although digital modes will be integrated into the VHF systems, voice communications will be dominant for the foreseeable future. Particularly for movement control, the safety implications for message errors relegate digital transmissions to a verification and secondary information role. Addition of the digital mode will reduce the voice operations duty cycle. The cited safety consideration also imposes significant limitations on the netting application, the relationship between channel access delays and safety criteria being nearly identical to that indicated in the operations model exercise data for the reduced channel assignment cases (ref. Section 3.3).

3.4.1 Digital applications

The earliest utilizations will concern direct data display and teleprinter operation for train service units and yard locomotives, and communications interface with micro/mini processors on locomotives and cabooses for data transfer or control involving track and wayside sensors and message storage devices. Communications between trains, road crews, and wayside stations and sensors will concern alerts, movement instructions, equipment monitor data, and status information regarding other trains or activities within nearby track areas. These communications, with appropriate display and printer outputs and alarms, could significantly enhance operational safety for train equipment and personnel, and right-of-way crews. For command/control functions involving variations in Train Orders, such digital data would complement the primary voice communications mode.

The digital modes would include the operational data and users listed:

a. Dispatcher to train - movement information for particular track sections and situation alerts (speed limits and locations and status of other trains or track within the track section).

b. Track sensor to train - speed limits and track activity or status identifier. This would be an automatically interrogated coded transponder mounted at the side or between tracks. Multiple track units may be employed to provide warning to train crew of improper speeds in congested areas.

c. Train or remote track sensor to track crew - train identification, location, and speed data to allow crew to prepare and clear tracks.

d. Train to dispatcher station - train interrogation of local computer regarding track status, alerts or movement instructions for specific track sections. Computers would store interrogating train information (identification, message, time, authentication/verification keys).

e. Track sensor to train and dispatcher - equipment problem warning with location, train identification tags. Subsequent coordination between trainmaster/dispatcher and train regarding action to repair or remove equipment would involve VHF links.

These modes require communications channels that accommodate voice and digital data. General status information would generally involve only digital data; forward transmission of authentication address, train identification, and the status message, with verification reply. Movement commands would include both voice and digital transmissions. As mentioned previously, a reduction in voice duty cycle and probably channel duty cycle is to be anticipated from these procedures.

These digital modes must be maximally compatible with existing VHF equipment. The applications cited can be accommodated by dual tone FSK, time multiplexed with the voice mode. Simultaneous voice data transmission (data-under-voice) presents significant equipment complications and increased channel usage (larger data error rates with resulting message retransmissions). This aspect is additionally aggravated by the effects of multipath propagation modes with moving link terminals.

The basic range of differences in BER performance for data-under-voice and time multiplexed voice-data modes are indicated by the listed measured data for S/N ratios of 9 dB and 15 dB.

MUX	BER (9 dB)	(BER (15 dB)
Data-Under-Voice	$2x10^{-3}$	$3.0x10^{-4}$
Time MUX (DFSK)	10^{-5}	$2.0x10^{-6}$

These data do not include signal fading, and are therefore optimistic, with the greatest sensitivity indicated for the data-under-voice mode.

Where voice and data are time multiplexed, the voice would probably precede data transmission to be maximally compatible with current operations. The user could initiate the channel with present "press-to-talk" operation, and after release of the operator switch, the digital component would be transmitted with the channel automatically released after verification. This mode can be implemented as an additional functional module for existing VHF equipment, with the only modification to control circuitry involving the automatic release element.

For the digital applications indicated, the bit rates for time MUX are listed.

a. action signaling - discrete address with authentication and verification - 100-300 BPS
b. movement control data - 300-500 BPS
c. status monitor with alert - 100-300 BPS

d. computer interrogation - train status, location, scheduling - 100-300 BPS

e. teleprinter operation - 100-300 BPS

These digital rates are readily compatible with control and display devices, and the bandwidth limitations of existing VHF channels. Two-tone operations are assumed for digital transmission speech, and data separation at the receiver is readily accomplished with active filters; 30 Hz - 2.2 kHz notches for speech and 2.7 kHz and 2.9 kHz notches for data components. These filters are readily available as mechanical or active electronic configurations.

With independent channels for each communications function, the error rate for receiver actuation and data message components is singularly dependent on signal amplitude. If, for compatibility reasons, two or more functions not directly associated with equipment movement or coordination were combined on a single channel, the error dependency would also include the digital address component. This would necessitate increased retransmissions in a manner analogous to that depicted in Figure 3.67. Combining digital messages on a common channel for movement-related functions would aggravate even the safety impact discussed in Section 3.3.1 because of the BER effects in address and data message components.

The track sensor applications previously mentioned include stored message devices that transmit to a passing train and wayside equipment monitors with transmission to the train and possibly to the dispatcher. Current emphasis for the former concerns speed, location, and service status information for trains approaching stopped trains or track maintenance crews. This type of sensor would be easily moved by track crews. Wayside sensors would primarily be concerned with monitoring passing equipment and alerting for hot bearings, flat wheels, and dragging or improperly protruding loads. Control and data logic would provide condition data and train identification if reliable automatic car identification devices are included in the sensor system.

For communications supporting operations not directly involved with equipment movement (i.e. car inspection, maintenance shops), combining functions on sets of common frequencies could be accomplished with the introduction of digital techniques. For most classification yards, this could ultimately provide two or three channels for equipment control functions.

With proper organization, the digital message component would lower voice utilization, thus probably reducing the channel duty cycle for these functions by as much as 30%. For the functions cited, a limited reassignment could be effected. This mode of operation will require a tone signaling technique for channel activation. With 5 to 10 addresses required for the considered functional combinations, this type of initialization provides advantages in equipment simplicity and reduced propagation sensitivity relative to other pulse code formats.

For many of the monitor sensor applications cited, microprocessors will be utilized for status decisions and alert initiation through the communications links. This mode is particularly important, relative to channel utilization efficiency, in the train-road crew-dispatcher data exchange. Processors would be integrated into locomotive signaling functions and wayside or track sensor systems.

With yard and right-of-way maintenance crews, the signaling format should include one "Alert" address that allows all users to be activated for a "broadcast" mode. Such action would be controlled by local supervisory or train or service locomotive stations.

3.4.2 Antenna applications

Railroad operations generally prevent maximum exploitation of directional antennas for compatibility improvement and spectrum usage conservation. Any form of directional antenna with adequate control components is totally impractical for moving equipment application. The use of directional antennas in urban yards for fixed control sites (i.e., yard master, hump master, maintenance facilities), particularly where several yards and interconnecting tracks may be within normal communications distances, was evaluated. Layouts for yards in Chicago were the basis, including the industrial and commercial buildings that cause propagation anomalies. Antenna parameters utilized to determine basic advantages are listed:

a. frequency range - 160-164 MHz
b. horizontal beamwidth - 38°
c. front-back ratio - 15 dB.

With multipath environments typical of urban yards, an effective distance advantage of 1-2 miles can be obtained from this type of antenna. Considering the differences in geometries between, for example, the AT&SF and EJE yards in

Chicago, causes a variation of 50% - 70% in this distance advantage. These results provide no practical improvement in spectrum utility for directional antennas. These results also negate consideration of any of the controlled array techniques where pattern switching could be coupled to frequency and yard operational functions. Pattern switching between receiving and departure areas, for example, could readily be accomplished with a diode switched array. The multipath problems and small yard areas, however, allow as indicated no real advantages for such an operation.

The data requirement cited for these sensor and digital operations are compatible with the channel bandwidth of the existing VHF assignments. Bandwidth considerations will not require additional channel assignments for railroad communications.

4.0 COMMUNICATIONS INVESTMENT DATA

The Communication and Signal Section of AAR initially had minimal information available on an industry-wide basis that could be used to develop actual total investment and cost of ownership information in radio facilities. However, the AAR has conducted two surveys that provide a basis for suitable estimates of facility investments and can also be used to predict the potential impact of possible VHF frequency reassignments or radio band changes for mobile communications.

The first study, started in the last quarter of 1973 and finished in 1974; was to develop the actual number of base stations and mobile units in service on each frequency in the railroad industry. Data were obtained on approximately 350 railroads, listing quantity of equipment in mobile, base and extra channel categories. From the standpoint of the number of railroads covered, this is a very comprehensive survey. In this study, no distinction was made between directly controlled and remotely controlled base stations, and the types of mobile units (locomotives, cabooses, automobiles, work equipments, hand-held, etc.) were not identified. This means that in order to determine a total investment figure, the cost per item will be the average of all mobile equipment or all base equipment.

The second survey, conducted during the last half of 1975, was designed to estimate the impact of the necessity of channel reassignments. A questionnaire was sent to 316 railroads asking for an estimate of cost related to three possible options. These were: 1) channel changes that involved only crystal replacement; 2) crystal replacement in channels used for end-to-end, point-to-train and right-of-way service and a complete change of equipment for confined yard operations; and 3) a complete change of equipment to provide operation in a different portion of the spectrum. Cost estimates by equipment type were given for the 900 MHz band. By mid-January, 1976, returns had been received from 140 railroads. Although these returns represent only 44 percent of those contacted, the percentage of total radio equipment investment represented is greater than 95%.

4.1 Current VHF Investment Summary

The data received from the 1974 AAR equipment inventory survey were tabulated by frequency channel and railroad. Each railroad that operated equipment in a given channel supplied quantity information pertaining to mobile equipment, base station equipment and multiple channel capacity (additional crystals). The total number of equipment in each category for each frequency was determined and the results of this tally are shown in Table 4.1. The total of each category is 65,043, 94,145, and 12,934 for crystals, mobile units, and base stations, respectively. This table for the AAR survey includes the UHF assignments used primarily for remote locomotive control (channels 47-49 and 47m-49m). These UHF equipments represent an insignificant element in the total investment cited. The survey represents only AAR membership response (excludes AMTRAK UHF equipments).

Total radio equipment investment was estimated by the AAR for the railroads responding in the above inventory using an average unit cost.* The results are as follows:

1.	Mobile Units			
	Average costs	=	$1,477	
	Number of units	=	95,145	
	Mobile unit investment	=		$140,429,165
2.	Base Stations			
	Average cost	=	$4,067	
	Number of units	=	12,934	
	Base station investment	=		$ 52,602,578
	TOTAL INVESTMENT			$193,031,743

(This cost estimate can be extended by adding the cost of additional crystals.)

3.	Crystals			
	Average cost	=	$ 100	
	Number of units	=	65,043	
	Crystal investment	=		$ 6,504,300
	NEW TOTAL			$199,536,043

From the results of an equipment inventory (1974) and an estimated average cost of equipment, it has been determined that approximately $200 million is invested in mobile radio communications equipment by the railroad industry.

*AAR Memo from L. R. Thomas, AAR Comm. & Signals Section, AAR

Table 4.1. Railroad Mobile Radio Equipment Inventory

Total Number of Multiple Channel Radios, Mobile and Base Stations

		*Multiple Channel Capacity	Mobile	Base
Channel 1T	(160.215)	31	255	20
Channel 1	(160.230)	462	1,885	219
Channel 2T	(160.245)	540	65	196
Channel 2	(160.260)	1,327	1,606	222
Channel 3T	(160.275)	74	211	18
Channel 3	(160.290)	1,419	772	298
Channel 4T	(160.305)	503	57	93
Channel 4	(160.320)	781	385	128
Channel 5T	(160.335)	84	161	32
Channel 5	(160.350)	864	1,218	280
Channel 6T	(160.365)	33	12	18
Channel 6	(160.380)	169	1,537	155
Channel 7T	(160.395)	50	23	14
Channel 7	(160.410)	456	5,361	488
Channel 8T	(160.425)	0	33	4
Channel 8	(160.440)	1,635	798	102
Channel 9T	(160.455)	2,521	357	45
Channel 9	(160.470)	866	898	334
Channel 10T	(160.485)	17	27	15
Channel 10	(160.500)	78	466	76
Channel 11T	(160.515)	33	67	8
Channel 11	(160.530)	1,173	992	254
Channel 12T	(160.545)	75	27	10
Channel 12	(160.560)	69	166	40
Channel 13T	(160.575)	6	49	6
Channel 13	(160.590)	822	4,764	622
Channel 14T	(160.605)	68	49	2
Channel 14	(160.620)	42	356	73
Channel 15T	(160.635)	0	19	5
Channel 15	(160.650)	3,098	4,740	617
Channel 16T	(160.665)	4	19	3
Channel 16	(160.680)	515	396	84
Channel 17T	(160.695)	79	89	11
Channel 17	(160.710)	306	283	71
Channel 18T	(160.725)	70	72	15
Channel 18	(160.740)	315	3,462	366
Channel 19T	(160.755)	30	65	11
Channel 19	(160.770)	313	1,982	189
Channel 20T	(160.785)	132	233	9
Channel 20	(160.800)	1,682	10,425	562
Channel 21T	(160.815)	28	72	6
Channel 21	(160.830)	3,388	317	129
Channel 22T	(160.845)	80	57	16
Channel 22	(160.860)	342	954	96
Channel 23T	(160.875)	27	140	14
Channel 23	(160.890)	296	2,988	268
Channel 24T	(160.985)	16	17	3
Channel 24	(160.920)	530	750	218
Channel 25T	(160.935)	1,158	77	184
Channel 25	(160.950)	87	6,878	582

		Multiple Channel Capacity	Mobile	Base
Channel 26T	(160.965)	101	38	15
Channel 26	(160.980)	441	823	124
Channel 27T	(160.995)	9	0	7
Channel 27	(161.010)	242	147	173
Channel 28T	(161.025)	250	295	21
Channel 28	(161.040)	1,017	252	112
Channel 29T	(161.055)	0	10	6
Channel 29	(161.070)	10,467	455	170
Channel 30T	(161.085)	17	19	6
Channel 30	(161.100)	1,813	6,984	1,047
Channel 31T	(161.115)	21	52	15
Channel 31	(161.130)	255	2,044	211
Channel 32T	(161.145)	8	90	6
Channel 32	(161.160)	2,313	353	181
Channel 33T	(161.175)	150	81	8
Channel 33	(161.190)	1,905	2,940	334
Channel 34T	(161.205)	30	333	3
Channel 34	(161.220)	1,546	456	92
Channel 35T	(161.235)	18	45	12
Channel 35	(161.250)	1,395	3,669	395
Channel 36T	(161.265)	501	166	38
Channel 36	(161.280)	436	888	235
Channel 37T	(161.295)	204	125	16
Channel 37	(161.310)	1,486	701	161
Channel 38T	(161.325)	16	129	28
Channel 38	(161.340)	1,607	125	59
Channel 39T	(161.355)	87	91	19
Channel 39	(161.370)	105	5,177	415
Channel 40T	(161.385)	136	152	22
Channel 40	(161.400)	88	1,785	414
Channel 41T	(161.415)	117	220	25
Channel 41	(161.430)	658	526	105
Channel 42T	(161.445)	98	137	15
Channel 42	(161.460)	1,272	859	273
Channel 43T	(161.475)	48	388	40
Channel 43	(161.490)	748	451	138
Channel 44T	(161.505)	95	157	15
Channel 44	(161.520)	4,644	125	222
Channel 45T	(161.535)	663	42	23
Channel 45	(161.550)	2,960	6,014	411
Channel 46T	(161.565)	382	93	50
Channel 47	(452.900)	0	1	24
Channel 47m	(457.900)	0	50	6
Channel 48	(452.925)	0	5	6
Channel 48m	(457.925)		6	0
Channel 49	(452.950)	0	8	6
Channel 49m	(457.950)	0	6	0
	TOTAL	65,043	94,145	12,934

TOTAL RADIO UNITS 107,079

* ADDITIONAL CRYSTALS

4.2 Maintenance Summary

Cost data derived by AAR for total annual maintenance are based on the inventory results and an estimate of per unit maintenance cost as derived from a survey of members of the radio liaison committee.**

Annual radio maintenance

Average annual cost	=	$ 149	
Number of units	=	107,079	
TOTAL MAINTENANCE	=		$15,945,771

The 107,079 units to be maintained are the sum of the mobile and base equipment in the operational inventory.

A further use of this table is to determine the percentage and estimated cost of the total equipment affected by the challenge of 33 channels in this band. The challenged frequencies are between and include channel 14 (160.620 MHz) to channel 26 (160.950 MHz) and channel 42 (161.460 MHz) to channel 46T (161.565 MHz). The sub-total of equipment included in these bands are listed in table 4.2.

Table 4.2 Challenged Channels

	Additional Crystals	Mobile	Base
14-26	13080	35252	3671
42-46T	10812	8129	1172
TOTAL	23892	43381	4843

These results indicate that the percentage of equipment in the challenged channels is 36.7%, 46.1%, and 37.4%, respectively, for crystals, mobile units, and base stations. The costs would be proportional because the same per unit estimates are used for challenged and unchallenged frequencies. These figures are not intended to infer cost of reassignment and/or replacement, because they do not include specific information regarding replacement such as cost of

**AAR memo from L. R. Thomas, AAR Comm. & Signals Section, AAR equipment in another radio band, additional equipment resulting from band changes, etc. An estimate of those costs (replacement and change) were included in the 1975 survey. The results of that survey are presented in the next section.

4.3 Proposed Reallocation Cost Estimates

The 1975 AAR reassignment cost survey was planned to estimate a cost to the railroad industry that could result if frequency channel changes were required. With only the knowledge of which channels could potentially be affected, but not knowing what specific changes might be required, the survey was conducted on the basis of three options. These were: 1) crystal changes only in the VHF band, 2) a combined crystal and equipment change dependent on radio use, and 3) equipment changes to the UHF band from all challenged frequency equipment.

As of January, 1976, survey responses had been received from 140 of the 316 addressees. The returns were in the form of cost estimates as requested in the survey letter, or to inform the survey committee that there were no assignments among the challenged channels; consequently, the railroad would be unaffected by the change.

The tally of the radio survey as of January 19, 1976, is as follows:

Estimated Cost to the Industry Based on the Survey Returns

Crystal Channel Frequency Element Change only	$ 9,781,983
Crystal Channel Frequency Element Change for EE, PT, and RW and Complete Transceiver Change for General	$ 71,677,004
Complete Transceiver Change	$188,873,804

These costs represent only direct exchange of existing VHF equipments. Additional facilities and the implementation cost elements are not included but are reflected in the basic conversion discussions in Section 3.3.3.4.

5.0 CONCLUSIONS

The previous sections have presented the analysis of VHF communications support to railroad operations, tabulated industry investment data in VHF radio equipment and supporting facilities, and discussed the technical and associated operational factors implicit with reduced channel availability or a reallocation of selected functions to either of two UHF spectral regions. Cost estimates for different levels of transition into UHF operations were also indicated.

As discussed previously in this report, thirty-three of the ninety-one VHF channels allocated by the FCC to the Railroad Radio Service are in a frequency band that is allocated internationally to the maritime mobile service. Because of the special footnote on the Radio Regulations of the International Telecommunications Union (ITU) (Footnote 287), the United States and Canada continued railroad communications on those thirty-three channels. The aforementioned Radio Regulations are being reviewed for possible revision at a World Administrative Radio Conference (WARC) scheduled to be held in 1979. United States preparation for the 1979 WARC must include a critical examination of Footnote 287 and, particularly, the need for retaining that part of the footnote on which the allocation of one-third of the railroad frequencies is based. There is interest in the maritime community in gaining access to those frequencies which are not available in U. S. waters because of Footnote 287 and consequent FCC actions. This prompted the U. S. Department of Transportation to initiate this study to define railroad usage of all VHF allocations, and the penalties associated with the considered reduction in allocations or transition of selected functions into the indicated UHF regions.

The methodology employed for analysis of VHF frequency usage emphasized the identification of relationships between railroad operations and VHF communications support components. (As indicated in previous discussions, enroute and yard operations were described in terms of the flow of resources and materiel with the linkage of communications events related to the effectiveness of control and safety operations.) These procedures are necessary to quantify the functional requirements and specific utility of the allocated spectrum for various priorities of command/control and safety elements. Such a definition of utilities and priorities in effective and safe operation of this major national transportation system is required, since the EM spectrum is a national resources with strong competition for allocations from government and private users. These analyses and the accompanying presentations contained in this Report identify these operational linkages, the large inventory of radio equipment, and the distribution of that equipment over the railroad systems of the United States.

Subsequent paragraphs summarize the conclusions regarding the VHF communications usage and requirements for U. S. railroads, based on the analyses and supporting data presented in the various sections of this report.

5.1 Communications Support Requirements

5.1.1 The VHF communications operations are fundamental and essential elements of railroad operations; fundamental to route and yard command/control, and equipment and personnel safety.

This relationship has been demonstrated through model exercises (for example, the yard resource exercises with the communications event histogram displays) and the communications and operations data collection tasks. These data and the similar enroute analyses have demonstrated the direct utilization of VHF radio in equipment movement control and inspection operations that directly affect safety and efficiency.

The communications availability displays are identified with such specific actions as: yardmaster task assignments to switch engines, movement control actions involving the yardmaster, locomotive engineer, and brakeman; and the absolute priority for the locomotive engineer-brakeman movement and car couple/uncouple types of coordination. With substitution of other communications modes (e.g., hand signals), increased damage and accident rates are to be expected because of the delays and/or message errors in train-train, wayside-train, and right-of-way crew-train communications. The alternative of drastic reductions in movement execution rates and the range of equipment or facility management to be compatible with any form of manual signalling or "wire" communications represents disastrous economic consequences to a primary national transportation resource and major labor union-industry contract problems. Within the past decade, recognition of the safety aspects of VHF radio for operating personnel has had primary recognition by union and management contract initiatives. The false and lost message potentials for the character of signal interference indicated by the compacted frequency assignments reduces link availability to an unacceptable level because of the increased link duty cycle per message. The cited accident potential accrues because of the reduced time windows in the communications-operations relationships resulting from normal open right-of-way speeds.

5.1.2 The VHF communication is not subordinate or peripheral to other yard or route signaling systems. Because of the obvious advantages in efficiency and safety, VHF radio has almost supplanted previous telephone (wire) and manual signal operations and equipments. The increased capability afforded by radio command/control has allowed the development of existing route and yard operational procedures during the past five to ten years. Yard operations and facility design (yard layout, trade capacities, switch engine requirements, operating and service personnel requirements and organization) have been based on the availability of current levels of communications support. As indicated previously, the communications capabilities afforded by current frequency assignments is therefore required if the current level of yard and train operations are to be retained. To implement other candidate modes considered for substitution of all or part of the existing communications, would result in an operational service degradation described previously. This includes reduced speeds in the yards and enroute, greatly increased times for inspection and equipment service, reduced utility for expensive yard engines and operating personnel, and significant increases in support personnel. These impacts were generally discussed in the analysis of communications availability and capability data derived from the model exercises.

5.1.3. Measurements indicate that railroad VHF operations employ generally good operating procedures that enhance spectrum usage efficiency. The usage data derived from the Barstow and Chicago area measurements indicate the quality and character of individual channel usage, and also to support the validation of the model predictions. The minor changes in model organization and input data because of these measurements were described previously in this report. With these adjustments, the model predictions correlated very satisfactorily with the measured data.

The measurements also indicated that a satisfactory discipline is maintained in the usage of the channels. Although the railroad industry has no controlled vocabulary as is utilized by many communications operations (military tactical units), no significant "wasted verbage" was noted in the channel monitoring. This factor is important in weighing the importance of the model derived and measured message rate and channel usage statistics.

5.1.4. Short term channel access is required for equipment movement control. The previous model exercises, which output channel delay in relation to reduced frequency assignments for yard and enroute equipment movement control and coordination, have demonstrated the operational compromises in efficiency and safety for various levels of access delay. An exponential access delay growth in relation to reduction in channel assignments is indicated for a constant level of facility/equipment operation. As anticipated, the rapid increases in delay rates for the yard equipment control operations relative to enroute train control demonstrates the larger sensitivity of the yard functions.

These short-term access criteria have obvious high sensitivity for moving equipment because of the control and safety considerations. For other source functions (inspection, local repair coordination), the efficiency and related operations cost effects predominate.

5.1.5 Current VHF allocations are adequate for new technology application requirements. The operations of the Railroad Radio Service are concentrated in 1.3 MHz of spectrum space at VHF. While railroad radio communications grew in a quantum fashion during the 1960's and early 1970's, no new spectrum was requested. Instead, over the years the railroads maximized use of the available spectrum through channel splitting. Indications are that voice communications on the railroads have, in general, "peaked out." New technology, e.g., the use of digital system is likely to be used increasingly in the railroads. With good spectrum management practice, such new technology can be introduced into railroad communications utilizing the presently allocated VHF frequencies. Foreseeable growth in railroad communications will not require added radio frequency spectrum if the channel complement, including those in Footnote 287, is retained.

The expected additional services for VHF channel support are discussed in Section 3.4 of this report. These include analog voice and digital data combinations between yard engines and route trains and control locations; and digital data exchange between trains and track and wayside sensors for routine transfer and alert or alarm purposes. Micro- and mini-processor direct interface is anticipated where a limited application of time multiplexing (analog voice + time series of data segments) may be required, particularly for remote sensor data transfer.

Data rate requirements have been indicated to extend to a maximum of 1 kBPS to 2 kBPS range, with most services accommodated in the 100 BPS to 500 BPS range. These requirements are readily accommodated with FSK modulation and the previously indicated time multiplexing within the current VHF channel width. Time multiplexing with data sequences following voice represents the easiest procedure for control (normal push-to-talk procedure), and is readily accommodated with the time spacing on even the channels with highest usage (switch engines, maintenance, and train service). Data-under-voice or other similar multiplexing techniques represent unnecessary costs and functional complexities, and would generally provide a system data error rate larger than the voice-data time multiplex method.

The analyses and related data regarding railroad VHF usage and the evaluations of the utility of reallocation options and the different operational modes, provide basic quantification regarding the necessities for support of train operation control functions and general efficiency of assigned spectrum usage as well as the economic and probable effectiveness degradation resulting from the proposed FCC adjustments within the Land Mobile allocations. As indicated previously, this evaluation of the requirements for allocation of such a critical national resource must relate to critical aspects of usage; in this case, sets of command/control and safety criteria.

The analyses and other data presented have demonstrated the primary role of VHF communications to the efficiency and safety of various railroad operations. The reduced availability evaluations have also indicated, with high confidence, the unacceptable compromise in communications capability and the directly identifiable operational safety and effectiveness. These analyses demonstrate the severe implications in railroad operations and economics, if even a major segment of the thirty three VHF assignments were withdrawn.

These data capabilities can be implemented as added functional modules to the existing transmitter and receiver equipments. No modifications to existing equipments are required; only additional data modules with signal and control cabling are necessary.

5.1.6 The Canadian/United States border agreement (Line A) presents some constraints in frequency reassignments. The problems in VHF frequency reassignment with reduced allocations indicated in previous sections of this report are to some degree impacted by this agreement because of the limitations on the usage of tertiary frequencies in the northern United States railroads. Because of the low density railroad trackage in this area of the United States, however, any renegotiation of this agreement to partially or wholly relieve this restriction would not in any useful manner relieve the problems in reassignment with a reduced allocation (removal of Footnote 287).

5.2 Performance and Cost Reallocation Penalties

5.2.1 A major investment and inventory exists; reallocation represents extreme cost and operational penalties.

The VHF service investment over about three decades by the railroad industry to a current level of about $200,000,000 is indicative of the importance of this function to operations. Reallocation of selected functions to UHF spectral regions represents an investment of nearly equal magnitude, considering direct equipment exchange and the additional relay systems required to achieve a nearly equal support capability. These additional relays are necessary because of composite media characteristic differences between the VHF and considered UHF regions as discussed in Section 5.2 of this report.

As discussed previously in this report, a major expansion in relay complement in yards and route areas is required to provide area coverage and availability equivalent to the existing VHF operations. The more severe engineering problems and relay density requirement concern the routes in the two national mountain ranges and the numerous urban yards. The expanded relay configurations in urban areas also imply increased UHF channel assignments to assure acceptable interference criteria.

Dividing the Railroad Radio Service into VHF and UHF components presents serious operational safety and system management or control problems. Since the communications equipments are used directly by operating and "field" crews, the problems in channel coordination and associated message transfer delays and errors (improper call actions) represent serious safety and command/control implications. If the UHF railroad assignments were in the urban port areas, a severe cost penalty would still be evident. This accrues because of the large mobile equipment utilization by the major railroads in urban yard areas.

5.3 Shared Service Potential

5.3.1 Urban/port railroad operations utilize all available channels.

The frequency assignments, as displayed for major U. S. coastal ports and the St. Louis area, indicate that nearly all railroad channels are assigned. Unassigned channels (numbers of 1 to 3 indicated) represent a severely limited potential for sharing with another user service. Since these are also not adjacent channels, the bandwidth constrains operations to voice, analog data, or low rate digital modes.

The potential for extending to a few additional channels in these areas through a well planned exercise of the frequency management software is discussed in the Recommendations Section (Section 6.0) of this report. Such an exercise would indicate a very limited reduction of channel requirement, probably 1 to 3 in New York, Los Angeles, and Houston. This prediction is indicated by geography and traffic density considerations. Even a temporary reassignment to another service is not advisable; however, since operational expansion by railroad services would be severely restricted.

Increased operational impacts occur because of the necessities for additional channels to serve the added relays, and the status monitoring and procedural control necessary if mobile or portable relays are employed for yard operations (ref. Section 5.2). The reassignment exercises for the challenged thirty three channels demonstrated the degree of difficulty to be encountered in satisfying service requirements with the remaining VHF channels. Even with all required iterations to test the potentially valid situations, the probability of successfully reassigning 25% of the affected services is nil. Reducing the distance constraint or the two channel separation criteria are impractical because of interference problems. This reassignment difficulty is obvious for train service functions because of the large geographic areas associated with individual licenses, and the consequent inter-actions that severely restrict the potential for reassignment. These inter-actions include competing railroads in near proximity and intra-system right-of-way and yard area interface.

5.3.2 Proposals for even limited sharing of VHF channels between the Railroad Radio Service and the Maritime Mobile Service presents intractable problems in major port areas.

Shared service on specific VHF channels between maritime and railroad operations in major port areas presents problems in management to assure no degradation in control capabilities and safety. The latter is particularly important for railroads as demonstrated through previous comments regarding critical communications access for movement control. Since yard areas and docking operations are in close proximity, no advantages are realized by physical separation. Switching operations near dock areas and the attendant critical communications access requirements would severely constrain the channel utility to any second user. Other channels in nearby yard areas are few in number and generally have moderately high activity (e.g., inspection, maintenance) and, therefore, provide limited utility for sharing.

6.0 RECOMMENDATIONS

This section summarizes specific actions that are considered necessary based upon review of the analyzed data and supporting information. The primary thrust of these recommendations concerns the efficiency of spectrum usage and the associated management facilities for the railroad industry, and the implication of the analyses described herein relative to the issues involved in the U. S. preparation for the 1979 WARC. These recommendations, in addition to the comments concerning the proposed allocation actions, cite specific technical considerations and management actions for the railroad industry oriented toward maximizing spectrum usage effectiveness and operations support capabilities. Effective management requires coordination between railroad organizations through the mechanics afforded by the AAR, and between the AAR and the U. S. Department of Transportation (DoT) and the FCC. This cooperative relationship would have procedural similarities to the maritime and airline industries coordination with the DoT and FCC.

These recommendations with comments regarding utility are presented.

1. The proposed reduced allocation or reallocation actions should be opposed.

This technical report should be the basis for the DoT expressions to the FCC and OTP, citing the operations requirements, spectrum usage, and cost impacts to the railroad industry for reduced VHF allocation, or UHF reallocation actions. Based on this utilization information, the DoT should recommend and support negative decision by FCC for the proposed Land Mobile channel allocation actions. The serious negative ramifications in efficiency and safety for all elements of the railroad industry has been indicated herein.

Additional information requirements regarding equipment deployments, investment and operational communications functional relationships for specific areas to support particular queries from WARC Task Groups can be provided by DoT through exercise of the data files and associated analysis routines developed for this program.

2. The railroad industry should implement and utilize the software information system developed for this program as the primary support for frequency management.

The software data programs developed to evaluate reassignment potential should be utilized by the AAR to support future assignment requirements, and to examine the possibilities for improving the utilization efficiency in high density urban areas. These programs can be installed on the multiprocessor facility available to AAR.

Maintenance of the data files for licenses, locations, and applications is obviously required. Data base coordination must also be effected with FCC and DoT to provide a common base for analysis in response to utilization and proposed reassignment queries. Data base maintenance includes the periodic updating and purging of active license files and proposed assignments.

This software system will afford the necessary analysis capability for AAR to effectively manage spectrum utilization, provide quantitative examination of proposed actions with regard to communications capability, and support the development of technical and operational specifications and regulations to minimize interference potential and maximize utilization effectiveness. The data files should also be extended to include UHF and microwave systems, since the same management and usage evaluation requirements prevail through the entire spectrum. Basic file structures would be identical with those developed for this VHF investigation; additional access keys and parameter thresholds must be incorporated that are appropriate for other system operations.

3. The AAR should review high density urban areas to maximize utilization.

The Chicago, St. Louis, New York, Boston, and Los Angeles areas should be examined using the software processing system regarding usage efficiency, and possible local assignment adjustments to remove interference situations. Restricted share service operations in functions not associated to equipment movement control or coordination (e.g., inspection, security, administration) should be examined to maximize channel utilization. This is important with regard to any future additional equipment control requirements in these urban areas.

4. Maintain strict operational management in communications operations.

The limited monitoring effort accomplished for this program indicated no improper use of VHF communications. The industry should periodically review operating rules and possibly establish occasional local monitoring exercises to assure a minimal misuse of all communications systems.

5. Minimize channel requirements for digital operations through signal formating and protocol.

The previous discussions regarding multiplexed digital and analog data operations have indicated the compatibility of time multiplexed techniques with the existing channel bandwidth. As discussed, the time multiplex mode has significant advantages over other simultaneous mixing methods in data transfer reliability, reduced signal level sensitivity, and interface compatibility with existing receiver and transmitter equipment.

Procedural control will have increased importance with digital operations to reduce to an absolute minimum the data error and "incorrect message" probabilities with digital modes. The usage control and aural and visual channel availability indicators discussed should be incorporated to minimize these error and delay problems. This requirement is obviously particularly critical for equipment movement control functions.

6. Limited port area reassignments be implemented if necessary to allow temporary service to other users.

With the previously recommended examination of high density usage areas, a small number of channels (approximately 1 to 3) should be available for temporary use by other services. If this would have high value for other operations (e.g., port maritime, local land transportation), a small number of channels could probably be temporarily released. The number and specific channels would as previously indicated be identified through exercise of the data processing software to quantify interference potential and temporary reassignments to assure acceptable operations. Only channels not utilized for equipment movement control should be considered. As mentioned previously, this action should only be considered for emergency situations because of the restrictions in extended service potential for railroad operations. The extremely limited capability provided to maritime or other users indicates the questionable economics associated with such sharing actions.

7. A general recommendation: Include radio communications functions in the resource planning activities of the railroad industry.

Since communications are integrated into operations to the depth demonstrated in these analyses, planning for communications requirements should be included in the design of operational facilities such as yard and track areas. Communication resources and modes of employment would then be identified with elemental operations, allowing for quantification of priorities in communications support functions and channel usage.

Such resource planning would utilize the data system of AAR for environment predictions to support assignment decisions, and provide basic guidance for decisions regarding fixed site (relays and passive reinforcement devices) equipments in high density regions. Significant enhancements would also be evident in the cost effectiveness of communications over a facility life cycle (development through operations phases). Through such planning, integrated communications requirements would be coupled directly to facility or equipment operations, allowing trade-off in procedures, siting, and equipment inventory to achieve specified ranges of performance criteria.

7.0. ACKNOWLEDGEMENTS

This research study was sponsored by the Federal Railroad Administration. The need for detailed information regarding the availabity and operational utility of radio channel spectrum to preserve and further enhance efficiency and safety was the prime motivation of this effort. Additional focus was provided by the deliberations of the membership of FRA's Railroad Operating Rules Advisory Committee. This committee's concern about an apparent need for additional channel spectrum to guard against safety-related degradation and the need to make known to the Federal Communications Commission (FCC) the ongoing requirements of the rail industry so that these needs would not be overlooked in the FCC's rationalization of frequency spectrum allocation was expressed in resolution to FRA requesting FRA to become involved. The committee membership included select representatives from rail transportation labor and management and state regulatory commissions.

Significant contribution by the membership of the Communications Liaison Committee of the Association of American Railroads was fundamental to the success of this program. The committee, composed of chief communications officers of major railroads, coordinated the input with their counterparts throughout the industry. Specifically, this committee reviewed operational descriptions and provided the data regarding investment and frequency assignments, and the capability analysis. These contributions assured validity of the discussion and analyses relative to railroad requirements and capabilities of VHF communications support. It was through this committee that the communications usage monitoring and measurement at the Barstow, California, classification facility and at other locations was made possible.

The Railway Progress Institute provided the introductions to the technical persons within the communications equipment manufacturing industry. Their input was of considerable importance.

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APPENDIX A - VHF COMMUNICATIONS SAFETY RELATIONSHIPS

Each year, in the operation of trains and support equipment, many conditions of peril to the safety of property and life occur. Many of these conditions are corrected through timely communications, and serious accidents are avoided. Others go undetected or are improperly reported, with a resultant heavy loss in property damage and loss of personnel through injury or death.

The VHF mobile radio, used by the railroads for routine operational message transfer, provides a key link in this vitally needed emergency communication. There are several reasons why VHF mobile radio can provide a communications need that is not available in any other form. These reasons are:

1. The fastest and surest way to contact the locomotive engineer, the person most able to provide corrective response in most emergency situations, is via the clear channel set in the engine cab. Many accidents can be avoided by an early warning of hazardous conditions or through a stoppage of train movement during malfunction conditions.

2. The fact that radios are used to some extent by all facets of railroad operations provides a readily available means for reporting of hazard conditions or potentially dangerous operations.

3. A natural extension of the railroad radio for reporting emergencies are the public and private radio systems and the telephone.

Many hazardous conditions have been corrected through reporting by radio and the damaging potential of accidents have been reduced through similar action. Numerous accounts of the use of mobile radio in emergency and accident situations are contained in industry files. The following paragraphs present examples of the several general categories of accident situations and cite actual recorded accounts of corrective action taken in these cases*:

*The reason for citing these cases is to impart the general conditions of occurrence and the resultant corrective actions. A detailed accounting of each incident is not intended.

1. Train Equipment Malfunctions - This category includes the "hot-box," loose cars, dragging apparatus, and derailed cars.

   a) Atchison, Topeka, and Santa Fe Railway

   "On the Southern Division in 1971, Second District, an extra west had headed into the siding at Landes to meet Train 400, an eastbound freight train. The extra west was moving slowly in siding when train went into emergency. The engineman observed Train 400 approaching on main track at maximum speed; he immediately notified Train 400 by radio that he had an emergency application and may be derailed, fouling main track. The engineman on Train 400 immediately applied brakes and train stopped only a few car lengths short of a derailed car from train on siding that was fouling the main track and had not affected block signals on the main track. Derailment was caused by a broken rail on siding. The use of radio in this case saved a collision and possibly lives."

   b) Louisville and Nashville Railroad

   "On March 16, 1976, trainmaster observed rear engine of S-141 train derailed. He called the engineer on the radio and got the train stopped, thus preventing other engines and cars from derailing."

2. Improper Train Movements - This category includes trains moving toward each other on the same track, one train overtaking another, and trains approaching a work crew.

   a) Chicago, Rock Island, and Pacific Railroad

   "Our sperry rail change-out gang started work at White City, Kansas at 7:30 am on our westbound track, after removing the

track from service. This gang consists of 1 burro crane, 1 electromatic jr. tamper, 1 hy-rail truck and has 6 men plus a foreman, 2 operators, and an asst. roadmaster for a total of 10 men. The crane, tamper, and truck started from White City and the asst. roadmaster went to the shop at Herington to secure some needed parts for the gang. While on his way to the shop, he picked up a radio conversation between the Herington relay office and a westbound train. Mr. Wixon asked the engineer of the train which track he was using and when told that he was using the westbound main, Mr. Wixon took steps to stop the train movement. Without the radio, we could have lost 9 men, 1 burro crane (valued at $171,000), an electromatic tamper (valued at $97,000), a hyrail vehicle (valued at $8,141). Even though this was a man failure, it would have been a costly accident."

b) Louisville and Nashville Railroad

"4/17/76, L.B. light engines southward, run red signal at Perth south meeting, northward train, north of Bourne North. Dispatcher at Latonia called northward train by radio, stopping same and getting them to back up before getting southward train to stop, possibly preventing head-on collision."

3. Track Disruptions - Including loose rails, torn-up tracks and wash-outs.

a) Union Pacific Railroad Company

"On May 1st at approximately 12:25 pm, a woman called the agent at Kimball to report rail raised in the air. Inspection developed that continous welded rail had been removed and was laying between east and west main tracks at MP 446.25 to MP

448.70. Evidently, the rail expanded from the sun's heat and raised from the ground and moved in a manner to foul the eastward main track with the possibility of swinging to the westward track. Rail on the north side of the westward track was reacting in the same manner. The report was phoned to the dispatcher and the dispatcher used radio to inform the train engineer to stop a train approaching that area."

b) Atchison, Topeka, and Santa Fe Railway

"April 16, 1976, an off-duty signal maintainer observed our main line being fouled and knocked out of line by a contractor's bulldozer. He contacted the dispatcher on the code phone, who relayed the information to an operator, and he contacted the train which got stopped before it reached the location."

4. Obstructions on Track - Such as stalled vehicles, debris, and livestock.

a) Atchison, Topeka, and Santa Fe Railway

"May 23, 1975, a section foreman observed an automobile setting on the main track at a private crossing with two flat tires. The section foreman contacted the operator by radio and informed him of the situation. An engineer on one of our trains overheard the radio transmission and stopped his train clear of the automobile. The operator contacted other trains in the vicinity and they were stopped until the automobile was pulled clear of the main track."

b) Atchison, Topeka, and Santa Fe Railway

"March 15, 1976, a Yellow Freight Lines tractor and trailer fouled both main tracks at MP 73.2. A radio conversation was

used to stop 963-F-3 and westward trains before they reached the location of the wreckage."

5. Personal Injury and Illness

a) Union Pacific Railroad

"At 4:05 am, April 3, 1976, at Kansas City, Kansas, a diesel unit 326, with 30 cars, moving 5 mph when brake platform on which switchman N.J. Henrich was standing gave away, causing him to fall between moving cars. During his fall, his right elbow caught between the car and pin lift, dragging him with move, and with his right hand he was able to press slim-line walkie-talkie radio button, requesting engineer to stop movement, while using his left hand to push himself away from drawbar trying to get clear."

b) The Denver and Rio Grande Western Railroad Company

"On April 21, 1975, Mr. H.V. Meek, System Roadmaster was traveling by Hy-Rail vehicle Westward from Gilluly siding. He apparently experienced discomfort and called another supervisor by radio to meet him at Detour.

In the meantime, Mr. Meek's discomfort increased and he called the train dispatcher by radio to have an ambulance sent from Provo. At this time, he was on rails about 35 miles from Provo.

Within six minutes the second supervisor arrived and found that Mr. Meek was apparently experiencing a heart attack. He set the Hy-Rail vehicle off the rails and proceeded by highway to meet the ambulance already en route.

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In the meantime, Mr. Meek's discomfort increased and he called the train dispatcher by radio to have an ambulance sent from Provo. At this time, he was on rails about 35 miles from Provo.

Within six minutes the second supervisor arrived and found that Mr. Meek was apparently experiencing a heart attack. He set the Hy-Rail vehicle off the rails and proceeded by highway to meet the ambulance already en route.

The diagnosis at the hospital indicated that Mr. Meek had experienced a massive heart attack. It is likely that had he not had radio equipment with which he could promptly summon assistance that his survival would have been jeopardized."

It becomes apparent from a review of these incidents and other similar accounts that, in many cases, after observation of a hazardous condition, only through an immediate contact with the train engineer can an accident be prevented or that the damaging potential be reduced. Also, frequently because of the size and makeup of a train, malfunctions occur that go unobserved by the train crew. Again, only through a direct and timely communication between the observer along the track and a crew member can timely corrective actions be taken.

APPENDIX B - CHANNEL REASSIGNMENT EVALUATION

This appendix contains the results of initial testing to determine the eligibility of reassigning challenged licenses to unchallenged frequencies. A description of the data files and evaluation programs is found in Section 3.2.2.2 of the main report. Comments and analyses of these data are also given in that section.

These data are displayed in matrix form. The column headings identify the subgroups by railroad and size (number of licenses issued to the railroad at the given channel). The row headings identify the unchallenged channels. A number at the row-column intersection indicates that the subgroup is eligible for reassignment to the specified channel. A subgroup may be eligible for reassignment to more than one channel.

The three tables (B-1, B-2, and B-3) contain the train service subgroups by channel, the general service subgroups by channel, and the train service subgroups ranked in order of assignable unchallenged channels, respectively.

Table B-1. Train Service Reassignment Eligibility

Channel 14 - 160.620 MHz

thru

Channel 26 - 160.980 MHz

and

Channel 42 - 161.460 MHz

thru

Channel 46 - 161.610 MHz

FREQUENCY- 161.625 MHZ. CHANNEL 14

	CIRR	GWR	LV	MEC	SLSF	SOO	URP	KP
	2	7	3	7	8	2	8	9
01T	2			7				
01	2			7				
02T	2			7				
02	2			7	8			
03T				7	8			
03				7	8	2	8	
04T				7				
04	2			7				
05T	2			7				
05	2			7				
06T				7				
06		7		7				
07T		7		7				
07	2	7		7				
08T	2	7						
08	2	7			8			8
09T	2	7						
09	2			7				
10T	2			7				
10	2		3	7				8
11T	2							
11	2							
12T	2							
12	2	7			8			8
13T								8
13							8	
14T				7			8	
27T	2	7		7	8	2		8
27	2			7	8			
28T					8			
28					8			
29T					8			
29	2			7	8			8
30T				7	8			8
30				7	8			8
31T				7				
31	2			7		2		
32T	2							
32	2							8
33T	2							
33	2	7			8			
34T	2	7			8			
34	2	7			8			
35T		7						
35								
36T								
36				7	8			
37T				7				
37				7				
38T	2			7				
38	2			7				
39T				7				
39								
40T								
40								
41T								
41	2						8	
42T	2			7			8	8

FREQUENCY- 160.635 MHZ. CHANNEL 15T

	MKT
	1
01T	1
01	1
02T	1
02	1
03T	1
03	1
04T	1
04	1
05T	1
05	1
06T	1
06	1
07T	1
07	1
08T	1
08	1
09T	1
09	1
10T	1
10	1
11T	1
11	1
12T	1
12	1
13T	1
13	1
14T	1
27T	1
27	1
28T	1
28	1
29T	1
29	1
30T	1
30	1
31T	1
31	1
32T	1
32	1
33T	1
33	1
34T	1
34	1
35T	1
35	1
36T	1
36	1
37T	1
37	1
38T	1
38	1
39T	1
39	1
40T	1
40	1
41T	1
41	1
42T	1

FREQUENCY- 160.650 MHZ. CHANNEL 15

	*	AMTK	ATSF	BN	EC	DH	DMIR	DS	FEC	ICG	LEF	LNW	SOU	SP
	*	1	327	216	2	1	5	4	18	1	3	2	78	3
01T	*	1								1		2		3
01	*	1								1		2		3
02T	*	1								1				
02	*	1					5			1	3			
03T	*	1					5			1				
03	*	1					5			1				
04T	*	1								1				
04	*	1						4	18	1				3
05T	*	1								1				
05	*	1								1				
06T	*	1								1	3			
06	*	1				1	5			1	3	2		
07T	*	1				1	5			1	3			
07	*	1				1	5			1	3			
08T	*	1					5	4		1	3			
08	*	1			2		5	4		1	3	2		3
09T	*	1					5	4		1	3			3
09	*	1					5	4	18	1	3			3
10T	*	1					5	4	18	1	3			
10	*	1					5	4	18	1	3	2		
11T	*	1					5			1				
11	*	1					5			1				
12T	*	1					5			1				
12	*	1				1	5	4		1	3	2		
13T	*	1								1	3	2		
13	*	1								1	3	2		
14T	*	1								1	3	2		
27T	*	1			2		5	4		1		2		3
27	*	1					5	4		1		2		3
28T	*	1					5			1		2		3
28	*	1					5			1	3	2		3
29T	*	1					5			1		2		3
29	*	1					5			1		2		3
30T	*	1								1		2		
30	*	1								1	3	2		
31T	*	1								1	3	2		
31	*	1					5	4	18	1	3	2		
32T	*	1								1		2		
32	*	1								1		2		3
33T	*	1								1		2		3
33	*	1			2					1	3	2		3
34T	*	1								1		2		3
34	*	1								1		2		3
35T	*	1					5			1				
35	*	1					5	4	18	1	3			
36T	*	1							18	1	3			
36	*	1				1			18	1	3			3
37T	*	1				1			13	1		2		
37	*	1			2	1	5	4	19	1		2		
38T	*	1			2					1		2		
38	*	1								1	3	2		3
39T	*	1								1	3	2		
39	*	1				1	5	4		1	3	2		
40T	*	1					5	4		1				
40	*	1								1				
41T	*	1								1				
41	*	1			2					1	3	2		
42T	*	1			2		5	4		1	3	2		

(ATSF, BN and SOU columns marked with vertical arrows from 01T to 42T.)

FREQUENCY- 160.665 MHZ. CHANNEL 16T

	*	BN
	*	2
01T	*	2
01	*	2
02T	*	
02	*	
03T	*	
03	*	2
04T	*	
04	*	
05T	*	
05	*	2
06T	*	2
06	*	2
07T	*	
07	*	
08T	*	
08	*	
09T	*	
09	*	
10T	*	
10	*	
11T	*	
11	*	2
12T	*	
12	*	
13T	*	
13	*	
14T	*	
27T	*	
27	*	
28T	*	
28	*	2
29T	*	
29	*	
30T	*	
30	*	
31T	*	
31	*	
32T	*	
32	*	
33T	*	
33	*	2
34T	*	2
34	*	2
35T	*	
35	*	
36T	*	
36	*	2
37T	*	
37	*	
38T	*	
38	*	2
39T	*	
39	*	
40T	*	
40	*	
41T	*	
41	*	
42T	*	

FREQUENCY- 166.660 MHZ. CHANNEL 16				
	GBW	LN	LOAM	SN
	6	13	2	3
01T	6		2	
01	6		2	
02T				
02				
03T				
03	6			
04T	6			
04	6			
05T	6			
05	6			
06T	6			
06	6		2	
07T	6			
07	6			
08T	6			
08			2	
09T				
09				
10T	6			
10	6		2	
11T	6		2	
11	6		2	
12T	6		2	
12	6		2	3
13T	6		2	3
13	6		2	
14T	6		2	
27T	6		2	3
27	6		2	3
28T	6		2	3
28	6		2	3
29T			2	3
29			2	3
30T			2	
30			2	
31T			2	
31	6		2	
32T	6		2	
32	6		2	3
33T	6			3
33	6			3
34T	6			
34	6		2	
35T				
35				
36T				
36	6			
37T	6			
37	6		2	
38T	6		2	
38	6		2	
39T			2	
39			2	3
40T			2	
40	6		2	
41T	6		2	
41	6		2	
42T	6		2	

FREQUENCY- 166.595 MHZ. CHANNEL 17T					
	BRC	MK	PENE	SLSF	SFN
	2	5	2	4	5
01T		5			
01		5			
02T					
02					
03T					
03	2	5	2		
04T					
04					
05T					
05		5			
06T					
06			2		5
07T			2		
07		5	2		
08T		5			
08		5			5
09T		5			
09		5			
10T		5			
10		5			5
11T					5
11					5
12T					5
12		5			5
13T		5			5
13		5			5
14T		5			5
27T	2	5			5
27		5			5
28T		5	2		5
28		5	2		5
29T					5
29					5
30T					5
30					5
31T					5
31	2	5			5
32T		5			5
32		5			5
33T		5			5
33					5
34T					5
34					5
35T		5			
35		5			
36T		5			
36		5	2		5
37T		5			5
37		5			5
38T		5			5
38		5	2		5
39T		5	2		5
39		5	2		5
40T					5
40					5
41T					
41		5			
42T		5			

FREQUENCY- 162.710 MHZ. CHANNEL 17

	*	BML	PC	SCL	SLSF	TS	VTS
	*	3	4	1	3	5	3
01T	*	3	4	1			
01	*	3	4	1			
02T	*	3	4	1			
02	*	3	4	1	3		
03T	*	3	4	1	3		
03	*	3	4	1	3		
04T	*	3	4	1			
04	*	3	4	1			
05T	*	3	4	1			
05	*	3	4	1	3		
06T	*	3	4	1			3
06	*	3	4	1			3
07T	*	3	4	1			3
07	*	3	4	1			3
08T	*		4	1			
08	*		4	1	3		
09T	*		4	1			
09	*	3	4	1			
10T	*	3	4	1			
10	*	3	4	1	3		
11T	*		4	1	3		
11	*		4	1	3		
12T	*		4	1	3		
12	*	3	4	1	3	5	3
13T	*	3	4	1			
13	*	3	4	1			
14T	*	3	4	1			
27T	*	3	4	1	3	5	
27	*	3	4	1	3	5	
28T	*	3	4	1	3	5	
28	*	3	4	1	3	5	
29T	*	3	4	1	3	5	
29	*	3	4	1	3	5	
30T	*	3	4	1	3		
30	*	3	4	1	3		
31T	*	3	4	1			
31	*	3	4	1			
32T	*	3	4	1			
32	*	3	4	1			
33T	*	3	4	1			
33	*	3	4	1	3		
34T	*	3	4	1	3		
34	*	3	4	1	3		
35T	*		4	1	3		
35	*		4	1	3		
36T	*		4	1	3		
36	*	3	4	1	3		3
37T	*	3	4	1			3
37	*	3	4	1			3
38T	*	3	4	1			3
38	*	3	4	1	3		3
39T	*	3	4	1			3
39	*		4	1			3
40T	*		4	1			
40	*		4	1			
41T	*	3	4	1			
41	*	3	4	1			
42T	*	3	4	1			

FREQUENCY- 162.725 MHZ. CHANNEL 18T

	*	LI	SLSF
	*	7	4
01T	*		
01	*		
02T	*		
02	*		
03T	*		
03	*		
04T	*		
04	*		
05T	*		
05	*		
06T	*		
06	*		
07T	*		
07	*		
08T	*		
08	*		
09T	*		
09	*		
10T	*		
10	*	7	
11T	*		
11	*		
12T	*		
12	*		
13T	*		
13	*		
14T	*		
27T	*		
27	*		
28T	*		
28	*		
29T	*		
29	*		
30T	*		
30	*		
31T	*		
31	*		
32T	*		
32	*		
33T	*		
33	*		
34T	*		
34	*		
35T	*		
35	*		
36T	*		
36	*		
37T	*		
37	*		
38T	*		
38	*		
39T	*		
39	*		
40T	*		
40	*		
41T	*		
41	*		
42T	*		

FREQUENCY- 160.740 MHZ. CHANNEL 13

	AMTK	ATSF	CSP	DFGN	KCS	LA	MRS	PS	SI	SP	UP
*	1	1	2	1	36	25	4	1	8	2	196
01T	1		2	1					8	2	
01	1		2	1					8	2	
02T	1			1					8	2	
02	1			1					8	2	
03T	1			1						2	
03	1			1				1		2	
04T	1			1						2	
04	1		2							2	
05T	1		2							2	
05	1		2						8	2	
06T	1		2	1					8	2	
06	1		2	1					8	2	
07T	1		2	1					8	2	
07	1		2	1					8	2	
08T	1		2	1					8	2	
08	1		2	1						2	
09T	1		2	1						2	
09	1		2	1						2	
10T	1		2	1						2	
10	1	1	2	1		25			8	2	
11T	1		2	1					8	2	
11	1		2	1					8	2	
12T	1			1						2	
12	1			1						2	
13T	1			1						2	
13	1		2	1				1		2	
14T	1		2	1				1		2	
27T	1	1	2	1		25				2	
27	1		2	1		25				2	
28T	1		2	1						2	
28	1		2	1						2	
29T	1		2	1					8	2	
29	1		2	1					8	2	
30T	1			1						2	
30	1			1						2	
31T	1			1						2	
31	1		2	1					8	2	
32T	1			1						2	
32	1			1						2	
33T	1			1						2	
33	1		2	1					8	2	
34T	1		2	1					8	2	
34	1			1					8	2	
35T	1			1						2	
35	1			1			4			2	
36T	1			1						2	
36	1		2	1					8	2	
37T	1		2	1					8	2	
37	1		2	1					8	2	
38T	1		2	1						2	
36	1		2	1						2	
39T	1		2							2	
39	1		2							2	
40T	1		2							2	
40	1		2	1					8	2	
41T	1		2	1					8	2	
41	1		2	1					8	2	
42T	1		2	1				1	8	2	

FREQUENCY- 16[illegible].77[illegible] MHZ. CHANNEL 15

*ACY	ADN	ALS	AMTK	ASAB	BN	GTW	LV	MILP	MTR	NS	PC	RI	SMV	SN	WIM	WP
* 8	4	7	1	3	7	2	5	94	3	3	2	2	1	3	3	7
01T *			1	3		2					2				3	
01 *			1	3		2					2				3	
02T *			1	3		2					2					
02 *	4		1	3	7	2					2	2	1			
03T *	4		1										1			
03 *	4		1						3				1			
04T *	4		1										1			
04 *	4		1	3								2	1		3	
05T *	4		1	3								2	1		3	
05 *	4		1	3								2	1		3	
06T *	4		1									2	1		3	
06 *	4		1		7							2	1		3	
07T *			1										1		3	
07 *			1	3									1		3	
08T *			1	3									1		3	
08 *			1	3	7							2	1			
09T *			1	3									1			
09 *			1	3									1			
10T *			1										1		3	
10 *	4		1		7	2					2		1		3	
11T *	4		1										1		3	
11 *	4		1	3									1		3	
12T *	4		1	3									1			
12 *	4		1	3	7							2	1	3		7
13T *	4		1										1	3		
13 *	4		1						3				1			
14T *	4		1						3				1			
27T *	4		1	3								2	1	3	3	
27 *	4		1	3								2	1	3		
28T *	4		1	3								2	1	3		7
28 *	4		1	3		2						2	1	3		7
29T *	4		1	3								2	1	3	3	7
29 *	4		1	3								2	1	3	3	7
30T *			1										1			
30 *			1										1			
31T *			1										1			
31 *	4		1	3	7								1		3	
32T *	4		1	3									1			
32 *	4		1	3										3		
33T *			1	3										3		
33 *			1	3								2		3	3	
34T *			1	3								2	1		3	
34 *	4		1	3								2	1			
35T *	4		1										1			
35 *	4	7	1										1			
36T *			1										1			
36 *			1			2					2	2	1		3	
37T *			1			2					2		1		3	
37 *	4		1		7	2				3	2		1		3	
38T *	4		1	3									1		3	
38 *	4		1	3								2	1		3	
39T *	4		1									2	1		3	
39 *	4		1									2	1	3	3	7
40T *			1												3	
40 *			1			2					2				3	
41T *			1												3	
41 *	4		1	3					3				1		3	
42T *	4		1	3					3				1		3	

FREQUENCY- 160.765 MHZ. CHANNEL 20T

	AMP	GA	ICG	LI	HA	HP
*	5	10	2	1	6	1
01T						
01						
02T						
02						
03T						
03						
04T						
04						
05T						
05						
06T						
06						
07T		10				
07		10				
08T						
08					6	
09T					6	
09	5	10			6	
10T	5	10			6	
10	5	10		1	6	
11T					6	
11					6	
12T					6	
12	5	10			6	1
13T						1
13						
14T						
27T					6	1
27					6	
28T						
28						
29T						
29	5					1
30T						
30						
31T						
31	5	10			6	
32T	5	10			6	
32	5	10			6	1
33T	5	10				
33	5	10				
34T						
34						
35T						
35						
36T						
36		10				
37T						
37						
38T						
38			2			
39T						
39						
40T						
40						
41T						
41						
42T						

FREQUENCY- 160.[illegible] MHZ. CHANNEL 2[illegible]

	AMTK	ATSF	CNJ	DMIF	DTI	MGA	PC	PRS	SLSF	SP	SSW
*	1	1	1	29	1	4	362	2	7	4	5
01T	1	1			1						
01	1	1			1						
02T	1	1			1						
02	1	1		29	1						
03T	1	1		29					7		
03	1	1		29		4			7		
04T	1	1							7		
04	1	1							7		
05T	1	1									
05	1	1									
06T	1	1									
06	1	1		29				2			
07T	1	1						2			
07	1	1									
08T	1	1									
08	1	1		29					7		5
09T	1	1		29							
09	1	1		29							
10T	1	1		29							
10	1	1	1	29	1						
11T	1	1									
11	1	1									
12T	1	1									
12	1	1		29					7		5
13T	1	1									
13	1	1				4					
14T	1	1				4					
27T	1	1						2		4	5
27	1	1						2		4	5
28T	1	1						2		4	
28	1	1		29	1			2	7	4	
29T	1	1		29					7		
29	1	1		29					7		5
30T	1	1									
30	1	1									
31T	1	1									
31	1	1		29							
32T	1	1									
32	1	1								4	
33T	1	1									
33	1	1									
34T	1	1									
34	1	1							7		5
35T	1	1									
35	1	1									
36T	1	1									
36	1	1			1			2			
37T	1	1			1						
37	1	1		29	1				7		
38T	1	1							7		
38	1	1									5
39T	1	1						2			5
39	1	1						2			5
40T	1	1						2			
40	1	1			1				7		
41T	1	1									
41	1	1				4					5
42T	1	1		[illegible]		4					5

FREQUENCY- 160.815 MHZ. CHANNEL 21T

	MP
	2
01T	
01	
02T	
02	
03T	
03	
04T	
04	
05T	
05	
06T	
06	
07T	
07	
08T	
08	
09T	
09	
10T	
10	
11T	
11	
12T	
12	
13T	
13	
14T	
27T	
27	
28T	
28	
29T	
29	
30T	
30	
31T	
31	
32T	
32	
33T	
33	
34T	
34	
35T	
35	2
36T	
36	
37T	
37	
38T	
38	
39T	
39	
40T	
40	
41T	
41	
42T	

FRECUENCY- 160.830 MHZ. CHANNEL 21

	BLE	ORGN	UTI	LI	SLSF	SOU	TS	WP
	24	18	9	23	3	29	5	7
01T								
01								
02T			9					
02								
03T								
03								
04T								
04								
05T								
05								
06T								
06								
07T								
07								
08T								
08		18						
09T								
09								
10T								
10			9	23				
11T								
11								
12T								
12		18					5	7
13T								
13	24							
14T	24							
27T		18					5	
27							5	
28T							5	7
28							5	7
29T							5	7
29							5	7
30T								
30								
31T								
31								
32T								
32								
33T								
33								
34T								
34								
35T								
35					3			
36T								
36			9					
37T								
37								
38T								
38								
39T								
39							5	7
40T								
40								
41T								
41	24							
42T	24							

FREQUENCY- 161.845 MHZ. CHANNEL 22T

	CO	MSV	PFR	P1	TRNA
	2	2	3	4	1
01T		2		4	
01		2		4	
02T		2		4	
02	2	2		4	
03T	2	2		4	
03		2		4	
04T		2			
04		2			
05T		2			
05	2	2		4	
06T		2		4	
06		2		4	
07T		2		4	
07		2		4	
08T		2			
08		2	3		
09T		2			
09		2			
10T		2		4	
10		2		4	
11T		2		4	
11	2	2		4	
12T	2	2		4	
12		2		4	
13T		2		4	
13		2		4	
14T		2		4	
27T			3	4	
27				4	
28T				4	
28		2		4	
29T		2		4	
29		2		4	
30T					
30					
31T					
31	2			4	
32T				4	
32				4	
33T					
33			3		
34T			3		
34	2	2		4	
35T		2		4	
35		2			1
36T					
36					
37T					
37	2	2	3	4	
38T	2	2	3	4	
38		2		4	
39T		2		4	
39		2		4	
40T		2		4	
40		2		4	
41T		2		4	
41		2	3	4	
42T		2	3	4	

FREQUENCY- 161.860 MHZ. CHANNEL 23

	CIFR	CRR	ICG	KGS	OCE
	2	15	33	2	3
01T	2	15		2	3
01	2			2	3
02T	2				3
02	2				3
03T					3
03					3
04T					
04	2	15			
05T	2				
05	2				
06T					
06				2	
07T					
07	2				3
08T	2				
08	2	15	33	2	
09T	2				
09	2				3
10T	2				3
10	2	15		2	3
11T	2	15	33	2	3
11	2	15	33	2	3
12T	2	15	33	2	3
12	2	15	33	2	
13T				2	
13				2	
14T				2	3
27T	2	15		2	3
27	2	15		2	3
28T				2	3
28			33	2	3
29T				2	3
29	2			2	3
30T				2	
30				2	
31T				2	
31	2			2	3
32T	2			2	3
32	2			2	3
33T	2			2	3
33	2			2	3
34T	2			2	3
34	2			2	3
35T					3
35					3
36T					3
36				2	3
37T					
37			33		
38T	2		33		
38	2		33	2	3
39T				2	3
39				2	3
40T				2	
40		15		2	
41T		15		2	
41	2	15	33	2	3
42T	2	15	33	2	3

FREQUENCY- 160.075 MHZ. CHANNEL 23T

	*BO	CW	MP
*	1	2	3
01T *		2	
01 *			
02T *			
02 *			
03T *			
03 *	1		
04T *			
04 *			
05T *			
05 *			
06T *		2	
06 *		2	
07T *			
07 *			
08T *			
08 *		2	
09T *			
09 *			
10T *			
10 *		2	
11T *		2	
11 *		2	
12T *		2	
12 *		2	
13T *		2	
13 *		2	
14T *		2	
27T *	1	2	
27 *		2	
28T *		2	
28 *		2	
29T *		2	
29 *		2	
30T *			
30 *			
31T *			
31 *	1		
32T *			
32 *		2	
33T *		2	
33 *		2	
34T *			
34 *			
35T *			
35 *			
36T *			
36 *		2	
37T *		2	
37 *		2	
38T *		2	
38 *		2	
39T *		2	
39 *		2	
40T *		2	
40 *			
41T *			
41 *			
42T *		2	

FREQUENCY- 16[illegible]50 MHZ. CHANNEL 23

	*BN	DS	CNN	CTS	ITC	KCS	LA	PC	PLE	PW	RI
*	1	3	153	1	1	1	1	1	13	1	1
01T *						1	1				1
01 *						1	1				1
02T *						1	1				
02 *	1					1	1				
03T *	1					1	1				
03 *	1					1	1			1	1
04T *						1	1			1	
04 *						1	1			1	
05T *						1	1				
05 *						1	1				1
06T *						1	1				1
06 *	1					1	1	1		1	1
07T *						1	1	1		1	
07 *						1	1	1		1	
08T *						1	1	1			
08 *	1					1	1	1			
09T *	1					1	1	1			
09 *	1					1	1	1		1	
10T *	1					1	1			1	
10 *	1			1		1	1			1	
11T *						1	1			1	
11 *						1	1			1	1
12T *						1	1				
12 *	1					1	1				
13T *						1	1				
13 *						1	1		13	1	
14T *						1	1		13	1	
27T *						1	1			1	
27 *						1	1			1	
28T *						1	1				
28 *	1					1	1	1			1
29T *	1					1	1				
29 *	1					1	1				
30T *						1	1				
30 *						1	1				
31T *						1	1				
31 *	1					1	1				
32T *						1	1				
32 *						1	1				
33T *						1	1				
33 *						1	1				1
34T *						1	1				1
34 *						1	1	1			1
35T *						1	1				
35 *					1	1	1				
36T *						1	1				
36 *				1		1	1			1	1
37T *		3				1	1			1	
37 *	1					1	1			1	
38T *						1	1			1	
38 *						1	1			1	1
39T *						1	1				
39 *						1	1				
40T *						1	1				
40 *						1	1				
41T *						1	1				
41 *						1	1		13		
42T *	1					1	1	1	13	1	

FREQUENCY- 160.905 MHZ. CHANNEL 24T

	NW	SCL	SLSF
*	2	5	3
01T		5	
01			
02T	2		
02	2		
03T	2		
03	2		
04T	2		
04	2	5	
05T	2		
05	2		
06T	2		
06	2		
07T			
07			
08T			
08			
09T			
09		5	
10T		5	
10	2	5	
11T		5	
11		5	
12T		5	
12	2	5	
13T			
13			
14T			
27T	2	5	
27	2	5	
28T	2		
28	2		
29T			
29			
30T			
30	2		
31T	2		
31	2		
32T			
32			
33T			
33	2	5	
34T	2		
34	2		
35T	2		
35	2		
36T	2		
36			
37T			
37			
38T			
38	2		
39T			
39			
40T			
40	2		
41T	2		
41	2		
42T	2	5	

FREQUENCY- 160.920 MHZ. CHANNEL 24

	ANTK	BAR	DFGW	DTS	ICG	SCL	SLC	SLSF	TENN	TS	TSE	UP
*	1	1	69	4	146	3	2	2	2	7	2	1
01T	1						2	2	2		2	1
01	1						2				2	1
02T	1						2				2	1
02	1	1					2				2	1
03T	1	1					2	2			2	1
03	1	1					2	2			2	1
04T	1	1					2	2			2	1
04	1	1				3	2	2	2		2	1
05T	1	1					2	2	2		2	1
05	1	1					2	2	2		2	1
06T	1	1					2	2			2	1
06	1	1					2	2			2	1
07T	1	1					2	2				1
07	1	1					2	2	2			1
08T	1						2	2				1
08	1		69				2	2			2	1
09T	1						2	2				1
09	1	1				3	2	2	2			1
10T	1	1				3	2	2	2			1
10	1	1		4		3	2	2	2		2	1
11T	1	1					2	2	2		2	1
11	1	1					2	2	2		2	1
12T	1	1					2	2	2		2	1
12	1	1	69				2	2	2	7	2	1
13T	1	1					2	2			2	1
13	1	1					2	2			2	1
14T	1	1					2	2			2	1
27T	1	1	69				2		2		2	1
27	1	1					2		2		2	1
28T	1	1					2		2	7	2	1
28	1	1					2	2	2	7	2	1
29T	1	1					2	2	2	7	2	1
29	1	1					2	2	2	7	2	1
30T	1	1					2		2		2	1
30	1	1					2				2	1
31T	1	1					2				2	1
31	1	1				3	2				2	1
32T	1	1					2		2		2	1
32	1	1					2		2		2	1
33T	1	1					2		2		2	1
33	1	1					2		2			1
34T	1	1					2					1
34	1	1					2	2				1
35T	1	1					2	2			2	1
35	1	1				3	2	2			2	1
36T	1	1				3	2				2	1
36	1	1		4		3	2		2		2	1
37T	1	1				3	2		2		2	1
37	1	1				3	2	2	2		2	1
38T	1	1					2	2	2		2	1
38	1	1					2	2	2		2	1
39T	1	1					2	2				1
39	1	1					2	2		7		1
40T	1	1					2	2				1
40	1	1					2	2	2		2	1
41T	1	1					2	2	2		2	1
41	1	1					2	2	2		2	1
42T	1	1					2	2	2		2	1

FREQUENCY- 160.935 MHZ. CHANNEL 25T

	*	AMTK	BO	CNJ	GTH	NH	RJG	WM
	*	1	70	15	3	1	34	21
01T	*	1			3	1		
01	*	1			3	1		
02T	*	1			3	1		
02	*	1			3	1		
03T	*	1			3	1		
03	*	1			3	1		
04T	*	1			3	1		
04	*	1			3	1		
05T	*	1				1		
05	*	1				1		
06T	*	1				1		
06	*	1			3	1		
07T	*	1			3	1		
07	*	1			3	1		
08T	*	1			3	1		
08	*	1			3	1		
09T	*	1			3	1		
09	*	1			3	1		
10T	*	1			3	1		
10	*	1			3	1		
11T	*	1			3	1		
11	*	1			3	1		
12T	*	1			3	1		
12	*	1			3	1		
13T	*	1			3	1		
13	*	1			3	1		
14T	*	1			3	1		
27T	*	1			3	1		
27	*	1			3	1		
28T	*	1				1		
28	*	1				1		
29T	*	1				1		
29	*	1				1		
30T	*	1				1		
30	*	1				1		
31T	*	1				1		
31	*	1				1		
32T	*	1				1		
32	*	1				1		
33T	*	1				1		
33	*	1				1		
34T	*	1				1		
34	*	1				1		
35T	*	1				1		
35	*	1				1		
36T	*	1				1		
36	*	1			3	1		
37T	*	1			3	1		
37	*	1			3	1		
38T	*	1			3	1		
38	*	1			3	1		
39T	*	1			3	1		
39	*	1			3	1		
40T	*	1				1		
40	*	1				1		
41T	*	1				1		
41	*	1				1		
42T	*	1			3	1		

FREQUENCY- 160.950 MHZ. CHANNEL 25

	AGS	AMTK	CG	CNTP	CH	GSF	GTH	ICG	KCS	KIT	LA	LSI	NS	SLSF	SOU	SP	WA
*	21	1	23	12	2	13	7	5	1	1	1	4	20	2	376	2	3
01T *		1			2						1			2		2	3
01 *		1									1			2			
02T *		1									1			2			
02 *		1									1	4		2			
03T *		1									1	4		2			
03 *		1								1	1	4		2			
04T *		1									1			2			
04 *		1				13					1			2			
05T *		1									1			2			
05 *		1									1	4		2			3
06T *		1			2						1	4		2			
06 *		1			2						1	4		2			
07T *		1									1	4		2			
07 *		1								1	1	4		2			3
08T *		1									1	4		2			3
08 *		1			2						1			2			3
09T *		1									1			2			3
09 *		1	23	12		13					1			2			3
10T *		1	23			13					1	4		2			3
10 *		1	23		2	13	7			1	1	4		2		2	3
11T *		1			2						1	4		2			3
11 *		1			2						1	4		2			3
12T *		1			2						1	4		2			3
12 *		1	23	12	2						1	4		2			3
13T *		1			2						1	4		2			
13 *		1			2						1	4		2			
14T *		1			2						1	4		2			
27T *		1			2						1	4		2		2	3
27 *		1			2						1	4		2		2	3
28T *		1		12	2						1	4		2		2	
28 *		1		12	2						1	4		2		2	
29T *		1			2						1	4		2			
29 *		1			2						1	4		2			3
30T *		1									1	4		2			
30 *		1									1	4		2			
31T *		1									1	4		2			
31 *		1	23			13				1	1	4		2			3
32T *		1								1	1	4		2			3
32 *		1			2						1	4		2		2	3
33T *		1			2						1	4		2			3
33 *		1			2						1	4		2			3
34T *		1									1	4		2			3
34 *		1						5		1	1	4		2			3
35T *		1									1	4		2			3
35 *		1									1	4		2			3
36T *		1									1	4		2			3
36 *		1			2	13	7				1	4		2			3
37T *		1			2		7				1	4		2			
37 *		1			2		7				1	4	20	2			
38T *		1			2						1	4		2			
38 *		1			2					1	1	4		2			3
39T *		1			2						1	4		2			
39 *		1			2						1	4		2			
40T *		1			2						1	4		2			
40 *		1					7			1	1	4		2		2	
41T *		1								1	1	4		2			
41 *		1								1	1	4		2			
42T *		1			2					1	1	4		2			

FREQUENCY- 160.965 MHZ. CHANNEL 26T	FDG
	3
01T	
01	
02T	
02	
03T	
03	
04T	
04	
05T	
05	
06T	
06	3
07T	3
07	
08T	
08	
09T	
09	
10T	
10	
11T	
11	
12T	
12	
13T	
13	
14T	
27T	
27	
28T	3
28	3
29T	
29	
30T	
30	
31T	
31	
32T	
32	
33T	
33	
34T	
34	
35T	
35	
36T	
36	
37T	
37	
38T	
38	
39T	3
39	
40T	
40	
41T	
41	
42T	

FREQUENCY- 160.980 MHZ. CHANNEL 26	ALM	AN	CNW	DRGH	HBL	ICG	LN	LRS	MNS	NPB	OPE	PC	SLSF
	4	3	2	16	2	7	8	2	3	5	2	4	2
01T		3							3		2		2
01		3							3		2		2
02T		3											2
02		3								5			2
03T								2		5			
03			2					2	3				
04T								2					
04		3						2			2		2
05T		3						2					2
05		3						2	3	5			2
06T								2	3				2
06	4							2	3		2		2
07T								2					
07		3					8	2					
08T		3						2					
08		3		16	2			2			2		2
09T		3						2			2		
09		3						2			2		
10T								2			2		
10	4				2		8	2			2		2
11T	4										2		2
11	4	3							3	5	2		2
12T	4	3								5	2		2
12	4	3		16				2			2		2
13T	4										2		2
13	4										2		2
14T	4										2		2
27T	4	3	2	16	2			2			2		2
27	4	3						2			2		2
28T	4										2		2
28	4								3		2		2
29T	4										2		2
29	4	3						2			2		2
30T	4												
30	4												
31T	4												
31	4	3	2				8	2		5			
32T	4	3					8	2					
32	4	3			2			2			2		
33T		3									2		
33		3							3		2		
34T									3		2		
34	4							2	3	5	2		2
35T											2		2
35											2		2
36T											2		
36									3		2		
37T													
37	4							2		5			2
38T	4	3						2		5			2
38	4	3			2		8	2	3		2		2
39T	4							2					
39	4							2					
40T	4							2					
40	4							2					2
41T	4							2					2
41	4	3					8	2					2
42T	4	3					8	2					2

FREQUENCY- 161.465 MHZ. CHANNEL 42

	*GN	OT	ICG	WM	WP
	2	4	161	22	9
01T	2	4			
01	2	4			
02T					
02					
03T					
03	2				
04T					
04					
05T					
05					
06T					
06					
07T					
07	2				
08T					
08					
09T					
09	2				
10T	2				
10	2	4			
11T					
11					
12T					
12					9
13T					
13					
14T	2				
27T	2				
27	2				
28T	2				9
28	2				9
29T	2				9
29	2				9
30T					
30					
31T					
31	2				
32T	2				
32	2				
33T	2				
33					
34T					
34					
35T	2				
35	2				
36T	2				
36	2	4			
37T		4			
37		4			
38T					
38	2				
39T	2				
39	2				9
40T					
40		4			
41T					
41	2				
42T	2				

FREQUENCY- 161.475 MHZ. CHANNEL 43

	*SOU
	26
01T	
01	
02T	
02	
03T	
03	
04T	
04	
05T	
05	
06T	
06	
07T	
07	
08T	
08	
09T	
09	
10T	
10	
11T	
11	
12T	
12	
13T	
13	
14T	
27T	
27	
28T	
28	
29T	
29	
30T	
30	
31T	
31	
32T	
32	
33T	
33	
34T	
34	
35T	
35	
36T	
36	
37T	
37	
38T	
38	
39T	
39	
40T	
40	
41T	
41	
42T	

FREQUENCY- 161.490 MHZ. CHANNEL 43

	*	AA	AMTK	ATSF	CHW	GI	DRGW	NW	RDG	SFP
	*	7	1	10	4	1	47	3	9	12
01T	*		1	10	4					
01	*		1	10						
02T	*		1	10						
02	*		1	10		1				
03T	*		1		4	1				
03	*		1		4	1				
04T	*		1		4					
04	*		1		4					
05T	*		1		4					
05	*		1		4					
06T	*		1	10						
06	*		1	10				3	9	
07T	*		1						9	
07	*		1							
08T	*		1							
08	*		1	10			47			
09T	*		1							
09	*		1		4					
10T	*		1			1				
10	*		1	10		1				
11T	*		1	10						
11	*		1	10	4					
12T	*		1	10	4					
12	*		1	10	4	1	47			
13T	*		1	10	4	1				
13	*		1	10	4	1				
14T	*		1	10	4	1				
27T	*		1	10	4	1	47			
27	*		1	10	4	1				
28T	*		1	10	4	1			9	
28	*		1	10	4	1			9	
29T	*		1	10						
29	*		1	10						
30T	*		1							
30	*		1		4					
31T	*		1		4					
31	*		1	10	4					
32T	*		1	10						
32	*		1	10						
33T	*		1	10						
33	*		1	10						
34T	*		1							
34	*		1		4	1		3		
35T	*		1		4					
35	*		1		4					
36T	*		1							
36	*		1	10		1			9	
37T	*		1							
37	*		1							
38T	*		1							
38	*		1	10	4					
39T	*		1		4				9	
39	*		1		4	1				
40T	*		1		4	1				
40	*		1		4					
41T	*		1							
41	*		1	10						
42T	*		1	10		1				

FREQUENCY- 161.505 MHZ. CHANNEL 44T

	*	ICG	SOU
	*	4	1
01T	*		1
01	*		1
02T	*		1
02	*		1
03T	*		1
03	*		1
04T	*		1
04	*		1
05T	*		1
05	*		1
06T	*		1
06	*		1
07T	*		1
07	*		1
08T	*		1
08	*		1
09T	*		1
09	*		1
10T	*		1
10	*		1
11T	*		1
11	*		1
12T	*		1
12	*		1
13T	*		1
13	*		1
14T	*		1
27T	*		1
27	*		1
28T	*		1
28	*		1
29T	*		1
29	*		1
30T	*		1
30	*		1
31T	*		1
31	*		1
32T	*		1
32	*		1
33T	*		1
33	*		1
34T	*		1
34	*		1
35T	*		1
35	*		1
36T	*		1
36	*		1
37T	*		1
37	*		1
38T	*		1
38	*		1
39T	*		1
39	*		1
40T	*		1
40	*		1
41T	*		1
41	*		1
42T	*		1

FREQUENCY- 161.520 MHZ. CHANNEL 44

	*	AMTK	ARC	BM	DH	EL	LN	PBP	RI	SOO	UP
	*	1	2	26	1	101	41	1	3	23	1
01T	*	1	2								1
01	*	1									1
02T	*	1									1
02	*	1									1
03T	*	1	2								1
03	*	1	2							23	1
04T	*	1	2								1
04	*	1	2								1
05T	*	1									1
05	*	1									1
06T	*	1									1
06	*	1		26	1						1
07T	*	1		26	1						1
07	*	1		26	1						1
08T	*	1	2								1
08	*	1	2					1	3		1
09T	*	1									1
09	*	1									1
10T	*	1									1
10	*	1	2						3		1
11T	*	1	2						3		1
11	*	1	2						3		1
12T	*	1	2						3		1
12	*	1	2		1				3		1
13T	*	1									1
13	*	1									1
14T	*	1									1
27T	*	1	2					1	3		1
27	*	1	2						3		1
28T	*	1	2								1
28	*	1	2								1
29T	*	1	2								1
29	*	1	2						3		1
30T	*	1									1
30	*	1									1
31T	*	1									1
31	*	1	2								1
32T	*	1									1
32	*	1									1
33T	*	1									1
33	*	1	2					1			1
34T	*	1	2					1			1
34	*	1	2						3		1
35T	*	1	2								1
35	*	1	2								1
36T	*	1	2								1
36	*	1	2	26	1						1
37T	*	1	2		1						1
37	*	1	2		1			1			1
38T	*	1	2					1			1
38	*	1									1
39T	*	1									1
39	*	1			1						1
40T	*	1	2								1
40	*	1	2								1
41T	*	1	2								1
41	*	1	2					1			1
42T	*	1	2					1			1

FREQUENCY- 161.535 MHZ. CHANNEL [illegible]

	*	ADN	ATSF	LI	SCU
	*	2	1	3	5
01T	*		1		
01	*		1		
02T	*		1		
02	*	2	1		
03T	*	2	1		
03	*	2	1		
04T	*	2	1		
04	*	2	1		
05T	*	2	1		
05	*	2	1		
06T	*	2	1		
06	*	2	1		
07T	*		1		5
07	*		1		5
08T	*		1		
08	*		1		
09T	*		1		
09	*		1		5
10T	*		1		5
10	*	2	1	3	5
11T	*	2	1		
11	*	2	1		
12T	*	2	1		
12	*	2	1		5
13T	*	2	1		
13	*	2	1		
14T	*	2	1		
27T	*	2	1		
27	*	2	1		
28T	*	2	1		
28	*	2	1		
29T	*	2	1		
29	*	2	1		
30T	*		1		
30	*		1		
31T	*		1		
31	*	2	1		5
32T	*	2	1		5
32	*	2	1		5
33T	*		1		
33	*		1		
34T	*		1		
34	*	2	1		5
35T	*	2	1		
35	*	2	1		
36T	*		1		
36	*		1		5
37T	*		1		
37	*	2	1		
38T	*	2	1		
38	*	2	1		
39T	*	2	1		
39	*	2	1		
40T	*		1		
40	*		1		
41T	*		1		
41	*	2	1		
42T	*	2	1		

FREQUENCY- 161.550 MHZ. CHANNEL 45

	*	ABB	AMTK	ATSF	AUCX	DRGW	EJE	MILW	NWP	PFP	RI	SLSF	SP	SSW	TRC	UP
	*	2	1	1	1	3	4	1	15	9	1	2	290	26	1	1
01T	*		1	↑	1					↑	1		↑		1	
01	*		1	│	1					│	1		│		1	
02T	*		1	│	1					│	1		│		1	
02	*		1	│	1			1		│	1	2	│		1	
03T	*		1	│	1					│	1	2	│		1	
03	*	2	1	│	1		4			│	1	2	│		1	
04T	*		1	│	1					│	1	2	│		1	
04	*		1	│	1					│	1	2	│		1	
05T	*		1	│	1					│	1	2	│		1	
05	*		1	│	1					│	1	2	│		1	
06T	*		1	│	1					│	1	2	│		1	
06	*		1	│	1			1		│	1	2	│		1	
07T	*		1	│	1					│	1		│		1	
07	*		1	│	1				15	│	1		│		1	
08T	*		1	│	1				15	│	1		│		1	
08	*		1	│	1	3		1	15	│	1	2	│		1	1
09T	*		1	│	1				15	│	1		│		1	
09	*		1	│	1				15	│	1		│		1	
10T	*		1	│	1				15	│	1		│		1	
10	*	2	1	│	1	3		1	15	│	1	2	│		1	1
11T	*		1	│	1			1		│	1	2	│		1	
11	*		1	│	1			1		│	1	2	│		1	
12T	*		1	│	1			1		│	1	2	│		1	
12	*		1	│	1	3		1	15	│	1	2	│		1	
13T	*		1	│	1	3			15	│	1	2	│		1	
13	*		1	│	1					│	1	2	│		1	
14T	*		1	│	1					│	1	2	│		1	
27T	*		1	│	1	3	4			│	1	2	│		1	
27	*		1	│	1					│	1	2	│		1	
28T	*		1	│	1				15	│	1	2	│		1	
28	*		1	│	1				15	│	1	2	│		1	
29T	*		1	│	1			1	15	│	1	2	│		1	
29	*		1	│	1	3		1	15	│	1	2	│		1	
30T	*		1	│	1	3				│	1	2	│		1	
30	*		1	│	1	3				│	1	2	│		1	
31T	*		1	│	1					│	1		│		1	
31	*		1	│	1		4	1		│	1		│		1	
32T	*		1	│	1			1		│	1		│		1	
32	*		1	│	1	3		1	15	│	1		│		1	1
33T	*		1	│	1			1		│	1		│			
33	*	2	1	│	1			1		│	1	2	│			
34T	*	2	1	│	1					│	1	2	│			
34	*	2	1	│	1					│	1	2	│	26	1	
35T	*		1	│	1					│	1	2	│		1	
35	*		1	│	1					│	1	2	│		1	
36T	*		1	│	1					│	1	2	│		1	
36	*		1	│	1			1		│	1	2	│		1	
37T	*		1	│	1			1		│	1		│		1	
37	*		1	│	1			1		│	1		│		1	
38T	*		1	│	1			1		│	1		│		1	
38	*		1	│	1			1	15	│	1	2	│		1	
39T	*		1	│	1				15	│	1	2	│		1	
39	*		1	│	1				15	│	1	2	│		1	
40T	*		1	│	1					│	1		│		1	
40	*		1	│	1					│	1		│		1	
41T	*		1	│	1					│	1		│		1	
41	*		1	│	1					│	1	2	│		1	
42T	*		1	↓	1	3			15	↓	1	2	↓		1	

FREQUENCY- 161.565 MHZ. CHANNEL 46T

	*	DRGW	SOU
	*	1	26
01T	*	1	↑
01	*	1	│
02T	*		│
02	*		│
03T	*		│
03	*		│
04T	*		│
04	*		│
05T	*		│
05	*		│
06T	*	1	│
06	*	1	│
07T	*	1	│
07	*	1	│
08T	*	1	│
08	*	1	│
09T	*	1	│
09	*		│
10T	*		│
10	*		│
11T	*		│
11	*		│
12T	*		│
12	*	1	│
13T	*		│
13	*		│
14T	*		│
27T	*	1	│
27	*		│
28T	*		│
28	*		│
29T	*		│
29	*		│
30T	*		│
30	*		│
31T	*		│
31	*		│
32T	*		│
32	*		│
33T	*		│
33	*	1	│
34T	*	1	│
34	*	1	│
35T	*	1	│
35	*		│
36T	*		│
36	*		│
37T	*		│
37	*		│
38T	*		│
38	*	1	│
39T	*	1	│
39	*	1	│
40T	*	1	│
40	*		│
41T	*		│
41	*		│
42T	*		↓

FREQUENCY- 161.610 MHZ.   CHANNEL 46

	*	ATSF	ORGW	FWD	HBT	LN	MILW	RI	SP
	*	1	1	2	1	1	2	167	1
01T	*	1		2	1				1
01	*			2	1				1
02T	*			2	1				1
02	*			2	1				1
03T	*			2	1				1
03	*			2	1				1
04T	*			2	1				1
04	*			2	1				1
05T	*			2	1				1
05	*			2	1				1
06T	*	1	1	2	1				1
06	*	1	1	2	1				1
07T	*		1		1	1			1
07	*		1		1	1			1
08T	*		1		1				1
08	*	1	1	2	1				1
09T	*		1		1				1
09	*				1	1			1
10T	*				1	1			1
10	*	1		2	1	1			1
11T	*	1		2	1				1
11	*	1		2	1				1
12T	*	1		2	1				1
12	*	1	1	2	1	1			1
13T	*	1			1				1
13	*	1			1				1
14T	*	1			1				1
27T	*	1	1	2	1				1
27	*	1		2	1				1
28T	*	1		2	1				1
28	*	1		2	1				1
29T	*	1		2	1				1
29	*	1		2	1	1			1
30T	*				1				1
30	*				1				1
31T	*				1				1
31	*			2	1	1			1
32T	*			2	1	1			1
32	*	1		2	1	1			1
33T	*	1		2	1	1			1
33	*	1	1	2	1	1			1
34T	*		1	2	1	1			1
34	*		1	2	1	1			1
35T	*		1	2	1				1
35	*			2	1				1
36T	*			2	1				1
36	*	1		2	1	1			1
37T	*	1		2	1				1
37	*	1		2	1				1
38T	*	1		2	1				1
38	*	1		2	1				1
39T	*	1		2	1				1
39	*	1		2	1				1
40T	*	1	1	2	1				1
40	*		1	2	1				1
41T	*			2	1				1
41	*			2	1				1
42T	*	1		2	1				1

Table B-2. General Service Reassignment Eligibility

Channel 14 - 160.620 MHz

thru

Channel 26 - 160.980 MHz

and

Channel 42 - 161.460 MHz

thru

Channel 46 - 161.610 MHz

FREQUENCY- 160.620 MHZ. CHANNEL 14

	ACY	BN	FJG	GFIN	LN	LV	NDH	MSW	NPT	NH	PTM	SM	SP	TCT	UKR	WP	ZGRC
*	2	3	2	1	3	4	2	2	2	3	2	3	9	3	1	16	1
01T				1			2				2	3			1		1
01				1			2				2				1		1
02T				1			2				2				1		1
02				1			2		2		2			3	1		1
03T			2	1			2				2				1		1
03	2		2	1		4	2	2			2				1		1
04T				1			2				2				1		1
04				1			2				2	3		3	1		1
05T				1			2				2			3	1		1
05				1			2				2			3	1		1
06T				1			2				2			3	1		1
06			2	1		4	2		2		2			3	1		1
07T			2	1		4					2				1		1
07			2	1		4					2				1		1
08T				1							2				1		1
08				1			2		2		2		9	3	1		1
09T				1			2				2				1		1
09				1			2				2	3			1		1
10T				1			2				2	3			1		1
10	2			1			2		2		2	3	9	3	1		1
11T				1					2		2				1		1
11		3		1					2		2				1		1
12T				1					2		2				1		1
12			2	1			2		2					3	1	18	1
13T				1			2								1		1
13				1			2	2							1		1
14T				1			2	2			2				1		1
27T				1			2				2		9	3	1		1
27				1			2				2			3	1		1
28T				1		4	2							3	1	18	1
28				1		4	2							3	1	18	1
29T				1			2		2					3	1	18	1
29				1			2		2		2			3	1	18	1
30T				1			2				2				1		1
30				1			2				2				1		1
31T				1			2				2				1		1
31		3		1			2		2		2	3			1		1
32T				1			2		2			3			1		1
32			2	1			2		2			3	9	3	1		1
33T	2			1			2		2					3	1		1
33	2	3		1					2					3	1		1
34T	2			1										3	1		1
34	2			1										3	1		1
35T				1			2								1		1
35			2	1			2					3			1		1
36T			2	1			2					3			1		1
36			2	1		4	2		2		2	3		3	1		1
37T			2	1			2		2		2	3			1		1
37			2	1			2		2		2	3			1		1
38T			2	1			2		2		2	3			1		1
38			2	1		4	2		2		2	3	9	3	1		1
39T			2	1		4	2				2			3	1		1
39			2	1		4	2				2			3	1	18	1
40T				1			2								1		1
40				1											1		1
41T				1											1		1
41		3		1				2							1		1
42T		3		1			2	2			2				1		1

FREQUENCY- 162.655 MHZ.   CHANNEL 15T

	*	PC	SLSF	SOU	SP	ZCRC
	*	1	1	2	1	2
01T	*	1	1			2
01	*	1	1			2
02T	*	1	1			2
02	*	1	1		1	2
03T	*	1	1		1	
03	*	1	1		1	
04T	*	1	1			
04	*	1	1	2		
05T	*	1	1			
05	*	1	1		1	
06T	*	1	1		1	
06	*	1	1	2	1	
07T	*	1	1	2	1	
07	*	1	1	2	1	
08T	*	1	1	2	1	
08	*	1	1	2	1	
09T	*	1	1	2		
09	*	1	1	2		
10T	*	1	1	2		
10	*	1	1	2	1	2
11T	*	1	1	2	1	
11	*	1	1	2	1	
12T	*	1	1	2	1	
12	*	1	1	2	1	
13T	*	1	1		1	
13	*	1	1		1	
14T	*	1	1		1	
27T	*	1	1	2	1	
27	*	1	1	2	1	
28T	*	1	1		1	
28	*	1	1		1	
29T	*	1	1		1	
29	*	1	1		1	
30T	*	1	1			
30	*	1	1			
31T	*	1	1			
31	*	1	1	2		
32T	*	1	1	2		
32	*	1	1	2	1	
33T	*	1	1		1	
33	*	1	1		1	
34T	*	1	1		1	
34	*	1	1	2	1	
35T	*	1	1		1	
35	*	1	1		1	
36T	*	1	1		1	
36	*	1	1	2	1	2
37T	*	1	1		1	2
37	*	1	1		1	2
38T	*	1	1		1	
38	*	1	1		1	
39T	*	1	1		1	
39	*	1	1		1	
40T	*	1	1			
40	*	1	1			2
41T	*	1	1			
41	*	1	1			
42T	*	1	1			

FREQUENCY- 16..65 MHZ.   CHANNEL 15

	*BMS	CLC	CNJ	CC	OOP	IGG	NS	PC	PHD	PW	RFP	SOU	SP	TOE	TRRA	UF	WYT	ZCRC
*	2	2	5	6	1	5	3	4	1	5	2	1	2	2	2	5	1	1
01T *		2			1				1			1	2					1
01 *		2			1				1				2					1
02T *		[illegible]			1								2				1	1
02 *	2	2			1								2					1
03T *	2	2			1							1						1
03 *	2	2			1					5		1						1
04T *	2	2			1					5		1						1
04 *	2	2			1					5		1	2					1
05T *	2	2			1							1	2					1
05 *	2	2			1							1	2					1
06T *	2	2			1								2					1
06 *	2	2			1	5			1	5			2	2				1
07T *	2	2			1				1	5			2					1
07 *	2	2			1				1	5			2					1
08T *	2	2			1				1				2					1
08 *	2	2			1				1				2	2				1
09T *	2	2			1													1
09 *	2	2			1			4		5		1						1
10T *	2	2			1					5								1
10 *	2	2	5		1				1	5			2	2			1	1
11T *	2	2			1					5			2	2				1
11 *	2	2			1					5		1	2	2				1
12T *	2	2			1							1	2	2				1
12 *	2	2			1				1			1	2	2				1
13T *	2	2			1							1	2	2				1
13 *	2	2			1					5		1	2	2				1
14T *	2	2			1					5		1	2	2				1
27T *	2	2			1				1	5		1	2	2				1
27 *	2	2			1				1	5		1	2	2				1
28T *		2			1							1	2	2				1
28 *		2			1			4				1	2	2				1
29T *		2			1							1	2	2				1
29 *	2	2			1				1			1	2	2				1
30T *	2	2			1				1				2	2				1
30 *	2	2			1				1				2	2				1
31T *	2	2			1				1				2					1
31 *	2	2			1		3		1				2					1
32T *	2	2			1								2					1
32 *	2	2			1								2					1
33T *	2	2			1								2					1
33 *		2			1				1				2	2				1
34T *		2			1				1					2				1
34 *		2			1	5	3	4	1			1		2				1
35T *					1				1			1						1
35 *					1				1			1	2		2			1
36T *					1				1			1	2					1
36 *	2	2			1				1	5		1	2	2			1	1
37T *	2	2			1				1					2				1
37 *	2	2			1		3		1					2				1
38T *		2			1				1					2				1
38 *		2			1	5			1	5		1	2	2				1
39T *		2			1				1			1		2				1
39 *	2	2			1				1			1		2				1
40T *	2	2			1				1			1		2				1
40 *	[illegible]	2			1				1			1		2				1
41T *		2			1				1					2				1
41 *		2			1				1				2	2				1
42T *	2	[illegible]			1				1	5			2	2				1

FREQUENCY- 1[illegible] MHZ. CHANNEL 16T

	*	CLIF	KIT	PG	SLSF	SOU	TP
	*	1	1	1	1	3	2
01T	*	1		1	1	3	2
01	*			1	1		2
02T	*			1	1		2
02	*			1	1		2
03T	*			1	1	3	2
03	*		1	1	1	3	2
04T	*			1	1	3	2
04	*	1		1	1	3	2
05T	*			1	1	3	2
05	*			1	1		2
06T	*			1	1		2
06	*			1	1		2
07T	*			1	1	3	2
07	*		1	1	1	3	2
08T	*	1		1	1	3	2
08	*	1		1	1	3	2
09T	*			1	1	3	2
09	*			1	1	3	2
10T	*			1	1		2
10	*	1	1	1	1		2
11T	*	1		1	1		2
11	*	1		1	1	3	2
12T	*	1		1	1	3	2
12	*	1		1	1	3	2
13T	*			1	1	3	2
13	*			1	1	3	2
14T	*			1	1	3	2
27T	*	1		1	1	3	2
27	*	1		1	1	3	2
28T	*			1	1	3	2
28	*			1	1	3	2
29T	*			1	1	3	2
29	*			1	1	3	2
30T	*			1	1	3	2
30	*			1	1	3	2
31T	*			1	1	3	2
31	*		1	1	1	3	2
32T	*		1	1	1	3	2
32	*			1	1	3	2
33T	*			1	1		2
33	*	1		1	1		2
34T	*	1		1	1		2
34	*	1	1	1	1	3	2
35T	*			1	1		2
35	*			1	1		2
36T	*			1	1		2
36	*	1		1	1		2
37T	*	1		1	1		2
37	*	1		1	1		2
38T	*	1		1	1	3	2
38	*		1	1	1		2
39T	*			1	1		2
39	*			1	1		2
40T	*	1		1	1		2
40	*	1	1	1	1		2
41T	*	1	1	1	1		2
41	*	1	1	1	1	[illegible]	2
42T	*	1	1	1	1	[illegible]	2

FREQUENCY- 163.565 MHZ.   CHANNEL 16

	AMTK	CO	ECHO	GBW	HBT	ICG	LN	PC	RYEA	SH	SLC	UP	VS	WCT	WCTU	ZCRC
	1	2	2	2	1	7	1	4	21	1	2	44	3	3	3	1
01T	1		2	2				4		1	2		3	3	3	1
01	1		2	2				4		1	2			3	3	1
02T	1			2				4		1	2			3	3	1
02	1	2		2	1			4		1	2			3	3	1
03T		2		2				4		1	2			3	3	1
03				2				4		1	2			3	3	1
04T				2				4		1	2					1
04	1			2	1			4		1	2		3			1
05T	1			2	1					1	2					1
05	1	2		2	1					1	2			3	3	1
06T				2	1					1	2			3	3	1
06			2	2	1	7		4		1	2		3	3	3	1
07T				2				4		1	2		3	3	3	1
07	1			2			1	4		1	2		3	3	3	1
08T	1			2			1	4		1	2		3	3	3	1
08	1		2	2	1		1	4		1	2		3	3	3	1
09T	1			2						1	2		3	3	3	1
09	1			2						1	2		3	3	3	1
10T	1			2						1	2		3	3	3	1
10	1		2	2	1			4		1	2		3	3	3	1
11T				2						1	2			3	3	1
11		2		2						1	2			3	3	1
12T		2		2						1	2			3	3	1
12	1		2	2	1		1	4		1	2		3	3	3	1
13T			2	2			1			1	2			3	3	1
13			2	2			1			1	2			3	3	1
14T			2	2			1			1	2			3	3	1
27T			2	2	1			4		1	2		3	3	3	1
27			2	2	1			4		1	2		3	3	3	1
28T			2	2	1		1			1	2			3	3	1
28			2	2	1		1			1	2			3	3	1
29T			2		1		1			1	2					1
29	1		2		1		1			1	2		3			1
30T			2							1	2					1
30			2					4		1	2			3	3	1
31T			2					4		1	2			3	3	1
31	1	2	2	2				4		1	2		3	3	3	1
32T	1		2	2				4		1	2		3	3	3	1
32	1		2	2	1		1	4		1	2		3	3	3	1
33T	1		2	2	1			4		1	2		3	3	3	1
33	1		2	2	1			4		1	2		3	3	3	1
34T	1		2	2	1					1	2		3	3	3	1
34	1	2	2	2	1	7	1			1	2		3	3	3	1
35T	1						1			1	2		3	3	3	1
35	1						1	4		1	2		3	3	3	1
36T	1							4		1	2		3	3	3	1
36	1			2	1			4		1	2		3	3	3	1
37T	1		2	2				4		1	2		3	3	3	1
37	1	2	2	2				4		1	2		3	3	3	1
38T	1	2	2	2				4		1	2		3	3	3	1
38	1		2	2	1	7		4		1	2		3	3	3	1
39T			2	2	1			4		1	2		3	3	3	1
39			2	2	1		1	4		1	2		3	3	3	1
40T			2	2				4		1	2		3			1
40	1		2	2				4		1	2		3			1
41T	1		2	2				4		1	2		3			1
41	1		2	2			1	4		1	2		3	3	3	1
42T	1		2	2			1	4		1	2		3	3	3	1

FREQUENCY- 160.695 MHZ. CHANNEL 17T

	ITC	SLSF
	2	2
01T		
01		
02T		
02		
03T		
03		
04T		
04		
05T		
05		
06T		
06		2
07T		
07		
08T		
08		
09T		
09		
10T		
10		
11T		
11		
12T		
12		
13T		
13		
14T		
27T		
27		
28T		
28		
29T		
29		
30T		
30		
31T		
31		
32T		
32		
33T		
33		
34T		
34		2
35T		
35		
36T		
36		
37T		
37		
38T		
38		2
39T		
39		
40T		
40		
41T		
41		
42T		

FREQUENCY- 163.715 MHZ. CHANNEL 17

	RBN	CO	DFI	LN	PC	PTR	RFP	SLSF	SP	UP	ZCRC
	21	1	5	1	5	3	7	3	3	7	1
01T				1					3		1
01				1							1
02T											1
02		1	5			3					1
03T			5								1
03			5	1							1
04T			5	1							1
04			5	1		3					1
05T			5	1		3					1
05			5	1		3					1
06T			5			3					1
06			5			3		3			1
07T			5								1
07			5	1							1
08T			5								1
08			5			3	3				1
09T			5								1
09			5	1							1
10T				1							1
10				1		3			3	7	1
11T				1							1
11				1							1
12T				1							1
12			5	1		3					1
13T			5								1
13			5								1
14T		1	5								1
27T			5	1		3	3		3	7	1
27			5	1		3			3		1
28T			5	1		3			3		1
28		1	5	1		3			3		1
29T			5			3					1
29			5			3					1
30T											1
30		1		1							1
31T		1		1							1
31	21	1	5	1							1
32T				1							1
32						3			3	7	1
33T						3					1
33			5			3	3				1
34T			5			3	3				1
34		1	5			3		3			1
35T			5								1
35			5	1							1
36T			5								1
36			5			3					1
37T			5								1
37			5	1			3				1
38T			5	1			3				1
38		1	5	1		3		3			1
39T			5			3					1
39			5			3					1
40T			5								1
40			5	1							1
41T				1							1
41				1			3				1
42T	21			1			3				1

FREQUENCY- 16[illegible].725 MHZ. CHANNEL 15T

	SLSF	SP	ZCEC
	6	3	1
01T			1
01			1
02T			1
02			1
03T			1
03			1
04T			1
04			1
05T			1
05			1
06T			1
06			1
07T			1
07			1
08T			1
08			1
09T			1
09			1
10T			1
10			1
11T			1
11			1
12T			1
12		3	1
13T		3	1
13			1
14T			1
27T			1
27			1
28T		3	1
28		3	1
29T		3	1
29		3	1
30T			1
30			1
31T			1
31			1
32T			1
32		3	1
33T			1
33			1
34T			1
34			1
35T			1
35			1
36T			1
36			1
37T			1
37			1
38T			1
38			1
39T			1
39		3	1
40T			1
40			1
41T			1
41			1
42T			1

FREQUENCY- 16[illegible] MHZ. CHANNEL 1[illegible]

	APC	FL	FS	GTW	ICC	LSTT	MICW	MTF	NW	PC	SOU	SP	UP	ZCEC
	2	4	2	7	6	1	1	2	1	5	4	2	51	3
01T	2						1	2				2		3
01	2						1	2				2		3
02T	2						1					2		3
02	2					1	1					2	51	3
03T						1	1					2		
03						1	1	2				2		
04T							1					2		
04	2						1					2		
05T	2						1							
05	2						1	2						3
06T	2						1	2						3
06	2				6	1	1	2						3
07T	2						1				4			
07	2						1				4			
08T	2						1							
08	2		2			1	1					2		3
09T	2					1	1							3
09	2					1	1				4			3
10T	2					1	1							3
10	2			7		1	1							3
11T	2						1							3
11	2						1	2				2		3
12T	2						1					2		3
12	2					1	1				4	2	51	3
13T	2						1							3
13	2						1							3
14T	2						1							3
27T	2		2				1					2	51	3
27	2						1					2		3
28T	2						1					2		3
28	2					1	1	2				2		3
29T	2					1	1					2		3
29	2					1	1				4	2		3
30T	2						1					2		3
30	2						1					2		3
31T	2						1					2		3
31	2					1	1				4	2	51	3
32T	2						1				4	2		
32	2						1				4	2		
33T	2						1					2		
33	2		2				1	2				2		3
34T	2		2				1	2				2		3
34	2				6		1	2		5	4	2	51	3
35T	2						1					2	51	3
35	2						1					2	51	3
36T	2						1					2		3
36	2			7			1	2				2		3
37T	2			7			1					2		3
37	2		2	7		1	1					2	51	3
38T	2		2				1					2	51	3
38	2						1	2				2		3
39T	2						1					2		3
39	2						1					2		3
40T	2						1						51	3
40	2			7			1						51	3
41T	2						1						51	3
41	2		2				1						51	3
42T	2		2			1	1						51	3

FREQUENCY- 160.755 MHZ. CHANNEL 197

	ATSF	BS	LV	PC	SOU	WKF
	2	1	1	3	4	2
01T		1				2
01		1				
02T		1				
02		1				
03T		1				
03		1				
04T		1				2
04		1			4	2
05T		1				2
05		1				2
06T		1				2
06		1			4	2
07T		1			4	2
07		1			4	2
08T		1				2
08		1				2
09T		1				2
09		1			4	2
10T		1			4	2
10		1	1		4	2
11T		1			4	2
11		1			4	2
12T		1			4	2
12		1			4	2
13T		1				2
13		1				2
14T		1				2
27T		1			4	2
27		1			4	2
28T		1				2
28		1				2
29T		1				2
29		1				2
30T		1				2
30		1				2
31T		1				2
31		1				2
32T		1			4	2
32		1			4	2
33T		1				
33		1				
34T		1				
34		1			4	2
35T		1				2
35		1				2
36T		1				
36		1			4	
37T		1				
37		1				2
38T		1				2
38		1				2
39T		1				2
39		1				2
40T		1				2
40		1				2
41T		1				2
41		1				2
42T		1				2

FREQUENCY- 160.770 MHZ. CHANNEL 19

	ATSF	LO	UCI	GTW	HET	KCS	LH	FFP	SLSF	SOU	JP	TP	TRMP	UP	ZCRC
	2	2	2	3	5	3	13	2	1	1	6	2	6	1	1
01T	2		2						1				6	1	1
01	2		2						1					1	1
02T			2						1					1	1
02			2	3	5				1					1	1
03T			2						1					1	1
03			2						1					1	1
04T									1					1	1
04				3	5				1					1	1
05T					5				1					1	1
05			2		5				1					1	1
06T	2		2		5				1					1	1
06	2		2	3	5				1					1	1
07T	2		2	3					1					1	1
07	2		2	3					1					1	1
08T				3					1					1	1
08				3	5				1			2		1	1
09T									1					1	1
09	2						13		1					1	1
10T	2		2				13		1					1	1
10	2	2	2		5		13		1			2	6	1	1
11T			2						1			2		1	1
11			2						1			2		1	1
12T			2						1			2		1	1
12			2	3	5				1			2		1	1
13T			2						1					1	1
13	2		2						1					1	1
14T	2		2						1					1	1
27T	2		2	3	5				1		6	2	6	1	1
27	2		2	3	5				1		6	2	6	1	1
28T	2		2		5				1		6		6	1	1
28	2		2		5				1		6		6	1	1
29T	2		2		5				1					1	1
29	2		2	3	5				1			2		1	1
30T	2								1					1	1
30	2								1					1	1
31T	2								1					1	1
31			2	3					1					1	1
32T			2						1					1	1
32			2		5				1		6		6	1	1
33T			2		5				1					1	1
33			2		5				1					1	1
34T			2		5				1					1	1
34	2		2		5				1			2		1	1
35T			2						1					1	1
35									1					1	1
36T									1					1	1
36		2		3	5				1		6			1	1
37T			2	3					1	1				1	1
37	2		2	3					1					1	1
38T			2						1					1	1
38			2		5				1		6	2		1	1
39T			2		5				1			2		1	1
39			2	3	5				1			2		1	1
40T			2						1					1	1
40			2						1				6	1	1
41T			2						1					1	1
41	2		2						1			2		1	1
42T	2		2	3					1			2		1	1

FREQUENCY- 160.725 MHZ. CHANNEL 25T

	ATSF	CO	SLSF	ZCRC
	2	2	2	2
01T				
01				
02T				
02		2		2
03T		2		2
03	2			
04T				
04				
05T				
05		2		2
06T				
06				
07T				
07				
08T				
08				
09T				
09				
10T				
10				
11T				
11		2		2
12T		2		2
12				
13T				
13				
14T				
27T	2			
27				
28T				
28				
29T				
29				
30T				
30				
31T				
31	2	2		2
32T				
32				
33T				
33				
34T				
34		2		2
35T				
35			2	
36T				
36				
37T				
37		2		2
38T		2		2
38				
39T				
39				
40T				
40				
41T				
41				
42T				

FREQUENCY- 160.500 MHZ. CHANNEL 2.

	HBT	ICG	KT	NVP	SCL	SLSF	SP	UP	HCT	WCTU	ZCFC	ZST
	1	1	3	3	6	4	1	13	3	3	3	4
01T		1	3	3			1		3	3		4
01				3			1		3	3		
02T				3			1		3	3		
02	1			3			1		3	3	3	
03T		1	3	3			1		3	3		
03		1	3	3			1		3	3		
04T		1	3	3			1					
04	1	1	3	3	6		1					4
05T	1		3	3			1					
05	1		3	3			1		3	3		
06T	1			3			1		3	3		
06	1	1		3		4	1		3	3		
07T		1		3			1		3	3		
07		1	3	3			1		3	3		
08T		1		3			1		3	3		
08	1	1		3			1		3	3		
09T		1		3			1		3	3		
09		1	3	3			1		3	3		4
10T		1	3	3			1		3	3		4
10	1	1	3	3	6		1		3	3		4
11T		1	3	3			1		3	3		
11		1	3	3			1		3	3		
12T		1	3	3			1		3	3		
12	1	1	3	3	6		1		3	3		
13T		1	3	3			1		3	3		
13		1	3	3			1		3	3		
14T		1	3	3			1		3	3	3	
27T	1		3	3	6		1		3	3		
27	1		3	3	6		1		3	3		
28T	1		3	3			1		3	3		
28	1	1	3	3			1		3	3	3	
29T	1	1	3	3			1					
29	1	1	3	3			1					
30T		1	3	3			1					
30		1		3			1		3	3	3	
31T				3			1		3	3	3	
31				3			1		3	3	3	4
32T			3	3			1		3	3		
32	1	1	3	3			1		3	3		
33T	1		3	3			1		3	3		
33	1		3	3			1		3	3		
34T	1			3			1		3	3		
34	1	1				4	1		3	3	3	
35T							1		3	3		
35			3				1		3	3		4
36T			3	3			1		3	3		4
36	1		3	3			1		3	3		4
37T			3	3			1		3	3		
37		1	3	3	6		1		3	3		
38T		1	3	3			1		3	3		
38	1	1	3	3		4	1		3	3	3	
39T	1	1		3			1		3	3		
39	1	1		3			1		3	3		
40T		1					1					
40		1	3				1					
41T		1	3				1					
41		1	3	3	6		1		3	3		
42T		1	3	3	6		1		3	3		

FREQUENCY- 16?.?15 MHZ. CHANNEL 21T

	*BS	CNJ	CO	MP	NW	ZCEC
*	1	2	1	1	2	1
01T						1
01						1
02T						1
02			1			1
03T			1			1
03						1
04T						1
04						1
05T						1
05			1			1
06T						1
06				1		1
07T						1
07						1
08T						1
08						1
09T						1
09						1
10T						1
10		2				1
11T						1
11			1			1
12T			1			1
12						1
13T						1
13						1
14T						1
27T						1
27						1
28T						1
28						1
29T						1
29						1
30T						1
30						1
31T						1
31			1			1
32T						1
32						1
33T						1
33						1
34T						1
34			1	1		1
35T						1
35						1
36T						1
36						1
37T	1					1
37			1			1
38T			1			1
38				1		1
39T						1
39						1
40T						1
40						1
41T						1
41						1
42T						1

FREQUENCY- 16?.?63. MHZ. CHANNEL 21

	*BN	ORGN	EL	GWF	NB	PC	SLSF	SP	TP	UP	WNFR
*	15	1	5	1	2	8	5	2	2	6	1
01T		1			2						
01		1			2						
02T		1									
02		1		1						6	1
03T		1									
03		1			2						
04T		1			2						
04		1		1	2						
05T		1		1							
05		1		1							
06T		1		1							
06		1		1	2						1
07T		1			2						
07		1			2						
08T		1									
08		1		1			5	2	2		1
09T		1									1
09		1									1
10T		1									
10		1		1				2	2		
11T		1							2		
11		1							2	6	
12T		1							2	6	
12		1		1			5		2	6	1
13T		1									1
13		1									1
14T		1									1
27T		1		1			5	2	2		1
27		1		1			5		2		1
28T		1		1	2		5				1
28		1		1	2		5				1
29T		1		1			5				
29		1		1			5		2		
30T		1					5				
30		1			2		5				1
31T		1									1
31		1								6	1
32T		1									
32		1		1	2			2			
33T		1		1	2						
33		1		1			5				
34T		1		1			5				
34		1		1			5		2		1
35T		1									1
35		1									1
36T		1									1
36		1		1	2						1
37T		1									
37		1					5			6	
38T		1					5			6	
38		1		1	2			2	2		1
39T		1		1	2				2		1
39		1		1	2				2		1
40T		1					5				
40		1					5				
41T		1									
41		1			2				2		
42T		1			2				2		

FREQUENCY- 160.845 MHZ. CHANNEL 22T	ATSF	SBK	SLSF	SP	ZCRC
*	2	5	3	6	1
01T	↑				1
01					1
02T					1
02					1
03T					1
03					1
04T					1
04					1
05T					1
05					1
06T					1
06			3		1
07T					1
07				6	1
08T				6	1
08				6	1
09T					1
09					1
10T					1
10		5		6	1
11T					1
11					1
12T					1
12				6	1
13T				6	1
13				6	1
14T				6	1
27T					1
27					1
28T				6	1
28				6	1
29T				6	1
29				6	1
30T					1
30					1
31T					1
31					1
32T					1
32				6	1
33T					1
33					1
34T					1
34			3	6	1
35T				6	1
35				6	1
36T					1
36					1
37T					1
37					1
38T					1
39			3		1
39T					1
39				6	1
40T					1
40					1
41T					1
41					1
42T	↓				1

FREQUENCY- 160.365 MHZ. CHANNEL 22	ATSF	CF	GMO	GSM	LN	PC	RFP	FYEA	SAN	SHER	SLSF	SP	UP
*	1	1	1	1	*	22	3	3	2	1	4	3	9
01T					↑	↑			2	1			↑
01													
02T							3						
02							3				4		
03T									2	1	4		
03	1		1						2	1	4		
04T									2	1	4		
04		1							2	1	4		
05T		1							2	1			
05		1							2	1			
06T		1							2				
06		1							2				
07T		1							2				
07		1							2	1			
08T									2	1			
08				1					2	1	4	3	
09T									2	1			
09		1							2	1			
10T		1							2	1			
10		1		1			3		2	1			
11T				1			3			1			
11				1			3			1			
12T				1			3			1			
12		1		1				6	2	1	4		
13T										1			
13										1			
14T										1			
27T	1	1	1	1					2	1	4	3	
27		1		1					2	1	4		
28T										1	4		
28										1	4		
29T										1	4		
29				1			3			1	4		
30T										1	4		
30										1	4		
31T										1			
31	1	1	1						2	1			
32T									2	1			
32									2	1		3	
33T													
33		1									4		
34T											4		
34				1					2	1	4		
35T													
35		1											
36T													
36							3		2	1	4		
37T							3			1	4		
37		1								1	4		
38T										1	4		
38				1						1		3	
39T				1									
39		1		1									
40T											4		
40										1	4		
41T										1			
41		1		1						1			
42T		1		1	↓	↓				1			↓

FREQUENCY- 16[illegible].575 MHZ. CHANNEL 23T

	BN	LN	SLSF	SOU	ZCRC	ZNC
	22	1	2	4	1	7
01T			1		1	
01			1		1	
02T			1		1	
02			1		1	7
03T			1		1	
03			1		1	
04T			1		1	
04			1		1	7
05T			1		1	7
05			1		1	7
06T			1		1	7
06			1		1	7
07T			1	4	1	7
07			1	4	1	7
08T			1		1	
08			1		1	
09T			1		1	
09			1	4	1	
10T			1		1	
10			1		1	
11T			1		1	
11	22		1		1	
12T			1		1	
12			1	4	1	7
13T			1		1	
13			1		1	
14T			1		1	
27T			1		1	7
27			1		1	7
28T			1		1	
28			1		1	
29T			1		1	
29			1	4	1	7
30T			1		1	
30			1		1	
31T			1		1	
31	22		1	4	1	7
32T			1	4	1	7
32			1	4	1	7
33T			1		1	
33			1		1	
34T			1		1	
34			1	4	1	
35T			1		1	
35		1	1		1	
36T			1		1	
36			1		1	7
37T			1		1	7
37			1		1	7
38T			1		1	
38			1		1	
39T			1		1	
39			1		1	7
40T			1		1	
40			1		1	
41T			1		1	
41			1		1	
42T			1		1	7

FREQUENCY- 161.59[illegible] MHZ. CHANNEL 23

	ATSF	BN	BC	CNJ	CNW	CO	LN	NSS	PC	SCL	SLSF	SP	UP	ZCRC
	1	1	9	8	15	5	1	2	2	16	4	73	2	3
01T	1		↑	↑	15		1					↑	2	
01	1				15								2	
02T	1				15								2	
02	1	1			15						4		2	3
03T	1	1									4			3
03	1	1						2			4			
04T	1										4			
04	1										4		2	
05T	1												2	
05	1								2				2	3
06T	1												2	
06	1	1						2					2	
07T	1												2	
07	1												2	
08T	1												2	
08	1	1									4		2	
09T	1	1												
09	1	1								16				
10T	1	1								16				
10	1	1					1	2		16			2	
11T	1												2	
11	1				15								2	3
12T	1				15								2	3
12	1	1			15						4		2	
13T	1												2	
13	1												2	
14T	1												2	
27T	1				15		1		2		4			
27	1						1		2		4			
28T	1						1				4			
28	1	1					1				4			
29T	1	1									4			
29	1	1									4			
30T	1										4			
30	1								2		4			
31T	1													
31	1	1			15	5				16				3
32T	1													
32	1						1							
33T	1													
33	1							2			4			
34T	1							2			4			
34	1				15	5		2			4		2	3
35T	1													
35	1													
36T	1													
36	1										4		2	
37T	1										4			
37	1	1			15						4			3
38T	1				15						4			3
38	1							2						
39T	1													
39	1													
40T	1				15						4			
40	1				15		1				4		2	
41T	1				15								2	
41	1				15								2	
42T	1	1	↓	↓	15							↓	2	

FREQUENCY- 161.375 MHZ. CHANNEL 23T

	BN	LN	SLSF	SOU	ZCRC	ZNC
*	22	1	1	4	1	7
01T *			1		1	
01 *			1		1	
02T *			1		1	
02 *			1		1	7
03T *			1		1	
03 *			1		1	
04T *			1		1	
04 *			1		1	7
05T *			1		1	7
05 *			1		1	7
06T *			1		1	7
06 *			1		1	7
07T *			1	4	1	7
07 *			1	4	1	7
08T *			1		1	
08 *			1		1	
09T *			1		1	
09 *			1	4	1	
10T *			1		1	
10 *			1		1	
11T *			1		1	
11 *	22		1		1	
12T *			1		1	
12 *			1	4	1	7
13T *			1		1	
13 *			1		1	
14T *			1		1	
27T *			1		1	7
27 *			1		1	7
28T *			1		1	
28 *			1		1	
29T *			1		1	
29 *			1	4	1	7
30T *			1		1	
30 *			1		1	
31T *			1		1	
31 *	22		1	4	1	7
32T *			1	4	1	7
32 *			1	4	1	7
33T *			1		1	
33 *			1		1	
34T *			1		1	
34 *			1	4	1	
35T *			1		1	
35 *		1	1		1	
36T *			1		1	
36 *			1		1	7
37T *			1		1	7
37 *			1		1	7
38T *			1		1	
38 *			1		1	
39T *			1		1	
39 *			1		1	7
40T *			1		1	
40 *			1		1	
41T *			1		1	
41 *			1		1	
42T *			1		1	7

FREQUENCY- 161.390 MHZ. CHANNEL 23

	ATSF	BN	BC	CNJ	CNW	CG	LN	NSS	PC	SCL	SLSF	SP	UP	ZCRC
*	1	1	9	8	15	5	1	2	2	16	4	73	2	3
01T *	1				15		1						2	
01 *	1				15								2	
02T *	1				15								2	
02 *	1	1			18						4		2	3
03T *	1	1									4			3
03 *	1	1						2			4			
04T *	1										4			
04 *	1										4		2	
05T *	1												2	
05 *	1								2				2	3
06T *	1												2	
06 *	1	1						2					2	
07T *	1												2	
07 *	1												2	
08T *	1												2	
08 *	1	1									4		2	
09T *	1	1												
09 *	1	1								16				
10T *	1	1								16				
10 *	1	1					1	2		16			2	
11T *	1												2	
11 *	1				16								2	3
12T *	1				19								2	3
12 *	1	1			18						4		2	
13T *	1												2	
13 *	1												2	
14T *	1												2	
27T *	1				19		1		2		4			
27 *	1						1		2		4			
28T *	1						1				4			
28 *	1	1					1				4			
29T *	1	1									4			
29 *	1	1									4			
30T *	1										4			
30 *	1								2		4			
31T *	1													
31 *	1	1			18	5				16				3
32T *	1													
32 *	1						1							
33T *	1													
33 *	1							2			4			
34T *	1							2			4			
34 *	1				18	5		2			4		2	3
35T *	1													
35 *	1													
36T *	1													
36 *	1										4		2	
37T *	1										4			
37 *	1	1			15						4			3
38T *	1				15						4			3
38 *	1							2						
39T *	1													
39 *	1													
40T *	1				15						[illegible]			
40 *	1				15		1				4		2	
41T *	1				15								2	
41 *	1				15								2	
42T *	1	1			15								2	

FREQUENCY- 16[illegible] MHZ.   CHANNEL 24T

	ALS	LV	SCL	SOU
	3	1	1	1
01T				1
01				
02T				
02			1	
03T				1
03				1
04T				1
04			1	1
05T			1	1
05			1	
06T			1	
06			1	
07T			1	
07			1	1
08T			1	
08			1	
09T			1	
09			1	1
10T			1	
10		1	1	
11T			1	
11			1	1
12T			1	1
12			1	1
13T				1
13				1
14T				1
27T			1	1
27			1	1
28T			1	1
28			1	1
29T			1	1
29			1	1
30T				1
30				1
31T				1
31			1	1
32T			1	1
32			1	1
33T			1	1
33			1	1
34T			1	1
34			1	1
35T				
35	3			
36T				
36				
37T				
37				
38T			1	
38			1	
39T				
39				
40T				
40				1
41T				1
41			1	1
42T			1	1

FREQUENCY- 160.920 MHZ. CHANNEL 24

	BLE	BN	GPO	HBT	KIT	LV	MILW	PC	PLE	RFP	RYEA	SH	SLSF	SOU	SP	WN
	6	1	5	2	6	5	1	1	2	1	1	3	4	1	2	2
01T		1					1					3		1		
01		1					1					3		1		
02T		1								1				1		
02		1		2						1			4	1		
03T		1											4	1		
03		1			6		1		2				4	1		
04T													4	1		
04	6			2									4	1		
05T	6			2										1		
05	6			2			1							1		2
06T	6			2			1							1		
06	6			2			1							1		
07T	6													1		
07	6	1			6							3		1		2
08T	6													1		2
08	6			2									4	1	2	2
09T														1		
09		1									1	3		1		
10T		1									1	3		1		
10		1		2	6					1	1	3		1	2	
11T		1								1				1		
11	6	1					1			1				1		
12T	6	1								1				1		
12	6			2							1	3	4	1		2
13T	6										1	3		1		2
13	6								2		1			1		2
14T	6	1							2		1			1		2
27T		1		2									4	1	2	2
27		1		2									4	1		2
28T		1		2							1	3	4	1		2
28	6	1		2			1				1	3	4	1		2
29T				2									4	1		2
29				2						1			4	1		2
30T													4	1		2
30	6										1	3	4	1		2
31T												3		1		2
31		1			5							3		1		2
32T		1			6							3		1		2
32	5	1		2								3		1	2	2
33T	6	1		2										1		
33	6	1		2			1						4	1		
34T		1		2			1						4	1		
34		1		2	6		1				1		4	1		
35T		1									1			1		
35		1									1			1		2
36T		1												1		
36		1		2			1			1			4	1		
37T										1				1		
37														1		2
38T												3		1		2
38	6	1		2	6		1					3		1	2	2
39T	6	1		2								3		1		2
39	[illegible]	1		2										1		2
40T														1		
40					6									1		
41T					[illegible]									1		
41	6	1			[illegible]				2					1		2
42T	6	1			[illegible]				2					1		2

FREQUENCY= 166.935 MHZ.   CHANNEL 25T

	ARL	BM	NM	FI	SLSF
	2	1	2	1	1
01T		1	2		1
01		1	2		1
02T		1	2		1
02		1	2		1
03T		1	2		1
03		1	2	1	1
04T		1	2		1
04		1	2		1
05T		1	2		1
05		1	2		1
06T		1	2		1
06		1	2		1
07T		1	2		1
07	2	1	2		1
08T	2	1	2		1
08	2	1	2		1
09T		1	2		1
09		1	2		1
10T		1	2		1
10	2	1	2		1
11T		1	2		1
11		1	2		1
12T		1	2		1
12	2	1	2		1
13T	2	1	2		1
13	2	1	2		1
14T	2	1	2		1
27T		1	2	1	1
27		1	2		1
28T	2	1	2		1
28	2	1	2		1
29T	2	1	2		1
29	2	1	2		1
30T		1	2		1
30		1	2		1
31T		1	2		1
31		1	2	1	1
32T		1	2		1
32	2	1	2		1
33T		1	2		1
33		1	2		1
34T		1	2		1
34	2	1	2		1
35T	2	1	2		1
35	2	1	2		1
36T		1	2		1
36		1	2		1
37T		1	2		1
37		1	2		1
38T		1	2		1
38		1	2		1
39T		1	2		1
39	2	1	2		1
40T		1	2		1
40		1	2		1
41T		1	2		1
41		1	2		1
42T	2	1	2		1

FREQUENCY- 160.950 MHZ. CHANNEL 25

	AEC	AGS	ATSF	BN	CLCO	CO	EL	GA	LN	LOPG	NS	NW	PC	RFP	SAN	SG	SLSF	SP	UP	ZCRC
	2	2	1	1	2	4	4	2	1	2	3	1	2	1	1	1	1	73	4	2
01T		2	↑	1	2	↑			1	2		1	↑		1			↑		
01					2				1	2		1								
02T					2					2		1								
02					2					2	3	1					1			2
03T								2			3	1			1		1			
03	2							2	1			1			1		1			
04T	2							2	1			1			1		1			
04	2			1	2			2	1	2		1			1	1	1			
05T					2			2	1			1			1					
05					2			2	1		3	1			1					
06T					2			2				1			1					
06				1	2		4	2		2		1			1	1				
07T					2		4	2		2		1			1	1				
07					2		4	2	1	2		1			1	1				
08T	2				2		4	2		2		1			1	1				
08	2			1	2		4	2		2		1		1	1	1	1			
09T	2				2			2		2		1			1	1				
09	2				2			2	1	2		1			1	1				
10T	2				2			2	1	2		1			1	1				
10	2	2			2			2	1	2		1			1	1				
11T	2			1	2			2	1	2		1								
11	2			1	2		4	2	1	2	3	1							4	
12T	2			1	2		4	2	1	2	3	1								
12	2			1	2		4	2	1	2		1			1	1	1			2
13T					2		4					1								2
13					2		4					1								2
14T					2		4					1								2
27T	2	2						2	1	2		1		1	1	1	1			2
27	2	2						2	1	2		1			1	1	1			2
28T	2	2							1			1				1	1			2
28	2	2		1			4		1			1				1	1			2
29T	2			1								1				1	1			
29	2			1	2					2		1				1	1			
30T					2							1					1			
30					2		4		1			1					1			2
31T					2				1			1								2
31	2				2			2	1	2	3	1			1	1			4	2
32T								2	1	2		1			1	1				
32		2					4	2		2		1			1	1				
33T							4			2		1				1				
33	2						4			2		1		1		1	1		4	
34T	2											1		1		1	1			
34	2			1				2			3	1			1	1	1			2
35T	2											1				1				
35	2								1	2		1				1				
36T	2									2		1				1				
36	2				2		4	2		2		1			1	1	1			
37T	2				2					2		1				1	1			
37	2			1	2				1	2	3	1		1		1	1			
38T	2				2				1	2	3	1		1		1	1			
38	2				2				1	2		1				1				2
39T	2				2					2		1				1				
39	2				2		4			2		1				1				
40T	2									2		1				1	1			
40	2	2		1					1	2		1				1	1			
41T	2			1					1	2		1				1				
41	2			1			4		1	2		1		1		1			4	
42T	2		↓	1	2	↓	4		1	2		1	↓	1		1		↓	4	

FREQUENCY- 160.965 MHZ. CHANNEL 25T

	*	BN	BRC	METC	MF	RDG	SLSF
	*	1	2	1	2	1	16
01T	*	1			↑	1	↑
01	*	1				1	
02T	*	1				1	
02	*	1				1	
03T	*	1				1	
03	*	1	2	1		1	
04T	*	1		1		1	
04	*	1				1	
05T	*	1				1	
05	*	1				1	
06T	*	1				1	
06	*	1				1	
07T	*	1				1	
07	*	1		1		1	
08T	*	1		1		1	
08	*	1		1		1	
09T	*	1		1		1	
09	*	1		1		1	
10T	*	1		1		1	
10	*	1				1	
11T	*	1				1	
11	*	1				1	
12T	*	1				1	
12	*	1		1		1	
13T	*	1				1	
13	*	1				1	
14T	*	1				1	
27T	*	1	2	1		1	
27	*	1		1		1	
28T	*	1		1		1	
28	*	1		1		1	
29T	*	1		1		1	
29	*	1		1		1	
30T	*	1		1		1	
30	*	1				1	
31T	*	1				1	
31	*	1	2			1	
32T	*	1		1		1	
32	*	1				1	
33T	*	1				1	
33	*	1				1	
34T	*	1		1		1	
34	*	1		1		1	
35T	*	1		1		1	
35	*	1		1		1	
36T	*	1				1	
36	*	1				1	
37T	*	1				1	
37	*	1				1	
38T	*	1				1	
38	*	1				1	
39T	*	1		1		1	
39	*	1		1		1	
40T	*	1				1	
40	*	1				1	
41T	*	1				1	
41	*	1				1	
42T	*	1		1	↓	1	↓

FREQUENCY- 160.965 MHZ. CHANNEL 26

	*	ATSF	BN	CTN	ORGK	FCIN	GTW	ICG	LN	FC	RFP	SLSF	SP	UBJ	UP	ZSCS
	*	1	4	2	2	2	2	2	1	2	3	1	3	2	6	4
01T	*	1	4		2		2	2		↑				2	↑	
01	*	1	4		2		2	2						2		
02T	*		4		2			2			3			2		
02	*		4		2						3	1		2		
03T	*		4		2							1				
03	*		4		2							1				
04T	*		4		2			2				1				
04	*		4		2			2				1				4
05T	*		4		2			2								
05	*		4		2	2		2								
06T	*	1	4		2			2								
06	*	1	4		2		2	2								
07T	*	1	4		2		2									
07	*	1	4		2		2									
08T	*		4		2		2									4
08	*		4	2	2		2	2				1				4
09T	*		4		2											4
09	*	1	4		2											4
10T	*	1	4		2											4
10	*	1	4		2	2	2	2			3			2		4
11T	*		4		2			2			3					4
11	*		4		2			2			3					4
12T	*		4		2			2			3					4
12	*		4		2	2	2	2				1	8			4
13T	*				2	2										
13	*	1			2	2										
14T	*	1			2	2										
27T	*	1		2	2	2	2	2				1				4
27	*	1			2	2	2	2				1				4
28T	*	1			2	2		2				1	6			
28	*	1			2	2		2				1	8			
29T	*	1			2							1	8			
29	*	1	4		2		2				3	1	8			4
30T	*	1			2		2					1				
30	*	1			2	2	2					1				
31T	*	1			2	2	2									
31	*		4		2	2	2									4
32T	*		4		2											
32	*		4		2			2								
33T	*				2											
33	*			2	2		2					1				4
34T	*			2	2	2	2					1				
34	*	1			2	2	2	2				1				
35T	*				2		2	2								
35	*				2		2	2								4
36T	*				2		2									4
36	*		4		2	2	2				3	1		2		4
37T	*				2		2		1		3	1		2		4
37	*	1		2	2		2	2				1		2		4
38T	*			2	2		2	2				1				4
38	*		4		2	2	2	2								
39T	*				2		2									
39	*				2		2						8			
40T	*				2		2					1				4
40	*				2		2	2				1		2		4
41T	*				2		2	2								4
41	*	1	4	2	2	2	2	2								4
42T	*	1	4	2	2	2	2	2		↓					↓	4

FREQUENCY- 161.450 MHZ. CHANNEL 42

	GN	CO	DRGW	PC	SCL	SLSF	SMA	SP	ZGKC
	71	1	4	0	15	5	2	4	3
01T									3
01									3
02T		1							
02		1				5	2	4	
03T						5	2		
03						5	2		
04T						5			
04					15	5		4	
05T								4	
05		1					2	4	
06T		1					2	4	
06		1					2	4	3
07T							2		
07							2		
08T							2		
08		1	4			5	2	4	3
09T		1							
09		1			15				
10T		1			15				
10		1			15		2	4	3
11T		1					2		
11		1					2		
12T		1					2		
12		1	4			5	2	4	3
13T		1					2		
13		1					2		
14T		1					2		
27T		1	4			5	2	4	3
27		1				5	2	4	3
28T		1				5	2	4	
28		1				5	2	4	
29T		1				5	2	4	
29		1				5	2	4	3
30T		1				5			3
30		1				5			3
31T		1							3
31		1			15				3
32T									
32							2		
33T							2		
33		1				5	2		3
34T		1				5	2		3
34		1				5	2		3
35T		1					2		3
35		1					2		3
36T							2		3
36						5	2	4	3
37T						5	2		3
37		1				5	2		3
38T		1				5	2		3
38		1					2	4	3
39T		1					2	4	3
39		1					2	4	3
40T						5			3
40						5			3
41T									3
41		1							3
42T		1							3

FREQUENCY- 161.475 MHZ. CHANNEL 43T

	GO	HP	ZGSC	ZMC
	1	4	1	9
01T		4	1	
01		4	1	
02T			1	
02	1		1	9
03T			1	
03		4	1	
04T			1	
04			1	9
05T			1	9
05		4	1	9
06T			1	9
06			1	9
07T			1	9
07		4	1	9
08T		4	1	
08		4	1	
09T		4	1	
09		4	1	
10T		4	1	
10		4	1	
11T			1	
11			1	
12T			1	
12		4	1	9
13T		4	1	
13			1	
14T	1		1	
27T		4	1	9
27		4	1	9
28T		4	1	
28	1	4	1	
29T		4	1	
29		4	1	9
30T			1	
30	1		1	
31T	1		1	
31	1		1	9
32T		4	1	9
32		4	1	9
33T		4	1	
33			1	
34T			1	
34	1		1	
35T		4	1	
35		4	1	
36T			1	
36			1	9
37T			1	9
37		4	1	9
38T		4	1	
38	1	4	1	
39T		4	1	
39		4	1	9
40T			1	
40			1	
41T			1	
41		4	1	
42T		4	1	9

FREQUENCY- 161.495 MHZ. CHANNEL 43

	DH	DNE	OTI	FP	NPI	NW	RYEA	SHEF	SOU	SP	SSW	ZORC	ZNOT
	8	2	5	1	3	2	2	1	3	2	3	2	1
01T								1			3		1
01											3		
02T			5										
02		2			3	2						2	
03T		2				2		1					
03		2						1					
04T								1					
04								1				2	
05T								1					
05						2		1					
06T													
06	8	2			3						3		
07T	8												
07	8						2	1					
08T							2	1					
08		2			3		2	1			3		
09T		2						1					
09		2						1				2	
10T		2						1				2	
10		2	5		3		2	1				2	1
11T					3			1					
11					3			1			3		
12T					3			1			3		
12	8	2			3		2	1		2	3	2	
13T							2	1		2	3	2	
13							2	1			3	2	
14T							2	1			3	2	
27T								1		2	3	2	1
27								1		2	3	2	1
28T							2	1		2		2	1
28		2					2	1		2		2	1
29T		2			3		2	1		2			
29		2			3		2	1		2	3		
30T								1					
30								1				2	
31T								1				2	
31		2			3	2		1			3	2	
32T					3			1			3		
32					3		2	1		2	3		1
33T										2			
33										2			
34T													
34						2	2	1			3		
35T							2						
35							2						
36T													
36	8		5		3			1					
37T	8				3			1					
37	8	2			3			1					
38T					3			1					
38					3			1			3	2	
39T											3	2	
39	8						2			2	3	2	
40T												2	
40								1				2	1
41T								1				2	
41								1			3	2	
42T		2					2	1			3	2	

FREQUENCY- 161.515 MHZ. CHANNEL 44T

	BN	CO	METS	PC	SLSF
	22	1	1	2	1
01T					1
01					1
02T					1
02		1			1
03T					1
03			1		1
04T			1		1
04					1
05T					1
05					1
06T					1
06					1
07T					1
07			1		1
08T			1		1
08			1		1
09T			1		1
09			1		1
10T			1		1
10					1
11T					1
11	22				1
12T					1
12			1		1
13T					1
13					1
14T		1			1
27T			1		1
27			1		1
28T			1		1
28		1	1		1
29T			1		1
29			1		1
30T			1		1
30		1		2	1
31T		1			1
31	22	1			1
32T			1		1
32					1
33T					1
33					1
34T			1		1
34		1	1		1
35T			1		1
35			1		1
36T					1
36					1
37T					1
37					1
38T					1
38		1			1
39T			1		1
39			1		1
40T					1
40					1
41T					1
41					1
42T			1		1

FREQUENCY- 161.525 MHZ. CHANNEL 44

	APA	BM	DTS	GWF	LV	NW	NWP	PC	FFP	RI	SCL	SLSF	SP	ZCRC
*	2	1	1	5	1	2	13	8	3	1	1	2	1	2
01T	2				1					1	1			
01	2				1					1	1			
02T	2				1				3	1	1			2
02	2			5	1				3	1	1	2		2
03T	2				1						1	2		
03	2				1	2					1	2		
04T	2				1						1	2		
04				5	1						1	2		
05T				5	1						1	2		
05				5	1					1	1	2		2
06T	2	1		5	1					1	1	2		2
06	2	1		5	1					1	1	2		2
07T	2	1			1						1			
07	2	1			1		13				1			
08T	2				1		13				1			
08	2			5	1		13			1	1	2		2
09T	2				1		13				1			2
09	2				1		13				1			2
10T	2				1		13				1			2
10	2		1	5	1		13		3		1	2		2
11T	2				1				3		1	2		2
11	2				1				3	1	1	2		2
12T	2				1				3	1	1	2		2
12	2	1		5	1		13			1	1	2	1	2
13T	2				1		13			1	1	2	1	2
13	2				1	2				1	1	2		2
14T	2				1	2				1	1	2		2
27T	2			5	1					1	1	2	1	2
27	2			5	1					1	1	2	1	2
28T	2			5	1		13				1	2	1	2
28	2			5	1		13				1	2	1	2
29T	2			5	1		13				1	2	1	2
29	2			5	1		13		3	1	1	2	1	2
30T	2				1						1	2		2
30	2				1						1	2		2
31T	2				1						1			2
31	2				1					1	1			2
32T	2				1					1	1			
32	2			5	1		13			1	1		1	
33T	2			5	1						1		1	
33	2	1		5	1						1	2	1	2
34T	2			5	1						1	2		2
34	2			5	1					1	1	2		2
35T	2				1						1	2		2
35	2	1			1						1	2		2
36T	2	1			1						1	2		
36	2	1	1	5	1				3	1	1	2		
37T	2	1			1				3	1	1			
37	2	1			1					1	1			2
38T	2	1			1					1	1			2
38	2	1		5	1		13			1	1	2		2
39T	2	1		5	1		13			1	1	2		2
39	2	1		5	1		13			1	1	2	1	2
40T	2				1						1			
40	2				1						1			
41T	2				1						1			
41	2				1	2				1	1	2		2
42T	2				1	2	13			1	1	2		2

FREQUENCY- 161.575 MHZ. CHANNEL 45T

	ATSF	BS	MP	PC	WUG	SLSF
*	1	1	3	9	1	2
01T			3		1	
01			3		1	
02T					1	
02					1	
03T					1	
03			3		1	
04T					1	
04					1	
05T					1	
05					1	
06T			3		1	
06			3		1	
07T					1	
07					1	
08T					1	
08			3		1	
09T					1	
09					1	
10T					1	
10			3		1	
11T			3		1	
11			3		1	
12T			3		1	
12			3		1	
13T					1	
13					1	
14T					1	
27T			3	9	1	
27			3		1	
28T			3		1	
28			3		1	
29T			3		1	
29			3		1	
30T			3		1	
30			3		1	
31T					1	
31					1	
32T					1	
32			3		1	
33T					1	
33					1	
34T					1	
34			3		1	
35T					1	
35					1	2
36T					1	
36			3		1	
37T		1	3		1	
37			3		1	
38T			3		1	
38			3		1	
39T					1	
39					1	
40T					1	
40					1	
41T					1	
41					1	
42T					1	

FREQUENCY- 161.550 MHZ. CHANNEL 45

	ATSF	BN	CC	CFE	EL	GTW	HBL	JT	KCT	LN	MANP	PC	SOU	UP	URR	WP	ZCRC	ZHRC	ZSTT
	5	12	2	4	2	6	2	3	2	8	3	2	2	4	1	5	3	1	1
01T	5			4				3			3					5		1	
01	5															5		1	
02T																		1	
02														4				1	
03T				4														1	
03	5			4											1	5		1	
04T	5			4														1	
04	5			4				3						4				1	
05T	5			4														1	
05	5			4												5	3	1	
06T	5										3							1	
06	5				2						3			4				1	
07T					2													1	
07				4	2											5		1	
08T				4	2											5		1	
08	5			4	2		2				3			4		5		1	1
09T				4	2									4		5		1	
09				4	2			3					2	4		5		1	
10T				4				3					2	4		5		1	
10	5			4		6	2	3		8	3		2	4		5		1	1
11T	5			4							3							1	
11	5	12		4							3						3	1	
12T	5			4							3							1	
12	5			4							3		2	4		5		1	1
13T	5										3					5		1	1
13	5										3				1			1	
14T	5		2								3				1			1	
27T	5			4			2				3			4		5		1	1
27	5			4							3			4		5		1	
28T	5			4							3			4		5		1	
28	5			4	2						3			4		5		1	
29T	5			4							3					5		1	
29	5			4							3		2			5		1	1
30T	5			4												5		1	1
30	5		2	4										4				1	1
31T			2	4										4				1	
31			2	4				3					2	4			3	1	
32T				4									2	4		5		1	
32	5			4			2				3		2	4		5		1	1
33T											3		2	4		5		1	
33											3		2	4		5		1	
34T													2	4		5		1	
34	5		2	4	2								2	4		5	3	1	
35T														4		5		1	
35								3						4		5		1	
36T								3						4				1	
36	5			4		6		3			3		2	4				1	
37T	5			4		6		3			3			4				1	
37	5			4		6		3			3			4		5		1	
38T	5			4							3			4		5		1	
38	5			4			2				3			4		5		1	
39T											3			4		5		1	
39											3			4		5		1	
40T											3			4				1	
40				4		6								4				1	
41T				4										4				1	
41	5			4										4	1	5		1	1
42T	5			4	2						3			4	1	5		1	1

FREQUENCY- 1[illegible]1.565 MHZ. CHANNEL 46T

	BN	KCS	LA	MP	NW	PBNT	PC	SBK	ZGPC
	2	1	1	1	1	1	2	15	5
01T		1							
01		1							
02T		1							
02	2	1							
03T	2	1							
03	2	1					2		
04T		1							
04		1							
05T		1							
05		1							
06T		1							
06	2	1	1			1			
07T		1				1			
07		1				1			
08T		1							
08	2	1	1						
09T	2	1							
09	2	1			1				
10T	2	1							
10	2	1	1					15	5
11T		1							
11		1							
12T		1							
12	2	1	1						
13T		1							
13		1							
14T		1							
27T		1	1		1				
27		1	1		1				
28T		1	1			1			
28	2	1	1			1			
29T	2	1							
29	2	1							
30T		1							
30		1							
31T		1							
31	2	1							
32T		1							
32		1							
33T		1							
33		1							
34T		1							
34		1	1						
35T		1							
35		1							
36T		1							
36		1			1	1			5
37T		1							
37	2	1							
38T		1							
38		1	1			1			
39T		1	1			1			
39		1	1			1			
40T		1							
40		1							
41T		1							
41		1	1						
42T	2	1	1						

Table B-3. Challenged Frequency Subgroups Ranked in Order of Assignable Unchallenged Channels

NOTES:

1. The first 40 subgroups are unassignable, indicated by the blanks at the row-column intersections.

2. The vertical lines divide groupings. The number (N) inset near the top of each line indicates that the subgroups to the right of that line were found to be assignable at (N) frequencies.

3. The notations at the heading of each subgroup is the railroad name, channel number, and the number of licenses in the subgroup.

	SOU	BN	ATSF	LN	SLSF	SLSF	KCS	UP	ACY	MILW	LV	PC	SOU	MP	CNW	SLSF	ICG	WM	RDG	CNJ	BO	AGS	KCS	SOU	ICG
	15	15	15	16	17T	18T	16	18	13	19	19	20	21	23T	23	24T	24	25T	25T	25T	25T	25	25	25	26
	78	218	327	13	4	4	36	196	8	34	5	362	29	3	153	3	146	21	34	15	70	21	1	376	7
01T																									
01																									
02T																									
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41T																									
41																									
42T																									

	PC	ICG	WM	SOU	AA	RFP	ICG	LN	EL	SP	RFP	ATSF	SOU	RI	MILW	LV	LI	MRS	ALS	NS	LI	ICG	CNJ	MP	SLSF
	26	42	42	43T	43	43	44T	44	44	45	45	45	46T	46T	46T	14	18T	18	19	19	20T	20T	20	21T	21
	4	161	22	26	7	12	4	41	101	290	9	1	26	167	2	3	7	4	7	3	1	2	1	2	3
01T																									
01																									
02T																									
02																									
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08																									
09T																									
09																									
10T																									
10																3	7				1		1		
11T																									
11																									
12T																									
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13T																									
13																									
14T																									
27T																									
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32T																									
32																									
33T																									
33																									
34T																									
34																									
35T																									
35																		4	7					2	3
36T																									
36																									
37T																									
37																				3					
38T																									
38																						2			
39T																									
39																									
40T																									
40																									
41T																									
41																									
42T																									

	LI	TRRA	BS	ITC	NS	ICG	SOO	LI	SSW	ATSF	DTS	DTS	NW	SOO	BRC	LA	DTI	DRGW	BO	DRGW	DRGW	CNW	DRGW	EJE	UP
	21	21	23	23	25	25	44	45T	45	16	23	24	43	14	17T	18	21	21	23T	24	26	26	43	45	45
	23	1	3	1	20	5	29	3	26	1	1	4	3	2	2	25	9	18	1	69	16	2	47	4	1
01T																									
01																									
02T									2				3				9								
02																									
03T																									
03							29							2	2				1			2		4	
04T																									
04																									
05T																									
05																									
06T																									
06													3												
07T																									
07																									
08T																									
08																		18		69	16		47		1
09T																									
09																									
10T																									
10	23							3		1	1	4				25	9								1
11T																									
11																									
12T																									
12																		18		69	16		47		
13T																									
13																									
14T																									
27T										1				2	2	25		18	1	69	16	2	47	4	
27																25									
28T																									
28																									
29T																									
29																									
30T																									
30																									
31T																									
31														2	2				1			2		4	
32T																									
32																									1
33T																									
33																									
34T																									
34						5			26				3												
35T																									
35		1		1																					
36T																									
36											1	4					9								
37T			3																						
37					20																				
38T																									
38																									
39T																									
39																									
40T																									
40																									
41T																									
41																									
42T																									

PS	BLE	PLE	CNTP	DM	UKR	MTR	WP	SP	MGA	CG	GTW	RDG	HBL	ABB	WP	WP	TS	GSF	WP	RDG	BO	BN	LN	DT	
	18	21	23	25	44	14	19	20T	20	26	25	25	26T	26	45	19	21	24	25	42	43	15	19	26	42
	1	24	13	12	26	8	3	1	4	4	23	7	3	2	2	7	7	7	13	9	9	2	7	8	4
01T																									4
01	4					5										6						7			4
02T																									
02																							7		
03T																									
03	1					8	3			4					2										
04T																									
04																			13						
05T																									
05																									
06T																									
06					26								3								9		7		
07T					26								3								9				
07					26																			8	
08T																									
08														2								2	7		
09T																									
09				12							23								13						
10T											23								13						
10											23	7		2	2				13				7	8	4
11T																									
11																									
12T																									
12				12				1			23					7	7	7		9			7		
13T								1																	
13	1	24	13			8	3			4															
14T	1	24	13			8	3			4															
27T								1	4					2								2			
27									4																
28T				12					4				3			7	7	7		9	9				
28				12					4				3			7	7	7		9	9				
29T																7	7	7		9					
29								1								7	7	7		9					
30T																									
30																									
31T																									
31											23								13				7	8	
32T																								8	
32								1	4					2											
33T																									
33															2							2			
34T															2										
34															2										
35T																									
35																									
36T																									
36					26							7							13		9				4
37T												7													4
37												7										2	7		4
38T																						2			
38														2										8	
39T													3								9				
39																7	7	7		9					
40T																									
40												7													4
41T																									
41		24	13			8	3			4												2		8	
42T	1	24	13			8	3			4												2		8	

	DH 15 1	TS 17 5	TS 21 5	PBR 21 3	SP 25 2	DH 44 1	PGR 44 1	PC 19 2	CO 21 2	NPB 26 5	WP 14 8	FEC 15 18	PBNE 17T 2	GTW 19 2	AWP 20T 5	DTI 20 1	PRS 20 2	PC 23 1	SCL 24 3	RI 44 3	DRGW 45 3	SSW 20 5	ICG 22 33	KIT 25 1	SOU 45T 5
	8							9			10											11			
01T					2			2						2		1									
01								2						2		1									
02T								2						2		1									
02								2	2	5				2		1									
03T									2	5															
03													2											1	
04T																									
04												18							3						
05T																									
05									2	5															
06T																									
06	1					1							2				2	1							
07T	1					1							2				2	1							5
07	1					1							2					1						1	5
08T																		1							
08				3			1				8							1		3	3	5	33		
09T																		1							
09												18			5			1	3						5
10T												18			5				3						5
10					2			2			8	18		2	5	1			3	3	3			1	5
11T																				3			33		
11									2	5										3			33		
12T									2	5										3			33		
12	1	5	5			1					8				5					3	3	5	33		5
13T											8										3				
13																									
14T																									
27T		5	5	3	2		1				8						2			3	3	5			
27		5	5		2												2			3		5			
28T		5	5		2								2				2								
28		5	5		2								2	2		1	2	1					33		
29T		5	5																						
29		5	5								8				5					3	3	5			
30T											8										3				
30											8										3				
31T																									
31									2	5		18			5				3					1	5
32T															5									1	5
32					2						8				5						3				5
33T															5										
33				3			1								5										
34T				3			1																		
34									2	5								1		3		5		1	5
35T																									
35												18							3						
36T												18							3						
36	1					1		2				18	2	2		1	2		3						5
37T	1					1		2				18		2		1			3						
37	1			3		1	1	2	2	5		18		2		1			3				33		
38T				3			1		2	5													33		
38													2									5	33	1	
39T													2				2					5			
39	1	5	5			1							2				2					5			
40T																	2								
40					2			2						2		1								1	
41T																								1	
41				3			1															5	33	1	
42T				3			1				8							1			3	5	33	1	

	GWR	SN	VTR	SN	GA	BN	SLSF	RI	SOL	MNS	WA	CRR	DRGW	LN	DS	DMIR	BN	SLSF	CI	NWP	SP	DRGW	MILW	RI	PW
*	14	16	17	19	20T	16T	20	23	24T	26	20T	22	46T	46T	15	20	23	14	43	45	15	46T	45	19	23
*	7	3	3	3	10	2	7	1	5	3	6	15	1	1	4	29	1	8	1	15	3	1	1	2	1
01T *						2		1	5	3		15									3	1			
01 *						2		1		3											3	1			
02T *																									
02 *																29	1	8	1				1	2	
03T *							7									29	1	8	1						
03 *						2	7	1		3						29	1	8	1						1
04T *							7																		1
04 *							7		5			15			4						3			2	1
05T *																								2	
05 *						2		1		3														2	
06T *			3			2		1		3			1									1		2	
06 *	7		3			2		1		3			1			29	1					1	1	2	1
07T *	7		3		10								1	1								1			1
07 *	7		3		10								1	1						15		1			1
08T *	7												1		4					15		1			
08 *	7						7				6	15	1		4	29	1	8		15	3	1	1	2	
09T *	7										6		1		4	29	1			15	3	1			
09 *					10				5		6			1	4	29	1			15	3				
10T *					10				5		6			1	4	29	1		1	15					1
10 *					10				5		6	15		1	4	29	1		1	15			1		1
11T *									5		6	15											1		1
11 *						2		1	5	3	6	15											1		1
12T *									5		6	15											1		
12 *	7	3	3	3	10		7		5		6	15	1	1	4	29	1	8	1	15		1	1	2	
13T *		3		3															1	15					
13 *																			1						1
14T *																			1						1
27T *	7	3		3					5		6	15	1		4			8	1		3	1		2	1
27 *		3		3					5		6	15			4			8	1		3			2	1
28T *		3		3														8	1	15	3			2	
28 *		3		3		2	7	1		3						29	1	8	1	15	3			2	
29T *		3		3			7									29	1	8		15	3		1	2	
29 *		3		3			7							1		29	1	8		15	3		1	2	
30T *																		8							
30 *																		8							
31T *																									
31 *					10						6			1	4	29	1						1		
32T *					10						6			1									1		
32 *		3		3	10						6			1						15	3		1		
33T *		3		3	10									1							3		1		
33 *	7	3		3	10	2		1	5	3			1	1				8			3	1	1	2	
34T *	7					2		1		3			1	1				8			3	1		2	
34 *	7					2	7	1		3			1	1				8	1		3	1		2	
35T *	7												1									1			
35 *															4										
36T *																									
36 *			3		10	2		1		3				1				8	1		3		1	2	1
37T *			3																				1		1
37 *			3				7								4	29	1						1		1
38T *			3				7																1		1
38 *			3			2		1		3										15	3	1	1	2	1
39T *			3																	15		1		2	
39 *		3	3	3											4				1	15		1		2	
40T *													1		4				1			1			
40 *							7					15	1						1						
41T *												15													
41 *												15													
42T *									5			15			4	29	1		1	15					1

12 13 14 15 16 17 18 19 20 21

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	*SLSF	SI	AN	DN	LEF	WA	UMIR	CHW	CW	NW	CW	ATSF	ATSF	MEC	CIRR	WIM	ASAB	CIRR	TENN	OPE	ALM	LNW	GTW	LRS	SLSF
*	17	18	26	42	15	25	15	43	23T	24T	25	43	46T	14	14	19	19	22	24	26	26	15	25T	26	26
*	3	8	3	2	3	3	5	4	2	2	2	10	1	7	2	3	3	2	2	2	4	2	3	2	2
01T		8	3	2		3		4	2		2	10	1	7	2	3	3	2	2	2		2	3		2
01		8	3	2								10		7	2	3	3	2		2		2	3		2
	26		27		28		29		30					32								33	34		
02T		8	3							2		10		7	2		3	2					3		2
02	3	8	3		3		5			2		10		7	2		3	2					3		2
03T	3						5	4		2				7									3	2	
03	3			2			5	4		2				7									3	2	
04T								4		2				7									3	2	
04			3					4		2				7	2	3	3	2	2	2			3	2	2
05T			3					4		2				7	2	3	3	2	2					2	2
05	3	8	3			3		4		2				7	2	3	3	2	2					2	2
06T		8			3				2	2	2	10	1	7		3								2	2
06		8			3		5		2	2	2	10	1	7		3				2	4	2	3	2	2
07T		8			3		5							7		3							3	2	
07		8	3	2	3	3	5							7	2	3	3	2	2				3	2	
08T		8	3		3	3	5								2	3	3	2					3	2	
08	3		3		3	3	5		2		2	10	1		2		3	2		2		2	3	2	2
09T			3		3	3	5								2		3	2		2			3	2	
09			3	2	3	3	5	4						7	2		3	2	2	2			3	2	
10T				2	3	3	5							7	2	3		2	2	2			3	2	
10	3	8		2	3	3	5		2	2	2	10	1	7	2	3		2	2	2	4	2	3	2	2
11T	3	8				3	5		2		2	10	1		2	3		2	2	2	4		3		2
11	3	8	3			3	5	4	2		2	10	1		2	3	3	2	2	2	4		3		2
12T	3		3			3	5	4	2		2	10	1		2		3	2	2	2	4		3		2
12	3		3		3	3	5	4	2	2	2	10	1		2		3	2	2	2	4	2	3	2	2
13T					3			4	2		2	10	1							2	4	2	3		2
13					3			4	2		2	10	1							2	4	2	3		2
14T				2	3			4	2		2	10	1	7						2	4	2	3		2
27T	3		3	2		3	5	4	2	2	2	10	1	7	2	3	3	2	2	2	4	2	3	2	2
27	3		3	2		3	5	4	2	2	2	10	1	7	2		3	2	2	2	4	2	3	2	2
28T	3			2			5	4	2	2	2	10	1				3		2	2	4	2			2
28	3			2	3		5	4	2	2	2	10	1				3		2	2	4	2			2
29T	3	8		2			5		2		2	10	1			3	3		2	2	4	2			2
29	3	8	3	2		3	5		2		2	10	1	7	2	3	3	2	2	2	4	2		2	2
30T	3													7					2		4	2			
30	3				3			4		2				7							4	2			
31T					3			4		2				7							4	2			
31		8	3	2	3	3	5	4		2		10		7	2	3	3	2			4	2		2	
32T			3	2		3						10			2		3	2	2		4	2		2	
32			3	2		3			2		2	10	1		2		3	2	2	2	4	2		2	
33T			3	2		3			2		2	10	1		2		3	2	2	2		2			
33	3	8	3		3	3			2	2	2	10	1		2	3	3	2	2	2		2			
34T	3	8				3				2					2	3	3	2		2		2			
34	3	8				3		4		2					2		3	2		2	4	2		2	2
35T	3			2		3	5	4		2										2					2
35	3			2	3	3	5	4		2										2					2
36T	3			2	3	3				2										2					
36	3	8		2	3	3			2		2	10	1	7		3			2	2			3		
37T		8							2		2		1	7		3			2			2	3		
37		8					5		2		2		1	7		3			2		4	2	3	2	2
38T			3						2		2		1	7	2	3	3	2	2		4	2	3	2	2
38	3		3	2	3	3		4	2	2	2	10	1	7	2	3	3	2	2	2	4	2	3	2	2
39T				2	3			4	2		2		1	7		3					4	2	3	2	
39				2	3		5	4	2		2		1			3					4	2	3	2	
40T							5	4	2		2		1			3					4			2	
40		8						4		2						3			2		4			2	2
41T		8								2						3			2		4			2	2
41		8	3	2	3					2		10			2	3	3	2	2		4	2		2	2
42T		8	3	2	3		5		2	2	2	10	1	7	2	3	3	2	2		4	2	3	2	2

	ARC	LOAM	MR	SRN	ADN	OCE	WON	KCS	SLSF	CSP	SLSF	GBW	RI	MSV	BML	TSE	FWD	SMW	LSI	ORGW	BAK	TRC	MKT	AMTK	ICG
*	44	16	17T	17T	19	22	45T	22	45	18	24	16	21	21	17	24	46T	19	25	18	24	45	15T	15	15
*	2	2	5	5	4	3	2	2	2	2	2	6	4	2	3	2	2	1	4	1	1	1	1	1	1
01T *	2	2	5			3		2		2	2	6	4	2	3	2	2			1		1	1	1	1
01 *		2	5			3		2		2		6	4	2	3	2	2			1		1	1	1	1
02T *						3							4	2	3	2	2			1		1	1	1	1
02 *					4	3	2		2				4	2	3	2	2	1	4	1	1	1	1	1	1
03T *	2				4	3	2		2		2		4	2	3	2	2	1	4	1	1	1	1	1	1
03 *	2		5		4	3	2		2		2	6	4	2	3	2	2	1	4	1	1	1	1	1	1
04T *	2				4		2		2		2	6		2	3	2	2	1		1	1	1	1	1	1
04 *	2				4		2		2	2	2	6		2	3	2	2	1			1	1	1	1	1
05T *					4		2		2	2	2	6		2	3	2	2	1			1	1	1	1	1
05 *			5		4		2		2	2	2	6	4	2	3	2	2	1	4		1	1	1	1	1
06T *					4		2		2	2	2	6	4	2	3	2	2	1	4	1	1	1	1	1	1
06 *		2		5	4		2	2	2	2	2	6	4	2	3	2	2	1	4	1	1	1	1	1	1
07T *										2	2	6	4	2	3			1	4	1	1	1	1	1	1
07 *			5			3				2	2	6	4	2	3			1	4	1	1	1	1	1	1
08T *	2		5							2	2	6		2				1	4	1		1	1	1	1
08 *	2	2	5	5				2	2	2	2			2		2	2	1		1		1	1	1	1
09T *			5							2	2			2				1		1		1	1	1	1
09 *			5			3				2	2			2	3			1		1	1	1	1	1	1
10T *			5			3				2	2	6	4	2	3			1	4	1	1	1	1	1	1
10 *	2	2	5	5	4	3	2	2	2	2	2	6	4	2	3	2	2	1	4	1	1	1	1	1	1
11T *	2	2		5	4	3	2	2	2	2	2	6	4	2		2	2	1	4	1	1	1	1	1	1
11 *	2	2		5	4	3	2	2	2	2	2	6	4	2		2	2	1	4	1	1	1	1	1	1
12T *	2	2		5	4	3	2	2	2		2	6	4	2		2	2	1	4	1	1	1	1	1	1
12 *	2	2	5	5	4		2	2	2		2	6	4	2	3	2	2	1	4	1	1	1	1	1	1
13T *		2	5	5	4		2	2	2		2	6	4	2	3	2		1	4	1	1	1	1	1	1
13 *		2	5	5	4		2	2	2	2	2	6	4	2	3	2		1	4	1	1	1	1	1	1
14T *		2	5	5	4	3	2	2	2	2	2	6	4	2	3	2		1	4	1	1	1	1	1	1
27T *	2	2	5	5	4	3	2	2	2	2		6	4		3	2	2	1	4	1	1	1	1	1	1
27 *	2	2	5	5	4	3	2	2	2	2		6	4		3	2	2	1	4	1	1	1	1	1	1
28T *	2	2	5	5	4	3	2	2	2	2		6	4		3	2	2	1	4	1	1	1	1	1	1
28 *	2	2	5	5	4	3	2	2	2	2	2	6	4	2	3	2	2	1	4	1	1	1	1	1	1
29T *	2	2		5	4	3	2	2	2	2	2		4	2	3	2	2	1	4	1	1	1	1	1	1
29 *	2	2		5	4	3	2	2	2	2	2		4	2	3	2	2	1	4	1	1	1	1	1	1
30T *		2		5				2	2						3	2		1	4	1	1	1	1	1	1
30 *		2		5				2	2						3	2		1	4	1	1	1	1	1	1
31T *		2		5				2							3	2		1	4	1	1	1	1	1	1
31 *	2	2	5	5	4	3	2	2		2		6	4		3	2	2	1	4	1	1	1	1	1	1
32T *		2	5	5	4	3	2	2				6	4		3	2	2	1	4	1	1	1	1	1	1
32 *		2	5	5	4	3	2	2				6	4		3	2	2		4	1	1	1	1	1	1
33T *			5	5		3		2				6			3	2	2		4	1	1		1	1	1
33 *	2			5		3		2	2	2		6			3		2		4	1	1		1	1	1
34T *	2			5		3		2	2	2		6			3		2	1	4	1	1		1	1	1
34 *	2	2		5	4	3	2	2	2		2	6	4	2	3		2	1	4	1	1	1	1	1	1
35T *	2		5		4	3	2		2		2		4	2		2	2	1	4	1	1	1	1	1	1
35 *	2		5		4	3	2		2		2			2		2	2	1	4	1	1	1	1	1	1
36T *	2		5			3			2							2	2	1	4	1	1	1	1	1	1
36 *	2		5	5		3		2	2	2		6			3	2	2	1	4	1	1	1	1	1	1
37T *	2		5	5						2		6			3	2	2	1	4	1	1	1	1	1	1
37 *	2	2	5	5	4		2			2	2	6	4	2	3	2	2	1	4	1	1	1	1	1	1
38T *	2	2	5	5	4		2			2	2	6	4	2	3	2	2	1	4	1	1	1	1	1	1
38 *		2	5	5	4	3	2	2	2	2	2	6	4	2	3	2	2	1	4	1	1	1	1	1	1
39T *		2	5	5	4	3	2	2	2	2	2		4	2	3		2	1	4		1	1	1	1	1
39 *		2	5	5	4	3	2	2	2	2	2		4	2			2	1	4		1	1	1	1	1
40T *	2	2		5				2		2	2		4	2			2		4		1	1	1	1	1
40 *	2	2		5				2		2	2	6	4	2		2	2		4	1	1	1	1	1	1
41T *	2	2						2		2	2	6	4	2	3	2	2		4	1	1	1	1	1	1
41 *	2	2	5		4	3	2	2	2	2	2	6	4	2	3	2	2	1	4	1	1	1	1	1	1
42T *	2	2	5		4	3	2	2	2	2	2	6	4	2	3	2	2	1	4	1	1	1	1	1	1

35 36 37 38 40 41 43 46 49 52 55 58

	*PC	SCL	AMTK	SP	AMTK	ATSF	AMTK	LA	KCS	AMTK	UP	SLC	AMTK	NW	AMTK	LA	SLSF	AMTK	SOU	AMTK	UP	ATSF	AMTK	AUCX	RI
*	17	17	16	18	19	20	20	23	23	24	24	24	25T	25T	25	25	25	43	44T	44	44	45T	45	45	45
*	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
01T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
01 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
02T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
02 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
03T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
03 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
04T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
04 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
05T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
05 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
06T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
06 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
07T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
07 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
08T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
08 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
09T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
09 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
10T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
10 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
11T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
11 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
12T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
12 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
13T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
13 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
14T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
27T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
27 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
28T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
28 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
29T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
29 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
30T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
30 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
31T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
31 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
32T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
32 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
33T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
33 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
34T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
34 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
35T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
35 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
36T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
36 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
37T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
37 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
38T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
38 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
39T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
39 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
40T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
40 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
41T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
41 *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1
42T *	4	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1

	HBT 46T	SP 46T
01T	1	1
01	1	1
02T	1	1
02	1	1
03T	1	1
03	1	1
04T	1	1
04	1	1
05T	1	1
05	1	1
06T	1	1
06	1	1
07T	1	1
07	1	1
08T	1	1
08	1	1
09T	1	1
09	1	1
10T	1	1
10	1	1
11T	1	1
11	1	1
12T	1	1
12	1	1
13T	1	1
13	1	1
14T	1	1
27T	1	1
27	1	1
28T	1	1
28	1	1
29T	1	1
29	1	1
30T	1	1
30	1	1
31T	1	1
31	1	1
32T	1	1
32	1	1
33T	1	1
33	1	1
34T	1	1
34	1	1
35T	1	1
35	1	1
36T	1	1
36	1	1
37T	1	1
37	1	1
38T	1	1
38	1	1
39T	1	1
39	1	1
40T	1	1
40	1	1
41T	1	1
41	1	1
42T	1	1

APPENDIX C - SPECTRUM UTILIZATION

The data sources used for the study and analysis of VHF railroad mobile radio reassignment and sharing are identified and described in the main body of the report under Section 3.2.2.1 - Master File Organization. This same data and the working files generated for that analysis were also used to assess and define the spectrum utilization by the railroads. The results of this assessment are presented in this appendix.

Using the working files as a source, a tally of licenses issued for each channel was obtained for both train service and general service. These data and the results of the 1974 equipment survey are given in Table C-1. The table is divided into two parts, with the primary channels listed in part one and the secondary channels in part two. The primary channel numbers are designated "1", "2", "3", etc. Channel "1" is at 160.230 MHz and consecutive primary channels are separated by 30 kHz. The secondary channel numbers are designated "1T", "2T", "3T", etc. Channel "1T" is at 160.215 MHz. The secondary channels are also separated by 30 kHz. However, the primary and secondary channels are interleaved, so that consecutive channels in the railroad mobile band have 15 kHz separation.

There are several observations to be made of the data in Table C-1. First, in regard to the number of licenses issued for each type of service, there is approximately a three-to-one ratio in the number of licenses used in train service as compared to those issued for use in general service. No similar observation can be made regarding the equipment inventory because the inventory was based on type of equipment, not utilization of that equipment. A second observation considers the distribution of licenses and equipment among the channels. The number of licenses issued for a given channel is the result of the number of railroads using that channel, the size of those railroads, the physical distribution of their lines and terminals, and the specific use of the channel capacity by each railroad. Consequently, there is no distinguishable pattern in the distribution within part one or part two of the table. However, there is a very definite difference in the number of licenses issued to primary channels and secondary channels. For train service, there are more than ten times as many licenses issued to the primary channels as to the secondary channels. The ratio for general services is a little less than

TABLE C-1 FCC VHF RAILROAD LICENSES

Part 1: (Primary Channels)

Channel No.	Frequency MHz	Utilization No. of Licenses TS	G	Equipment Inventory Mult. Channel	Mobile	Base	Total
1	160.230	187	61	462	1885	219	2566
2	160.260	197	32	1327	1606	222	3155
3	160.290	110	225	1419	772	298	2489
4	160.320	125	36	781	385	128	1294
5	160.350	183	107	864	1218	280	2362
6	160.380	91	94	169	1537	155	1861
7	160.410	400	119	456	5361	488	6305
8	160.440	63	60	1635	798	102	2535
9	160.470	294	100	866	898	334	2098
10	160.500	50	45	78	466	76	620
11	160.530	207	52	1173	992	254	2419
12	160.560	27	37	69	166	40	275
13	160.590	688	72	822	4764	622	6208
14	160.620	45	67	42	356	73	471
15	160.650	663	50	3098	4740	617	8455
16	160.680	24	98	515	396	84	995
17	160.710	19	53	306	283	71	660
18	160.740	277	91	315	3462	366	4143
19	160.770	155	50	313	1982	189	2484
20	160.800	417	45	1682	10425	562	12669
21	160.830	118	48	3388	317	129	3834
22	160.860	55	60	342	954	96	1392
23	160.890	177	142	296	2988	268	3552
24	160.920	240	43	530	750	218	1498
25	160.950	494	109	87	6878	582	7547
26	160.980	60	69	441	823	124	1388
27	16 .010	153	24	242	147	173	562
28	161.040	32	93	1017	252	112	1381
29	161.070	168	49	10467	455	170	11092
30	161.100	1102	93	1813	6984	1047	9844
31	161.130	220	36	255	2044	211	2510
32	161.160	120	133	2313	353	181	2847
33	161.190	453	40	1905	2940	334	5179
34	161.220	58	56	1546	456	92	2094
35	161.250	348	51	1395	3669	395	5459
36	161.280	180	92	436	888	235	1559
37	16o.310	115	71	1486	701	161	2348
38	161.340	32	57	1607	125	59	1791
39	161.370	404	58	105	5177	415	5697
40	161.400	408	50	88	1785	414	2287
41	161.430	57	48	658	526	105	1289
42	161.460	198	113	1272	859	273	2404
43	161.490	94	62	748	451	138	1337
44	161.520	206	43	4644	125	222	4991
45	161.550	358	68	2960	6014	411	9385
*46	161.610	176	0				
	TOTALS:	10248	3202	56433	89153	11745	157331

TABLE C-1 FCC VHF RAILROAD LICENSES

Part 2: (Secondary Channels)

Channel No.	Frequency MHz	Utilization No. of Licenses TS	G	Equipment Inventory Multi Channel	Mobile	Base	Total
1T	160.215	18	35	31	255	20	306
2T	160.245	213	14	540	65	196	801
3T	160.275	1	24	74	211	18	303
4T	160.305	69	13	503	57	93	653
5T	160.335	39	27	84	161	32	277
6T	160.365	0	24	33	12	18	63
7T	160.395	5	20	50	23	14	87
8T	160.425	0	9	0	33	4	37
9T	160.455	23	19	2521	357	45	2923
10T	160.485	0	21	17	27	15	59
11T	160.515	1	11	33	67	8	108
12T	160.545	4	17	75	27	10	112
13T	160.575	5	17	6	49	6	61
14T	160.605	3	4	68	49	2	119
15T	160.635	1	7	0	19	5	24
16T	160.665	2	9	4	19	3	26
17T	160.695	18	4	79	89	11	179
18T	160.725	11	10	70	72	15	157
19T	160.755	0	13	30	65	11	106
20T	160.785	25	8	132	233	9	374
21T	160.815	2	8	28	72	6	106
22T	160.845	12	17	80	57	16	153
23T	160.875	6	36	27	140	14	181
24T	160.905	10	6	16	17	3	36
25T	160.935	145	7	1158	77	184	1419
26T	160.965	3	17	101	38	15	154
27T	160.995	1	8	9	0	7	16
28T	161.025	27	15	250	295	21	566
29T	161.055	6	8	0	10	6	16
30T	161.085	5	4	17	19	6	42
31T	161.115	16	5	21	52	15	88
32T	161.145	3	8	8	90	6	104
33T	161.175	6	8	150	81	8	239
34T	161.205	27	29	30	333	3	366
35T	161.235	2	17	18	45	12	75
36T	161.265	42	7	501	166	38	705
37T	161.295	6	12	204	125	16	345
38T	161.325	1	22	16	129	28	173
39T	161.355	9	21	87	91	19	197
40T	161.385	39	15	136	152	22	310
41T	161.415	38	17	117	220	25	362
42T	161.445	12	10	98	137	15	250
43T	161.475	28	15	48	388	40	476
44T	161.505	5	27	95	157	15	267
45T	161.535	11	17	663	42	23	728
46T	161.565	29	30	382	93	50	525
	TOTALS	929	692	8610	4916	1148	14674

five-to-one. Correspondingly, a similar distribution of equipment would be expected. The ratio of total equipment between the primary and secondary channels is also greater than ten-to-one.

One cause for this uneven distribution could result from the way the channels were initially allocated and later reallocated. The channels were initially authorized at 60 kHz separation. This separation was later reduced to 30 kHz and still later to 15 kHz. A second reason for this uneven distribution is that a guard channel is often used between train service assignments in a given territory (state, group of states or area).

The totals of equipment collectively owned by the railroad industry show 94,145 mobile units and 12,934 base-station units. An additional 65,043 crystals are listed in the multiple-channel category. This number of units and the distribution among the various types continually changes to meet the requirements of the individual railroad companies.

A report of the distribution of railraods licensed to use VHF mobile radio equipment and the distribution of these licenses by state is given in Table C-2. Also, mappings of these distributions are shown in Figures C-1 and C-2. A similar distribution showing railroads and channels is contained in Table C-3. A mapping of the channel information by state is given in Figure C-3.

TABLE C-2. RAILROAD AND LICENSE DISTRIBUTION BY STATE

State Name	Number of Railroads	Number of Licenses	State Name	Number of Railroads	Number of Licenses
Alabama	11	489	Nebraska	8	250
Arizona	4	110	Nevada	3	78
Arkansas	14	213	New Hampshire	6	24
California	20	736	New Jersey	10	178
Colorado	12	259	New Mexico	5	83
Connecticut	2	40	New York	17	559
Delaware	3	25	North Carolina	16	400
Dist. of Columbia	6	19	North Dakota	4	206
Florida	13	453	Ohio	22	506
Georgia	15	770	Oklahoma	9	244
Idaho	7	152	Oregon	14	345
Illinois	28	493	Pennsylvania	28	588
Indiana	12	156	Rhode Island	2	14
Iowa	11	202	South Carolina	6	341
Kansas	8	325	South Dakota	4	34
Kentucky	13	317	Tennessee	14	432
Louisiana	21	416	Texas	30	672
Maine	6	62	Utah	5	155
Maryland	7	113	Vermont	6	56
Massachusetts	4	98	Virginia	15	420
Michigan	19	215	Washington	8	526
Minnesota	14	537	West Virginia	8	377
Mississippi	10	319	Wisconsin	9	145
Missouri	24	436	Wyoming	5	79
Montana	4	408			

TABLE C-3. RAILROAD AND CHANNEL DISTRIBUTION BY STATE

State Name	Number of Railroads	Number of Channels	State Name	Number of Railroads	Number of Channels
Alabama	11	72	Nebraska	8	26
Arizona	4	22	Nevada	3	16
Arkansas	14	35	New Hampshire	6	11
California	20	65	New Jersey	10	37
Colorado	12	41	New Mexico	5	13
Connecticut	2	12	New York	17	56
Delaware	3	15	North Carolina	16	39
Dist. of Columbia	6	12	North Dakota	4	14
Florida	13	38	Ohio	22	58
Georgia	15	49	Oklahoma	9	31
Idaho	7	27	Oregon	14	43
Illinois	28	69	Pennsylvania	28	62
Indiana	12	40	Rhode Island	2	5
Iowa	11	24	South Carolina	6	31
Kansas	8	42	South Dakota	4	9
Kentucky	13	47	Tennessee	14	63
Louisiana	21	44	Texas	30	46
Maine	6	16	Utah	5	35
Maryland	7	30	Vermont	6	18
Massachusetts	4	24	Virginia	15	66
Michigan	19	46	Washington	8	41
Minnesota	14	43	West Virginia	8	28
Mississippi	10	27	Wisconsin	9	23
Missouri	24	63	Wyoming	5	10
Montana	4	25			

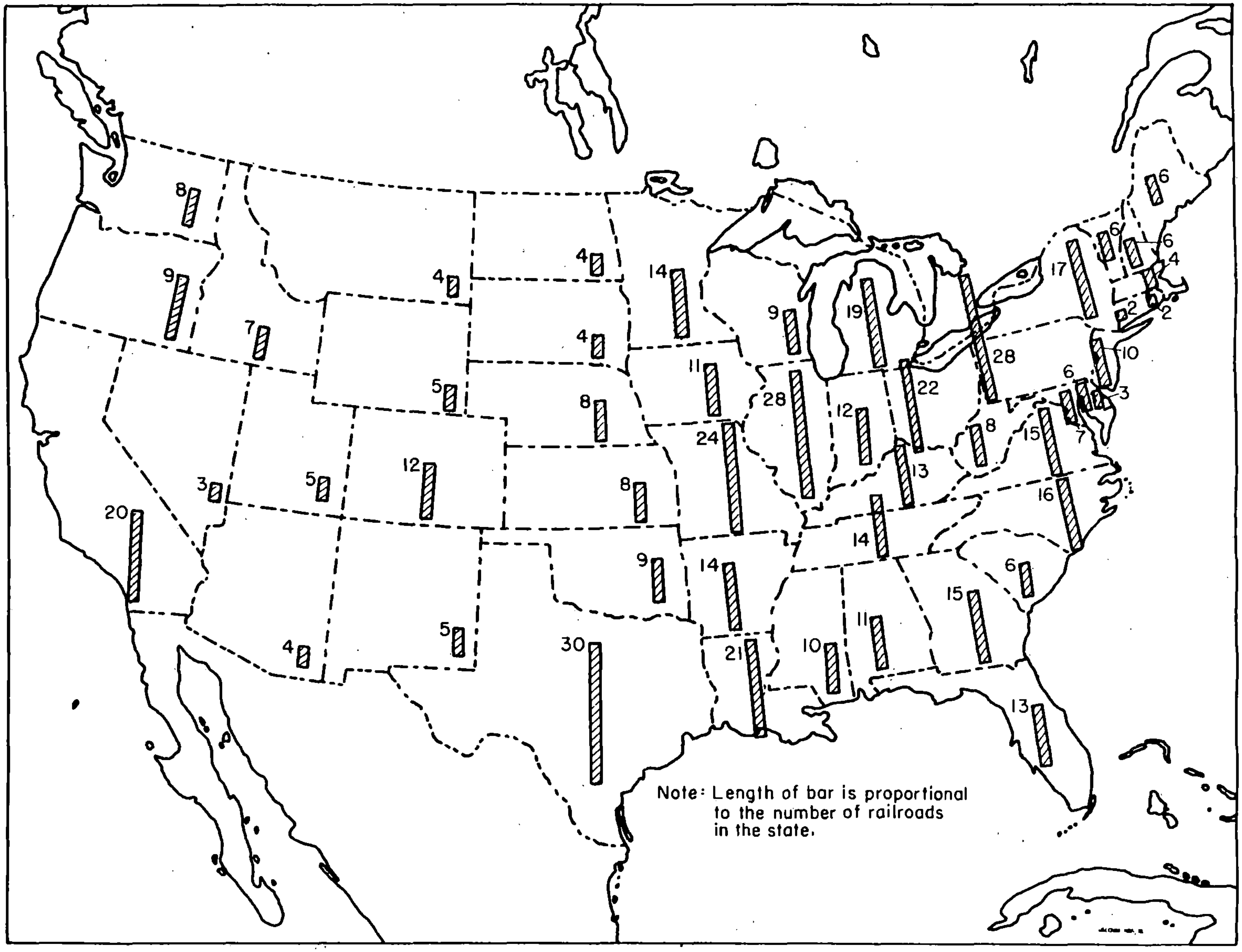

Figure C-1. A map of the number of railroads operating in each state.

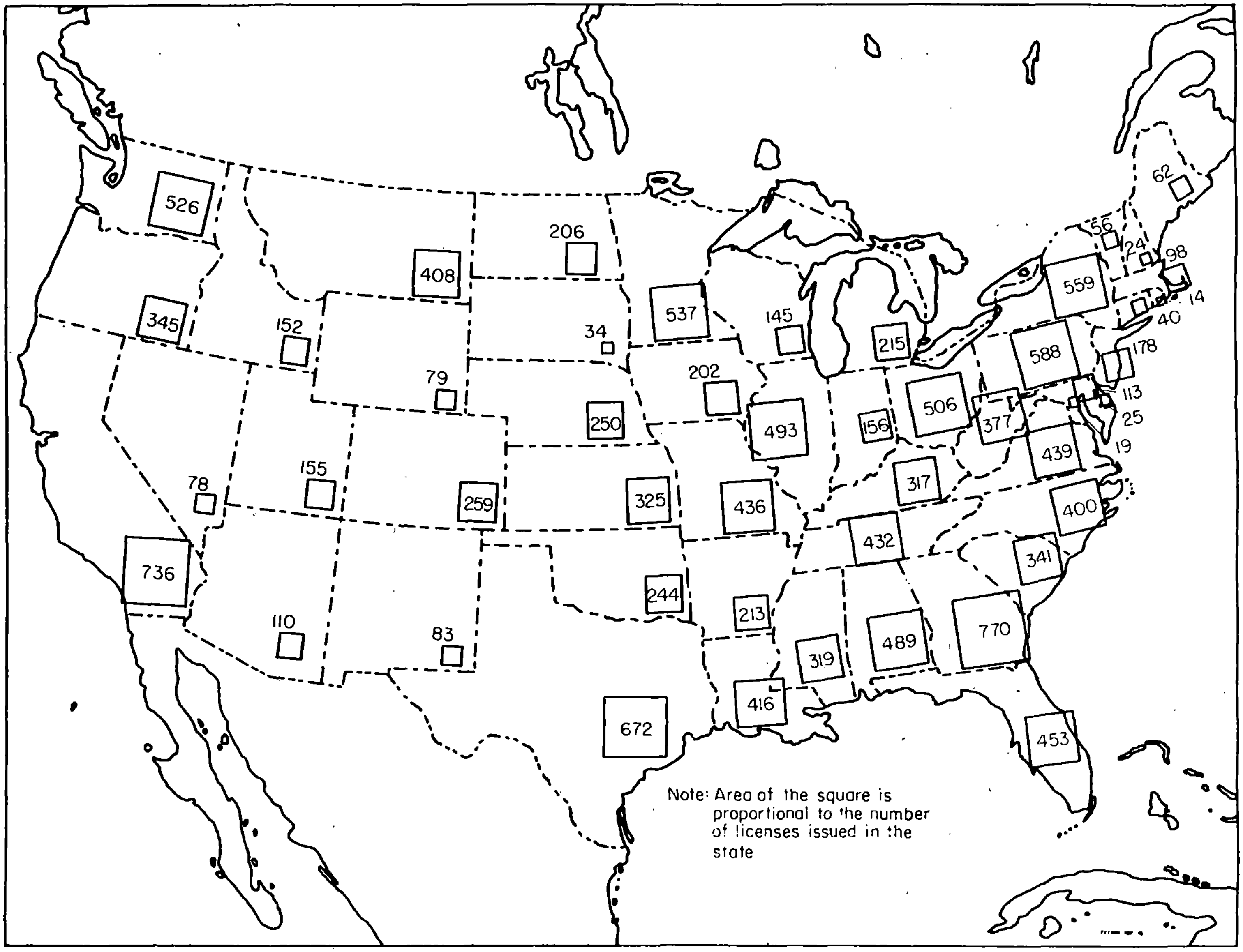

Figure C-2. A map of the number of mobile radio licenses issued to all railroads in each state.

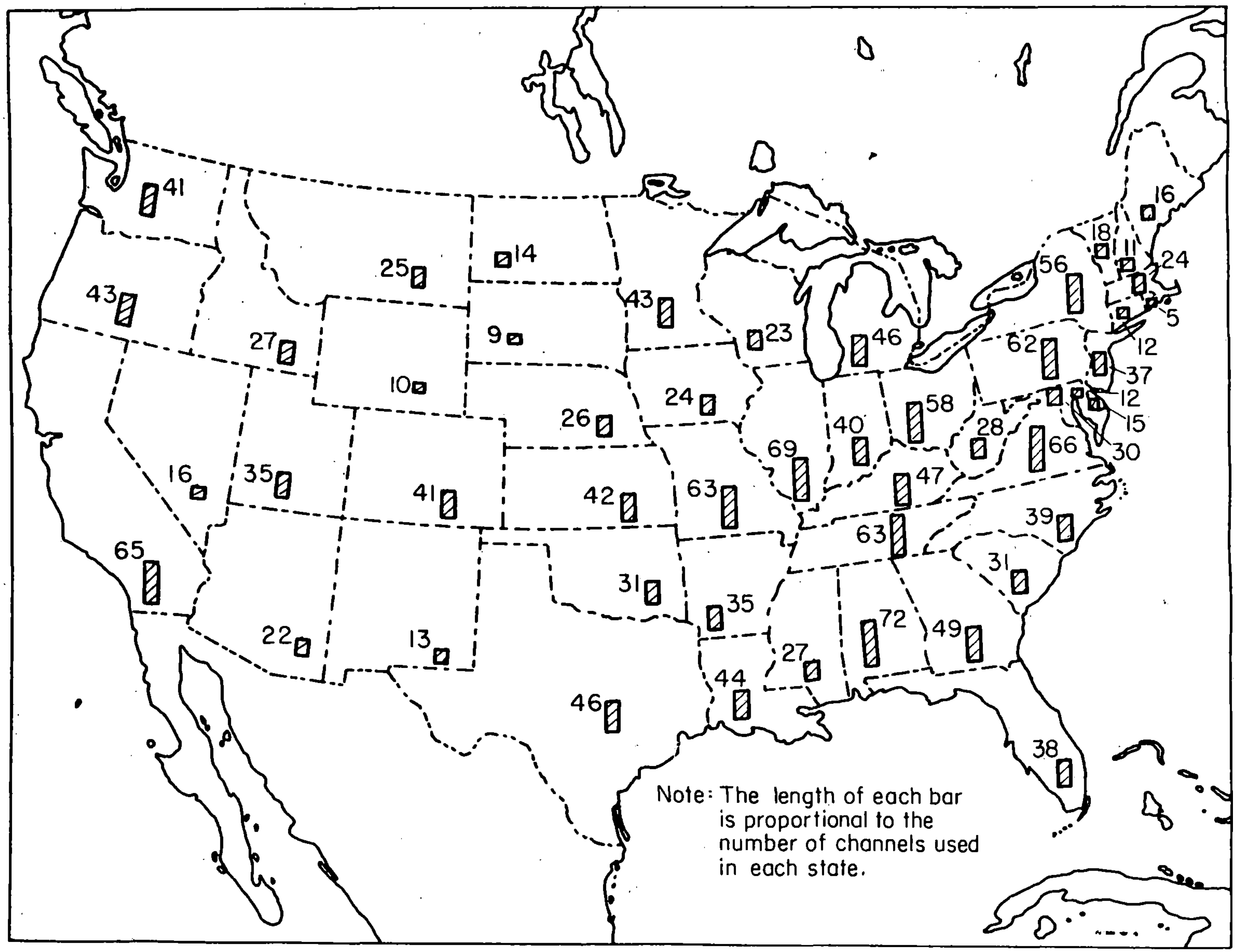

Figure C-3. A map of the number of channels used by all railroads in each state.

APPENDIX D - RAILROAD LICENSE DISTRIBUTION

Tables C-2 and C-3 in Appendix C list the total number of railroads that have been issued VHF radio frequency licenses, the number of licenses, and the number of VHF channels in use as distributed in the United States by state. These tables give only summations. In this appendix, the railroads and the corresponding number of licenses issued are identified. In the following pages, a short table is given for each state. The first column contains the railroad abbreviation. The second contains the number of licenses issued, and the third column gives the number of channels to which these licenses are issued. Totals are given for the first column (railroads) and the second column (licenses). Note that these lists contain only those railroads to whom licenses in the VHF mobile radio band have been issued and the totals may not correspond to the number of railroads operating in a given state.

A list of abbreviation identifications is given at the end of the appendix. The inclusion of a railroad name on the abbreviation list does not imply current radio frequency licensing of that railroad.

Table D-1 Railroad VHF License Distribution

ALABAMA

	LIC	CHN
AGS	20	2
ASAB	2	2
BS	16	14
HS	2	1
ICG	22	7
LN	117	17
SCL	72	8
SLSF	39	12
SOU	163	19
TASD	7	2
WA	28	8
11	488	

ARKANSAS

	LIC	CHN
ADN	6	2
ALM	2	2
BXN	2	1
DQE	1	1
ECHO	2	1
GNA	5	2
KCS	53	5
LA	5	5
LNW	2	2
MP	85	8
RI	13	3
SLSF	18	3
SSW	16	6
TP	2	2
14	212	

ARIZONA

	LIC	CHN
APA	2	1
ATSF	35	7
SMA	2	1
SP	70	13
4	109	

CALIFORNIA

	LIC	CHN
ABL	2	1
ATSF	88	17
BN	6	3
CCT	5	2
HBL	4	2
LAJ	3	1
METC	5	4
MR	6	2
NWP	32	4
RYEA	4	2
SERA	3	1
SMV	2	2
SN	9	3
SP	375	34
TRC	2	2
TS	15	4
UP	26	8
VCY	2	1
WP	142	13
YW	2	1
20	735	

COLORADO

	LIC	CHN
ATSF	26	6
BN	12	3
CS	7	2
CW	6	3
DRGW	140	15
GWR	13	2
MANP	3	1
MP	14	2
RI	7	2
RYEA	2	1
SLC	4	2
UP	22	9
12	258	

CONNECTICUT

	LIC	CHN
GTW	3	3
PC	36	9
2	39	

DISTRICT OF COLUMBIA

	LIC	CHN
BO	6	4
PC	1	1
RYEA	2	1
SOU	3	3
WATC	4	2
WMAT	2	1
6	18	

DELAWARE

	LIC	CHN
BO	3	3
PC	12	7
RDG	9	5
3	24	

FLORIDA

	LIC	CHN
AMTK	1	1
AN	9	3
ASAB	2	2
FEC	89	6
GSF	4	2
JT	10	6
LN	14	5
LOPG	2	1
MBT	2	1
RYEA	2	1
SCL	310	19
SLSF	3	2
SOU	4	1
ZST	4	1
14	456	

GEORGIA

	LIC	CHN
AGS	2	2
AWP	22	6
CG	46	2
CIRR	4	2
GA	64	8
GSF	21	2
LN	34	11
RYEA	2	1
SAN	3	2
SCL	359	17
SG	1	1
SM	6	2
SOU	197	20
VS	3	1
WA	5	5
15	769	

IDAHO

	LIC	CHN
APC	2	1
BN	46	10
CSP	8	4
MILW	4	1
SI	8	2
UP	81	16
WIM	2	1
7	151	

ILLINOIS

	LIC	CHN
ALS	12	6
ATSF	17	4
BN	45	6
BO	16	5
BRC	14	6
CEI	15	1
CIW	2	1
CNW	30	7
CWI	1	1
DRI	2	1
EJE	5	2
GMO	4	2
ICG	175	14
IHB	2	1
ITC	7	3
LN	16	5
MI	2	2
MILW	10	5
MP	18	2
NW	7	2
PC	26	4
RI	27	6
RYEA	2	1
SOO	5	4
SOU	16	2
SSW	4	4
TPW	3	1
TRRA	9	6
26	492	

INDIANA

	LIC	CHN
AWW	4	1
BO	10	6
CSS	2	1
EJE	5	2
ICG	10	4
IU	2	2
LN	53	7
MILW	1	1
NW	7	3
PC	38	8
RYEA	2	1
SOU	21	5
ZCRC	12	5
13	167	

IOWA

	LIC	CHN
ATSF	1	1
BN	35	5
CIC	2	1
CNW	51	2
DCI	4	2
DRI	2	1
ICG	41	4
MILW	18	1
RI	39	5
UP	4	3
WR	4	2
11	201	

KANSAS

	LIC	CHN
ATSF	113	13
CNW	1	1
KCS	5	5
MKT	8	2
MP	93	5
RI	52	9
SLSF	18	6
UP	34	6
ZMSI	2	1
9	326	

KENTUCKY

	LIC	CHN
CAD	2	1
CARR	1	1
CNTP	12	2
CO	53	16
CRR	1	1
FCIN	2	2
ICG	77	13
KIT	15	5
KT	3	1
LN	126	14
MILW	1	1
NW	7	1
SOU	16	3
ZCRC	10	6
14	326	

LOUISIANA

	LIC	CHN
AGS	4	2
ALM	4	2
ATSF	1	1
CNW	1	1
ICG	93	13
KCS	62	6
LA	97	5
LN	8	4
LOAM	2	1
MP	38	2
NLC	1	1
NLG	2	1
NOPB	5	2
RYEA	2	1
SOU	6	3
SP	27	7
SSW	5	4
STER	2	1
TP	33	3
TRMP	20	3
WWF	2	1
ZNOT	1	1
ZNOU	2	1
23	418	

MAINE

	LIC	CHN
BAR	28	4
BM	5	3
BML	7	2
GTW	9	3
MEC	8	2
PTM	4	2
ZNC	5	3
7	66	

MARYLAND

	LIC	CHN
BO	46	12
CTN	2	1
NW	1	1
PBR	10	5
PC	24	3
WM	21	4
WMAT	8	4
7	112	

MASSACHUSETTS

	LIC	CHN
BM	61	11
GTW	7	4
PC	22	5
PW	7	4
4	97	

MINNESOTA

	LIC	CHN
BN	255	19
CNW	26	2
DMIR	161	8
DNE	2	1
GBW	2	2
GTW	14	2
ICG	3	3
MDW	6	3
MILW	13	3
MNS	12	3
MTFR	4	2
RI	6	3
RYEA	2	1
SOO	28	3
14	536	

MICHIGAN

	LIC	CHN
AA	15	3
CLC	2	1
CNW	10	2
CO	34	6
DC	2	1
DM	6	1
DT	4	1
DTI	34	7
DTS	4	2
ELS	2	1
GTW	47	11
LSI	7	2
MILW	1	1
NW	8	3
PC	24	10
PHD	1	1
SOO	2	2
UBD	6	3
WYT	3	2
ZCRC	32	13
20	246	

MISSISSIPPI

	LIC	CHN
AGS	18	2
CCR	1	1
CGR	2	1
ICG	252	17
LN	5	2
MB	2	1
MSE	2	1
MSV	2	1
SLSF	19	6
SOU	15	4
10	318	

MISSOURI

	LIC	CHN
ALS	1	1
ATSF	10	1
BN	35	5
BVS	1	1
CNW	3	1
GMO	1	1
ICG	22	6
ITC	3	3
KCPS	1	1
KCS	47	6
KCT	4	3
MI	2	2
MILW	6	2
MKT	14	2
MP	111	9
MRS	8	3
NW	28	9
RI	21	3
RYEA	5	2
SLRX	1	1
SLSF	101	24
SSW	2	1
TRRA	7	5
UP	1	1
24	435	

MONTANA

	LIC	CHN
BAP	3	2
BN	389	23
MILW	13	1
UP	2	1
4	407	

NEBRASKA

	LIC	CHN
BN	93	5
CNW	21	2
GRIN	2	2
MILW	1	1
MP	15	2
RI	9	2
RYEA	2	1
UP	106	13
8	249	

NEVADA

	LIC	CHN
SP	47	8
UP	17	5
WP	13	5
3	77	

NEW HAMPSHIRE

	LIC	CHN
BM	9	4
BMS	2	1
CLCO	2	1
CSR	2	1
GTW	5	3
WLFB	3	1
6	23	

NEW JERSEY

	LIC	CHN
CNJ	60	7
EL	26	6
LHR	7	2
LV	9	6
ME	2	1
PATH	3	2
PC	29	10
PRS	27	3
RDG	12	4
RR	2	1
10	177	

NEW MEXICO

	LIC	CHN
ATSF	50	5
CS	2	1
RI	2	1
SP	26	4
TNM	2	2
5	82	

NEW YORK

	LIC	CHN
BM	5	5
BO	15	3
DH	96	5
EL	111	7
FJG	2	1
GNW	6	2
LHR	5	2
LI	122	11
LV	1	1
MSTR	4	1
NJ	2	1
NW	6	3
PC	147	25
RYEA	5	2
SB	10	2
SBK	20	2
SIRT	1	1
17	558	

NORTH CAROLINA

	LIC	CHN
AEC	2	1
AR	7	2
ARC	2	1
BEM	2	1
CF	1	1
CLIF	1	1
CRR	5	1
DS	4	1
LN	2	2
LRS	2	1
NS	24	4
NW	4	1
RYEA	2	1
SCL	225	19
SOU	106	11
WSS	10	2
16	399	

NORTH DAKOTA

	LIC	CHN
BN	181	10
CNW	2	2
MILW	2	1
SOO	20	2
4	205	

OHIO

	LIC	CHN
AA	3	3
ABB	2	1
ACY	10	2
BLE	18	6
BO	50	9
CO	53	14
CUVA	2	1
DTI	18	2
DTS	6	4
EL	52	5
FPE	2	1
LN	2	2
LT	1	1
NSS	2	1
NW	83	14
PC	183	24
PLE	6	5
RT	2	1
RYEA	5	2
SOU	3	3
TT	2	1
ZCRC	16	6
22	521	

OKLAHOMA

	LIC	CHN
ATSF	26	1
KCS	38	5
MKT	11	1
MP	10	2
RI	18	3
SLSF	116	21
SS	2	1
TOE	4	2
TP	18	2
9	243	

OREGON

	LIC	CHN
BN	88	10
COP	5	1
KN	2	1
LPN	2	1
NPT	5	2
OCE	3	2
OPE	2	1
RYEA	2	1
SP	137	16
UP	80	15
VSL	4	2
WCT	6	2
WCTU	6	2
WW	2	2
14	344	

PENNSYLVANIA

	LIC	CHN
ALOS	4	2
BLE	46	5
BO	15	6
CBL	4	2
CI	4	4
DH	22	4
EL	32	4
LEF	5	2
LV	8	3
MCRR	2	2
MGA	10	3
MKC	1	1
MSW	2	1
MTR	3	1
NB	2	1
NW	8	3
PAM	2	1
PBNE	6	3
PC	195	26
PLE	30	3
POV	1	1
PS	5	2
RDG	121	9
SH	6	3
SRC	2	1
UMP	2	1
URR	31	5
WM	18	3
28	587	

RHODE ISLAND

	LIC	CHN
PC	9	3
PW	4	2
2	13	

SOUTH CAROLINA

	LIC	CHN
CNL	2	2
CRR	2	1
LC	2	1
PIC	2	1
SCL	269	20
SOU	63	8
ZSCS	4	1
7	344	

SOUTH DAKOTA

	LIC	CHN
BN	11	3
CNW	13	1
ICG	4	4
MILW	5	1
4	33	

TENNESSEE

	LIC	CHN
CCR	1	1
CNTP	13	2
CRP	6	2
GMO	1	1
ICG	120	18
LN	117	15
MP	7	4
RI	3	2
RYEA	4	1
SHER	2	2
SLSF	36	17
SOU	116	17
SSW	1	1
TENN	4	2
ZHRC	1	1
15	432	

TEXAS

	LIC	CHN
ANR	2	1
ATSF	86	5
BRR	4	2
FWB	1	1
FWD	14	2
GHH	2	2
GSW	1	1
GWF	6	2
HBT	12	6
KCS	27	5
LA	48	5
MCSA	2	1
MKT	22	2
MP	121	4
PCN	2	1
PTR	3	1
PVS	3	1
QAP	3	2
RI	25	5
RSS	2	1
RYEA	4	2
SLSF	9	2
SP	141	20
SRN	5	1
SSW	17	3
TCT	4	2
TM	6	2
TN	2	1
TP	95	6
TSE	2	1
30	671	

UTAH

	LIC	CHN
CBC	3	1
DRGW	64	11
SP	7	5
UP	64	17
WP	16	5
ZSTT	2	2
6	156	

VERMONT

	LIC	CHN
BM	5	3
GMRC	1	1
GTW	26	4
MPB	4	2
SJLC	10	2
VTR	9	4
ZNC	12	2
7	67	

VIRGINIA

	LIC	CHN
CHW	4	1
CO	60	23
CRR	3	1
FG	2	1
LN	4	1
NFD	1	1
NPB	5	1
NS	5	3
NW	125	13
PC	1	1
RFP	72	34
SCL	70	8
SOU	59	7
WMAT	6	4
WN	2	1
ZCRC	19	11
16	438	

WASHINGTON

	LIC	CHN
BN	426	26
LPN	1	1
MILW	21	1
RYEA	2	1
SI	4	2
STC	2	1
UP	67	13
WW	2	2
ZTC	2	1
9	527	

WYOMING

	LIC	CHN
BN	20	1
CNW	2	1
CS	4	1
CW	1	1
UP	51	7
5	78	

WISCONSIN

	LIC	CHN
BN	43	12
CNW	43	2
DMIR	2	2
GBW	21	3
LSTT	1	1
MILW	11	2
MTW	2	1
RYEA	2	1
SOO	19	3
9	144	

WEST VIRGINIA

	LIC	CHN
BO	200	5
CO	54	9
MGA	6	3
NW	87	7
PC	15	3
WM	12	3
WNFR	1	1
WVN	1	1
ZCRC	38	11
9	414	

WASHINGTON, D. C.

	LIC	CHN
AA	4	4
ALM	2	2
ALS	6	6
AMTK	23	23
ASAB	2	2
ATSF	31	28
AUCX	3	3
AWP	5	5
BLE	5	3
BM	2	2
BN	61	35
BO	7	4
CCR	1	1
CEI	1	1
CHV	1	1
CNW	6	6
CRR	3	3
CS	2	2
DH	7	7
DQE	2	2
DRGW	20	13
DRI	1	1
DTI	3	3
DTS	3	3
EL	13	7
FCIN	2	2
FWD	2	2
GBW	3	3
GTW	24	15
ICG	37	28
ITC	4	4
KCPS	1	1
KCS	8	8
KCT	2	2
LA	8	8
LHR	2	2
LN	30	17
LNW	2	2
LSI	2	2
LV	8	7
MB	1	1
MEC	2	2
MGA	1	1
MILW	5	4
MKT	4	4

TASD Term. Rwy. Alabama State Docks
TN Texas & Northern Rwy.
TP Texas & Pacific Lines
TCT Texas City Term. Rwy.
TM Texas Mexican Rwy.
TNM Texas-New Mexico Rwy.
TOE Texas, Oklahoma & Eastern RR
TRMP Texas Pacific-Missouri Pacific Term. RR of New Orleans
TSE Texas South-Eastern RR
TS Tidewater Southern Rwy.
TPW Toledo, Peoria & Western RR
TT Toledo Term. RR
TRC Trona Rwy.

UP Union Pacific RR
URR Union RR (Pittsburgh)
UMP Upper Merion & Plymouth RR

VSL Valley & Siletz RR
VCY Ventura County RR
VTR Vermont Rwy.
VS Voldosta Southern RR

WW Walla Walla Valley Rwy.
WIM Washington, Idaho & Montana Rwy.
WMAT Washington Metropolitan Area Transit Authority
WATC Washington Term. Co.
WWR Washington-Western Rwy. Co.
WAS Waynesburg Southern Rwy.
WM Western Maryland Rwy.
WP Western Pacific RR
WA Western Rwy. of Alabama
WVN West Virginia Northern RR
WW Winchester & Western RR
WNFR Winifrede RR
WSS Winston-Salem Southbound Rwy.
WLFB Wolfeboro RR
WYT Wyandotte Term. RR

YN Youngstown & Northern RR
YS Youngstown & Southern Rwy.
YW Yreka Western RR

UBD Union Belt of Detroit
KOG Kansas, Oklahoma & Gulf
NUP New Orleans Union Pass Term.
GF Georgia & Florida RR
CLC Cadillac & Lake City RR
WCT White City Term.
NEO Northeast Oklahoma RR
IN Illinois Northern RR

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