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SOAC

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

VOLUME VII. POST-REPAIR TESTS

NOVEMBER 1975
FINAL REPORT

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16. Abstract

This document presents the test results for the State-of-the-Art Car Post-Repair Engineering Test Program conducted at the DOT High-Speed Ground Test Center, Pueblo, Colorado, from March 18th to 29th, 1974. The SOAC has been developed under UMTA's Urban Rapid Rail Vehicle and Systems Program to enhance the attractiveness of rapid rail transportation to the urban traveller.

The test data continuity between the original HSGTC Engineering Tests and the Post-Repair Test was established. Test data of variations from the original data have not been significant in terms of overall vehicle performance.

A description of test procedures, equipment and facilities was provided in the original six-volume report, UMTA-MA-06-0025-75-1 through -6.

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PREFACE

Following completion of engineering tests in July 1973, the State-of-the-Art Car (SOAC) vehicles sustained damages in an accidental collision which necessitated repairs and initiated study and operations to verify the validity of the previously recorded test data in relation to the repaired vehicles. This report documents those post-repair engineering tests.

The SOAC vehicles were developed by the U.S. Department of Transportation, Urban Mass Transportation Administration. Designed and produced by Boeing Vertol Company, under contract with the UMTA Office of Research and Development, Rail Technology Division, the vehicles were tested in an engineering test program under contract DOT-TSC-580 awarded to Boeing Vertol Company by the DOT Transportation Systems Center for the Urban Rail Supporting Technology Program sponsored by the UMTA, OR&D, Rail Technology Division.

The engineering tests were based on the "General Vehicle Test Plans for Urban Rapid Transit Cars", TSC Ground Systems Programs Specification No. GSP-064, published in April 1972 for the URST Program. The procedures for testing based on the GVTP and used for both the original engineering testing and the post-repair engineering testing, are described in Report No. UMTA-MA-06-0025-75-1 thru -6, "State-of-the-Art Car Engineering Tests at Department of Transportation High Speed Ground Test Center", January 1975, Final Test Report.

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1. INTRODUCTION

A series of Engineering Tests on the State-of-the-Art Transit Car (SOAC) units No.1 and No. 2 were carried out during the period of April 1973 to July 1973 at the U.S. Department of Transportation High Speed Ground Test Center, Pueblo, Colorado (HSGTC); see Ref. 1. The follow-on program to demonstrate reliability under Simulated Revenue Service was interrupted by an accidental collision of the SOAC train with a standing gondola car on August 11, 1973 (See Ref 2). After completion of repairs to the No. 2 Car, an Abbreviated Test and Demonstration Program was carried out at HSGTC from February 27, 1974 to April 10, 1974 with the Engineering Tests being conducted from March 18th to 29th. This report presents the test descriptions and test results of the Abbreviated Engineering Test portion of the program along with plots of the original test program results for direct comparison.

1.1 SOAC TEST VEHICLE DESCRIPTION AND STATUS

The SOAC cars represent a baseline definition of available technology for rail transit equipment. Each of the two SOAC cars, Ref. (1) Volume I, are 75 feet long by 9-3/4 feet wide. The underframe, sides, and roof structures are of welded high-strength low-alloy steel supporting a shell consisting of spot welded stainless steel skin and molded fiberglass ends. The propulsion system of traction motors, gearboxes, power supplies and control systems provide operations in both driving and braking modes. The four 600 VDC motors are mounted two to a truck and connected electrically in series. The motors are full compensated D.C. with separately excited fields and have a continuous rating of 175 HP at 1560 rpm (460 amps).

Control of the motors is by force commutated DC-DC chopper in the armature circuit and by AC-AC phase delay rectifiers in the separate field circuits. AC power is supplied to the auxiliary power motor generator set which in turn supplies power to the traction motor field control and to the on-board accessory equipment such as air conditioning, etc. Control subsystems provide for load weigh, jerk rate and wheel spin-slide compensation, as well as dynamic-friction brake blending.

Dynamic braking is supplied by the traction motors acting as generators with resistor grids supplying braking force and by friction brake shoes on each wheel actuated by air cylinders.

SOAC Car No. 1 was not damaged by the collision and its condition was unchanged from the original Engineering Test Program. SOAC Car No. 2 was restored to its original condition by replacement of body structure and equipment at the damaged end. Additional details are provided in SOAC Final Report, Ref. (3) Volume V.

1.2 SOAC ABBREVIATED TEST PLAN AND OBJECTIVES

The following tests were conducted in accordance with procedures outlined in revised Test Vehicle Plan Ref. 4.

- Acceleration
- Deceleration - Blended Braking
- Power Consumption
- Structures
- Noise Interior/Exterior

The object was to establish the test data continuity for the repaired SOAC car and the original HSGTC Engineering Tests.

1.3 SOAC INSTRUMENTATION SYSTEMS AND STATUS

1.3.1 Ride Qualities, Structural and Performance Tests

Electrical signals from the vehicle mounted transducers are conducted by cables to an interface panel which is connected to an instrumentation console containing two magnetic tape recorders, two light beam oscillographs, a time code generator, a temperature recorder and signal conditioners. Any 28 selected test parameters can be recorded on tape and displayed on the oscillographs. In addition, wheel speeds may be recorded directly on the oscillographs; total power is recorded on tape and displayed on a mechanical counter. The time code generator provides signals that are recorded on both tape and the oscillograph. The oscillographs provide quick-look data to evaluate test progress and results during testing (See Figure 1-1).

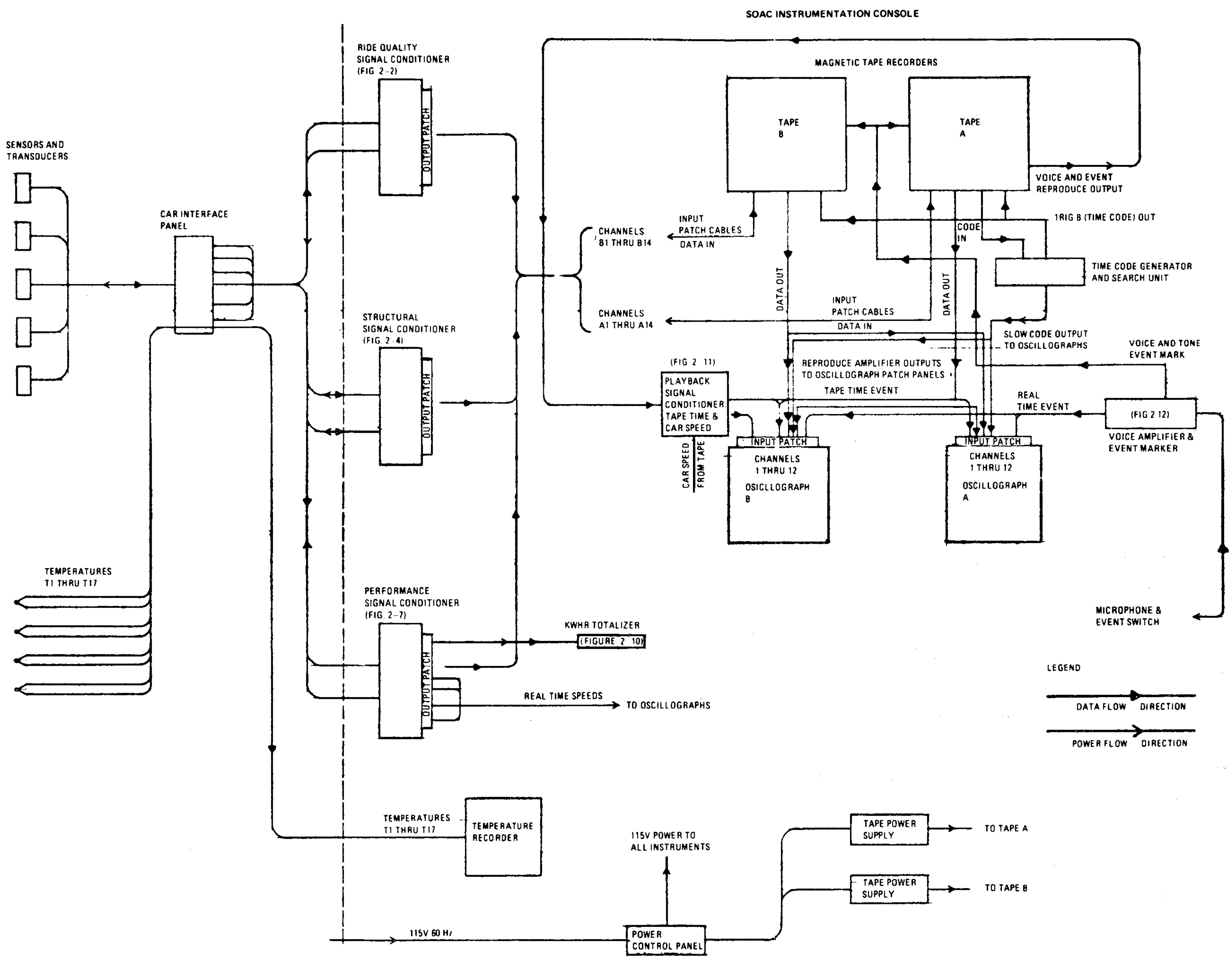


Figure 1–1. SOAC Instrumentation System Block Diagram

1.3.2 Noise Tests

The instrumentation used for noise measurement consisted of a 1-inch condenser microphone with battery operated cathode follower and a 1/4-inch single-channel tape recorder (See Figure 7-1).

1.3.3 Status for Abbreviated Test Program

Prior to the August 11, 1974 accident, the SOAC Instrumentation Console and a majority of the transducers had been removed from Car No. 2. The undercar instrumentation cabling was inspected and repaired by Garrett Corporation technicians during car repair at the Boeing Vertol facility in Philadelphia, Pa. The transducers which were on the car at the time of the accident were checked at the Garrett Corporation facility. Only four (4) strain gaged Damper Rod Connecting Links required replacement. In addition, the truck frame strain gages were replaced while the trucks were disassembled at the Vertol facility. Prior to the start of the Abbreviated Test Program, the SOAC Instrumentation System was checked and found to be operational.

2. TEST RESULTS

2.1 GENERAL

A comparison between the Post-Repair Test data set and the data obtained from the original HSGTC Test Program shows the two sets to be compatible, and this establishes a continuity between the two sets. The Repaired SOAC Car/ Performance and response are slightly different than the original car but not to a significant degree. The repaired Instrumentation System operated satisfactorily, as it did in the original tests.

2.2 TEST RESULTS SUMMARY

- Performance

  The repaired SOAC demonstrated slightly higher acceleration and deceleration rates than the original configuration. All of the weight and controller input trends are similar to the original tests. Since the rates were to be re-set to lower values for subsequent Demonstration operation on the transit properties, the rate differences reported here are not important. Rate changes in the SOAC propulsion system are relatively easy within the bands indicated.

- Power Consumption

  The retest power consumption for the SOAC was 12 percent lower than the original tests. This could be attributable to a "hotter" car (quicker starts and stops) and also to driver technique. The SOAC test driver's had considerably more experience in driving the SOAC to a schedule during the Retest Program.

- Ride Quality

  Car body ride quality, as indicated by ride roughness was not significantly different from the original test data. Only the higher speeds show a slightly higher level. This variation is probably due to rougher tracks or wheel conditions. The rougher conditions is exhibited in the higher levels of journal box accelerations for the Retest data.

- <u>Noise</u>

  Some variations in the post-repair noise levels were noted, particularly at the higher speeds. Although not fully explainable, the higher values at the high speed are partly attributable to the "rough" conditions described above. The installation of return air silencers in the airflow system returned the Noise Levels to the original test envelopes.

- <u>Structures</u>

  As in the original tests, a detailed analysis of the structure loads and levels was not accomplished. However, a cursory examination indicates trends in levels and phasing of loads to be similar to the original tests.

3. ACCELERATION TESTS

3.1 TEST DESCRIPTION AND PROCEDURES

In general, testing consisted of accelerating the test car or train from a standing stop to its maximum achievable speed over a 4000-foot section of level track at various combinations of Master Controller inputs, car weights and track line voltages. SOAC-P-2001-TT Baseline Test Procedure was used for each test run. The log of test runs and records is presented in Table 3-1.

3.2 TEST DATA

The test parameters recorded on magnetic tape and displayed on direct read-out oscillographs are presented in Table 3-2.

Distance data is obtained using the event marker which is triggered at the start and at each of the 500-foot markers along the track. For time-speed-distance data, zero time is based on first perceived car motion and not controller input.

The digitized data obtained from the tape recordings was taken at a sampling rate of one per second using filtering on applicable channels.

3.3 TEST RESULTS

Figure 3-1 presents the acceleration control characteristics from the original SOAC tests and the repaired SOAC tests for 105,000-lb cars in one and two car train configurations. Acceptable data was obtained for the repaired SOAC at Master Controller inputs of 0.875 amp and 0.75 amp; however, in attempting to obtain full service acceleration with a "P" signal of 1.0 amp, the track voltage dropped below the nominal 600 volts due to the limited capacity of the trackside electric generator. The estimated data for a "P" signal of 1.0 amp was obtained by applying the change in acceleration rate between the "P" signal of 0.75 amp and 0.857 amp.

Table 3–1. SOAC Acceleration Test Run Log.

TYPE OF WHEELS: RESILIENT

DATE	RUN NO.	RECORD NO.	DATA SHEET NO.	TYPE OF TEST	P-SIG	MAX OR INITIAL SPEED (MPH)	CAR WEIGHT (LB)	CAR NO.	DIR	LINE VOLTS	NOTES
3/22/74	224	1045	14B	Control	1.0	79	105,000	2	Fwd	600	After Car Repair
		1051		Response	1.0	79					
		1057		and Car	0.75	60					
		1102		Weight	0.75	72					
3/25/74	227	1609	14B	Control	1.0	74	105,000	1	Fwd	560	After Car Repair
		1614		Response	0.75	64		2		600	
		1622		and Car	0.75	74				600	
		1628		Weight	0.875	71				600	
3/26/74	229	1428	14B	Control	1.0	60	130,000	2	Fwd	600	After Car Repair
		1434		Response	0.75	60					
				and Car							
				Weight							
3/27/74	230	1309	14B	Control	1.0	80	90,000	2	Fwd	600	After Car Repair
		1313		Response	0.75	60					
		1319		and Car	0.75	74					
				Weight							

Table 3–2. Laboratory Tape Recorder Data Sheet

Test Title Performance

Specimen P/N SOAC Specimen S/N No. 2 Car Test Location Pueblo

Date 7/14/73 Test Eng ______ Tech RPM-DLB Tape Type & Size 1-inch x 7200 ft 3M

Tape Recorder Model No. 3614 Tape Recorder S/N 7291 Tape Speed 1-7/8 IPS Record Mode FM

Chan No.	Parameter Description	Transducer Type & S/N	Sig Cond Gain or Atten	Tape FS Level	Record Elect Type	Record Elect C.E.	Remarks	Quick-Look Oscillograph Location
1	Long Accel 301	±0.25 G's		±5.0 VDC	FM	3.375 KC	± 0.25G's = ± 5.000 VDC	R/H
2	Line E 302	Volt/Div S/N D02		±5.0 VDC	FM	3.375 KC	Zero VDC = -5.00 VDC +1000 VDC = +5.00 VDC	L/H
3	Line I 303	3000 AMP Hall Device		±5.0 VDC	FM	3.375 KC	Zero ADC = -5.00 VDC + 2000 ADC +5.00 VDC	L/H
4	#1 Arm E 304	Volt/Div S/N 001		±5.0 VDC	FM	3.375 KC	+ 1200 VDC = 5.00 VDC	L/H
5	#1 Arm I 305	1000 AMP AM-A-C		±5.0 VDC	FM	3.375 KC	+ 1000 ADC = 5.00 VDC	R/H
6	#1 Field I 306	150 A S/N 57	3 Turns 50A =5.0 VDC x 1	±5.0 VDC	FM	3.375 KC	± 50 ADC = ±5.00 VDC	L/H
7	#2 Arm E 307	Volt/Div S/N 003		±5.0 VDC	FM	3.375 KC	+ 1200 VDC = 5.00 VDC	L/H
8	#2 Arm I 308	1000 AMP AM-A-C		±5.0 VDC	FM	3.375 KC	+ 1000 ADC = 5.00 VDC	R/H
9	#2 Field I 309	500A AM-A-C	5 Turns 50A =2.5 VDC x 2	±5.0 VDC	FM	3.375 KC	± 50 ADC = ± 5.00 VDC	L/H
10	P Wire I 310	1.0 AMP AM-A-C		±5.0 VDC	FM	3.375 KC	+ 1.0 ADC = 5.00 VDC	R/H
11	Analog Valve I 311	5.0 AMP AM-A-C		±5.0 VDC	FM	3.375 KC	5.0 ADC = 5.00 VDC	L/H
12	Speed 315	Monopole		±5.0 VDC	FM	3.375 KC	80 MPH = 626.5 HZ	R/H
13	Brake Press 318	Tabor 0-200 PSIG Mod 185		±5.0 VDC	FM	3.375 KC	100 PSIG = 5.00 VDC	R/H
14	Time Code	IRIG B		±5.0 VDC	FM	3.375 KC		Both (2)
Edge A							NOTE: D.S. #14 for Post-Wheel Change Data Only	
Edge B	Voice & Event				Dir			Both (2)

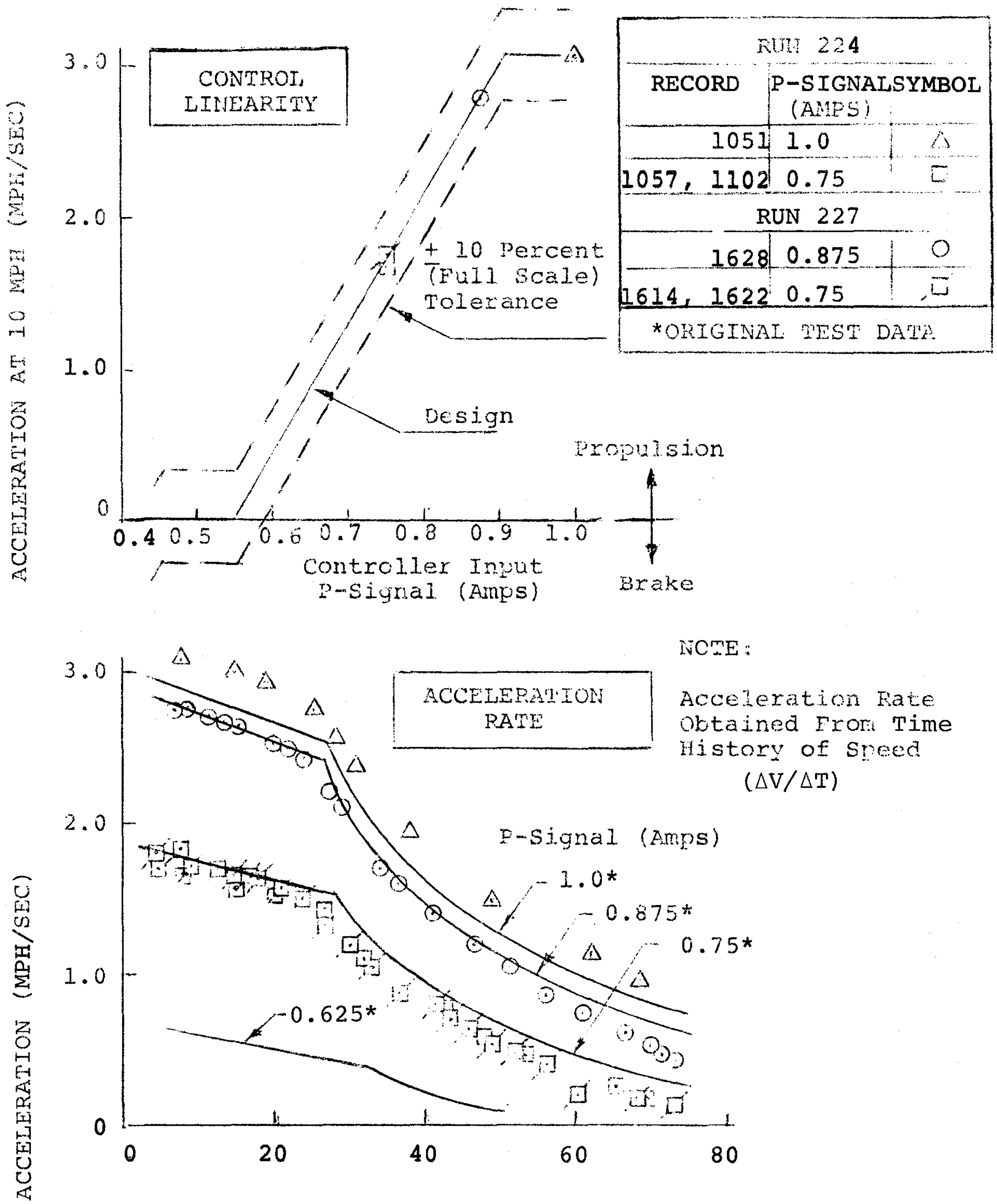


Figure 3—1. Acceleration Control Characteristics

Figure 3-2 presents the acceleration vs car weight from the original SOAC tests and the repaired SOAC tests for three different car weights operating in single car configuration.

3.4 DISCUSSION OF TEST RESULTS

In Figure 3-1, the calculated acceleration vs car speed data as plotted for "P" signal = 1.0 amp from the repaired SOAC tests shows higher accelerations for the same car speeds than the original data. This is undoubtedly due to the uncertainty of assumptions involved. This discrepancy is not reflected in the control linearity plot of acceleration vs controller input; since the calculated data is still within the ± 10% full scale tolerance band.

In Fiqure 3-2, there are some noticeable differences between the original SOAC test data and the repaired SOAC data. These could be due to a zero shift of the accelerometer or may be due to the type of filters used in digitizing the magnetic data tapes.

3.5 CONCLUSION

The acceleration test results for the repaired SOAC cars are sufficiently close to those obtained from the original tests to conclude that there was no appreciable change in the acceleration characteristics of the SOAC cars due to the repair modifications.

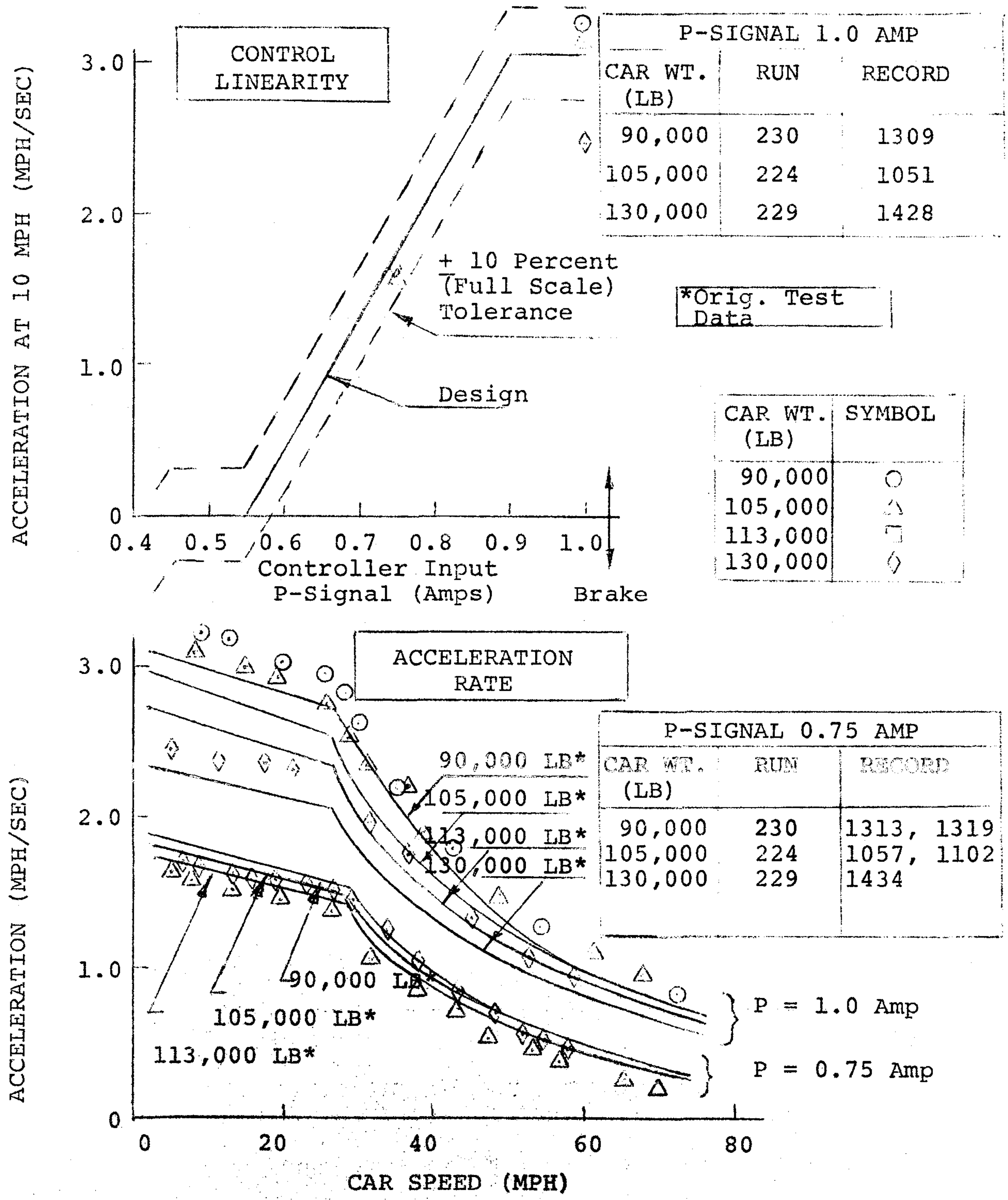


Figure 3–2. Acceleration versus Car Weight

4. DECELERATION TESTS

4.1 TEST DESCRIPTION AND PROCEDURES

In general, the deceleration testing was performed by accelerating the car or train consist to the deceleration test target speed prior to entering the Station 300 to 340 test zone. At the beginning of the test zone, the motorman applied blending braking by means of the Master Controller. Braking runs were made at car weights of 90,000, 105,000, and 130,000 lb for single car operation and 105,000 lbs for 2-car consist. SOAC-P-3001-TT Baseline Test Procedure was used for each test run. The log of test runs and records is presented in Table 4-1.

4.2 TEST DATA

The test parameters recorded on magnetic tape and displayed on direct read-out oscillographs are presented in Table 4-2.

Time and distance to stop were recorded from hand-held stopwatches and a surveyor's steel chain with 0.1 foot markings. Event marks on the magnetic tape records were used for time measurements also.

The digitized data obtained from the tape recordings was taken at a sampling rate of one or two second intervals, using filtering on applicable channels.

4.3 TEST RESULTS

Figure 4-1 presents the deceleration control characteristics from the original SOAC tests and from the repaired car tests for 105,000-lb cars in one and two car train configurations and for "P" signal control inputs of 0.0 amps (full service) and 0.25 amps. It was noted that the distance required to stop the two car train from a 79 mph "brake" entry speed was 1,410 ft. The single car retest distance for the same brake entry was 1,468 ft. Previous testing with solid wheels at the SOAC specification deceleration rate, required a distance of 1,687 feet.

Table 4–1. SOAC Deceleration Test Run Log

TYPE OF WHEELS: RESILIENT

DATE	RUN NO.	RECORD NO.	DATA SHEET NO.	TYPE OF TEST	P-SIG	MAX OR INITIAL SPEED (MPH)	CAR WEIGHT (LB)	CAR NO.	DIR	LINE VOLTS	NOTES
3/22/74	224	1110 1119	14B	Blended Braking	0.0 0.25	79 78	105,000	2	Fwd	600	After Car Repair
3/25/74	227	1604 1637	14B	Blended Braking	0.0 0.25	79 80	105,000 (Train)	1 2	Fwd	600	After Car Repair
3/26/74	229	1414 1422	14B	Blended Braking	0.0 0.25	60 60	130,000	2	Fwd	600	After Car Repair
3/27/74	230	1247 1254	14B	Blended Braking	0.0 0.25	80 80	90,000	2	Fwd	600	After Car Repair

Table 4–2. Laboratory Tape Recorder Data Sheet

Test Title Performance Test Type Deceleration

Specimen P/N SOAC No. 2 Car Specimen S/N ______ Test Location Pueblo

Date ______ Test Eng ______ Tech ______ Tape Type & Size 1 in. x 7200 ft 3M

Tape Recorder Model No. 3614 Tape Recorder S/N 7291 Tape Speed 1-7/8 IPS Record Mode FM

Chan No.	Parameter Description	Transducer Type & S/N	Sig Cond Gain or Atten	Tape FS Level	Record Elect		Remarks	Quick-Look Oscillograph Location
					Type	C.E.		
1	301 Long Accel	±0.25G's		±5.00VDC	FM	3.375 KC	± 0.25G's = ± 5.00 VDC	R/H
2	302 Line E	Volt/Div. S/N 002		±5.00VDC	FM	3.375 KC	Zero VDC = -5.00 VDC + 1000 VDC = +5.00 VDC	L/H
3	303 Line I	3000 Amp Hall Device		±5.00VDC	FM	3.375 KC	Zero ADC = -5.00 VDC + 2000 ADC = +5.00 VDC	L/H
4	304 #1 Arm E	Volt/Div S/N 001		±5.00VDC	FM	3.375 KC	+ 1200 VDC = 5.00 VDC	L/H
5	305 #1 Arm I	1000 Amp AM-A-C		±5.00VDC	FM	3.375 KC	+ 1000 ADC = 5.00 VDC	R/H
6	306 #1 Field I	150A S/N 57	3 Turns 50A=5.0 VDC x 1	±5.00VDC	FM	3.375 KC	± 50 ADC = ± 5.00 VDC	L/H
7	307 #2 Arm E	Volt/Div S/N 003		±5.00VDC	FM	3.375 KC	+ 1200 VDC = 5.00 VDC	L/H
8	308 #2 Arm I	1000 Amp AM-A-C		±5.00VDC	FM	3.375 KC	+1000 ADC = 5.00 VDC	R/H
9	309 #2 Field I	500 A AM-A-C	5 Turns 50A=2.5 VDC x 2	±5.00VDC	FM	3.375 KC	± 50 ADC = ± 5.00 VDC	L/H
10	310 P Wire I	1.0 Amp AM-A-C		±5.00VDC	FM	3.375 KC	+ 1.0 ADC = 5.00 VDC	R/H
11	311 Analog Valve I	5.0 Amp AM-A-C		±5.00VDC	FM	3.375 KC	5.0 ADC = 5.00 VDC	L/H
12	315 Speed	Monopole		±5.00VDC	FM	3.375 KC	80 MPH = 626.5 HZ	R/H
13	318 Brake Press	Tabor 0-200 PSIG Mod 185		±5.00VDC	FM	3.375 KC	100 PSIG = +5.00 VDC	R/H
14	Time Code	Irig B		±5.00VDC	FM	3.375 KC		Both (2)
Edge A							NOTE: D.S. #14 for Post-Wheel Change Data Only.	
Edge B	Voice & Event				Dir			Both (2)

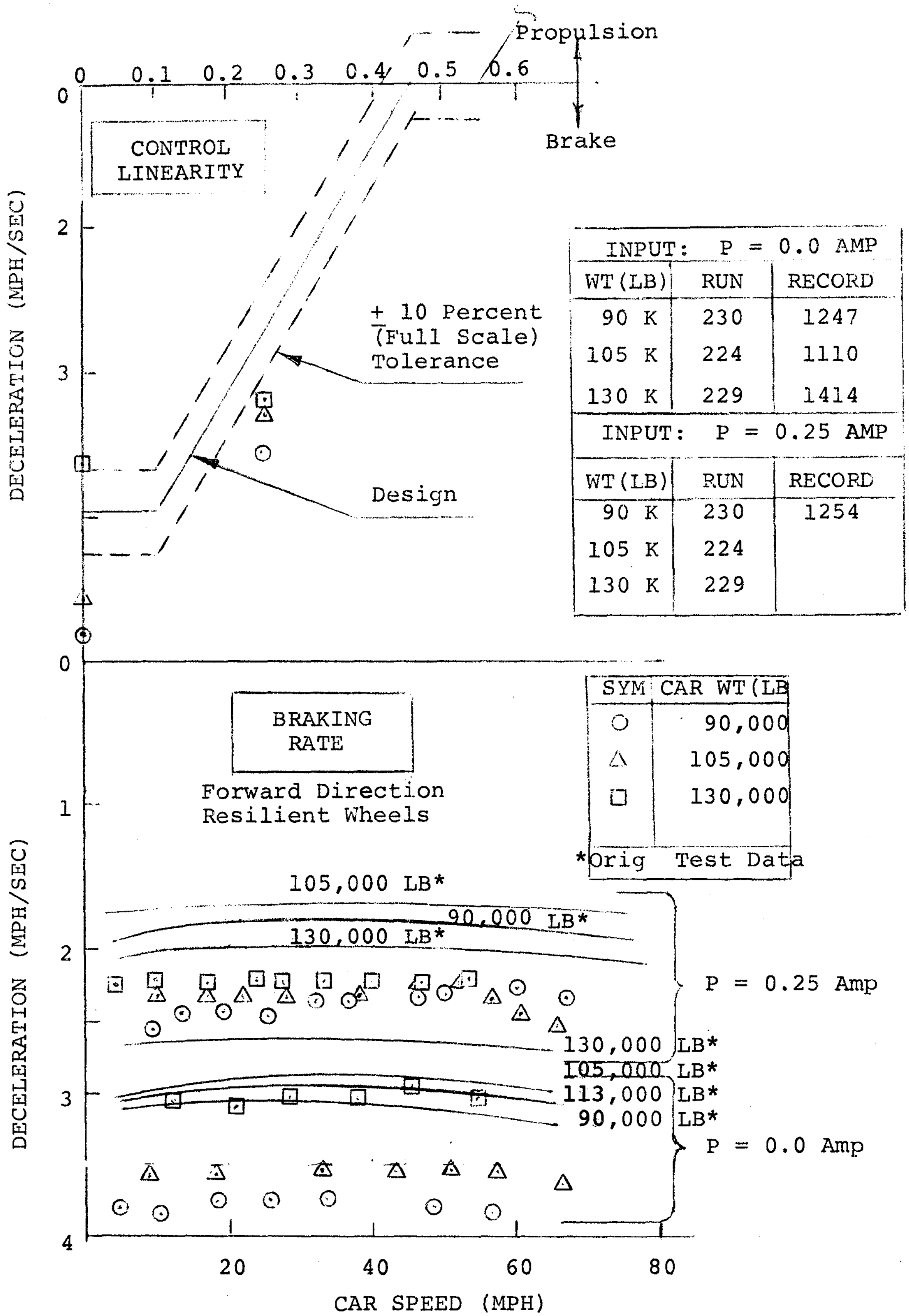


Figure 4—1. Blended Braking Load Weight Compensation

Figure 4-2 presents the blended braking load weight compensation control characteristics from the original tests and the repaired car tests for various car weights in single car configuration, and for "P" signal control inputs of 0.0 amps and 0.25 amps. It was noted that the distance required to stop the 90,000-lb car from a brake entry speed of approximately 80 mph was 1,450 ft. the same as for the 105,000-lb car.

4.4 DISCUSSION

The deceleration rates for all the repaired car tests exceeded those measured during the original test program and also exceeded the SOAC specification rates. In addition, the control linearity for the repaired car tests exceeded the ± 10% (full scale) tolerance band.

This result is significant, but no adjustments were made to the SOAC control system during the test program at the HSGTC. The SOAC Transit Property Demonstration Program allows the SOAC acceleration and deceleration rates to be set to property limits.

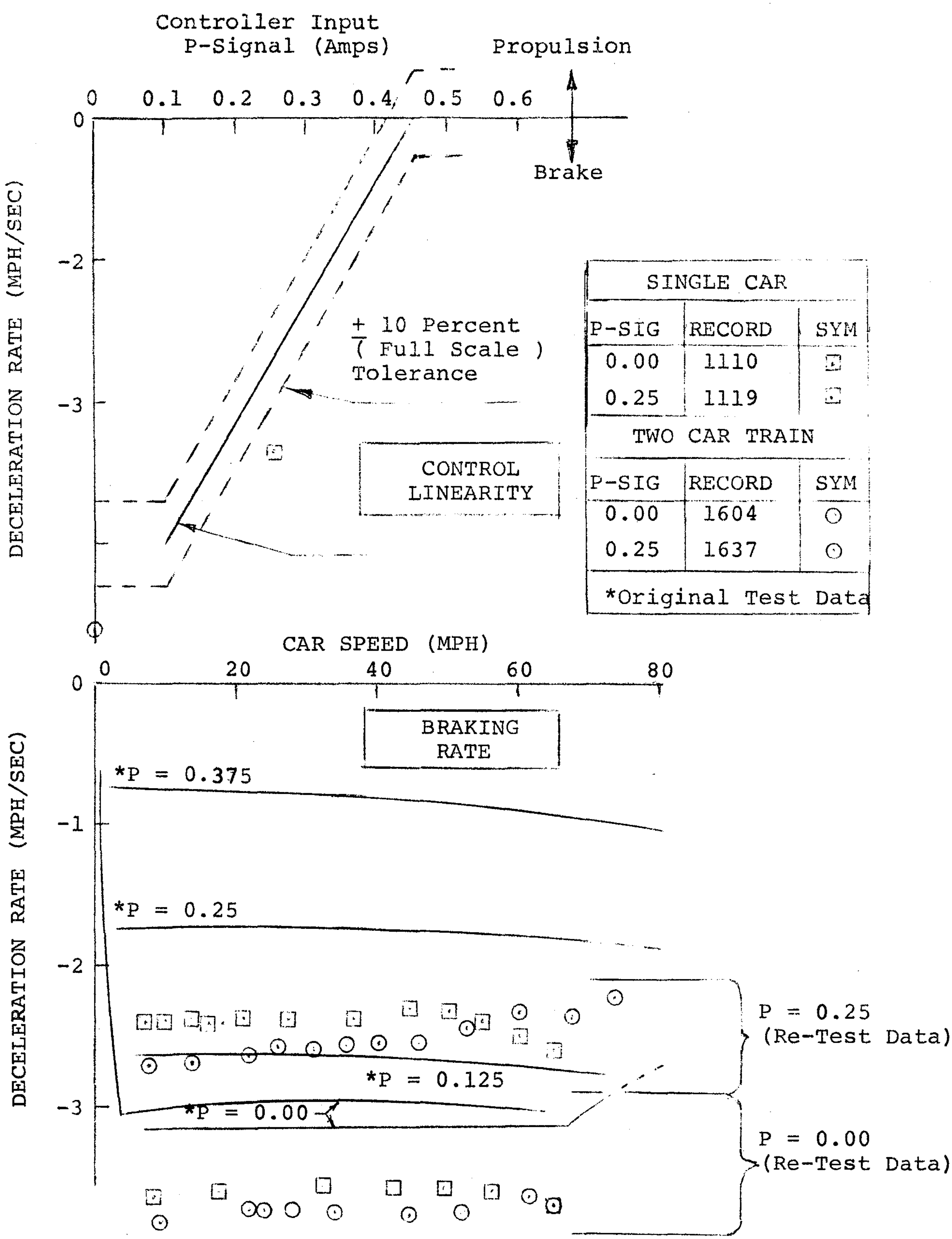


Figure 4–2. Blended Braking Control Characteristics (105,000-lb Car Weight)

5. POWER CONSUMPTION AND UNDERCAR EQUIPMENT TEMPERATURE TESTS DURING SIMULATED TRANSIT OPERATION

5.1 TEST DESCRIPTION AND PROCEDURES

Schedule service performance in terms of power consumption, schedule speed and undercar equipment temperatures were evaluated during sample service runs on a 9.25 mile, 15 station ACT-1 synthetic transit route as shown in Figure 5-1. The route was run from Station A to Station X and return for each round trip. Two round trips were made, one at 105,000-lb car weight and one at 90,000-lb; see Table 5-1 for Test Run Log. The baseline Power Consumption Test Procedure RB-PC-5011-TT was used for each test run. Air temperatures within several equipment enclosures were measured during each run.

5.2 TEST DATA

The test data reduction for the power consumption tests consisted of counting the kilowatt-hour pulses recorded during the test. Current signals were digitized and processed to obtain the rms values for the motor armature and field currents, see Tables 5-3 and 5-4.

The temperature data reduction consisted of determining the peak parameter temperatures and adjusting to a 125°F ambient temperature (one-to-one basis). Table 5-5 summarizes these adjusted equipment temperatures for two test runs (149 and 153) from the original SOAC tests and for two test runs (228 and 230) following car repair. The performance level of the car during the synthetic route tests approximates the one-hour rating of the traction system.

5.3 DISCUSSION

The rms values for the armature and field currents for the 90,000-lb car weight are shown in Table 5-4. A comparison of the energy consumption between the original test runs and those following car repairs shows the latter to be approximately 12% less than the former.

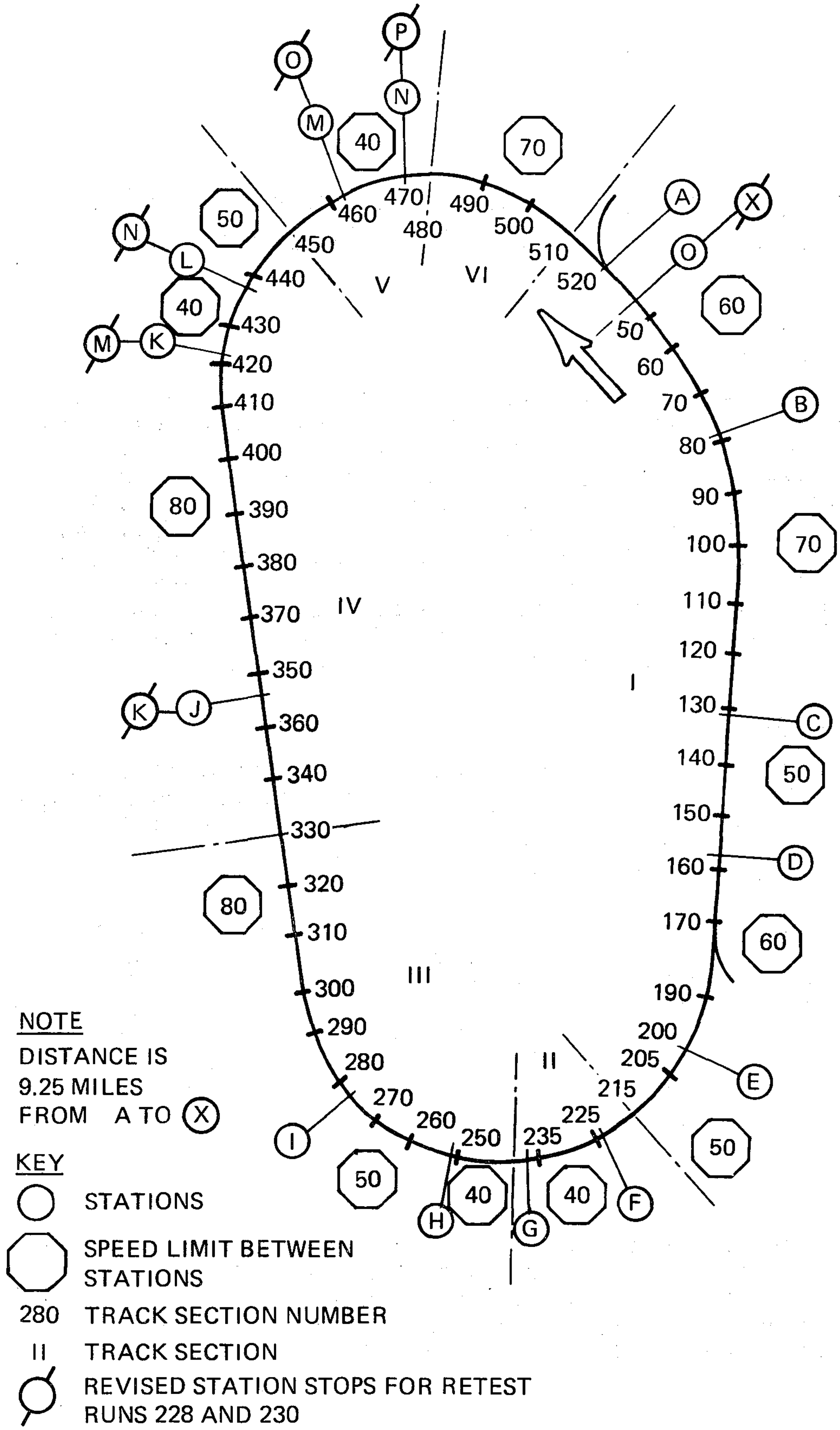


Figure 5–1. ACT-1 Synthetic Transit Route as Revised for Post-Repair Testing

Table 5–1. SOAC Power Consumption: Undercar Equipment Temperature Test Run Log

(TYPE OF WHEELS: SOLID AND RESILIENT)

DATE	RUN NO.	RECORD NO.	DATA SHEET NO.	TYPE OF TEST	P-SIG	MAX OR INITIAL SPEED (MPH)	CAR WEIGHT (LB)	CAR NO.	DIR	LINE VOLTS	NOTES
3/26/74	228	952	15B	ACT-1 Route (CCW)	1.0 0.0	Various 80	105,000	2	Fwd	600	Resilient Wheels Retests After Car Repairs
		1018		ACT-1 Route (CW)					Rev		
	230	1333	15B	ACT-1 Route (CW)	1.0 0.0	Various 80	90,000	2	Fwd	600	Resilient Wheels Retests After Car Repairs
	1405			ACT-1 Route (CW)					Rev		

Table 5–2. Laboratory Tape Recorder Data Sheet

Test Title Energy Consumption Test Type Energy Consumption

Specimen P/N SOAC NO. 2 Car Specimen S/N ______ Test Location Pueblo

Date ______ Test Eng ______ Tech ______ Tape Type & Size 1 in. x 7200 ft 3M

Tape Recorder Model No. 3614 Tape Recorder S/N 7291 Tape Speed 1-7/8 IPS Record Mode FM

Chan No.	Parameter Description	Transducer Type & S/N	Sig Cond Gain or Atten	Tape FS Level	Record Elect Type	Record Elect C.E.	Remarks	Quick-Look Oscillograph Location
1	Long. Accel 301			5.00VDC	FM	3.375 KC	±0.25G's = ±5.00VDC	R/H
2	Line E 302			10.00 VDC	FM	3.375 KC	Zero VDC = Zero VDC +1000 VDC = -10.00VDC	L/H
3	Line I 303			10.00 VDC	FM	3.375 KC	Zero Amps DC = Zero VDC +2000 Amps DC = -10.00 VDC	L/H
4	#1 Arm E 304			5.00VDC	FM	3.375 KC	1200 VDC = 5.00 VDC	L/H
5	#1 Arm I 305			5.00VDC	FM	3.375 KC	1000 ADC = 5.00 VDC	R/H
6	#1 Fld I 306			5.00VDC	FM	3.375 KC	±50 ADC = ±5.00 VDC	L/H
7	#2 Arm E 307			5.00VDC	FM	3.375 KC	±1200 VDC = ±5.00 VDC	L/H
8	#2 Arm I 308			5.00VDC	FM	3.375 KC	+1000 ADC = +5.00 VDC	R/H
9	#2 Fld I 309			5.00VDC	FM	3.375 KC	±50 ADC = ±5.00 VDC	L/H
10	P Wire I 310			5.00VDC	FM	3.375 KC	+1.0 ADC = +5.00 VDC	R/H
11	Total Pwr Consumption 317			5.00VDC	FM	3.375 KC	1.0 Pulse/0.1 KW	L/H
12	Speed 315			5.00VDC	FM	3.375 KC	80 MPH = 626.5 Hz	R/H
13	Brake Press 318			5.00VDC	FM	3.375 KC	100 PSIG = +5.00 VDC	R/H
14	Time Code	IRIG B		5.00VDC	FM	3.375 KC		Both (2)
Edge A								
Edge B	Voice & Event				Dir			Both (2)

Table 5–3. Summary of SOAC Energy Consumption and RMS Values for Armature and Field Currents on Act-1 Synthetic Transit Route (105,000-Pound Car, Run 228).

STATIONS (TWO DIRECTIONS)	MAXIMUM SPEED (MPH)	DISTANCE (MILES)	ENERGY (KW-HR)* TOTAL	ENERGY (KW-HR)* PER CAR MILE	TIME BETWEEN STATIONS (SEC)	I^2 ARMATURE-SEC $x10^6$	I^2 FIELD-SEC $x10^3$
A-B	60	0.75	7.8	10.4	86.0	20.2	52.62
B-C	70	1.00	10.75	10.75	102.5	26.15	59.25
C-D	50	0.50	5.0	10.0	79.0	14.5	48.12
D-E	60	0.75	7.8	10.4	93.0	19.9	53.63
E-F	50	0.50	5.4	10.8	86.0	14.25	50.25
F-G	40	0.25	3.5	14.0	67.0	10.9	42.0
G-H	40	0.25	3.55	14.2	64.5	9.1	37.25
H-I	50	0.50	5.15	10.3	79.0	14.5	50.0
I-K	80	1.50	14.6	9.73	130.5	39.15	60.8
K-M	80	1.25	13.75	11.0	115.0	33.3	61.13
M-N	40	0.25	3.9	15.6	64.5	12.2	45.63
N-O	50	0.50	5.5	11.0	79.5	16.1	51.88
O-P	40	0.25	3.65	14.6	67.0	10.8	43.38
P-X	70	1.00	10.95	10.95	107.0	28.85	56.88
Total x	(2)	18.5	202.6	10.95**	2440	539.8×10^6	1425.64×10^3

SCHEDULE SPEED: 27.3 MPH

RMS VALUE ~ AMP $\left(\frac{\Sigma I^2 \Delta t}{\Delta t}\right)^{1/2}$

ARMATURE	FIELD
470.3	24.17

*INCLUDES AUXILIARY POWER

**ORIGINAL TEST DATA = 12.43

Table 5–4. Summary of SOAC Energy Consumption and RMS Values for Armature and Field Currents on ACT-1 Synthetic Transit Route (90,000-Pound Car, Run 230)

STATIONS (TWO DIRECTIONS)	MAXIMUM SPEED (MPH)	DISTANCE (MILES)	ENERGY (KW-HR)* TOTAL	ENERGY (KW-HR)* PER CAR MILE	TIME BETWEEN STATIONS (SEC)	I^2 ARMATURE-SEC $x10^6$	I^2 FIELD-SEC $x10^3$
A-B	60	0.75	6.4	8.55	74.5	16.82	49.22
B-C	70	1.00	8.8	8.8	89.0	22.78	55.79
C-D	50	0.50	5.4	10.8	119.0	12.5	61.87
D-E	60	0.75	6.6	8.8	80.5	16.9	52.3
E-F	50	0.50	4.58	9.17	69.0	12.96	46.6
F-G	40	0.25	3.25	12.98	56.0	9.67	41.9
G-H	40	0.25	3.43	13.72	54.5	9.32	34.94
H-I	50	0.50	4.4	8.8	65.5	12.75	46.82
I-K	80	1.50	12.38	8.25	105.0	29.59	58.5
K-M	80	1.25	11.17	8.94	97.5	28.75	55.23
M-N	40	0.25	3.63	14.5	58.5	9.1	33.55
N-O	50	0.50	4.68	9.36	65.0	13.88	48.05
O-P	40	0.25	3.2	12.83	56.0	9.44	43.78
P-X	70	1.00	8.99	8.99	99.5	23.93	53.3
Total x	(2)	18.5	173.8	9.39	2179	456.78×10^6	1363.7×10^3

SCHEDULE SPEED: 27.5 MPH

RMS VALUE ~ AMP

$$\left(\frac{\Sigma I^2 \Delta t}{\Delta t}\right)^{1/2}$$

ARMATURE	FIELD
457.8	25.0

*INCLUDES AUXILIARY POWER

TABLE 5-5. SUMMARY OF UNDERCAR EQUIPMENT TEMPERATURES ON SYNTHETIC TRANSIT ROUTE (105,000- AND 90,000-POUND CARS ADJUSTED TO 125°F AMBIENT SOAC DESIGN GOAL)

PARAMETER	NO.	PEAK TEMPERATURE F ORIGINAL RUN 149	RUN 153	POST-REPAIR RUN 228	RUN 230
Propulsion blower, outlet air	4	135	146	-	-
Chopper box, Interior air	8	141	150	145	147
Chopper box, outlet air	3	142	148	155	175
Traction motor, outlet air	12	183	182	165	175
Traction motor, No. 3 frame	1	151	151	-	-
PCU, Interior air	6	147	156	152	160
PPCU, Interior air	9	178	177	154	164
APCU, Interior air	10	155	165	149	163
Motor smoothing reactor	7	167	166	155	155
Brake grid air	5	820*	850*	790*	735*
Motor-alternator, Outlet air	11	169	168	163	172
Air conditioner, Condenser, Input air	2	162	157	-	-
Test ambient air		75	79	60	70

NOTES

(1) Performance level - duty cycle: 1-hour rating

(2) PCU = Power control unit

(3) PPCU = Propulsion power control unit

(4) APCU = Auxiliary power control unit

(5)

Run	Car Weight (Pounds)
149	105,000
153	105,000
228	105,000
230	90,000

*Peak recorded temperatures during brake applications.

6. RIDE QUALITY TESTS

6.1 TEST DESCRIPTION AND PROCEDURES

Testing for ride quality vibration measurements consisted primarily of following the Baseline Test Procedures SOAC-R-2001-TT, SOAC-R-3001-TT and SOAC-R-4001-TT (abbreviated) for Acceleration, Deceleration and Steady Speed Runs respectively. The test runs were as follows:

Test Run 221	March 20, 1974	SOAC No. 2 Car	(90,000 Lb)
Test Run 223	March 20, 1974	SOAC No. 2 Car	(105,000 Lb)
Test Run 232	March 28, 1974	SOAC No. 2 Car	(90,000 Lb)

The original ride quality tests were performed at five (5) speeds over each of the six (6) track sections for a total of 30 data points. Data from these tests showed that the track construction had very little influence on the vibration levels; therefore, this series of tests was restricted to a speed sweep (five speeds) over Track Section I, (see Figure 5-1), and a single pass over the five (5) remaining track sections. This is a total of ten data points.

The accelerometer locations during these tests were exactly the same as the original test program. The selection rationale is repeated below:

a. Forward, mid and rear car centerline vertical accelerometers were located to obtain the effect of car body vertical flexible modes, and vertical/pitch rigid body modes on car body vibration.

b. Forward, mid and rear car centerline lateral accelerometers were located to obtain the effect of flexible and rigid lateral/yaw modes on car body vibration.

c. It was assumed that there was no longitudinal flexibility of the car, therefore only longitudinal pickup was necessary to measure the rigid body motion.

d. Vertical mid-car centerline, mid-car righthand and mid-car lefthand accelerometers were used to determine the effect of the rigid body roll modes on vibration.

e. Forward car centerline lateral and forward car ceiling lateral were used to determine the effect of frame racking or car body torsion modes on vibration.

f. The location of journal box accelerometers was selected to determine truck response from track vertical, lateral, and cross level alignments.

Accelerometers used to measure car floor accelerations were rigidly mounted directly to the underside of the floor support structure. The lateral accelerometer at the ceiling was mounted to a stanchion. Truck accelerometers were mounted to brackets rigidly attached to the journal boxes and traction motors.

Car body and journal box locations are given in Table 6-1.

6.2 TEST DATA

As with the original SOAC tests, the accelerometer outputs were recorded on magnetic tape and digitized to obtain the peak vibration amplitudes and Power Spectral Densities. A review of the plotted data from the tests of the repaired car showed that the peak amplitudes for the mid-car vertical accelerations ocurred at the same frequencies as for the original car. These are as follows:

1.5 Hz	Rigid Body Suspension Mode
7.5 Hz	First Car Body Vertical Bending Mode
15.0 Hz	Second Car Body Vertical Bending Mode
30.0 Hz	Component Induced Vibration Frequency

Table 6–1. Ride Quality Accelerometer Locations

Parameter	Direction	Range	Frequency
CAR BODY			
• Linear Accelerations			
Fwd car floor, truck centerline	Vertical	±.30 G	30 Hz
Fwd car floor, truck centerline	Lateral	±.30 G	30 Hz
Fwd car floor, truck centerline	Longitudinal	±.30 G	30 Hz
Centerline car floor, rear end	Vertical	±.30 G	30 Hz
Centerline car floor, rear end	Lateral	±.30 G	30 Hz
Fwd car floor LH, truck centerline	Vertical	±.30 G	30 Hz
Centerline car floor, mid-car	Vertical	±.30 G	30 Hz
Centerline car floor, mid-car	Lateral	±.30 G	30 Hz
Car floor RH, mid-car	Vertical	±.30 G	30 Hz
Car floor LH, mid-car	Vertical	±.30 G	30 Hz
Centerline car ceiling, mid-car	Lateral	±.30 G	30 Hz
• Angular Accelerations			
Mid-car centerline	Pitch Roll Yaw	±.4 Rad/Sec.	5 Hz
TRUCK			
• Linear Accelerations			
Fwd RH wheel, front	Vertical	±25 G	30 Hz
Fwd RH wheel, front	Lateral	±25 G	30 Hz
Aft RH wheel, front	Vertical	±25 G	30 Hz
Aft RH wheel, front	Lateral	±25 G	30 Hz
Fwd LH wheel, front	Vertical	±25 G	30 Hz
Aft LH wheel, front	Vertical	±25 G	30 Hz
Fwd RH wheel, rear	Lateral	±25 G	30 Hz
Aft RH wheel, rear	Lateral	±25 G	30 Hz
Fwd motor housing at cg	Vertical	±15 G	30 Hz
Fwd motor housing at cg	Lateral	±15 G	30 Hz

The test data was further processed to develop the ride roughness values. Ride roughness is a weighted vibration parameter which accounts for human response characteristics. This parameter and the data reduction method is the same as for the original tests and is described in reference 1.

Figure 6-1 shows a typical peak amplitude and power spectral density plot of the ride quality accelerometer retest data. Appendix B contains 120 similar plots which can be compared to the original data in reference 1.

Figures 6-2 through 6-7 present a comparison of some of the original ride roughness values with those of retest. Figures 6-8 through 6-11 present the peak journal vibration amplitudes vs frequency at car speeds of 35, 45, and 80 mph. Figure 6-12 shows a comparison of the original and retest vibration levels together with the SOAC design goals for vertical and lateral accelerations at mid-car and aft car centerline locations respectively.

6.3 Discussion

Test run No. 221 test speeds were higher than those specified in the test procedures due to an error in the SOAC Speed Maintaining System, nevertheless, the data has been included in this report. The maximum true speed was 94 mph.

With respect to the original tests, all levels in Figure 6-1 except the 15.0 Hz response are lower. The 15.0 Hz bending mode is sharply dependent upon speed and a very small difference in speed between the original and the re-tests could account for the level differences.

The first comparison, Figure 6-2, shows the effect of speed for the SOAC aft car lateral ride roughness for the original and the retest cases. The data are very similar with only the 80 mph point being slightly higher.

Figure 6-3 shows the effect of speed for the SOAC forward car vertical ride roughness. The data between the two tests is very similar. The retest levels diverge and become higher than the original test levels above 50 mph. The journal box accelerations reveal that the test track or wheels were rougher during the re-

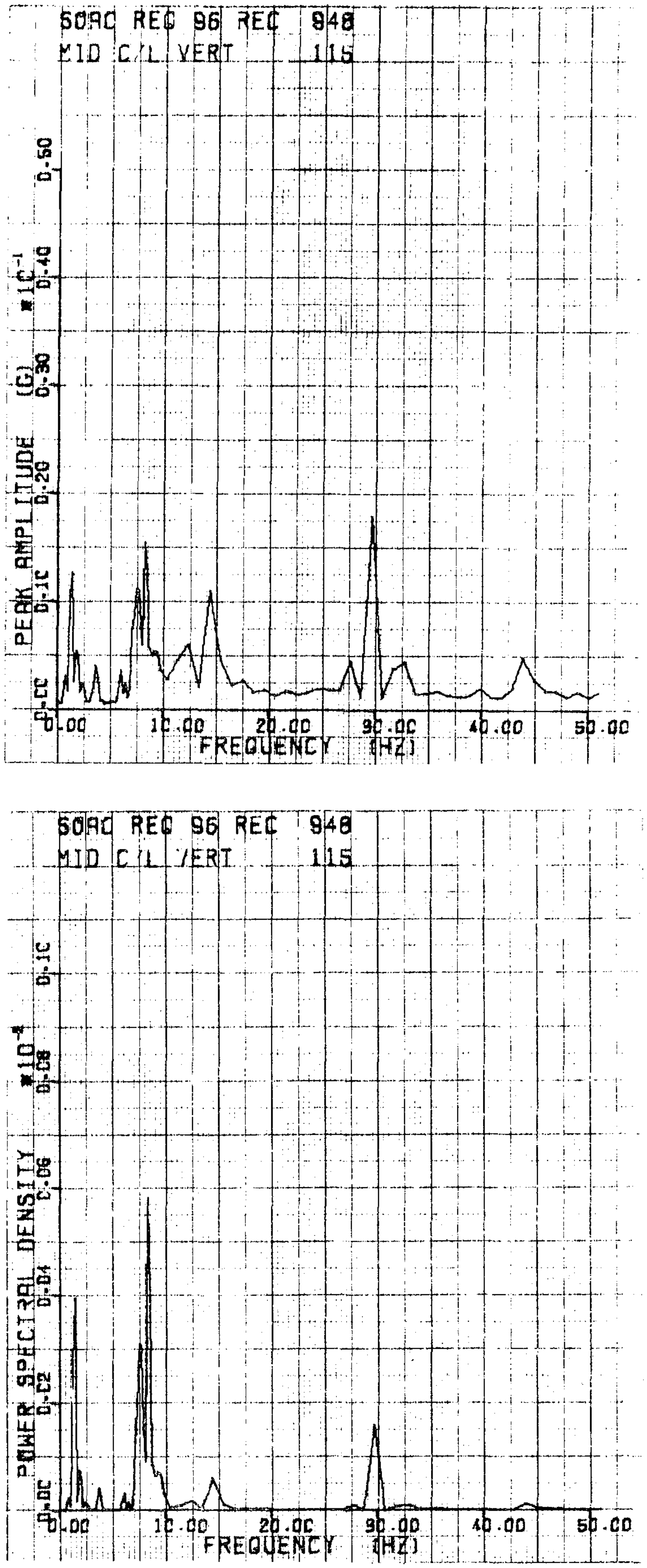


Figure 6–1. Typical Accelerometer Peak Amplitude and Power Spectrum (High-Density Car, 90,000 Pounds, 45 MPH, Track Section 1)

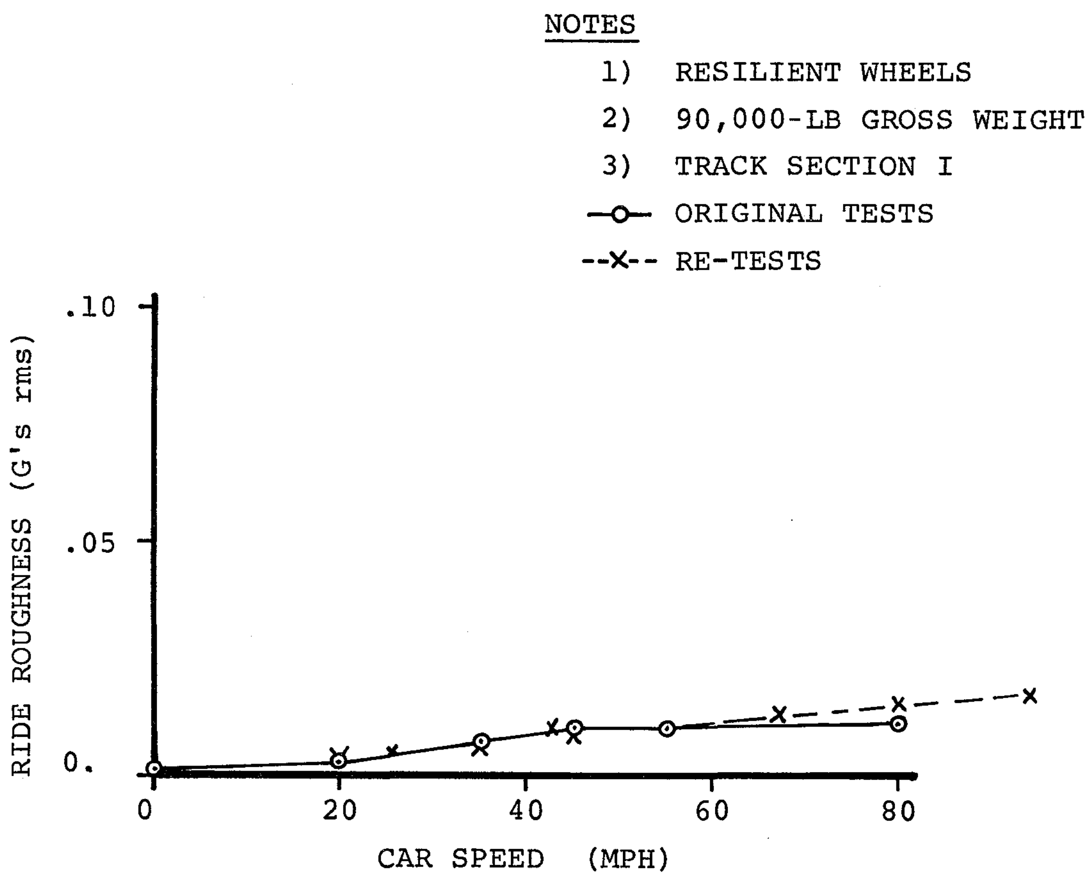


Figure 6–2. Effect of Speed on Aft Car Centerline Lateral Ride Roughness (High Density Car, 90,000 Pounds)

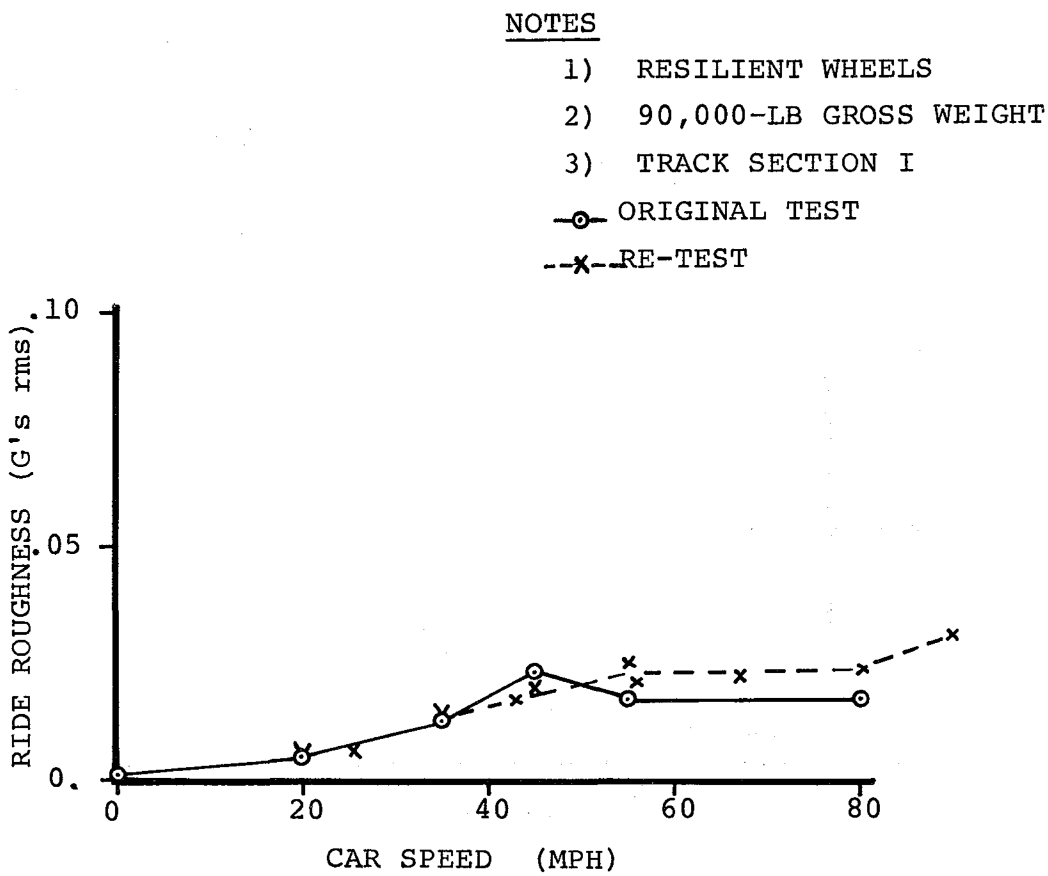


Figure 6–3. Effect of Speed on Forward Car Centerline Vertical Ride Roughness (High Density Car, 90,000 Pounds)

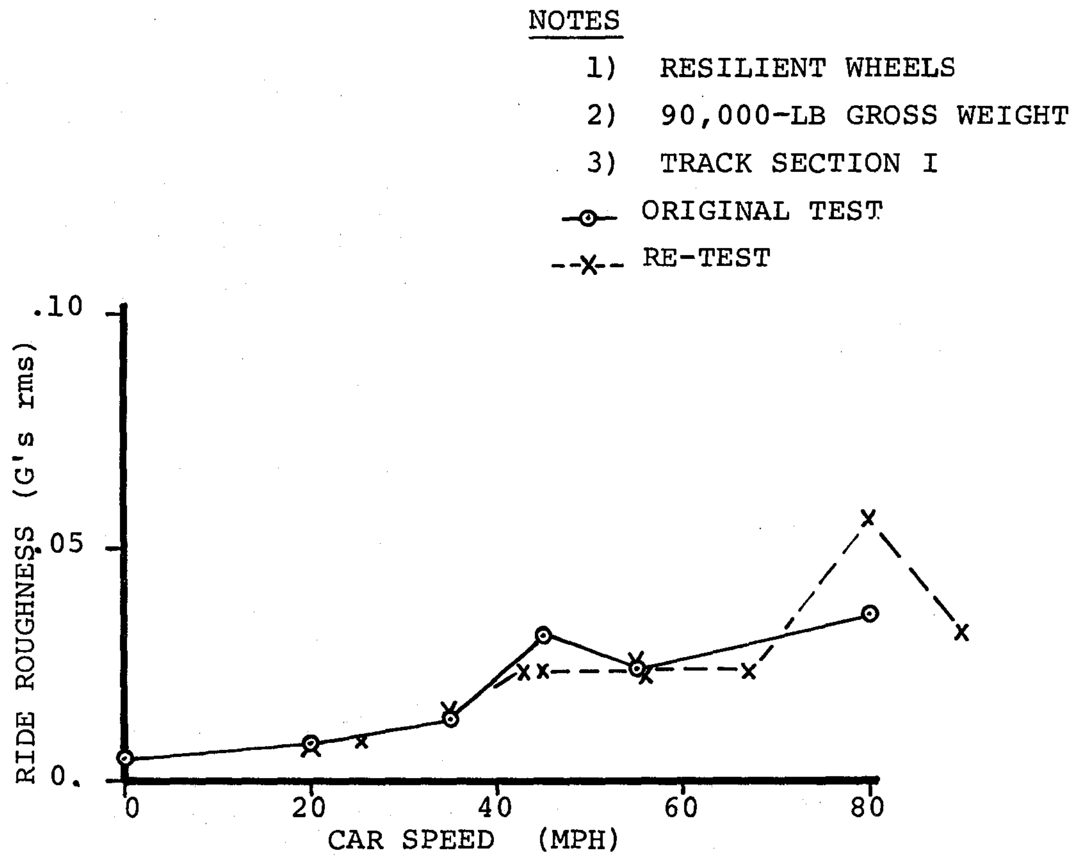


Figure 6–4. Effect of Speed on Mid Car Centerline Vertical Ride Roughness (High Density Car, 90,000 Pounds)

test period. The values of the car body ride roughness and the car speeds at these higher values is consistant with their being induced by these "rougher" conditions.

The mid car vertical ride roughness as a function of speed is shown in Figure 6-4. The two sets of test data are very similar except at the 80 mph point. This is the point where the wheel revolution frequency induces the second car body bending response. The "rougher" test conditions appears to have excited a greater response than in the original tests. Examination of the peak amplitude spectral analysis plot for this data point (Figure B-71 of Appendix B) reveals that the 15.0 Hz response is strongly dominant in the 80 mph test, and supports the conclusion above.

The three comparisons mentioned above are for the 90,000-pound empty weight High Density SOAC. Although there are some exceptions, most of the vibrations at specific frequencies are lower, but not noticeably different from the levels experienced in the original tests. The following comparisons are made for the 105,000 lb High Density SOAC.

Figure 6-5 shows the speed effects for the rear aft car lateral ride roughness. The levels are the same as the forward car vertical ride roughness, Figure 6-6, where the levels are similar for both sets of data.

Figure 6-7 shows the mid-car vertical ride roughness levels as a function of speed. The divergence of the ride roughness levels for the higher speeds is consistent with the "rougher" test conditions described above for the 90,000-pound car tests and for the journal box accelerations described below.

Figures 6-8 through 6-10 show the journal box acceleration levels for the 90,000- and 105,000-lb car tests. As shown, the levels are twice as high as the original data, but in a low significance range. The reason for these level changes may be found in the test track use during the interim between the original and retest programs (August to December 1973). Track Section I is the only access rail between the Test Center and the commercial rail lines. This section of track saw a great deal of heavy freight traffic due to the FRA construction at the Test Center. The rails over Track Section I were therefore rougher, or more irregular, than they were during the original tests. It is obvious that in order to ensure more accurate repeatability in the test data, considerably more attention must be made with respect to track condition, even for an isolated test track such as the Rail Transit Test Track. If the Retest journal levels shown were more significant, or if more accurate repeatability were required, the track would have to be corrected and the tests repeated.

Comparison of the retest data to the SOAC ride quality goals is shown in Figure 6-11. As noted in the previous discussion, most of the levels are below the original test data levels. As mentioned the level of the second order bending mode at 15 Hz is strongly dependent upon speed and this might account for the difference between the retest and original test data levels.

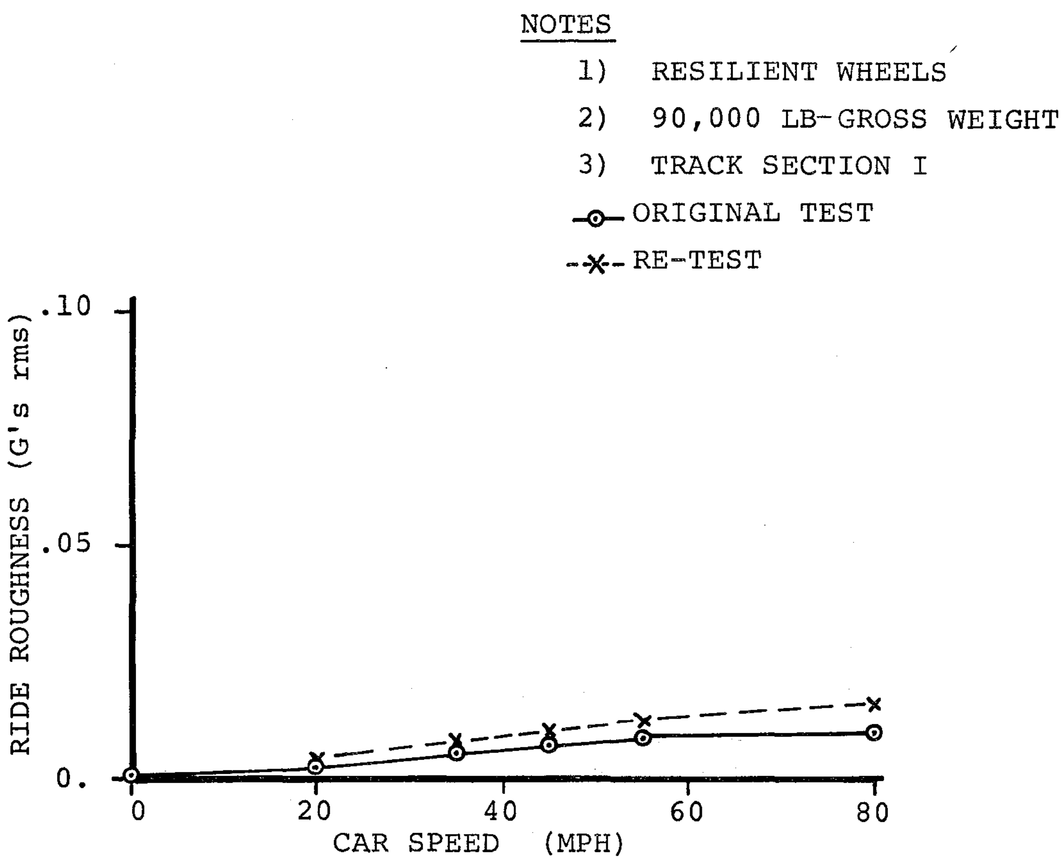


Figure 6–5. Effect of Speed on Aft Car Centerline Lateral Ride Roughness (High Density Car, 105,000 Pounds)

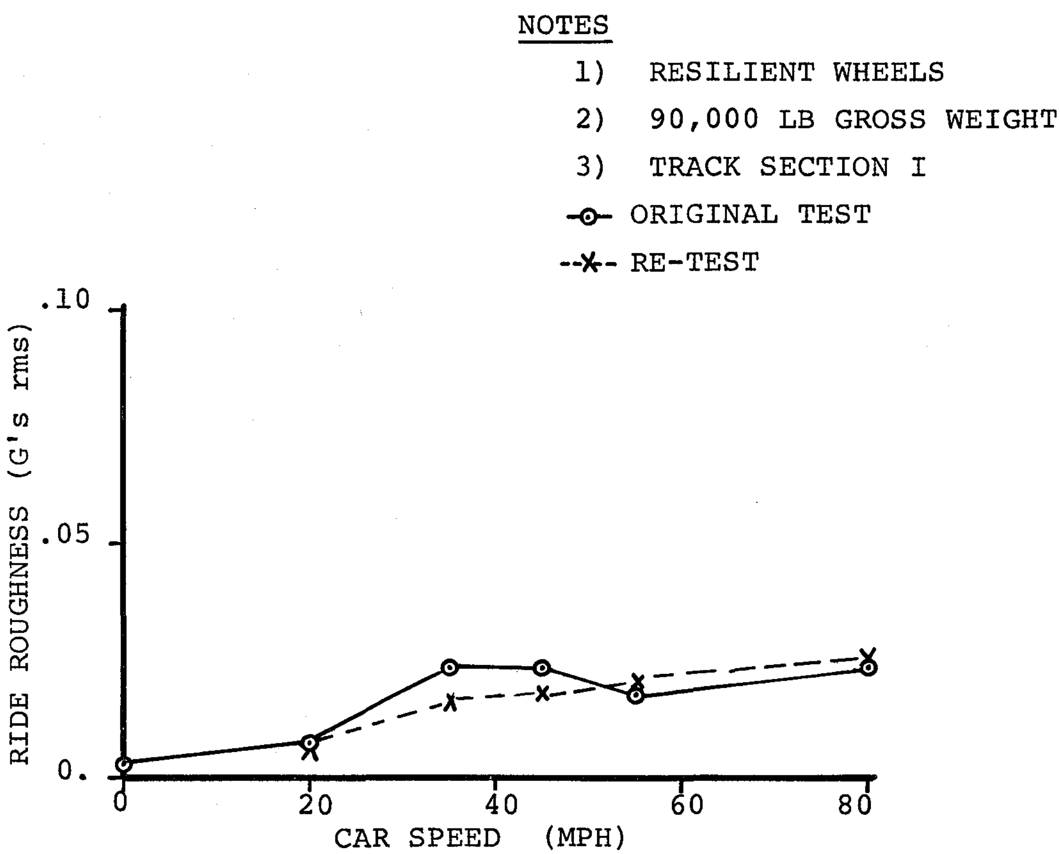


Figure 6–6. Effect of Speed on Forward Car Centerline Vertical Ride Roughness (High Density Car, 105,000 Pounds)

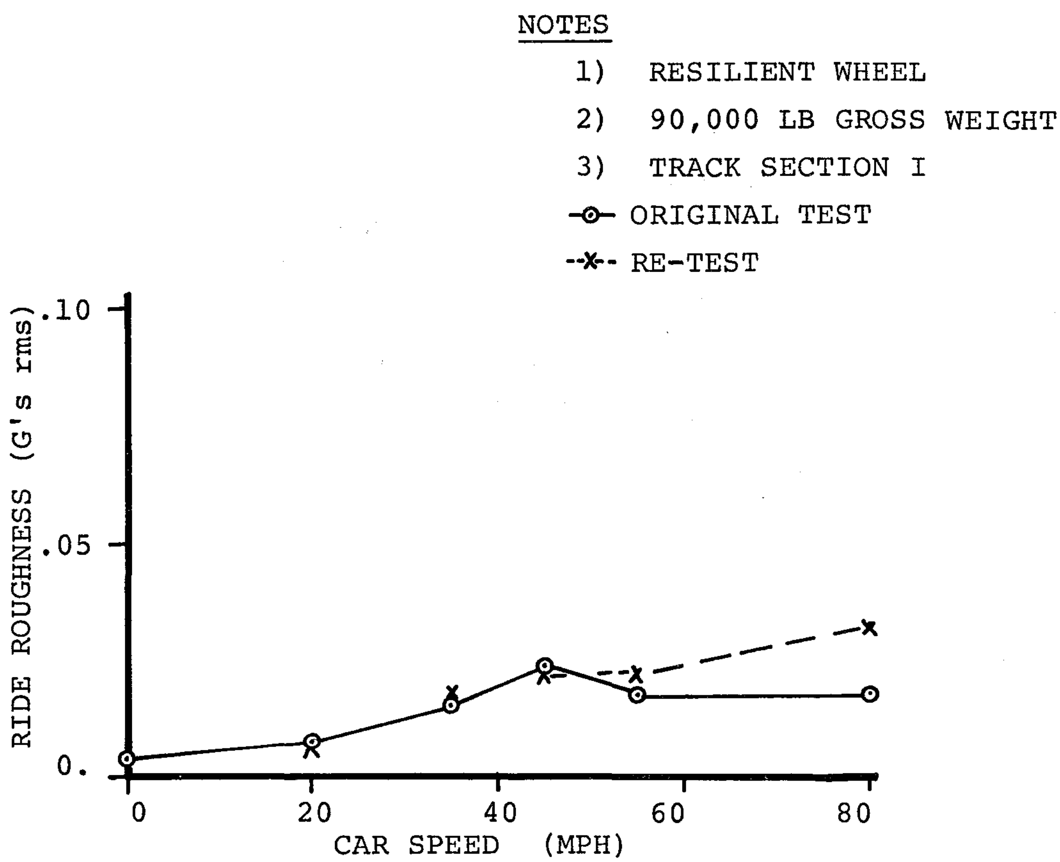


Figure 6–7. Effect of Speed on Mid Car Centerline Vertical Ride Roughness (High Density Car, 105,000 Pounds)

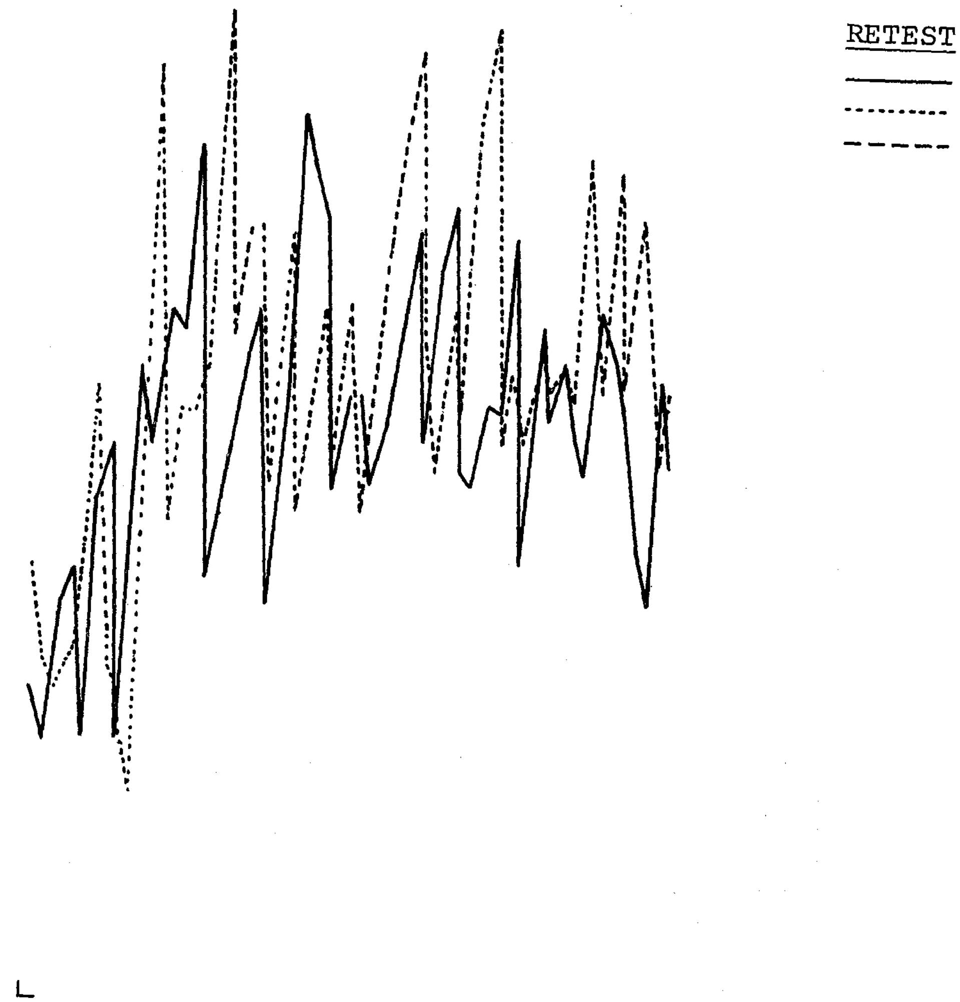


Figure 6–8. Effect of Speed on No. 1 Axle Lateral Acceleration (High-Density Car, 90,000 Pounds)

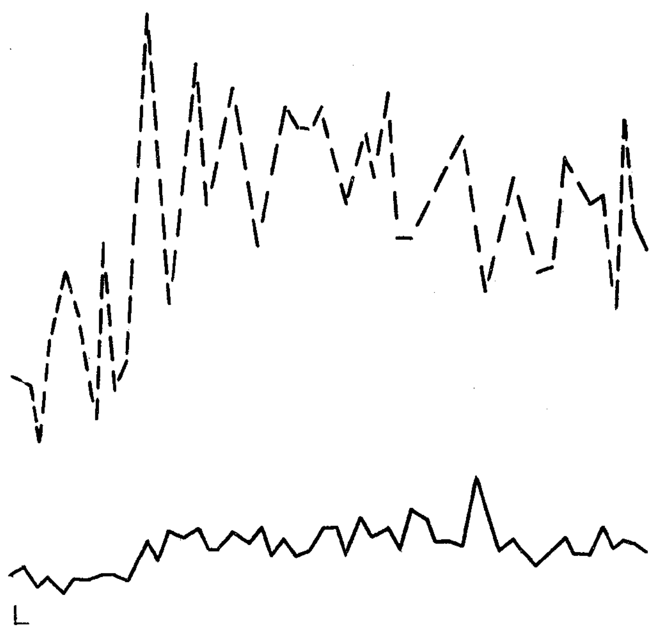


Figure 6–9. Effect of Speed on No. 1 Axle Vertical Acceleration (High-Density Car, 90,000 Pounds)

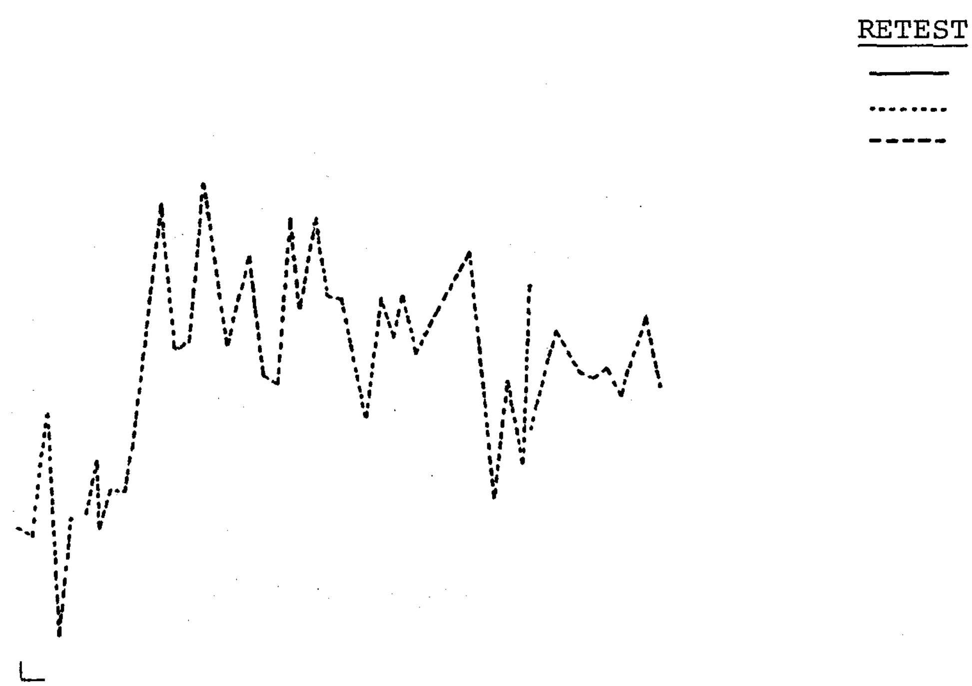


Figure 6–10. Effect of Speed on No. 1 Axle Lateral Acceleration (High-Density Car, 105,000 Pounds)

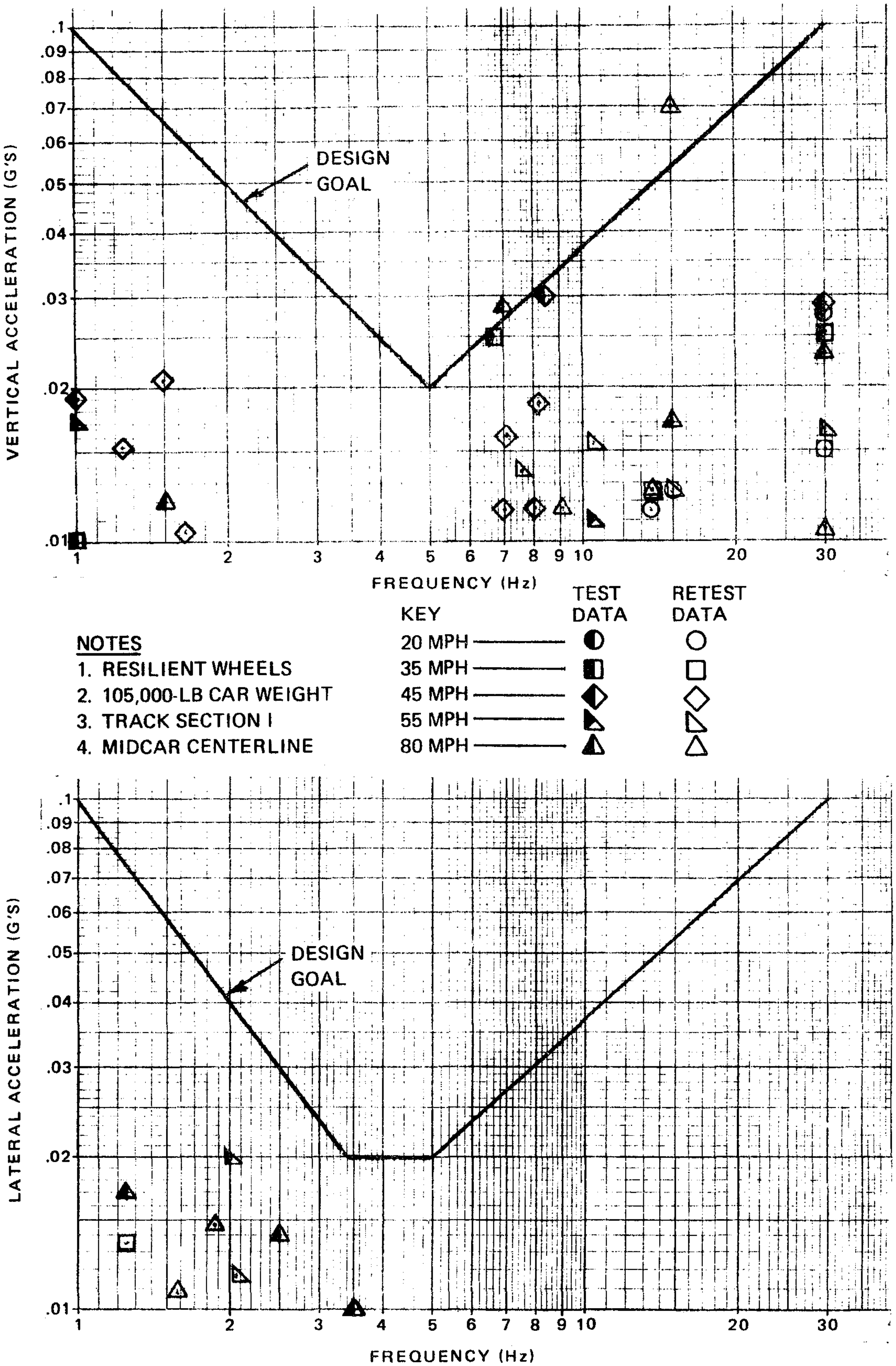


Figure 6–11. Comparison of High-Density Car Ride Quality and Goals

7. INTERIOR NOISE TESTS

7.1

An additional test objective for the interior noise tests over and above that of obtaining post-repair vs original test data comparisons, is to obtain an evaluation of the effectiveness of the air duct silencer installation in reducing the blower noise propagating into the car through the grills to give more uniform sound levels throughout the car, see Figure 7-3.

7.2 TEST DESCRIPTION AND PROCEDURES

Interior noise measurements were taken on Car No. 2 with resilient wheels while at rest, and while operating over the HSGTC Rail Transit Test Track Section I at a constant speed, which was varied between test runs from 15 to 70 mph. The test data was obtained from a portable noise measurement system (see Figure 7-1) consisting basically of a 1/2-inch condenser microphone and a two (2) channel tape recorder operating at 7 1/2 ips with a gain/attenuation system consisting of 10 dB incremental steps. The microphone was placed at the car locations shown in Figure 7-2 and positioned at the ear level height of a seated passenger unshielded from the noise sources. All testing was done with a car weight of 90,000 lb. The test procedure was in accordance with Baseline Test Set SOAC-PN-1001-TT-1. The log of test runs and records is presented in Table 7-1.

7.3 TEST DATA

The magnetic tape records were processed through a data reduction system utilizing an "A" weighting network as shown in Figure 7-1. All data has been converted to sound pressure levels referenced to 2.0×10^{-5} newtons/square meter.

7.4 TEST RESULTS

The plot of weighted sound levels versus car speed as shown in Figure 7-4 compares the post-repair test results with those obtained from the original tests. Figure 7-5

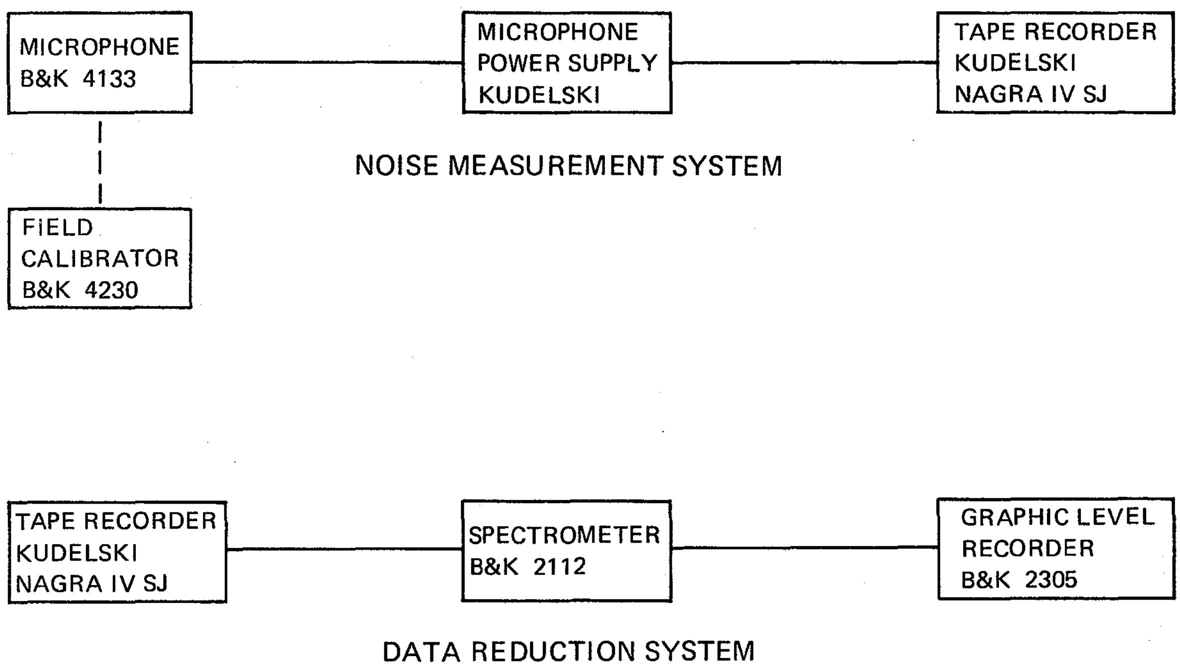
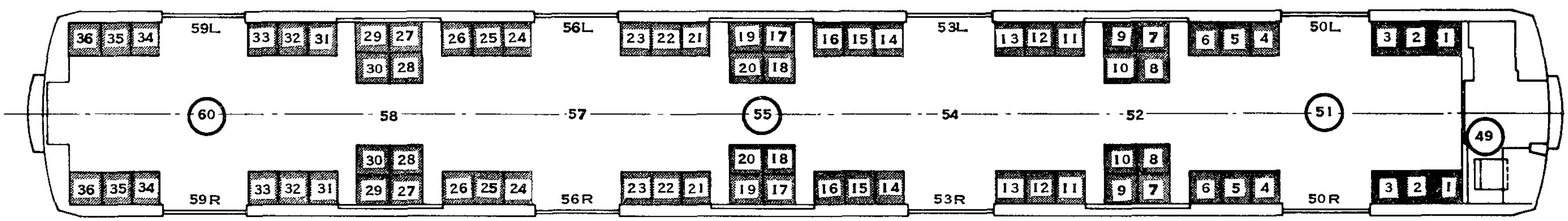


Figure 7—1. Block Diagrams for Data Acquisition and Reduction Systems



NOTES
1. NO. 2 CAR (HIGH-DENSITY) SEATING PLAN
2. ◯ RETEST MICROPHONE LOCATION

Figure 7–2. Interior Noise Measurement Positions

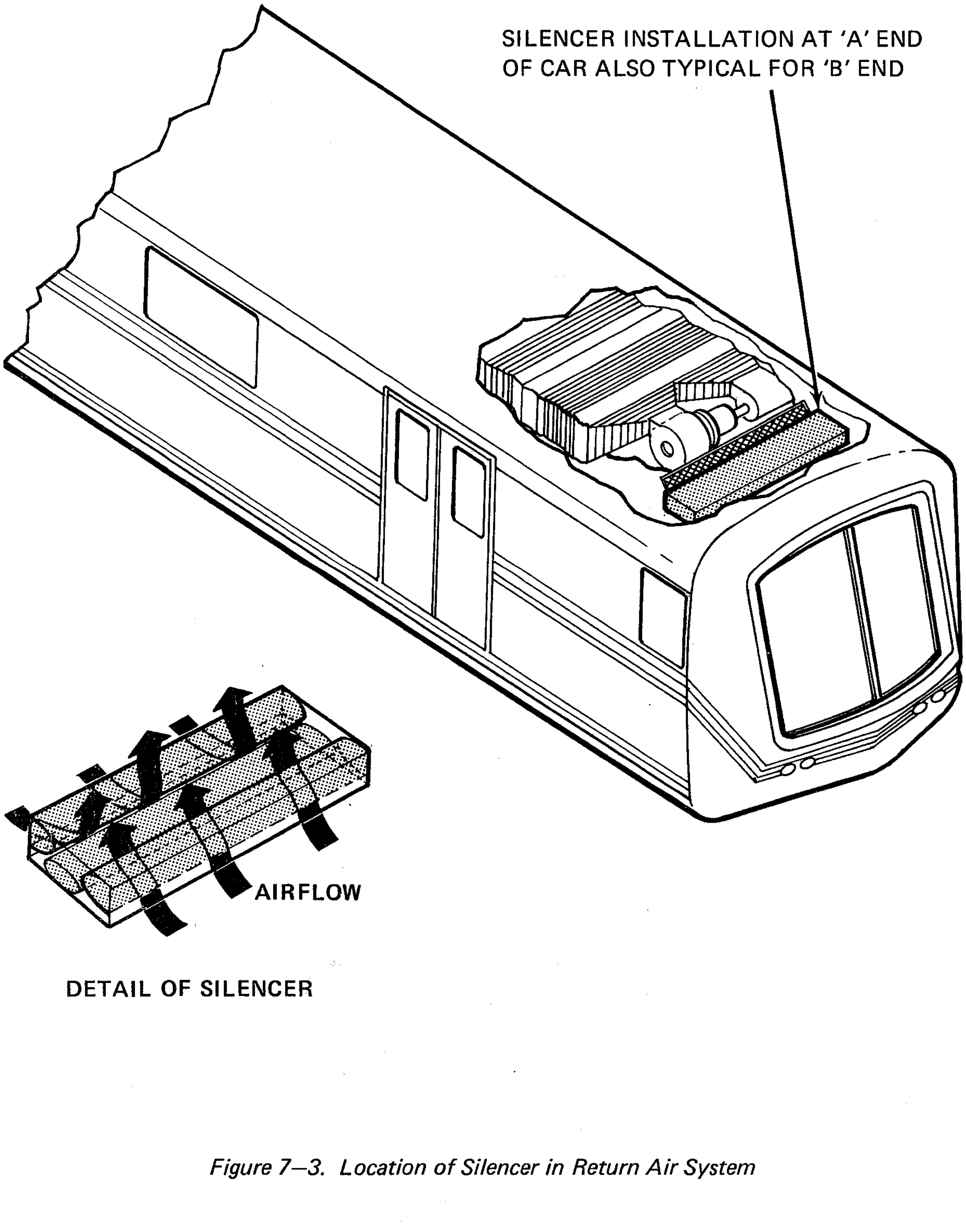


Figure 7–3. Location of Silencer in Return Air System

Table 7–1. Interior Noise Test Data (Sheet 1 of 2)

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG	TRACK SEC	VELOCITY MPH	LOC	TAPE NO.	TEST PT	WEIGHTED SOUND LEVEL (dBA)
2	No return air supp-ressors	90,000	Resilient, wheel flats	1	0	49	13-B-24	1	65.5
						51		2	64
						55		4	62.5
						60		5	69
					15	49		7	66
						51		8	65
						55		9	64
						60		10	69
					25	49		14	65.5
						51		13	65
						55		12	64.5
						60		11	69
					35	49		15	67.5
						51		16	66
						55		17	65
						60		18	67.5
					50	49		22	67.5
						51		21	66
						55		20	66
						60		19	70
					70	49		23	77
						51		24	73
						55		25	71.5
						60		26	77.5

Table 7–1. Interior Noise Test Data (Sheet 2 of 2)

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG	TRACK SEC	VELOCITY MPH	LOC	TAPE NO.	TEST PT	WEIGHTED SOUND LEVEL (dBA)
2	With return air suppressors installed	90,000	Resilient, trued wheels	I	0	49	13-B-25	18	61
						51		19	63
						55		20	64
						60		21	65
					17	49	13-B-25	24	61.5
						51		25	64
						55		2	66
						60		3	67
					29	49	13-B-26	4	62.5
						51		5	64
						55		6	64
						60		7	74.5
					42	49		12	64
						51		11	64.5
						55		10	64.5
						60		9	76
					61	49		13	69
						51		14	68.5
						55		15	68
						60		16	71
					86	49		17	74.5
						51		18	74.5
						55		22	70
						60		21	73.5

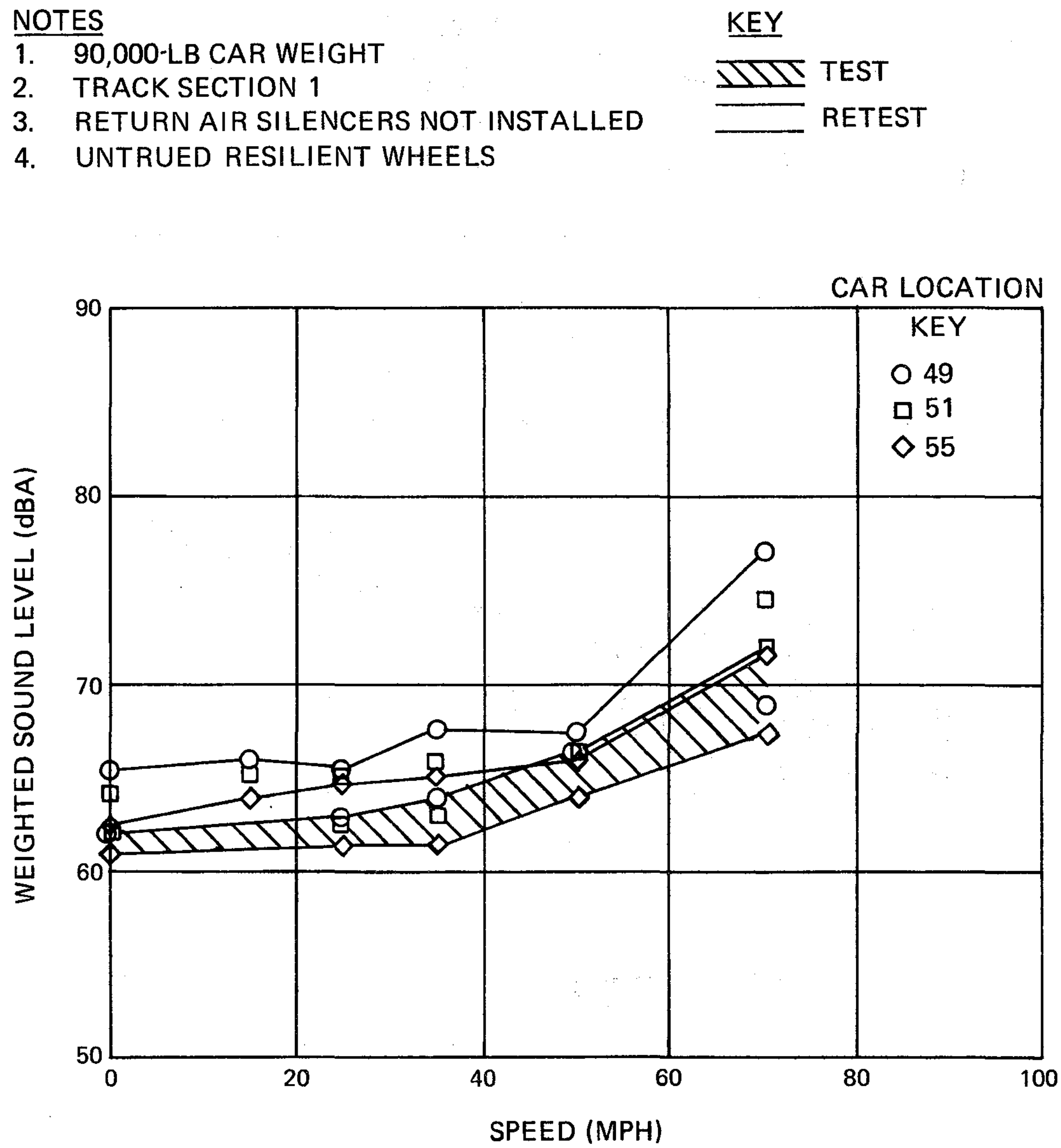


Figure 7—4. Comparison of Interior Noise Levels of SOAC No. 2 Car Before and After Repair

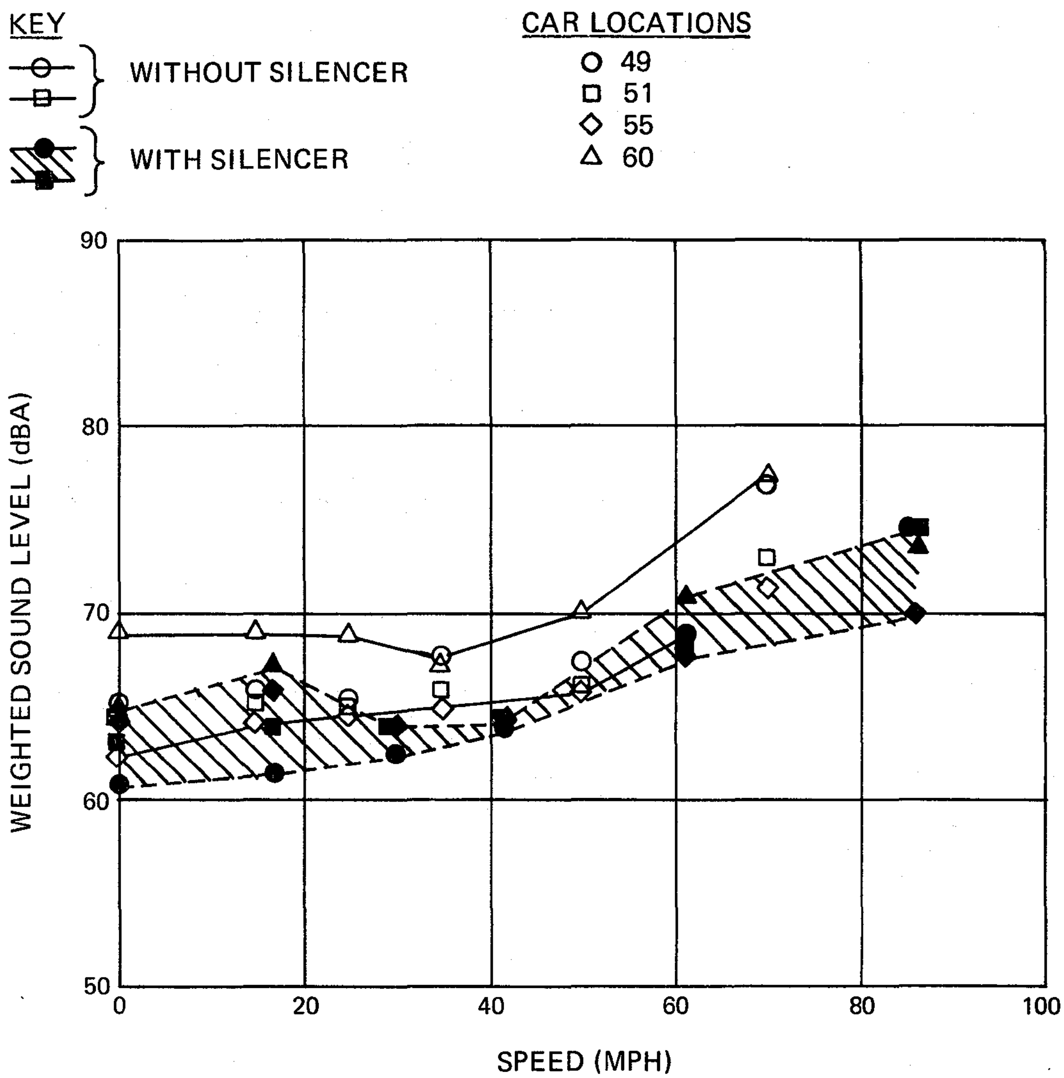


Figure 7–5. Comparison of Interior Noise Levels Before and After Silencer Installation

presents the sound levels with and without the air conditioning duct silencer installation, as obtained during the post-repair testing.

7.5 DISCUSSION OF TEST RESULTS

Figure 7-4 shows sound levels for the post-repair testing to be higher than the original test by 2-4 dB, including the car at rest. The reasons for this difference are not known but the following items are pertinent:

(a) The noise from the air conditioning system blower at the forward end of the car near Location 49 (see Figure 7-2) may be greater after the repair than before. No airflow or noise data were obtained during the original test program which would bear this out.

(b) Several flats were not completely removed from the wheels prior to the re-test. Therefore, there would be some additional noise due to these flats. Figure 7-5 shows the noise level at Location 60 was reduced generally to levels that existed at other locations prior to silencer installation.

7.6 CONCLUSION

The post-repair measured sound levels without the silencer installation fall within the total envelope of the baseline data measured in both SOAC cars. Additionally, it may be concluded that the air conditioning air duct silencer installation did have a beneficial effect in providing more uniform sound levels throughout the car.

8. WAYSIDE NOISE TESTS

8.1 TEST DESCRIPTION AND PROCEDURE

The acoustic noise levels generated by the No. 2 SOAC car equipped with resilient wheels at a car weight of 90,000 lb were measured at distances of 15, 50 and 100 feet from the track centerline on the outside of the test oval and at a height of 3 feet above the plane of the tracks at track Station 156 located in Track Section I (see Figure 8-1). Test measurements were made with the car at rest and with the car travelling at constant speeds of 15, 25, 35, 50 and 70 mph past the microphone location. The test procedure was in accordance with Baseline Test Set SOAC-CN-1001-TT.

8.2 TEST DATA

The magnetic tape records were processed through a data reduction system utilizing an "A" weighting network as shown in Figure 7-1. All data was analyzed in terms of "A" weighted sound levels (dBA) and normalized to account for several ambient wind conditions as was done for the original test data.

8.3 TEST RESULTS

A plot of "A" weighted sound levels versus car speed is shown in Figure 8-2 comparing the post-repair test results with the original test results for the recording microphone located 50 feet from the track centerline. Figure 8-3 presents the post-repair test sound levels versus car speed with the microphone located at 15, 50 and 100 feet from the track centerline.

8.4 DISCUSSION OF TEST RESULTS

The test data from the original test program showed a sound level of 70 dBA for the No. 2 car at rest, and equipped with steel wheels. The data for the same car equipped with resilient wheels at rest was slightly lower. The difference was attributed, at least in part, to wind and weather and the fact that the microphone was positioned slightly beyond the prescribed 50-foot

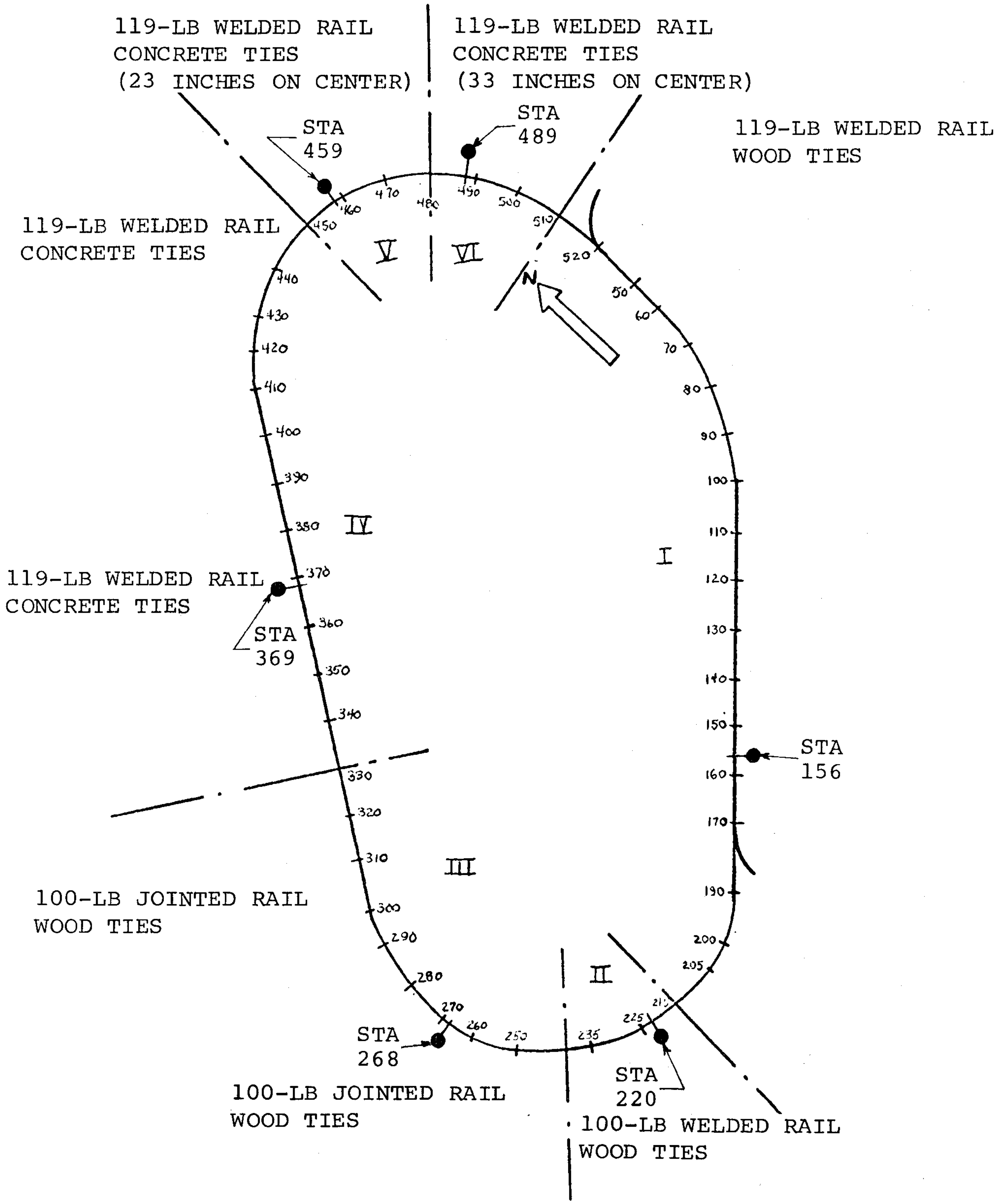


Figure 8–1. Microphone Locations for Wayside Noise Survey on UMTA Rail Transit Test Track

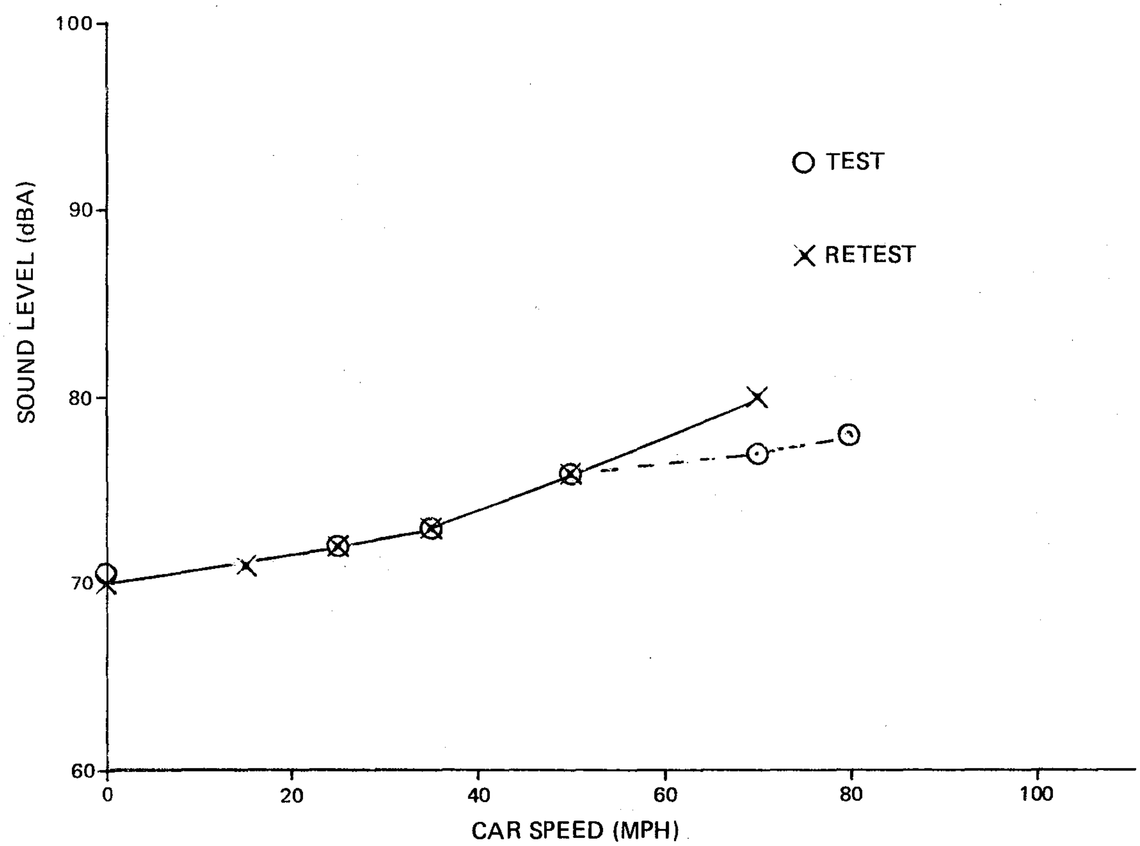


Figure 8–2. Comparison of Wayside Noise Levels Measured 50 Feet from Track for Post-Repair and Original Tests

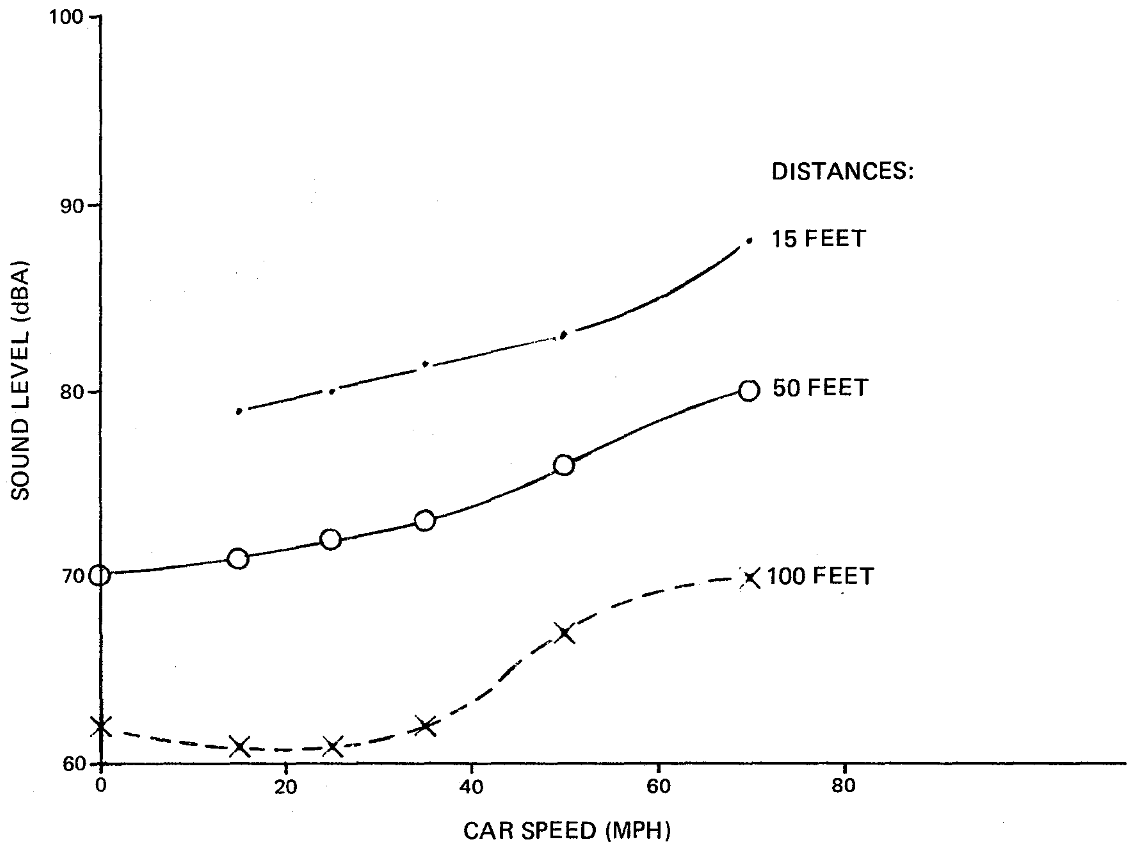


Figure 8–3. Effect of Distance on Wayside Noise Levels

distance. Therefore, the test data for the resilient wheels were normalized to pass through 70 dBA at zero mph. In keeping with this precedent, the post-repair test data were also normalized in the same manner.

A review of the post-repair test data in Figure 8-2 in comparison to the original data, shows the former to be slightly higher from 50 mph up to 70 mph. This has been attributed, in some measure, to slight wheel flats which were audible during the tests.

A review of the data plotted in Figure 8-3, which presents the noise levels with the microphone at 15, 50 and 100 feet, shows that the reduction in level in going from 50 to 100 feet is somewhat greater than the 6 dBA expected according to the inverse square law.

8.5 CONCLUSION

The post-repair test results are in substantial agreement with those from the original tests.

9. STRUCTURE TESTS

9.1 SUMMARY

Test Sequence

Test Run 232, March 29, 1974, SOAC No. 2 at 90,000 lbs.

Test Procedures

SOAC-S-1001-TT, SOAC-S-2001-TT and SOAC-S-3001-TT were the test procedures used for these tests.

Objective

The objective of this test sequence was to determine the changes, if any, in the SOAC truck component loads due to the August 11, 1973 accident and subsequent repair.

Status

After the test run was completed and the data were reduced conistent with the original SOAC HSGTC Tests, the load levels were found to be consistent with the original test data.

9.2 TEST DESCRIPTION

The accident of August 11, 1973, caused some damage to the structural section of the SOAC instrumentation system. All of the displacement transducers and mounting brackets had been removed prior to the above incident, and were therefore not affected. During the accident, all of the damper rods connecting links were destroyed. These were calibrated strain sensors. The connecting links were replaced, Garrett AiResearch applied strain gages and calibrated the system.

During the repair program, the SOAC trucks underwent an intensive series of inspections and tests which necessitated the removal of the truck frame strain gages. These were replaced at the Boeing Vertol facility prior to the truck assembly build-up.

The undercar cabling assemblies were either damaged or cut during car shipment. These assemblies were checked and repaired by Garrett technicians at the Boeing Vertol facilities. System checks on the structural section of the SOAC instrumentation system were completed at the HSGTC prior to the test runs. A description of the truck load paths as reported in the original tests follows.

The purpose for examining the structural integrity of railcar trucks is to determine if strain levels exist within the assembly which are significant with respect to their effect on the useful life of the component. Present technology in truck designs is based largely on static conditions. Components are designed to a static set of conditions and healthy safety factors are added. However, very little is known about the dynamic conditions of the completed assembly. Very little data is available on the loads induced in a railcar truck under normal operating conditions. A description of this loading is required to predict the useful life of the system and to determine the operating design safety margins.

On the running rail interface side, loads are induced into the SOAC trucks from the axles through the chevrons (① on Figure 9-1). These are determinable by measuring the deflections of the chevrons while the vehicle is operating. The deflections may be converted to loads through a statically determined relationship of deflection as load characteristic for the chevron. For the SOAC chevrons this is a temperature dependent linear relationship of 30,000 lb per inch (1). During the SOAC testing, the chevron temperature was monitored to assure that it remained within a tolerance band which validated the above relationship.

On the car body interface side, loads are induced into the SOAC truck assembly through the airsprings, the damper assemblies, and the bolster anchor rods. The method for examining these loads is described below.

The main loads are induced through the airsprings. The static loads are determined by the vehicle weight. This can be converted to air pressure in the airspring. Changes in airspring volume, which occur only by vertical deflections, reflect changes in pressure and therefore, load changes. The loads induced through the airspring are determinable by measuring the airspring deflections.

The damper assemblies function is to dampen the rate of change of loads between the trucks and the car body. The damper rod connecting link (② on Figure 9-1) is a convenient path and was instrumented for the SOAC tests. The two vertical and two lateral connecting links were

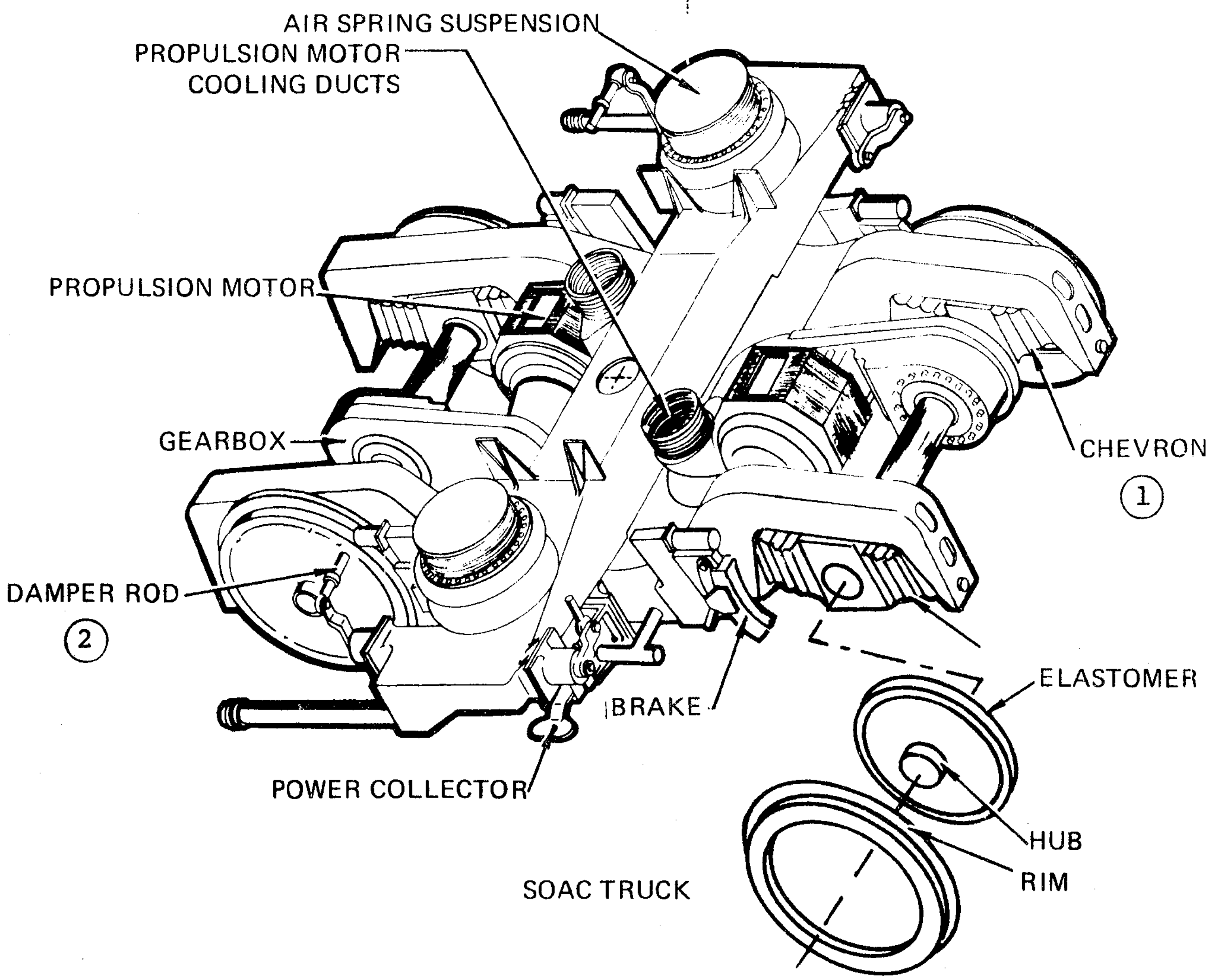


Figure 9–1. SOAC Truck Assembly Instrumentation

strain gaged and calibrated at the Garrett AiResearch facility.

Longitudinal forces are induced into the truck by the vehicle acceleration, through the axles and through the Bolster Anchor Rod Assemblies. The SOAC Bolster Anchor Rod Assembly is a rod and-tube assembly and does not lend itself to instrumenting by strain gaging.

The method used was a deflection measurement which could be correlated to longitudinal acceleration to determine load. This correlation need be done only once at a known vehicle weight.

In addition to sensing the loads induced into the truck assembly, two points were selected to monitor the loads within the truck frame. Static load tests completed during the SOAC design cycle defined the load paths within the truck frame. Two of the highest stress level locations were selected to be monitored during this test. These locations were strain gaged and A/C coupled in order that only the alternating loads could be examined.

9.3 INSTRUMENTATION

The complete description of the SOAC structural section of the SOAC instrumentation system is described in Reference 1, Volume 6. Table 9-1 is the structural parameter list.

9.4 TEST DATA

As with the original data, the structural parameters were recorded in analog form on magnetic tapes and played back through an oscillograph to obtain a time history strip chart. A listing of the test points is found below:

STRUCTURAL RETEST TEST POINTS

Run 232, March 29, 1974, SOAC No. 2, 90,000 lbs

RECORD NUMBER	SPEED, MPH	TRACK SECTION
1027	20	I
1030	35	I
1032	50	I
1035	60	I
1037	60	North Rail Gap
1038	60	IV
1039	60	V
1040	60	IV
1041	60	III
1043	60	II
1044	80	I
1045	Braking	I
1046	Acceleration	I

Table 9—1. Structures Test Instrumentation Locations

Channel	Forward Truck	Range
1	LH Air spring Vertical Displacement	± 1.0 In.
2	RH Airspring Vertical Displacement	± 1.0 In.
3	LH Airspring Lateral Displacement	± 1.0 In.
4	RH Airspring Lateral Displacement	± 1.0 In.
5	LH Vertical Damper Load	± 1500 Lb
6	RH Vertical Damper Load	± 1500 Lb
7	LH Lateral Damper Load	± 1500 Lb
8	RH Lateral Damper Load	± 1500 Lb
9	RH Bolster Anchor Rod Displacement	± .25 In.
10	LH Bolster Anchor Rod Displacement	± .25 In.
11	RH Fwd Chevron Vertical Displacement	± 1. In.
12	LH Fwd Chevron Vertical Displacement	± 1. In.
13	RH Aft Chevron Vertical Displacement	± 1. In.
14	LH Aft Chevron Vertical Displacement	± 1. In.
15	RH Fwd Chevron Lateral Displacement	± 1.00 In.
16	RH Aft Chevron Lateral Displacement	± 1.00 In.
17	Truck Frame Strain Gage Absolute	0-10,000 psi
18	Truck Frame Strain Gage Absolute	0-10,000 psi
19	Temperature of RH Fwd Chevron	
	Aft Truck	
20	RH Fwd Chevron Vertical Displacement	± 1. In.
21	RH Fwd Chevron Lateral Displacement	± 1.0 In.

Figure 9-2 is a strip chart of one test point, i.e. 60 mph over Track Section III. This chart illustrates that the relationships of load levels and phasing are similar to the original test data. No significant trends or data differences can be reported.

Figure 9-3 shows the right hand foreward axle chevron vertical displacement plotted as a function of speed in comparison with the original test data. As noted above, there is no significant difference.

Figure 9-4 compares the right hand forward axle lateral displacement with the original test data, and again there is no significant differences.

Figure 9-5 compares one of the truck frame strain gage levels to the original data. Although the 80 mph data is slightly higher than the original data, it remains well below the design criteria for truck loads.

It can be concluded that the structural section of the SOAC instrumentation system was successfully repaired and that the original test data remains a valid baseline.

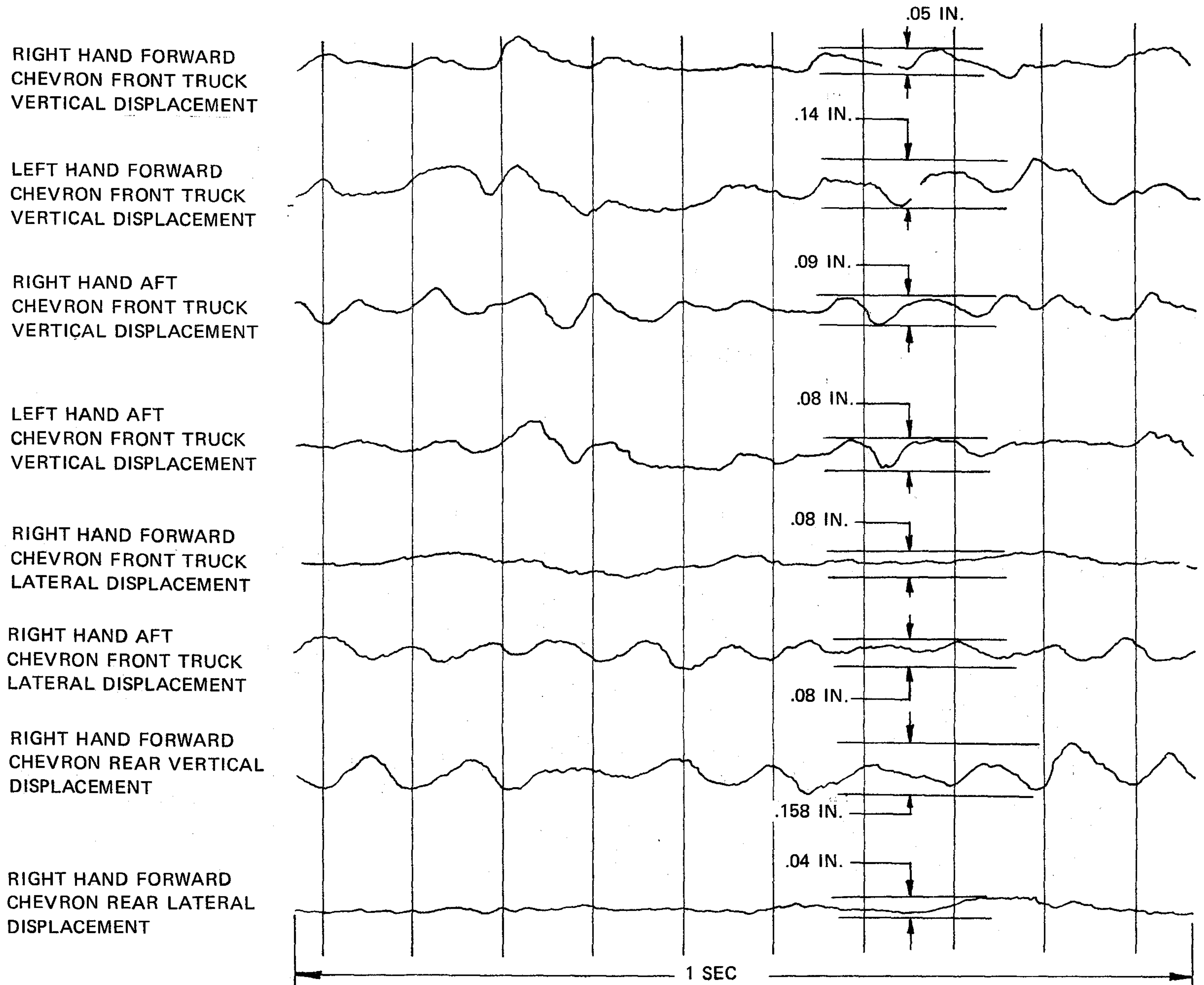


Figure 9–2. SOAC Structures Retest: 90,000-Pound Gross Weight, 60-MPH Speed, Track Section III (Sheet 1 of 4)

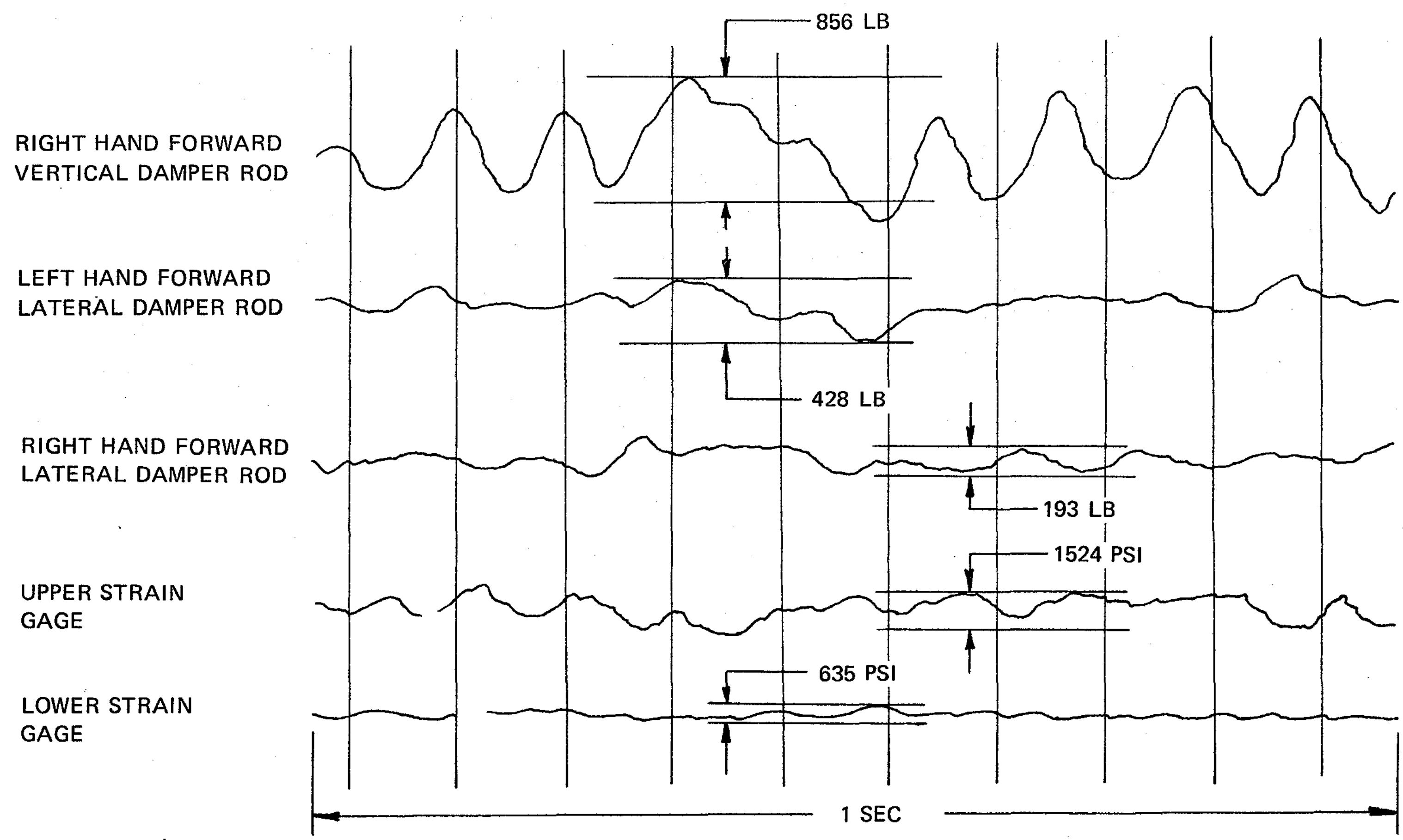


Figure 9–2. SOAC Structures Retest: 90,000-Pound Gross Weight, 60-MPH Speed, Track Section III (Sheet 2 of 4)

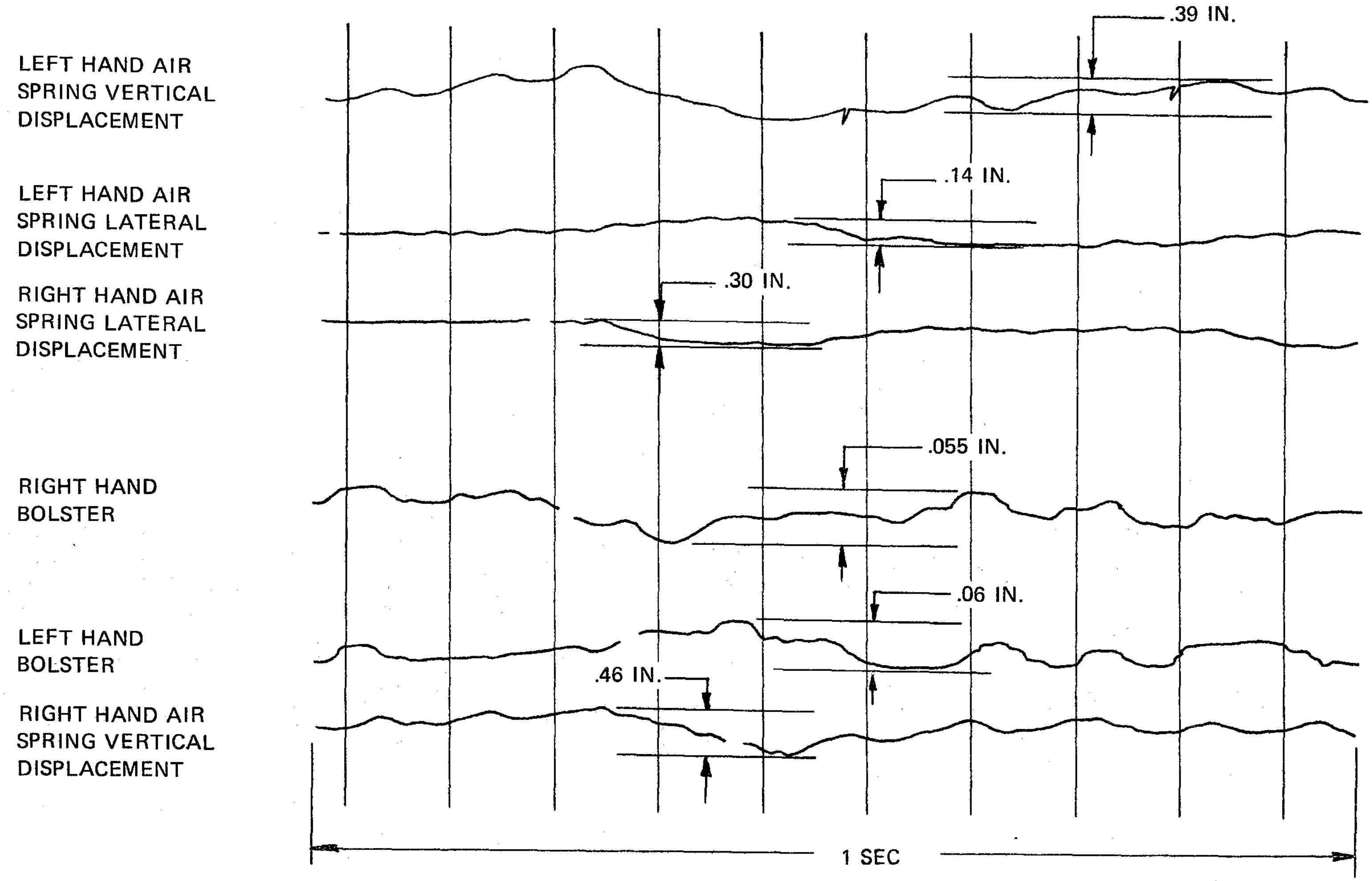


Figure 9–2. SOAC Structures Retest: 90,000-Pound Gross Weight, 60-MPH Speed, Track Section III (Sheet 3 of 4)

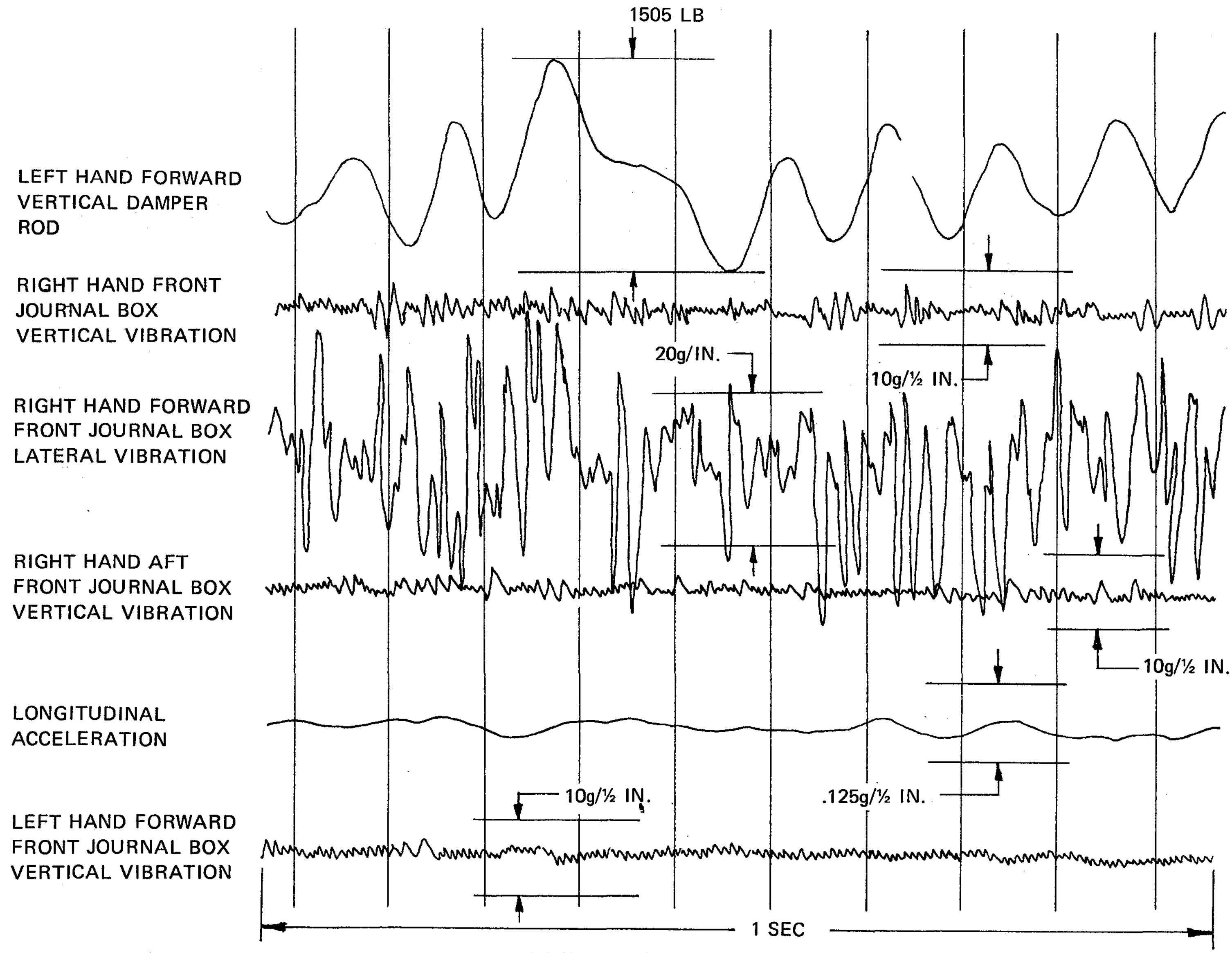


Figure 9–2. SOAC Structures Retest: 90,000-Pound Gross Weight, 60-MPH Speed, Track Section III (Sheet 4 of 4)

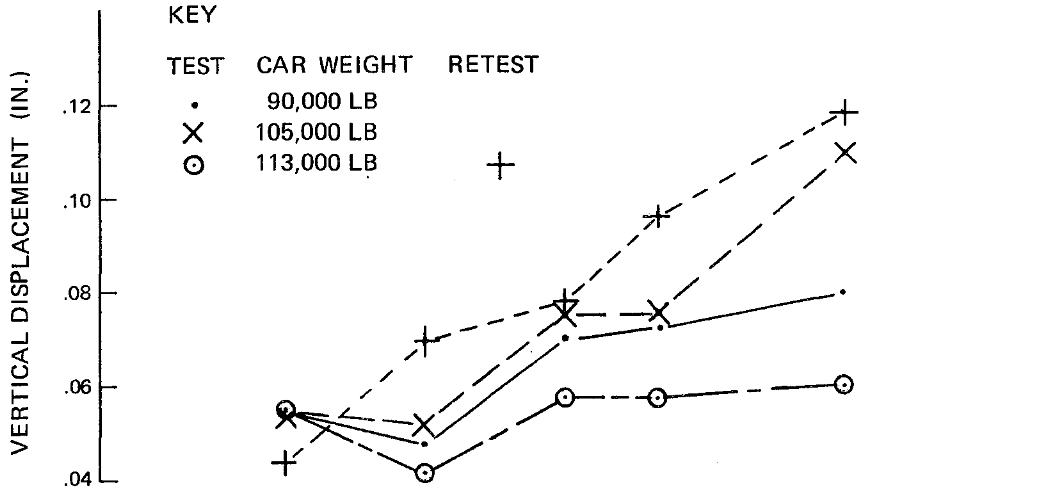


Figure 9–3. Forward Axle Right-Hand Chevron Vertical Displacement vs Speed

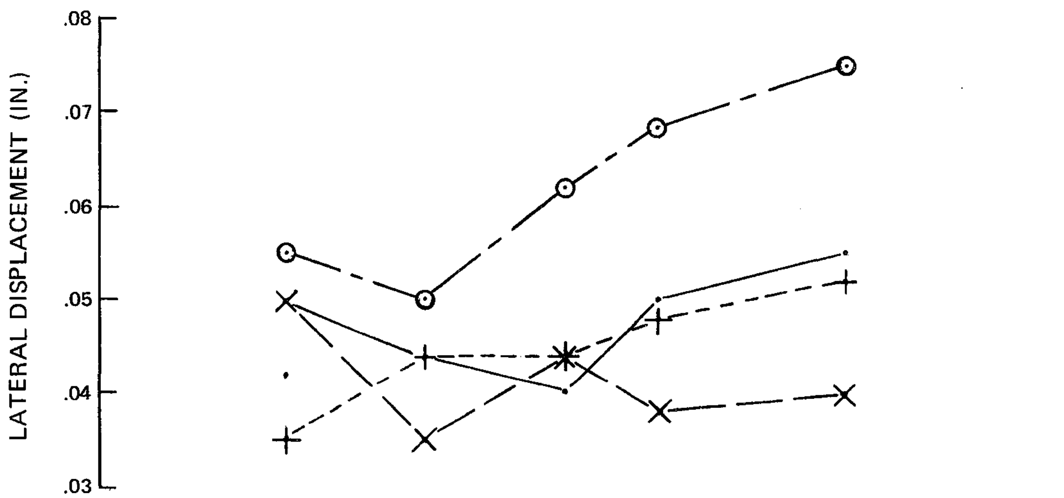


Figure 9–4. Forward Axle Right-Hand Chevron Lateral Displacement vs Speed

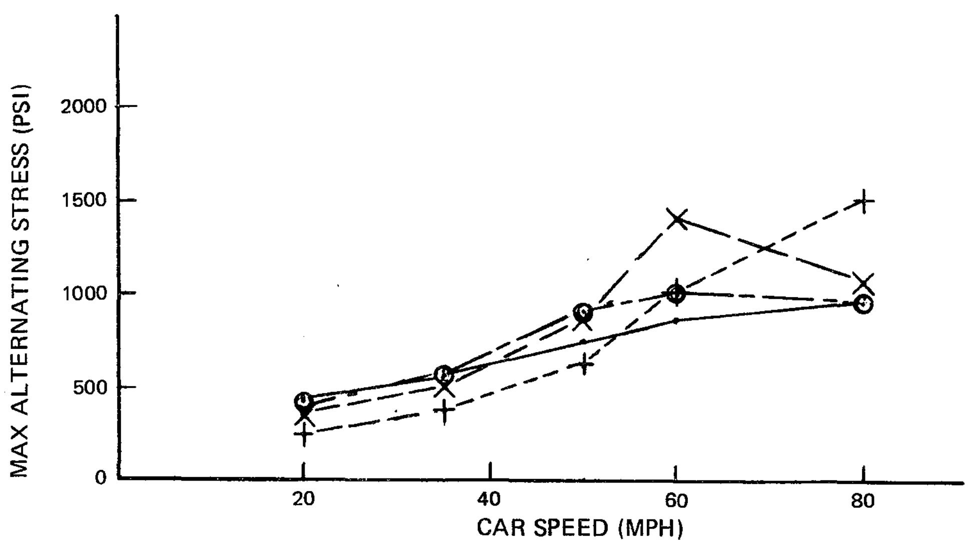


Figure 9–5. Upper Truck Frame Stress vs Speed

REFERENCES

1. SOAC State-of-the-Art Car Engineering Tests at Department of Transportation HSGTC, Report No. UMTA-MA-06-0025-75-1, January 1975; Boeing Vertol Company, Philadelphia, PA.

2. Railroad Accident Report - Collision of the SOAC Transit Cars with a Standing Car, HSGTC, Pueblo, Colorado, August 11, 1973. Report No. NTSB-RAR-74-2, National Transportation Safety Board, Washington DC, May 1974.

3. SOAC Volume V - Post Repair Testing, Report No. UMTA-IT-06-0026-74-12, December 1974.

4. State-of-the-Art Car Test Program (Test Plan and Procedures for Post Repair Testing of SOAC at HSGTC) Document No. D174-10007-1 Appendix I, Boeing Vertol Company, Philadelphia, PA., January 1974.

APPENDIX A

TEST SET SUMMARIES

The following test sets are summarized in this appendix.

Description	Test Set Number
• Acceleration	SOAC-P-2001-TT
• Deceleration, Blended Braking	SOAC-P-3001-TT
• Power Consumption	SOAC-PC-5011-TT
• Ride Quality	SOAC-R-2001-TT SOAC-R-3001-TT SOAC-R-4001-TT
• Structures	SOAC-S-1001-TT SOAC-S-2001-TT SOAC-S-3001-TT
• Effect of Speed, Interior Noise	SOAC-PN-100-TT

TEST TITLE: ACCELERATION

TEST SET NUMBER: SOAC-P-2001-TT

TEST OBJECTIVE:

To substantiate the SOAC car's level of performance following car repairs.

TEST DESCRIPTION:

The SOAC car was accelerated at the required controller command (P-Signal) on level tangent tract. The following combinations were tested:

PROCEDURE OPTION	PRIME VARIABLE	TEST CONDITIONS
(4)	Controller Level	P = 1.0 & 0.75
(6)	Line Voltage	Nominal 600 volts
(5)	Car Weights	90,000, 105,000 and 130,000 Lb
(3)	Car Direction	Fwd
(7)	Train Consist	No. 2 car (High Density and Two car train

STATUS:

The post-repair acceleration test results were sufficiently close to those obtained from the original tests to conclude that there was no appreciable change in the acceleration characteristics due to the car repairs.

TEST TITLE: DECELERATION - BLENDED BRAKING

TEST SET NUMBER: SOAC-P-3001-TT

TEST OBJECTIVE:

To substantiate the SOAC car's level of performance following car repairs.

TEST DESCRIPTION:

The SOAC car was decelerated at the required controller command (P-signal) on level tangent track. The following test combinations were tested:

PROCEDURE OPTION	PRIME VARIABLE	TEST CONDITIONS
(5)	Controller Level	P = 0 & 0.25
(6)	Car Weights	90,000, 105,000, and 130,000 Lb
(7)	Line Voltage	Nominal 600 Volts
(8)	Train Consists	No. 2 car (High Density) Two Car Train
(4)	Train Direction	Fwd
	Car Speed	80 mph, (60 mph @ 130 KW)

STATUS:

The deceleration (or braking) rates of the Post Repair Tests exceeded those of the original tests, and the SOAC specification rates. In addition, the control linearity for the repaired cars exceeded the 10% (full scale) tolerance band. In neither case were the results sufficiently different to warrant further adjustements to the systems while at the HSGTC.

TEST TITLE: POWER CONSUMPTION

TEST SET NUMBER: SOAC-PC-5011-TT

TEST OBJECTIVE:

To substantiate the SOAC car's energy consumption, summary comparative data was obtained during this test in order to develop the methodology for presenting the property test results. The synthetic route is the same as the route used on the Engrg. tests.

TEST DESCRIPTION:

The SOAC car was operated over a simulated route, stops from Station A to O, and round trip from O to A. Total power consumed (traction plus auxiliary) using normal service performance was measured for each stop and the round trip.

PROCEDURE OPTION	PRIME VARIABLE	TEST CONDITIONS
(1)	Car Weight	105,000 Lb
(4)	Line Voltage	Nominal 600 Volts
(5)	Train Consist	No. 2 Car (High Density)

STATUS:

The rms values for the armature and field currents for the 90,000-lb car weight were slightly less than those for the 105,000-lb car weight. A comparison of the energy consumption between the post-repair testing and the original test runs shows the former to be approximately 12% lower.

TEST TITLE: RIDE QUALITY

TEST SET NUMBER: SOAC-R-2001-TT
SOAC-R-3001-TT
SOAC-R-4001-TT

TEST OBJECTIVE:

To determine the effect of the SOAC repair on the SOAC Ride Quality.

TEST DESCRIPTION:

The Ride Quality measurements were obtained with SOAC Car No. 2 travelling over Section I of the Transit Test Track (HSGTC) at five different speeds and a single pass over the five remaining track sections. Car weights were 90,000 lbs and 105,000 lbs.

STATUS:

A comparison of Post-Repair Ride Quality Test data to the original test data shows that for the former, most acceleration levels are lower. The level of the second order bending mode at 15 Hz is strongly dependent upon speed and since the Post-Repair test was run at a higher speed, this might account for differences between the re-test and original test data levels.

TEST TITLE: STRUCTURES

TEST SET NUMBER: SOAC-S-1001-TT
SOAC-S-2001-TT
SOAC-S-3001-TT

TEST OBJECTIVE:

To determine that truck component loads are similar to the SOAC tests prior to repair.

TEST DESCRIPTION:

The structural loads induced into the body and the truck frame stresses were measured on No. 2 SOAC Car at 90,000 lbs car weight, while travelling at various speeds around the transit test track from 20 mph to 80 mph.

STATUS:

Generally, the test loads and stresses as measured during the Post Repair Testing were consistent with those obtained during the original test program.

TEST TITLE: EFFECT OF SPEED-INTERIOR NOISE

TEST SET NUMBER: SOAC-PN-100-TT

TEST OBJECTIVE:

To determine the effect of the SOAC repair on SOAC Interior Noise Level, and to evaluate the effectiveness of the air conditioning air duct silencer installation.

TEST DESCRIPTION:

Interior noise measurements were taken on Car No. 2 with resilient wheels while at rest and while operating over the HSGTC transit test track (Section I) at constant speed, which was varied between test runs from 15 to 70 mph.

STATUS:

The Post-Repair measured sound levels without the silencer installation fall within the total envelope of the baseline data measured in both SOAC cars. The air duct silencer installation had a beneficial effect in providing more uniform sound levels throughout the car.

TEST TITLE: EFFECT OF SPEED - WAYSIDE NOISE

TEST SET NUMBER: SOAC-CN-1001-TT

TEST OBJECTIVE:

To determine the effect of the SOAC repair on SOAC Wayside Noise Levels.

TEST DESCRIPTION:

Wayside noise levels were measured for Car No. 2 at a weight of 90,000 pounds with resilient wheels. The measurements were taken at 0, 15, 25, 35, 50 and 70 mph with the microphones placed at 15, 50 and 100 feet from the track centerline.

STATUS:

The Post-Repair test results are in substantial agreement with those from the original tests.

APPENDIX B

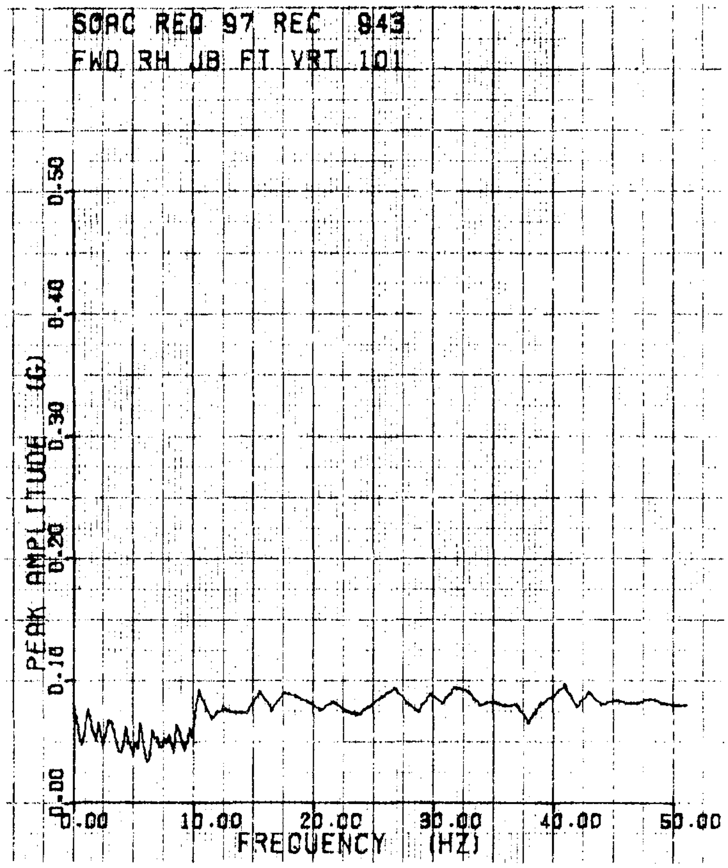
RIDE QUALITY PEAK AMPLITUDE AND POWER SPECTRAL MACHINE PLOTS

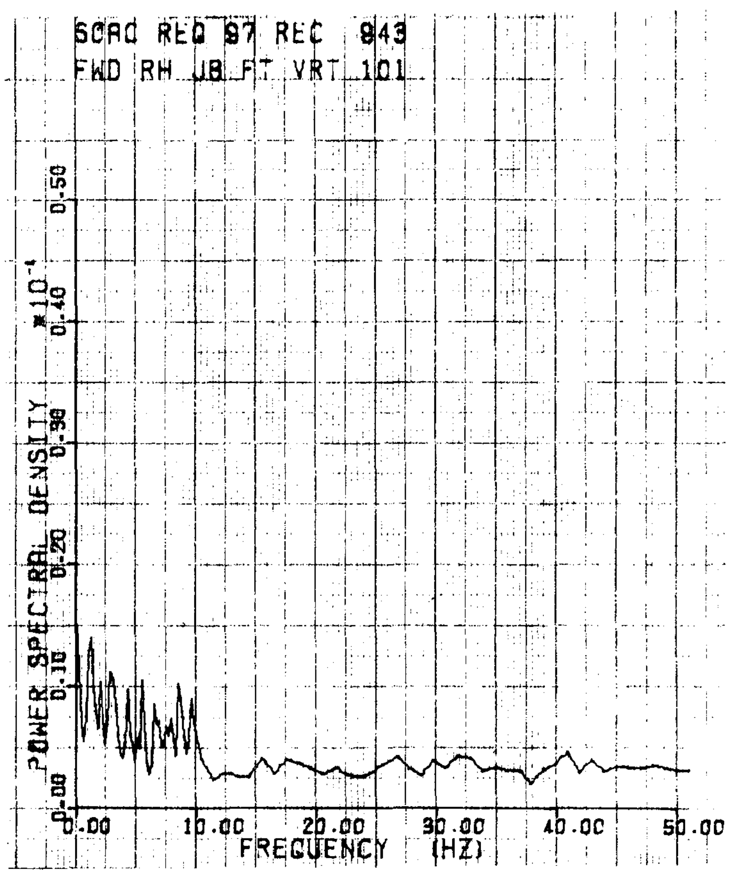
Figures B-1 through B-120 are machine plots of ride quality peak amplitude and power spectral density. Figures B-1 through B-80 are for the 90,000-pound car; Figures B-81 through B-120 are for the 105,000-pound car.

Sensor location can be determined by the second line of notation at the top of each plot. A sample notation is as follows:

FWD RH JB FT VRT 101

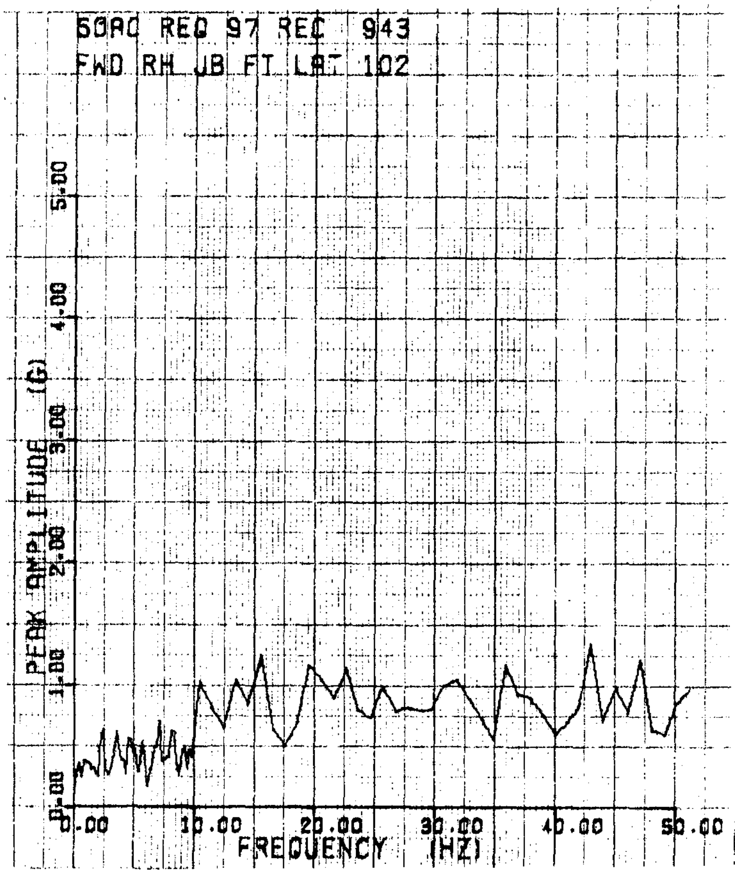
This represents: forward right-hand journal box front vertical acceleration; the numeral is a run number. Other abbreviations include: C/L, centerline; LAT, lateral; LONG, longitudinal; and MID, mid-car.

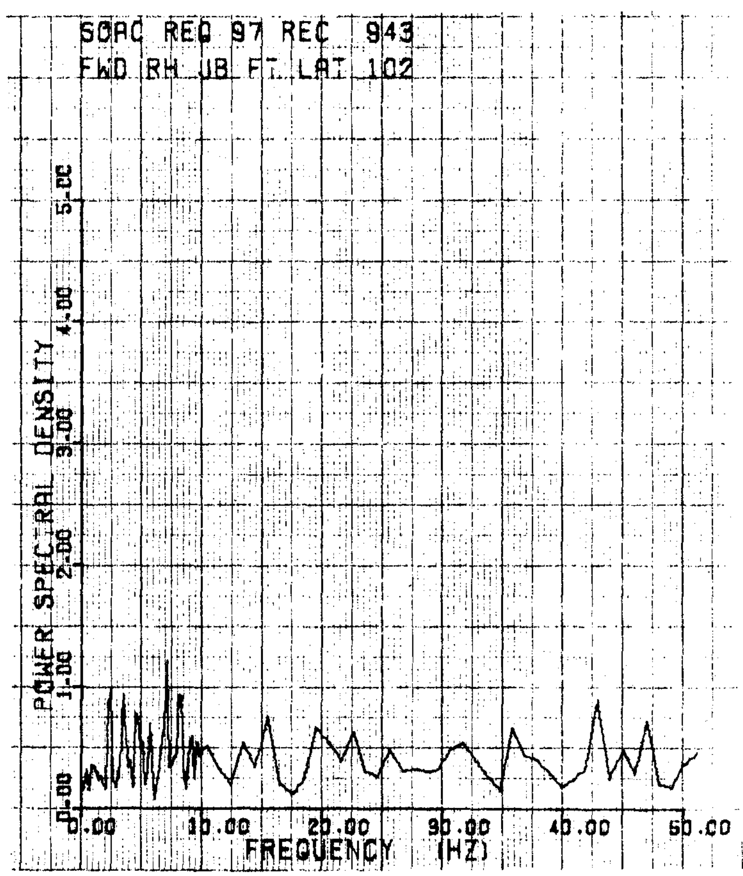




HIGH DENSITY CAR
90 KLB 3/29/74
20 MPH TRK SEC I

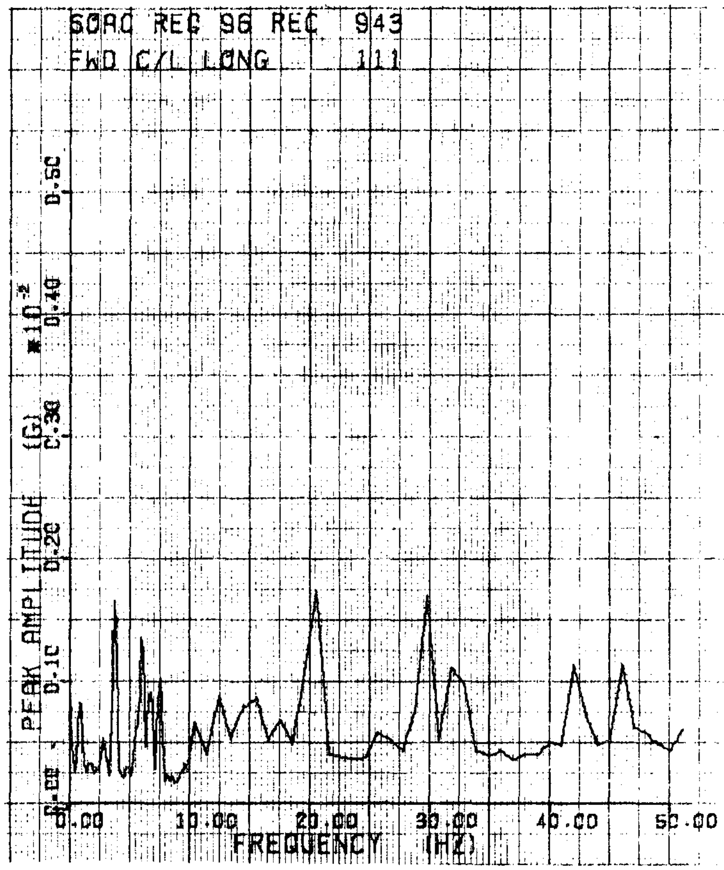
Figure B-1

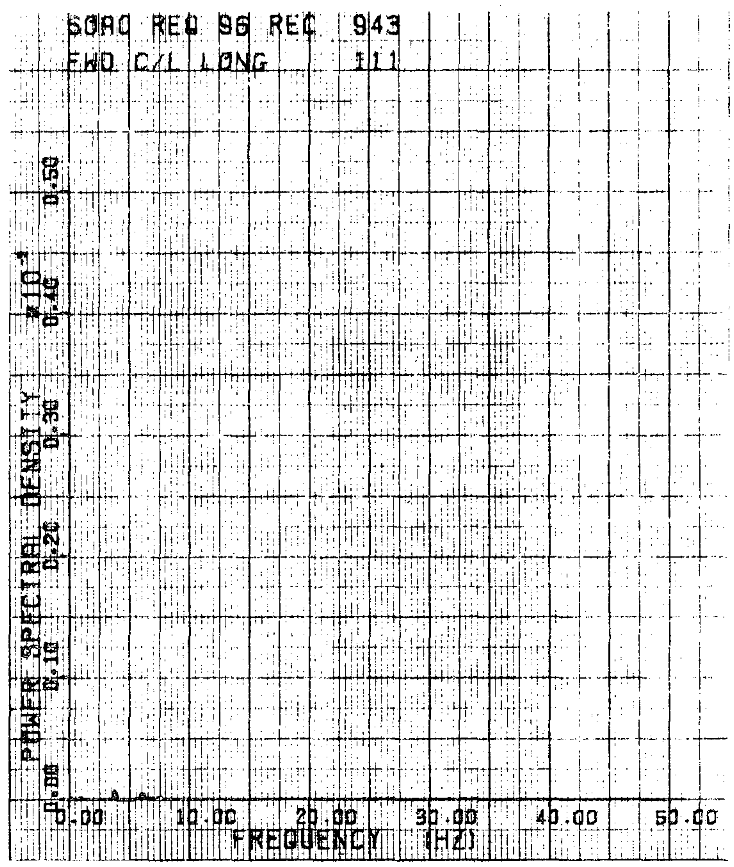




HIGH DENSITY CAR
JO KLB 3/29/74
20 MPH TRK SEC 1

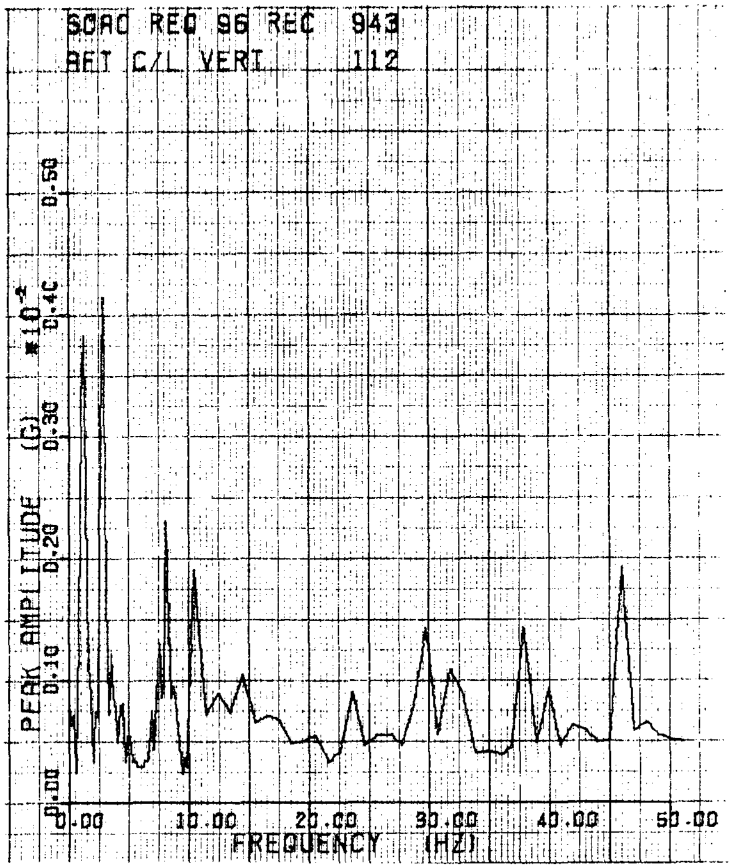
Figure B-2

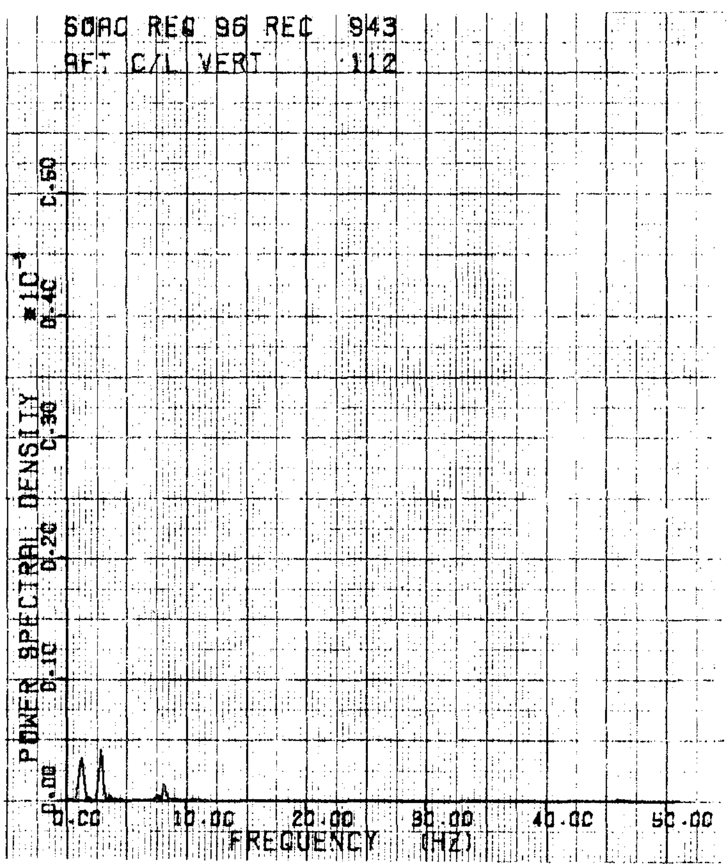




HIGH DENSITY CAR
00 KLB 5/29/74
20 MPH TRK SEC I

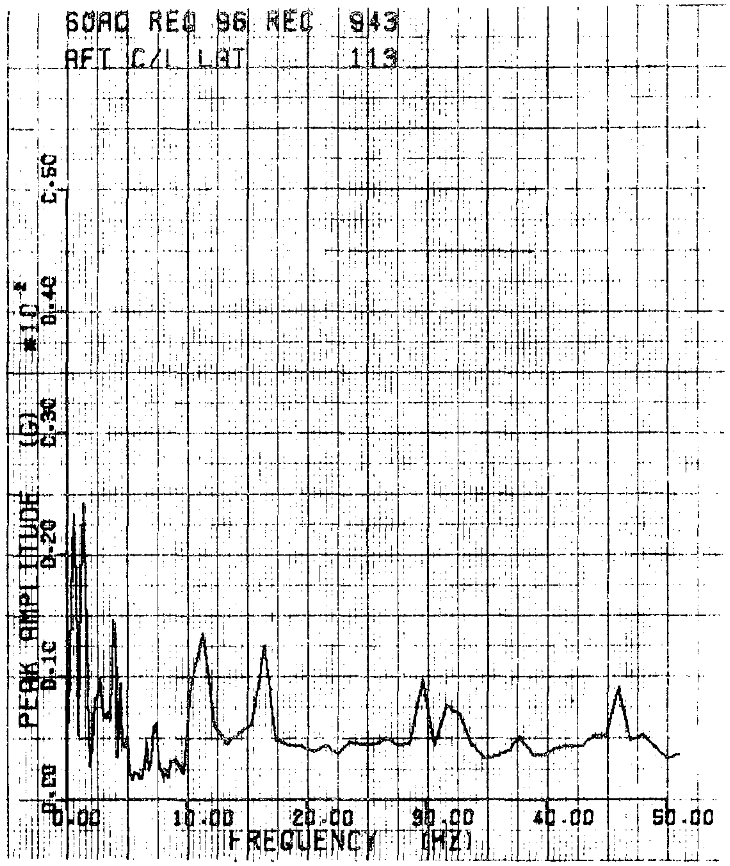
Figure B-3

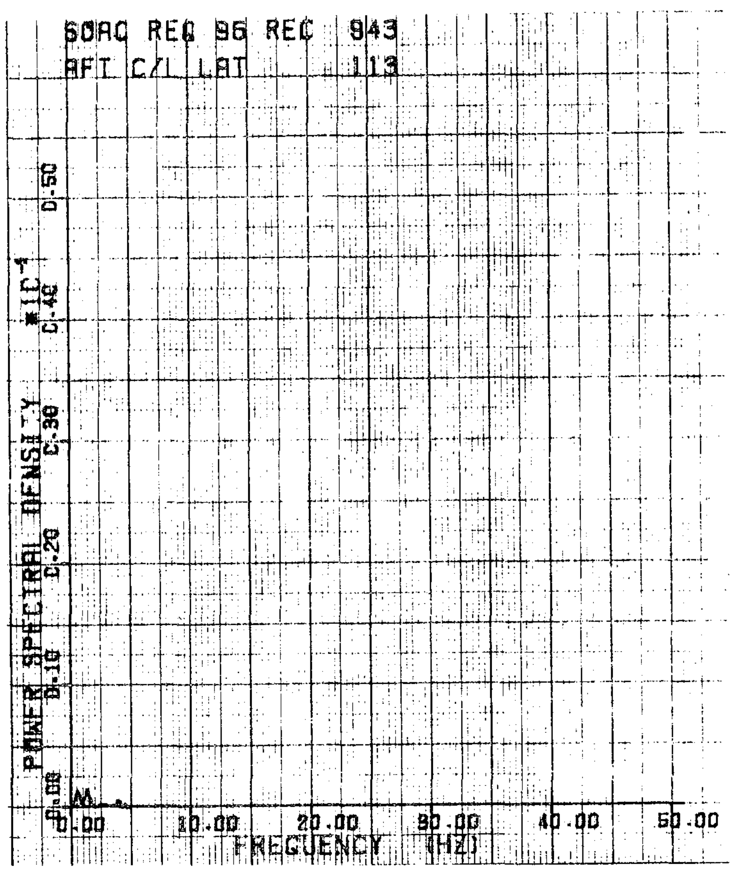




HIGH DENSITY CAR
90 KLB 3/29/74
20 MPH TRK SEC I

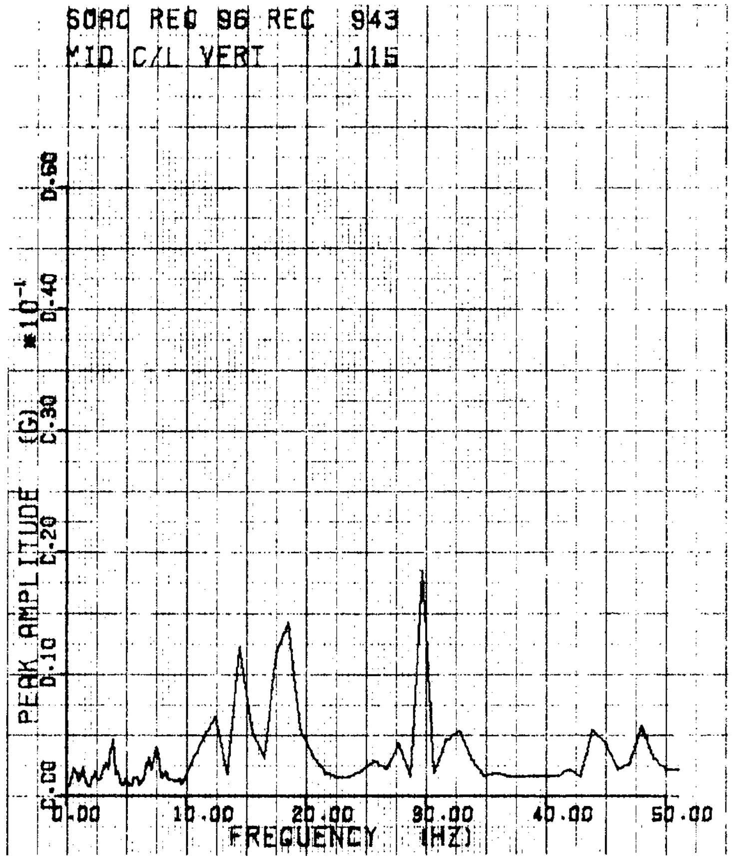
Figure B-4

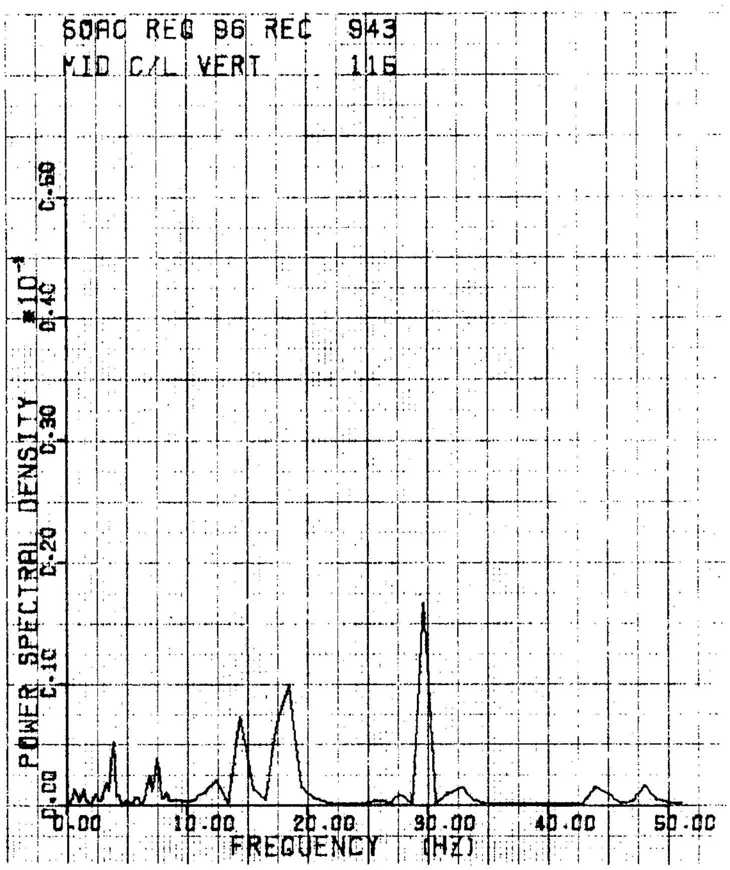




HIGH DENSITY CAR
30 KLB 3/29/74
20 MPH TRK SEC I

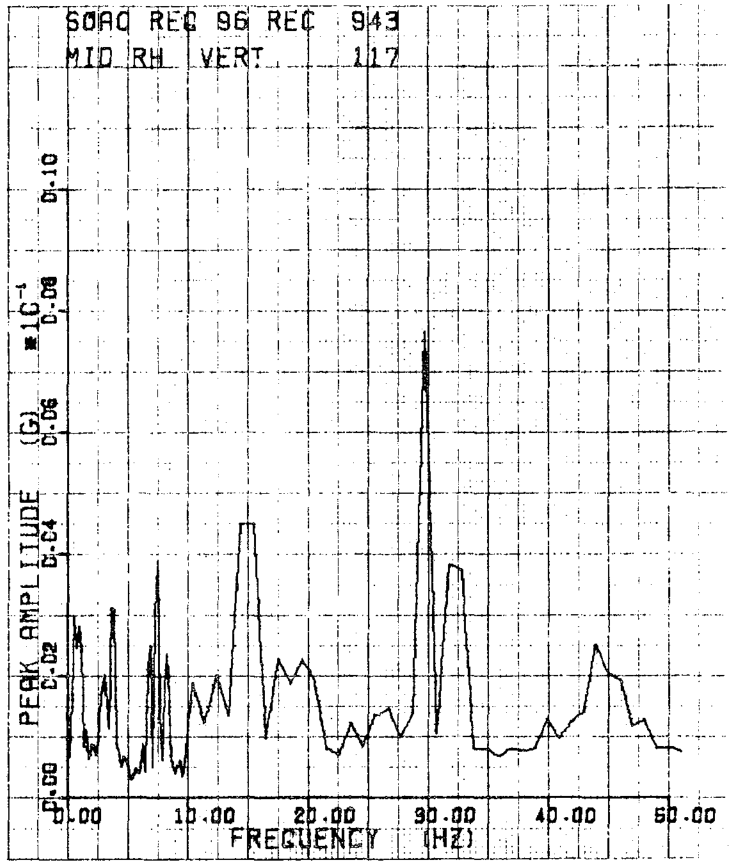
Figure B-5

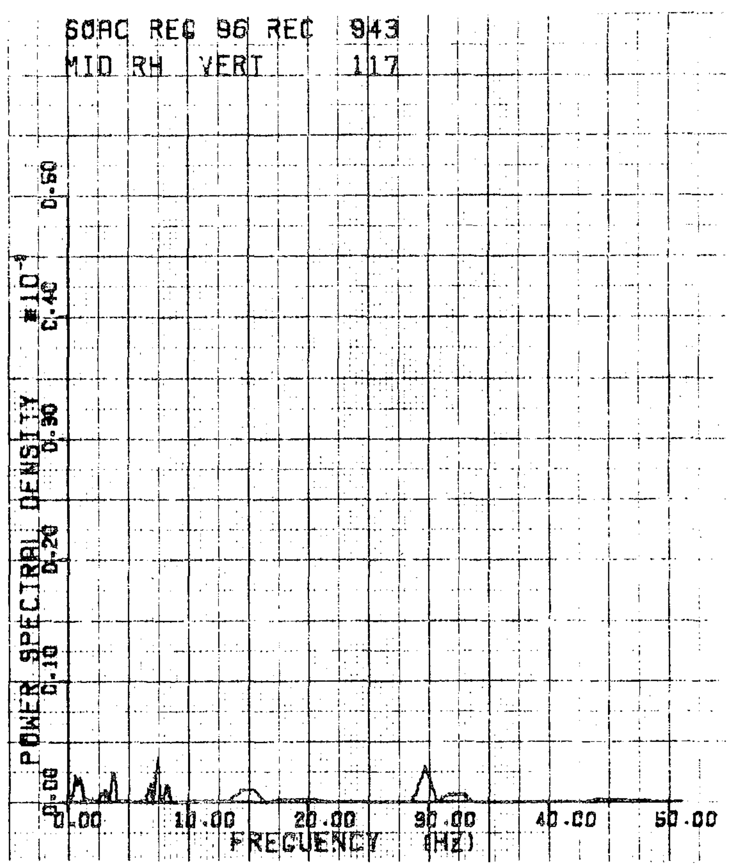




HIGH DENSITY CAR
90 KLB 3/29/74
20 MPH TRK SEC I

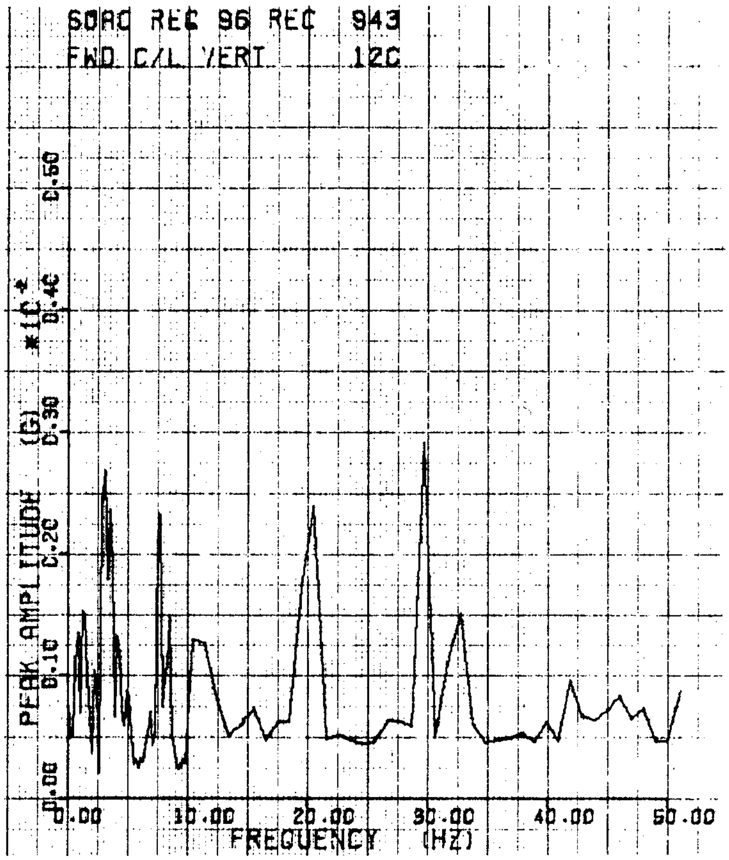
Figure B-6

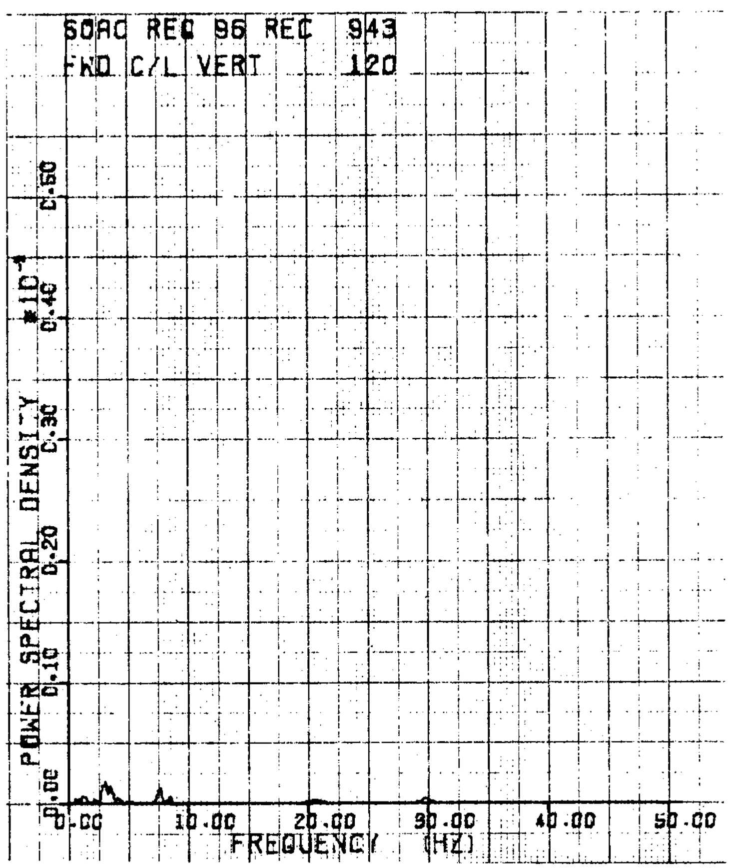




HIGH DENSITY CAR
30 KLB 5/29/74
20 MPH TRK SEC I

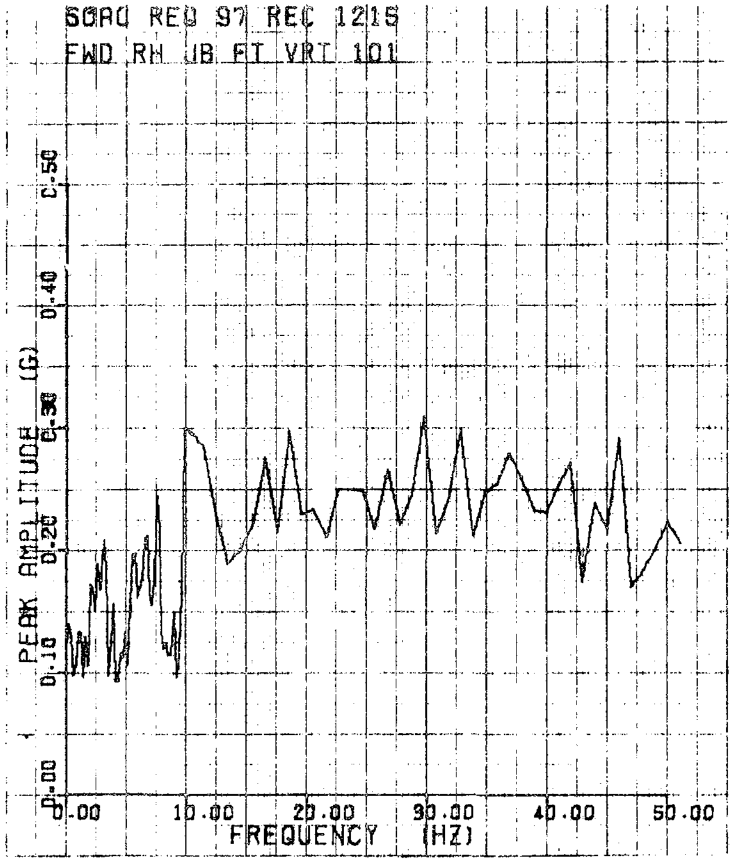
Figure B-7

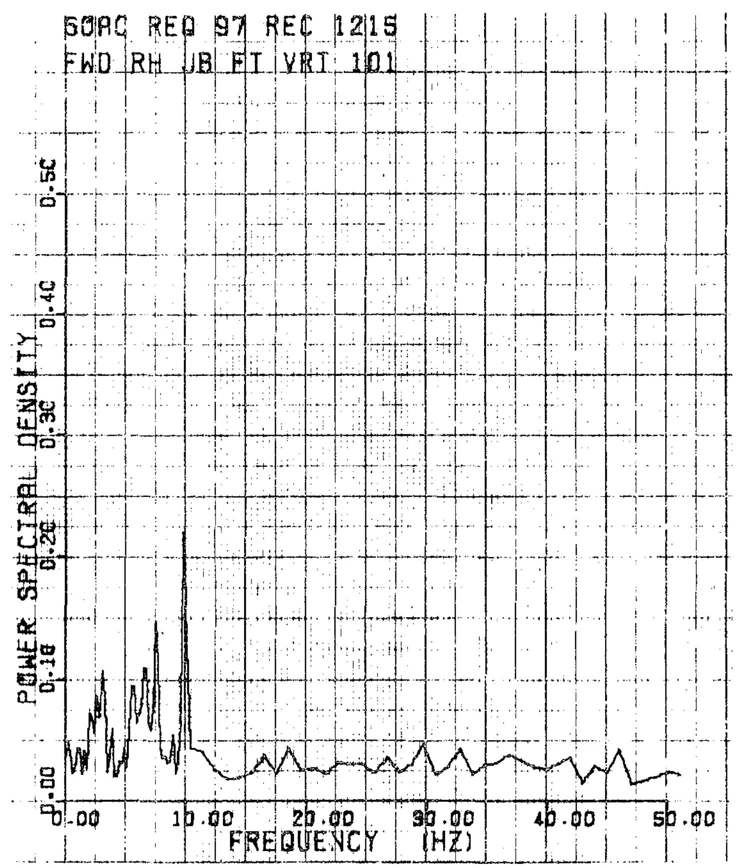




HIGH DENSITY CAR
90 KLB 3/29/74
20 MPH TRK SEC I

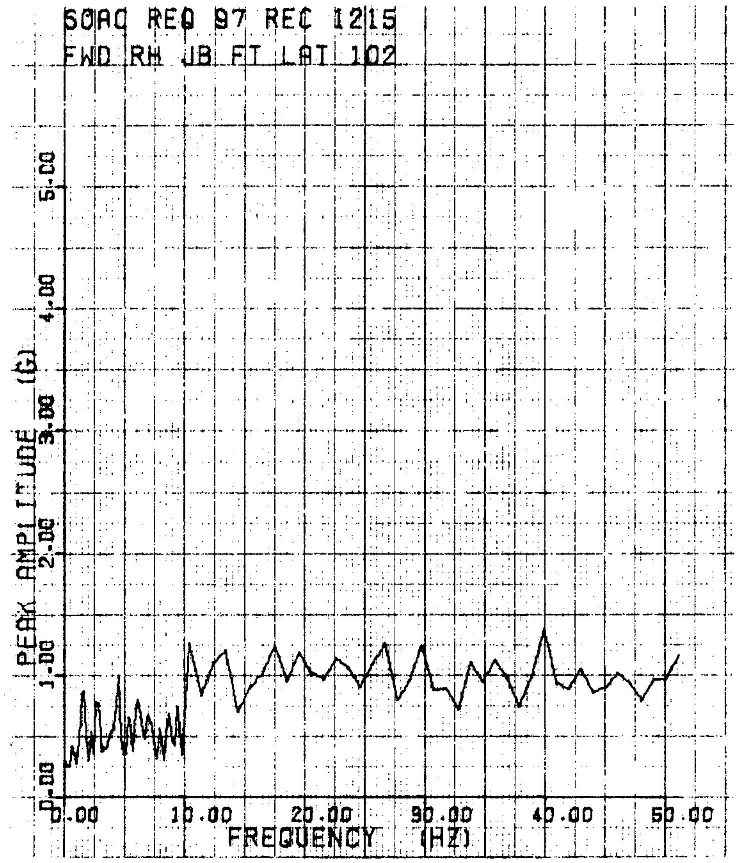
Figure B-8

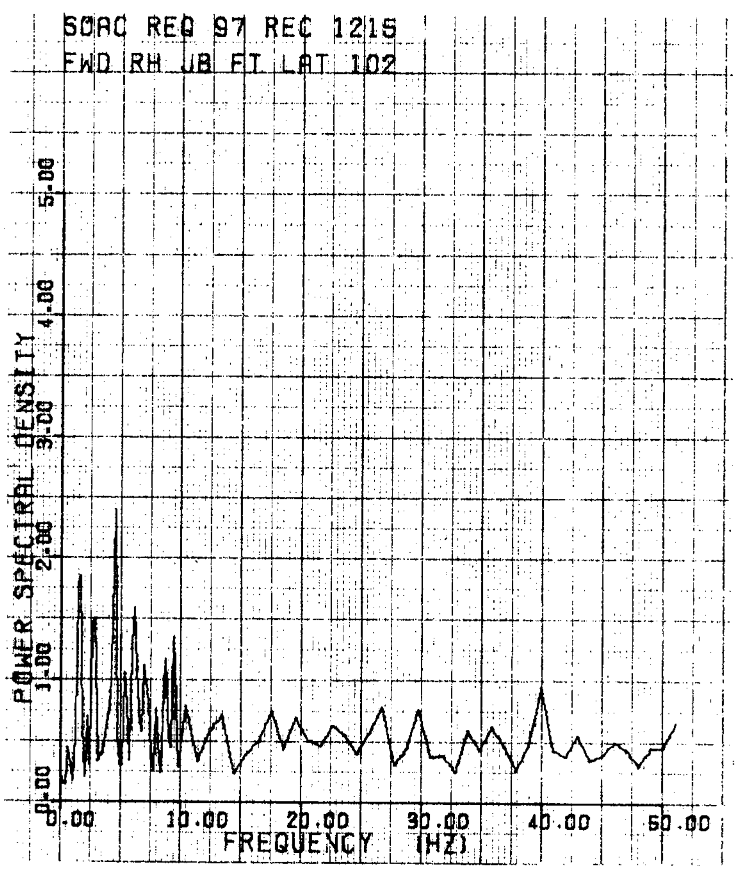




HIGH DENSITY CA
90 KLB 3/29/7
25.0 MPH TRK SEC

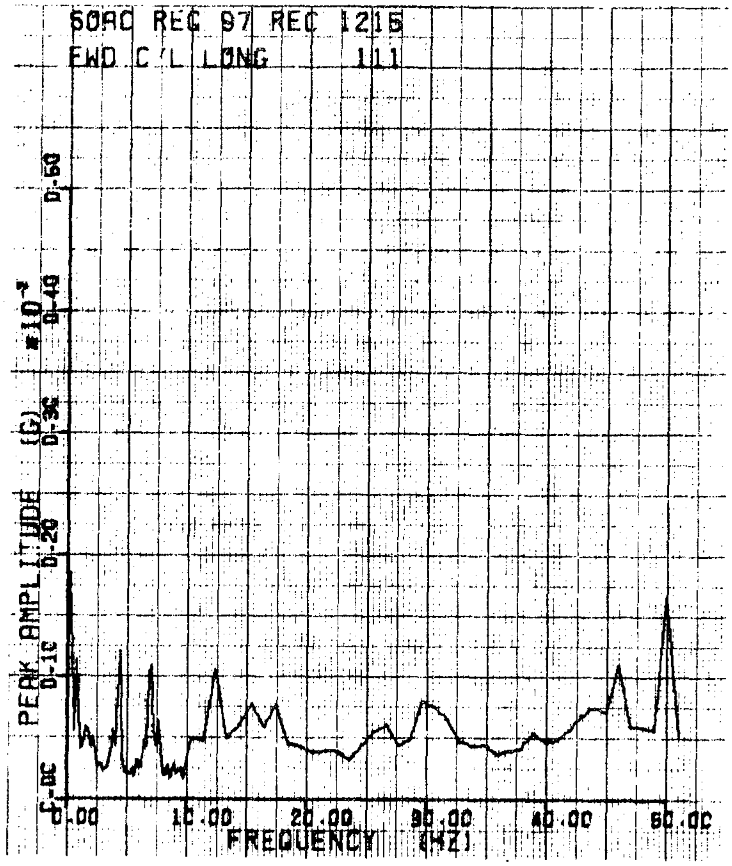
Figure B-9

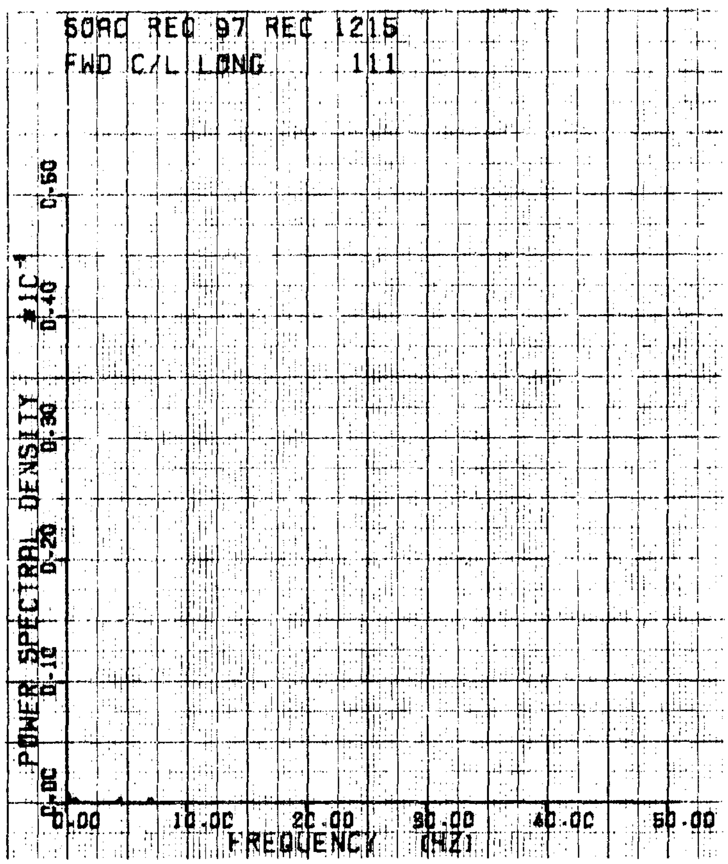




HIGH DENSITY CAR
90 KLB 3/29/74
25.0 MPH TRK SEC I

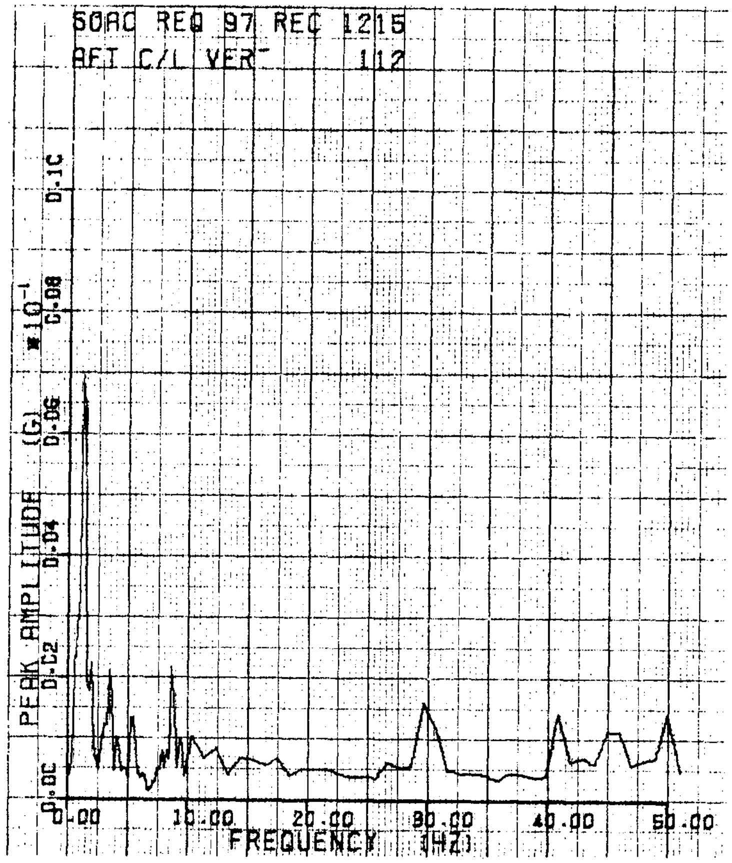
Figure B-10

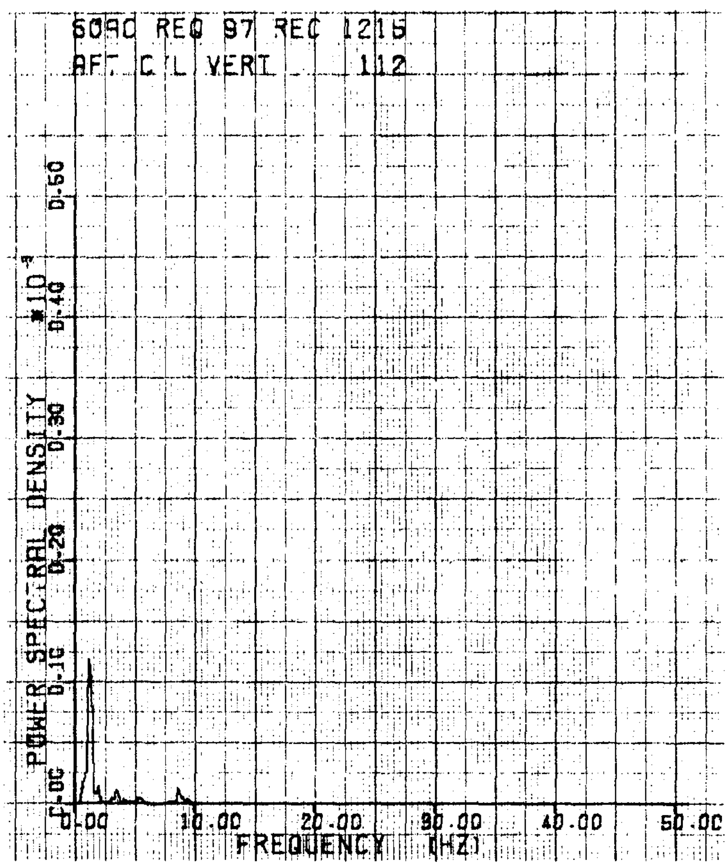




HIGH DENSITY CAR
90 KLB 3/29/74
25.6 MPH TRK SEC 1

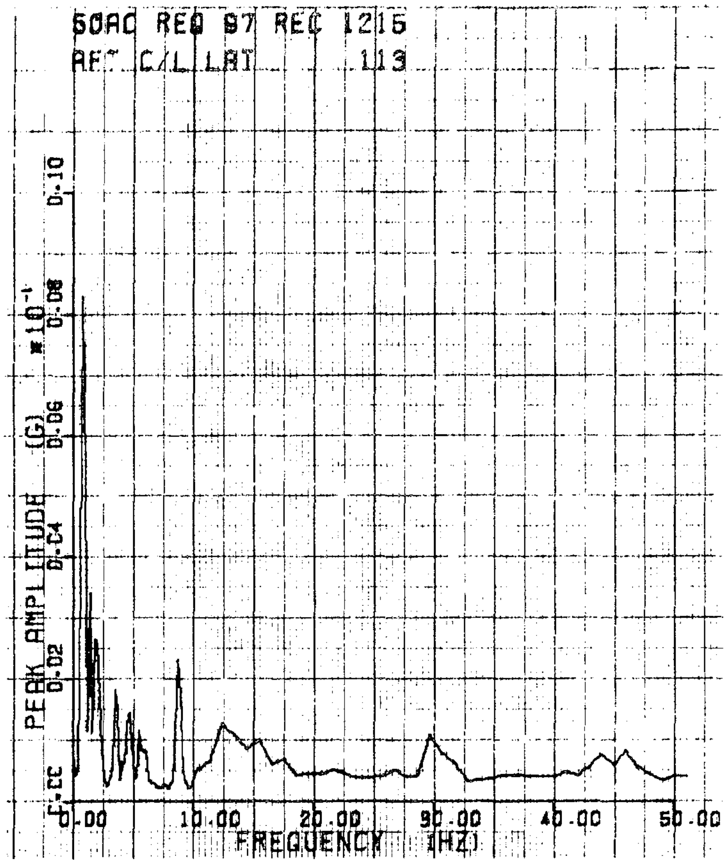
Figure B-11

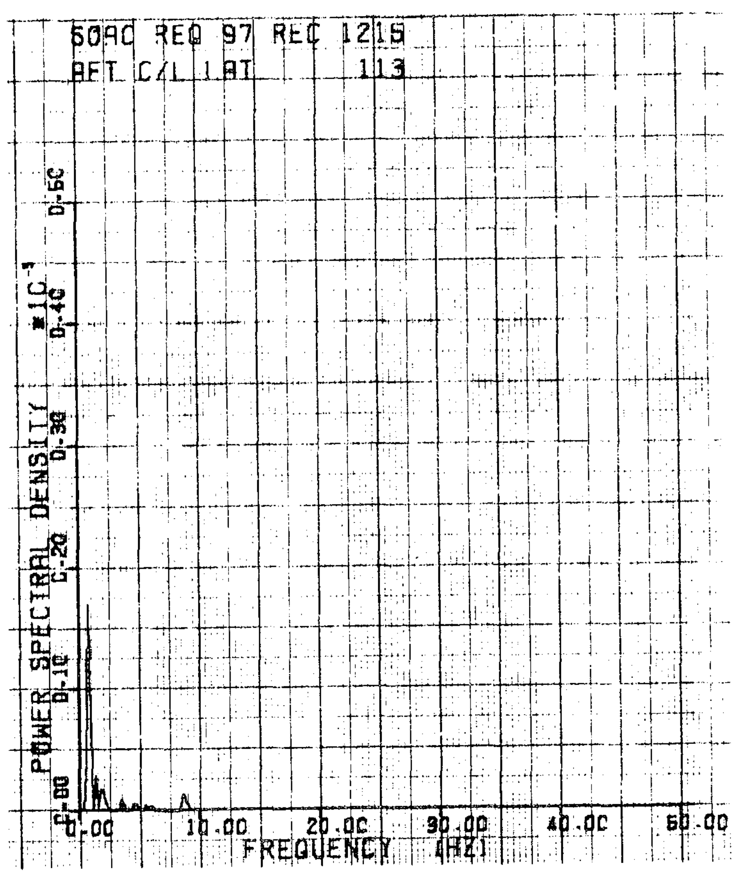




HIGH DENSITY CAR
90 KLB 3/29/74
25.6 MPH TRK SEC I

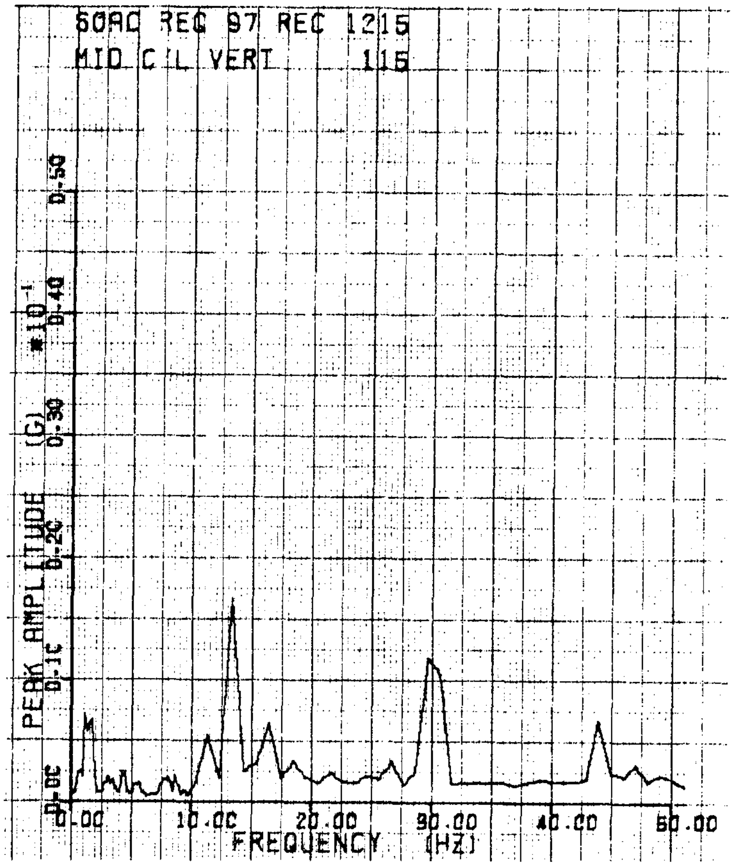
Figure B-12

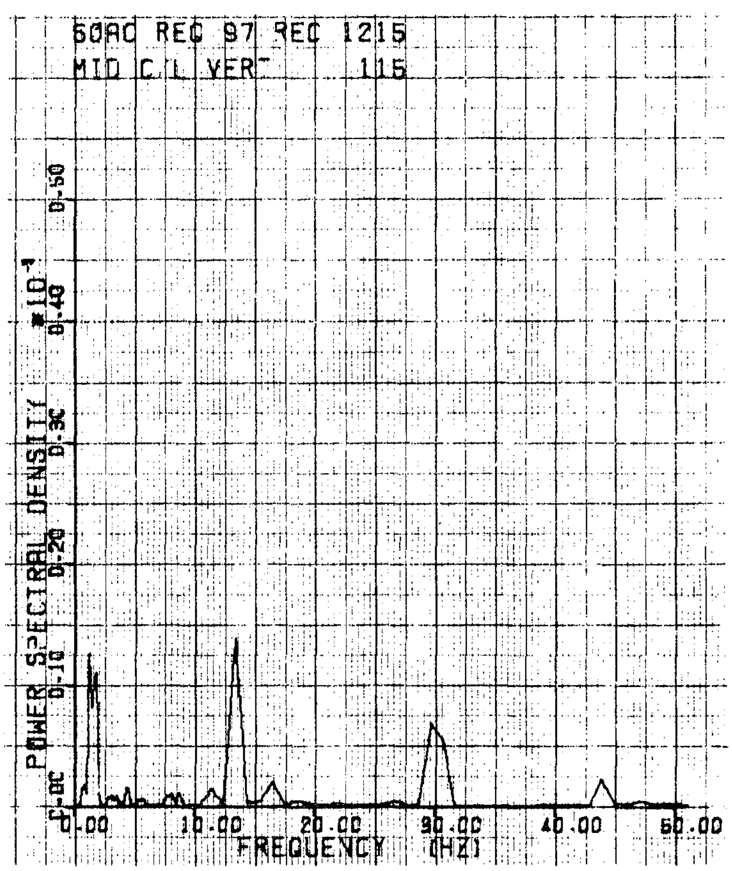




HIGH DENSITY CAR
30 KLB 3/29/74
25.6 MPH TRK SEC I

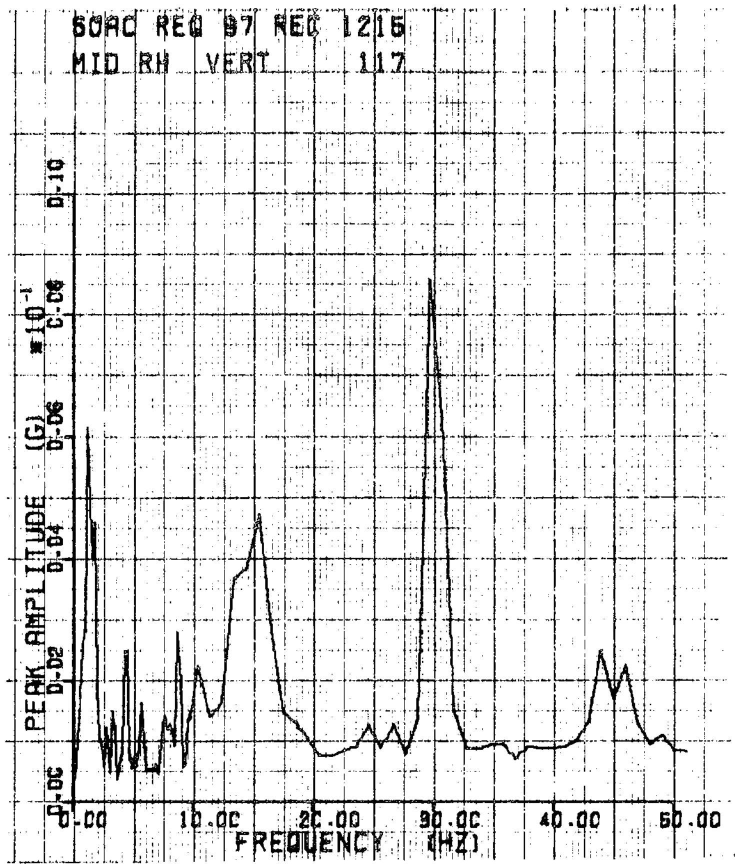
Figure B-13

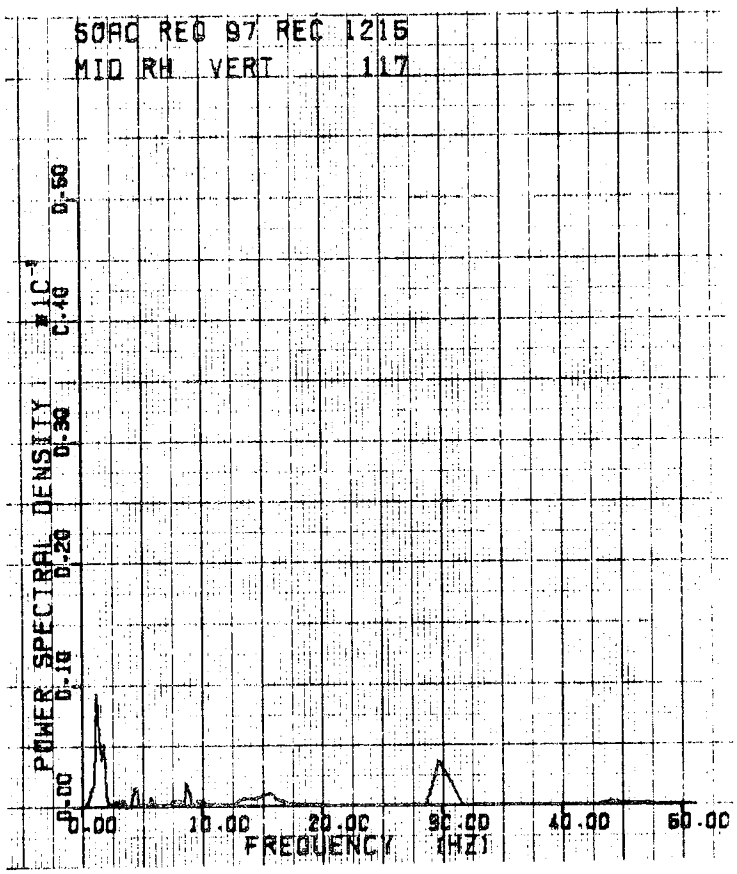




HIGH DENSITY CAR
30 KLB 3/20/74
25.6 MPH TRK SEC I

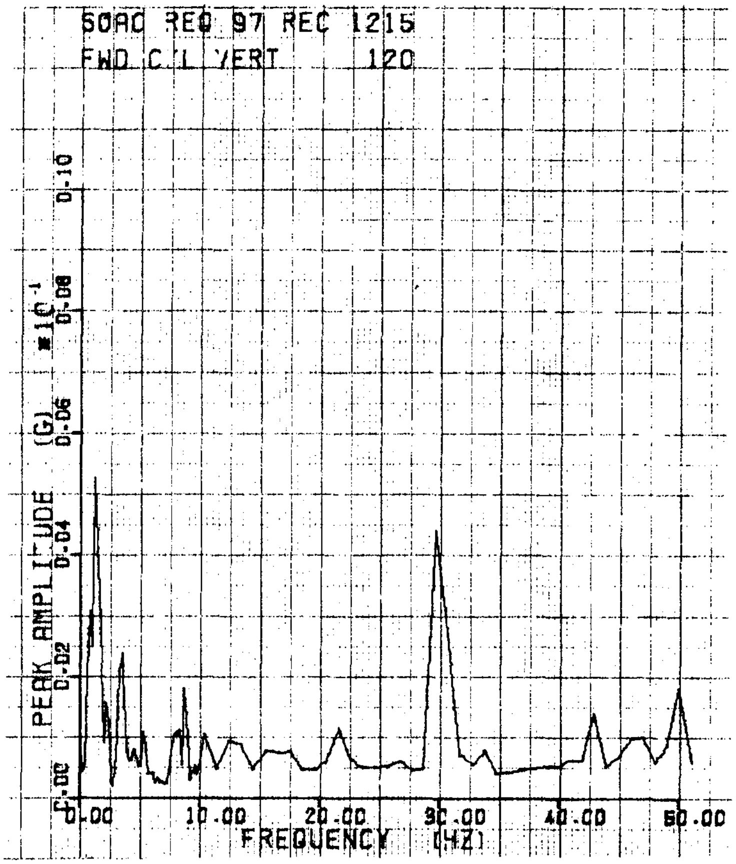
Figure B-14

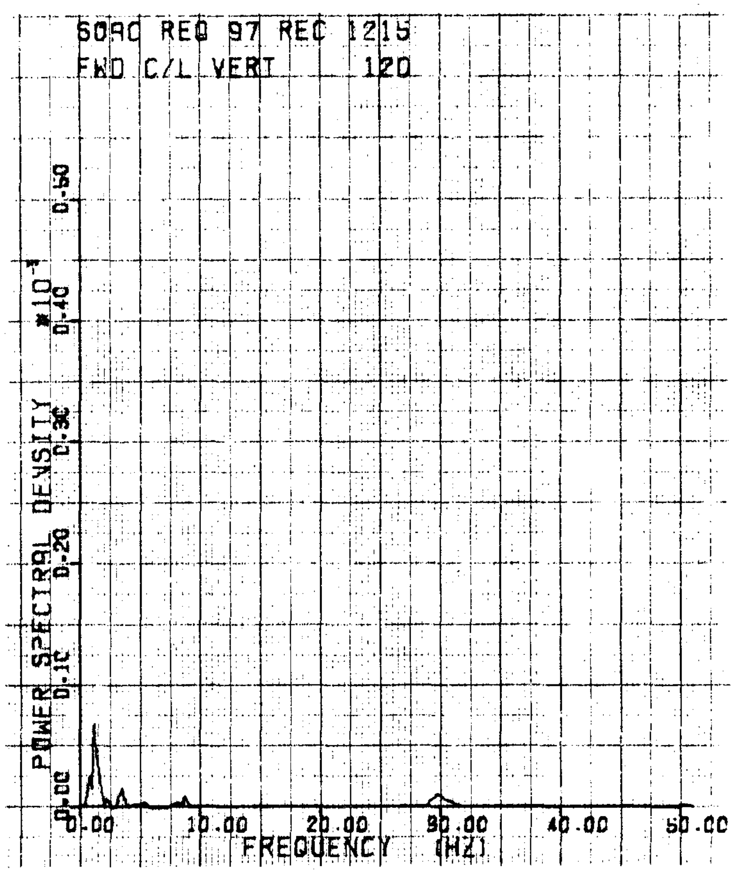




HIGH DENSITY CAR
90 KLB 3/29/74
25.6 MPH TRK SEC I

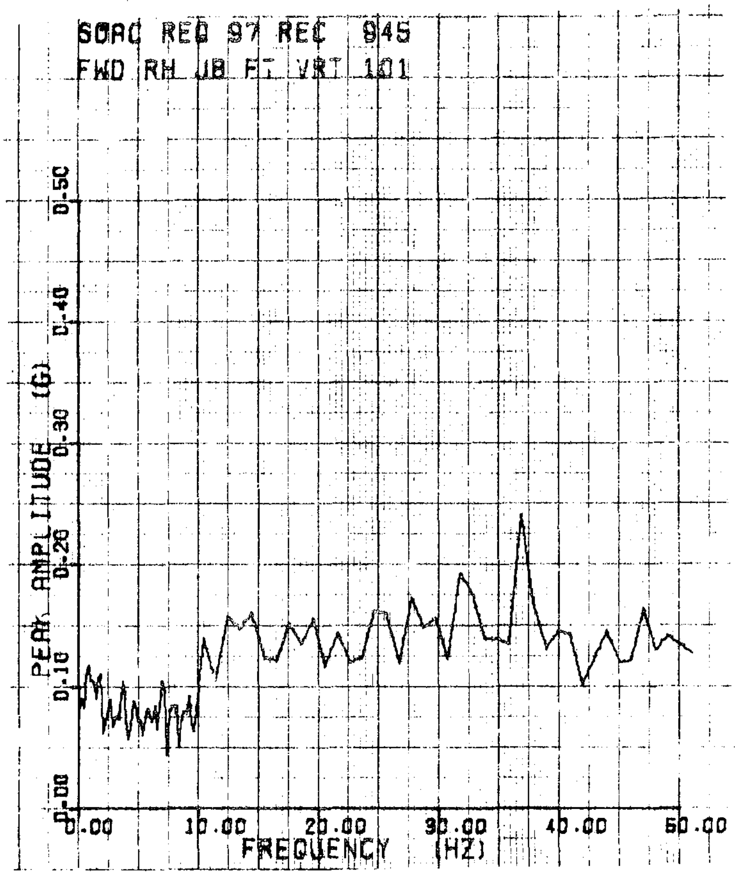
Figure B-15





HIGH DENSITY CAR
30 KLB 3/29/74
25.6 MPH TRK SEC 1

Figure B-16


SOAC REQ 97 REC 945
FWD RH JB FT VRT 101
PEAK AMPLITUDE (G)
0.00
0.10
0.20
0.30
0.40
0.50
0.00
10.00
20.00
30.00
40.00
50.00
FREQUENCY (HZ)

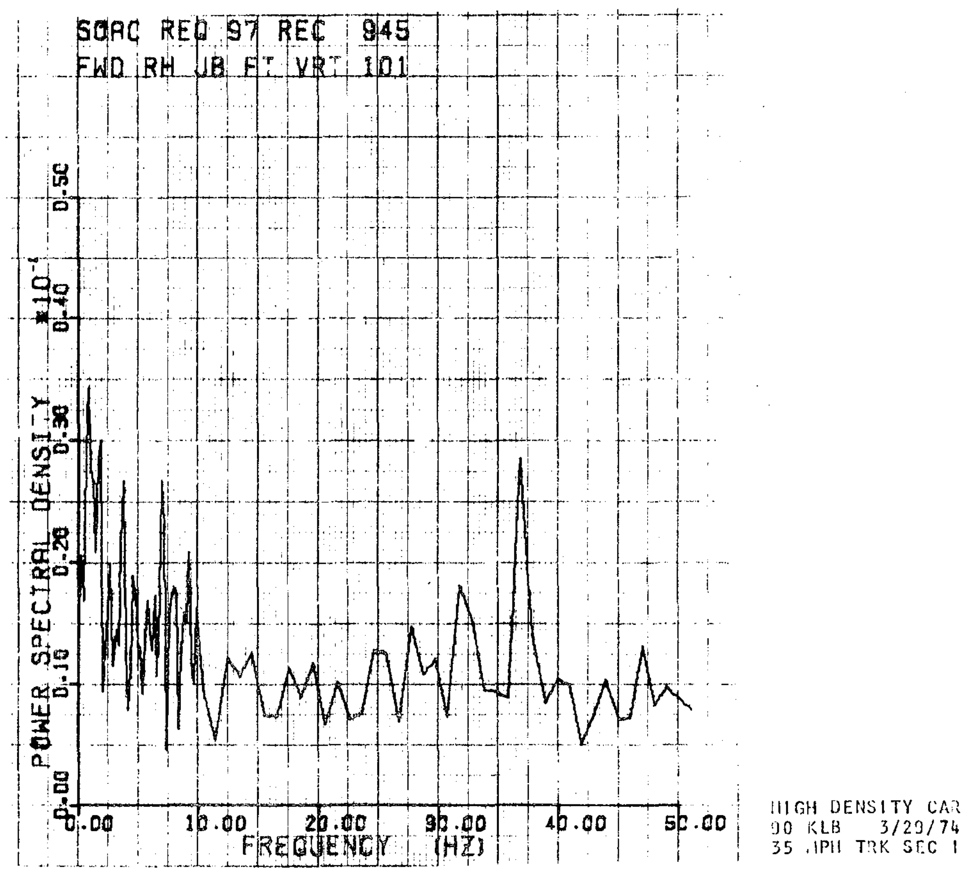
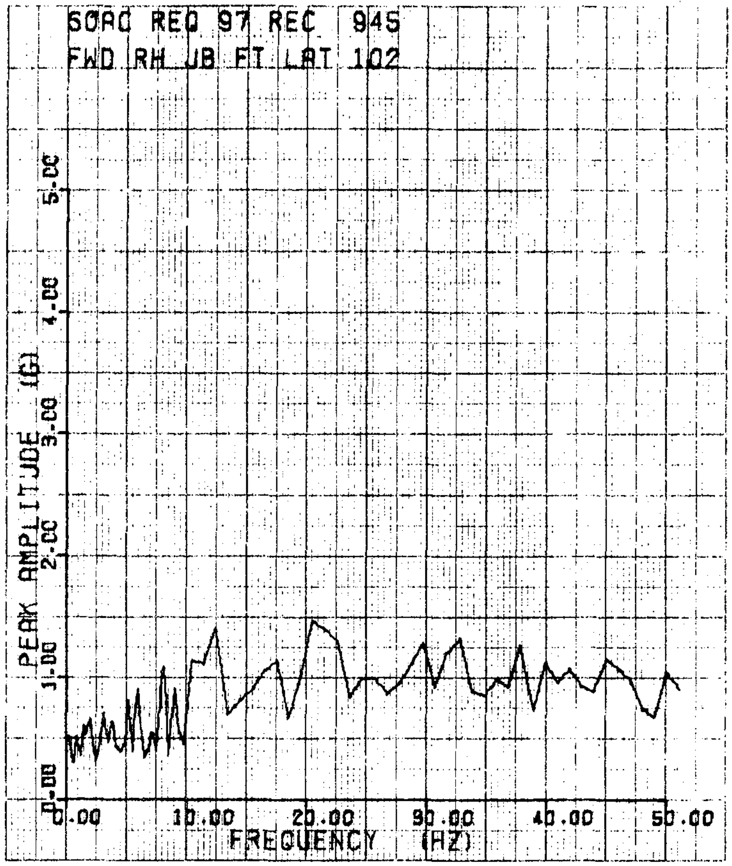
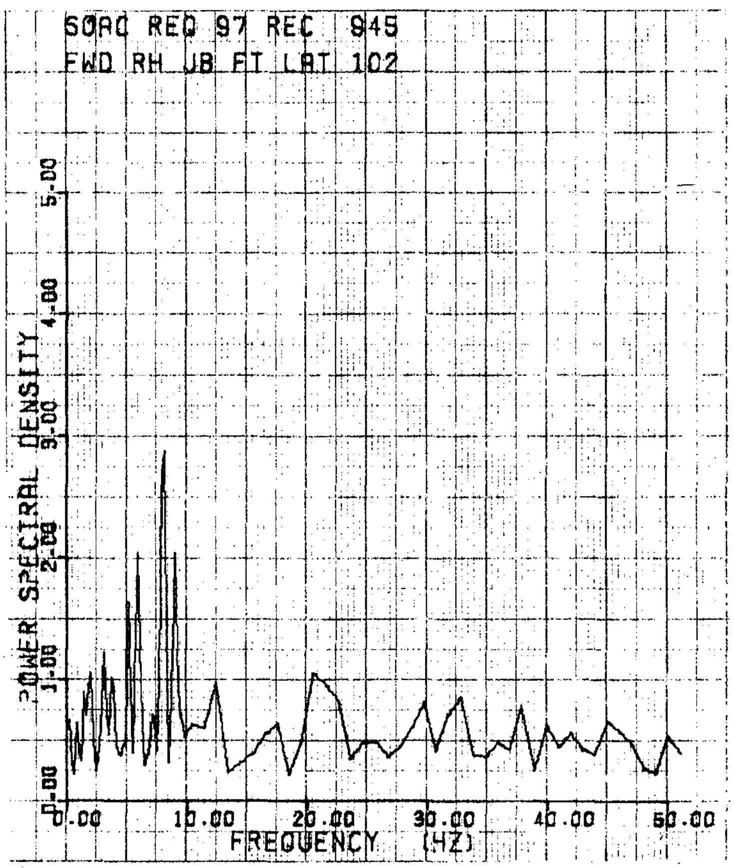

SOAC REQ 97 REC 945
FWD RH JB FT VRT 101
POWER SPECTRAL DENSITY *10⁻¹
0.00
0.10
0.20
0.30
0.40
0.50
0.00
10.00
20.00
30.00
40.00
50.00
FREQUENCY (HZ)
HIGH DENSITY CAR
90 KLB 3/29/74
35 MPH TRK SEC 1

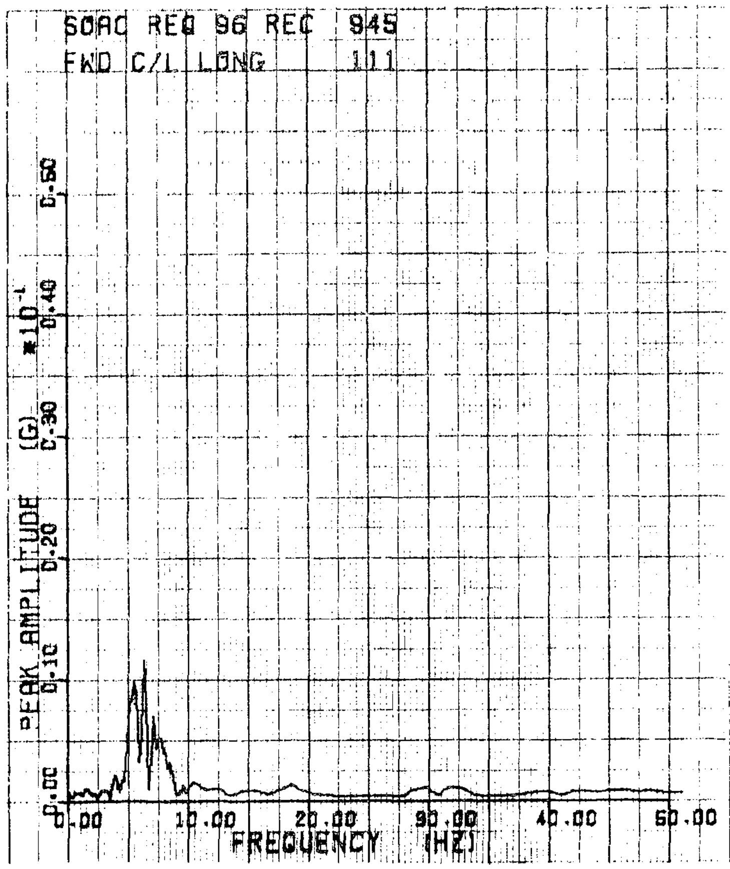
Figure B-17

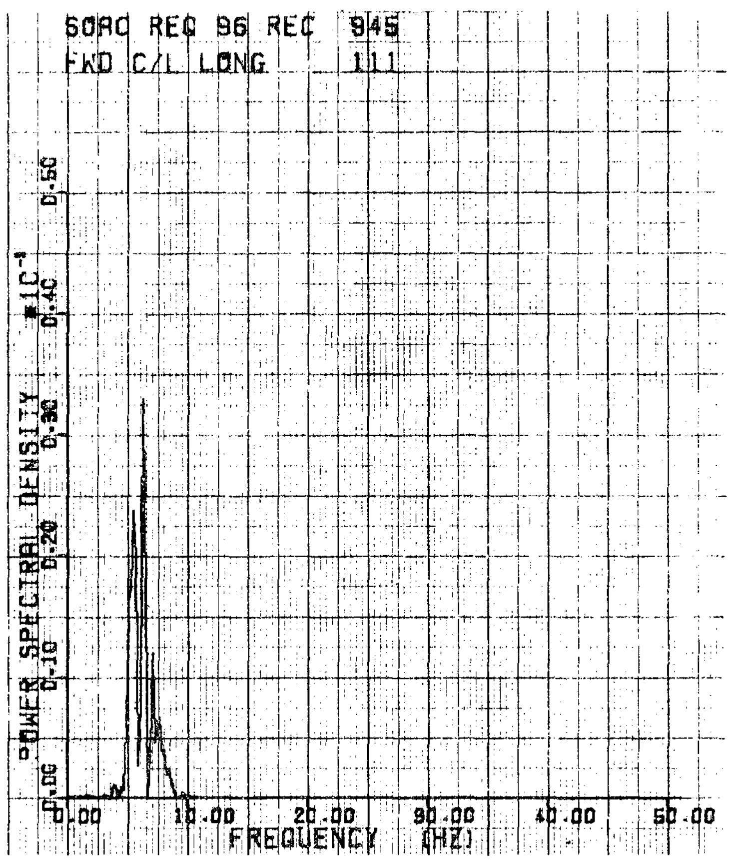




HIGH DENSITY CAR
90 KLB 3/29/74
35 MPH TRK SEC I

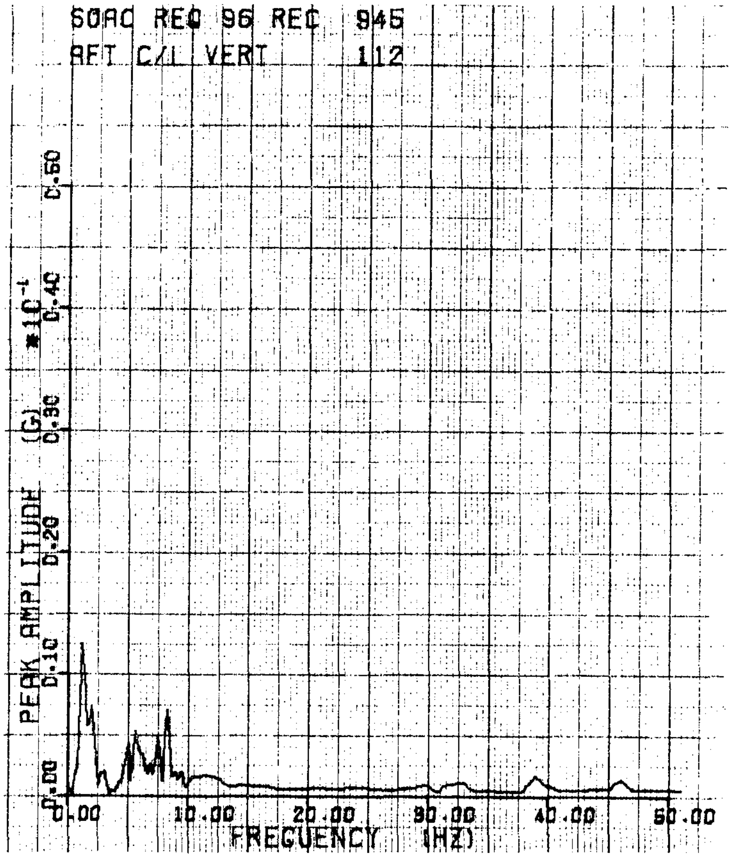
Figure B-18

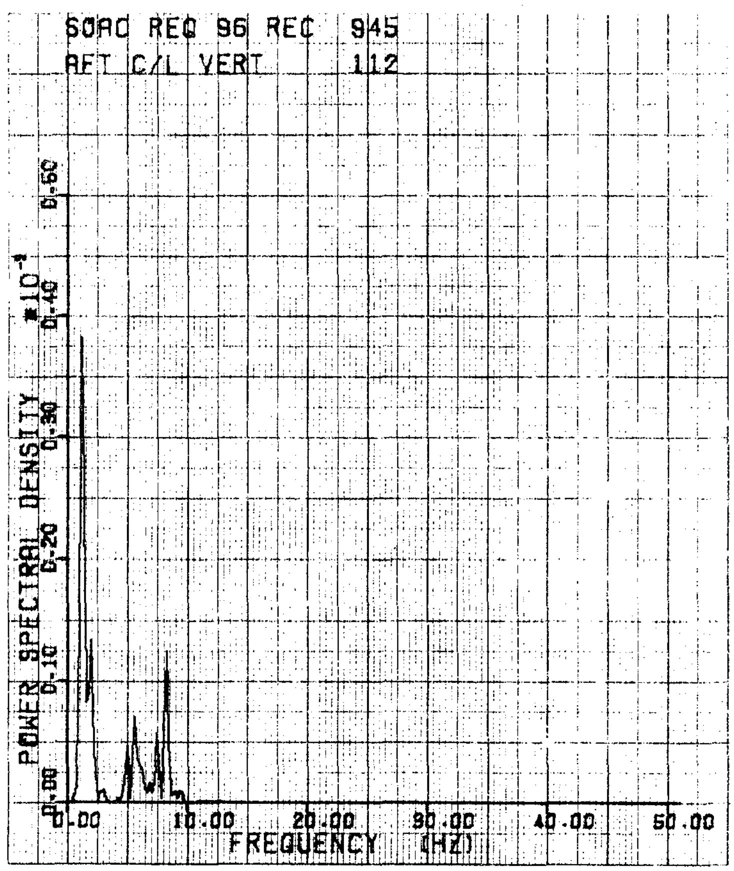




HIGH DENSITY CAR
90 KLB 3/21/74
35 MPH TRK SEC I

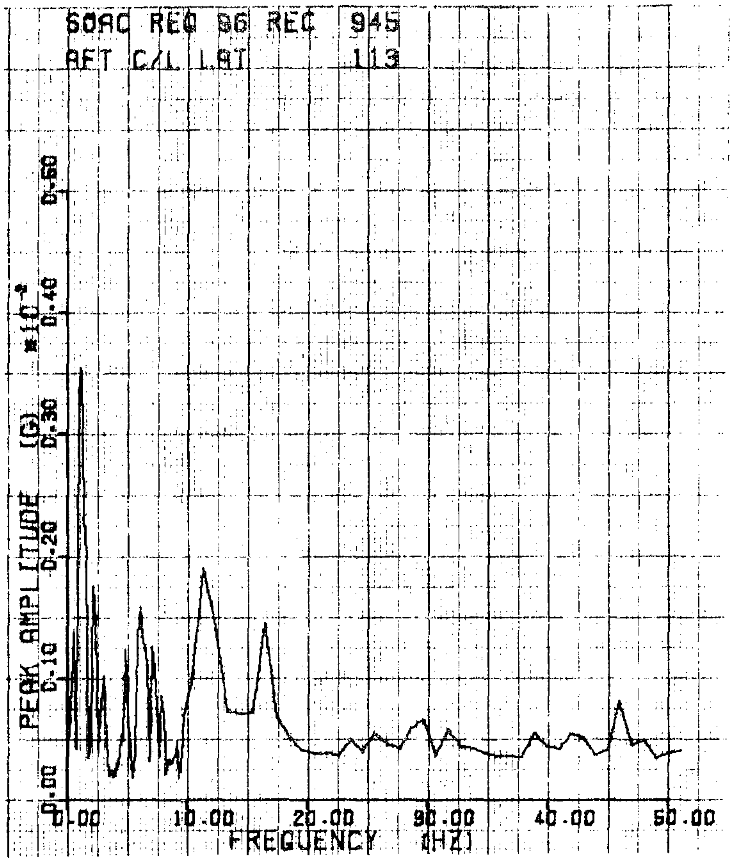
Figure B-19

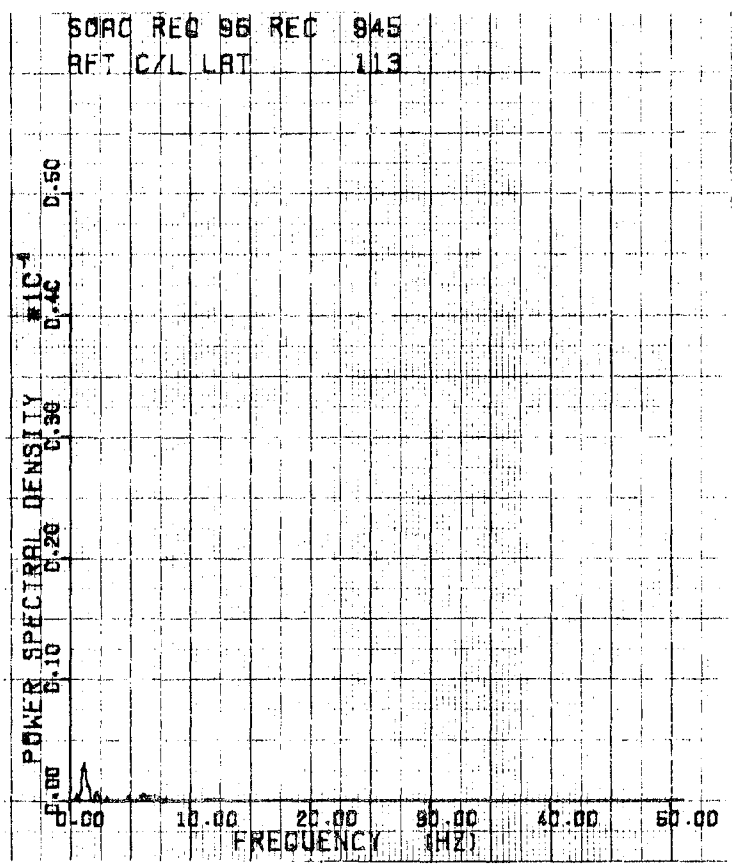




HIGH DENSITY CAR
90 KLB 3/29/74
35 MPH TRK SEC I

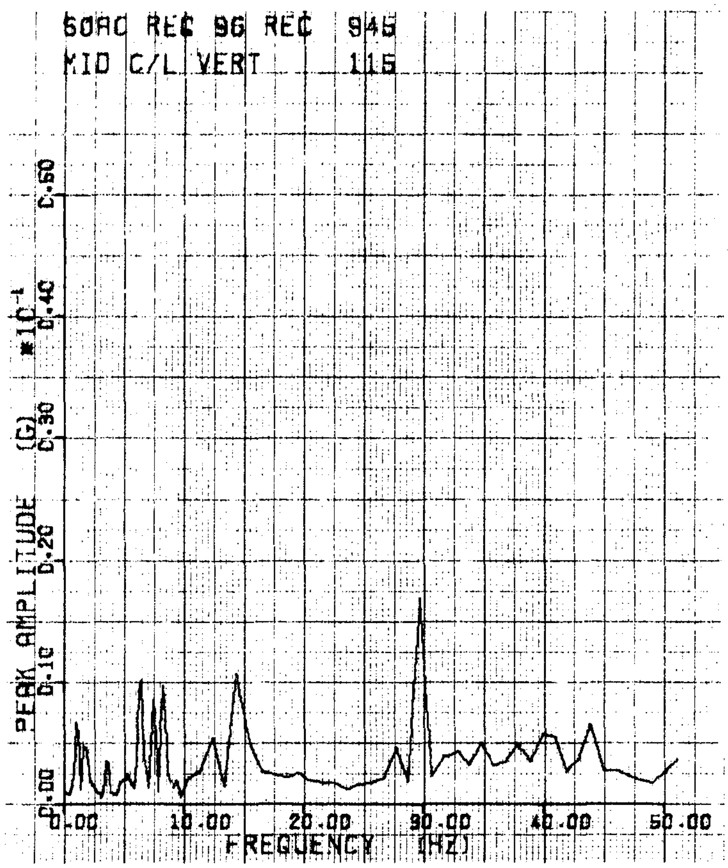
Figure B-20

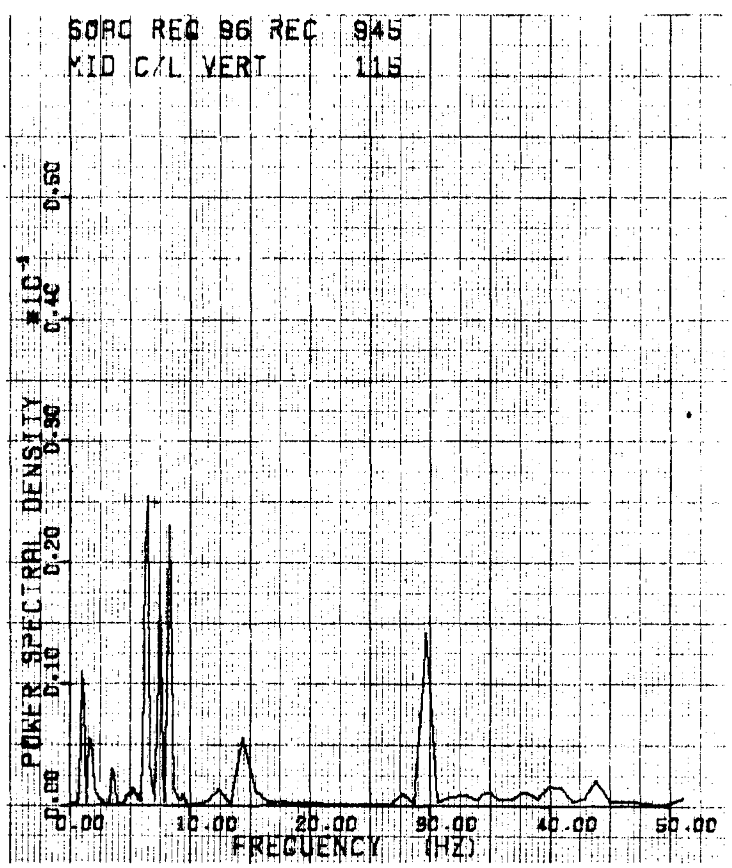




HIGH DENSITY CAR
90 KLB 3/29/74
35 MPH TRK SEC I

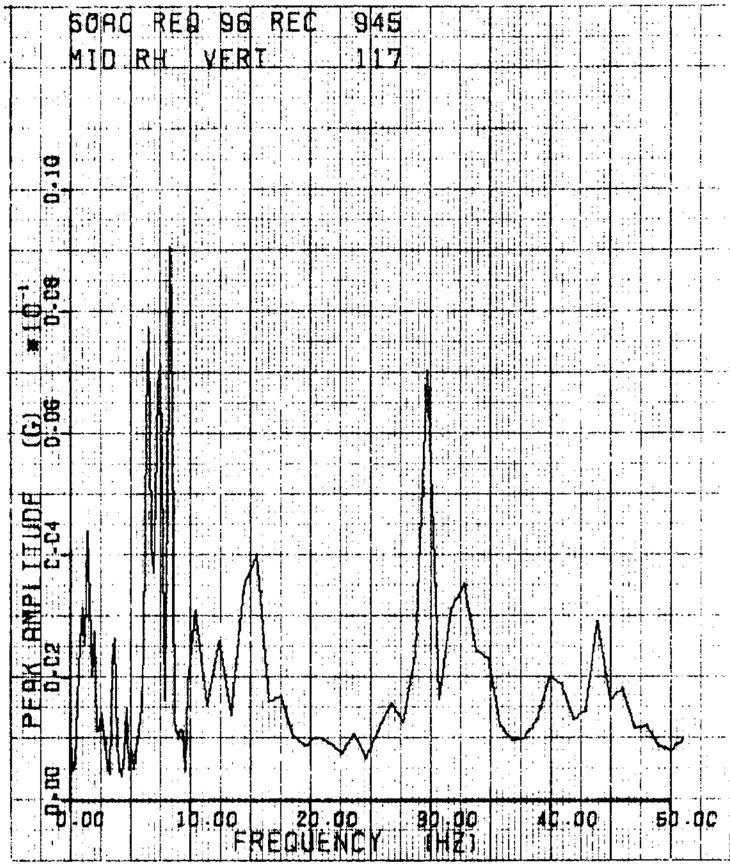
Figure B-21

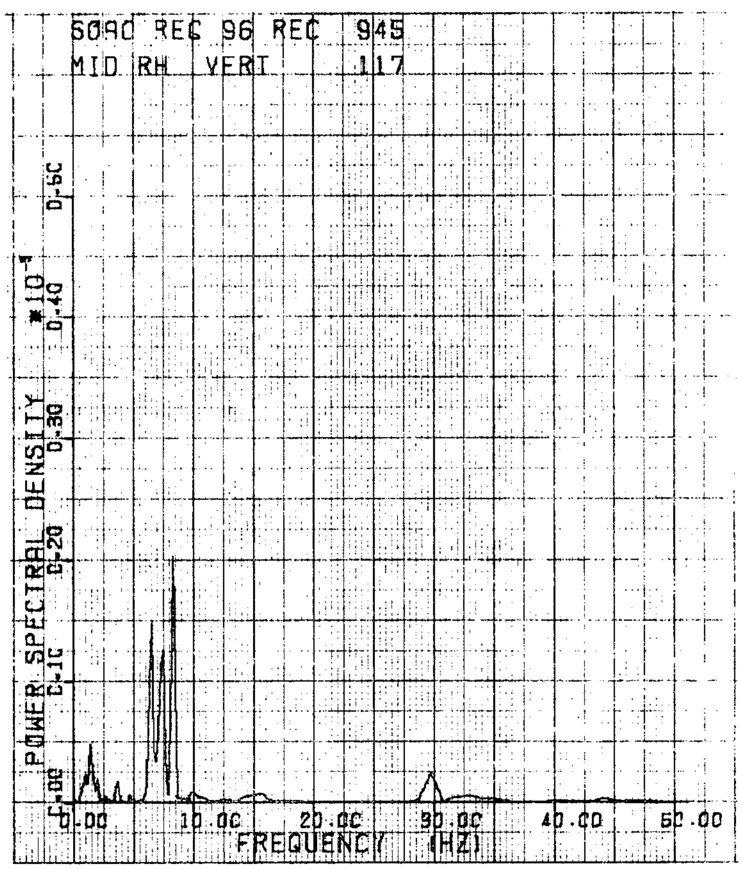




HIGH DENSITY CAR
90 KLB 3/29/74
35 MPH TRK SEC I

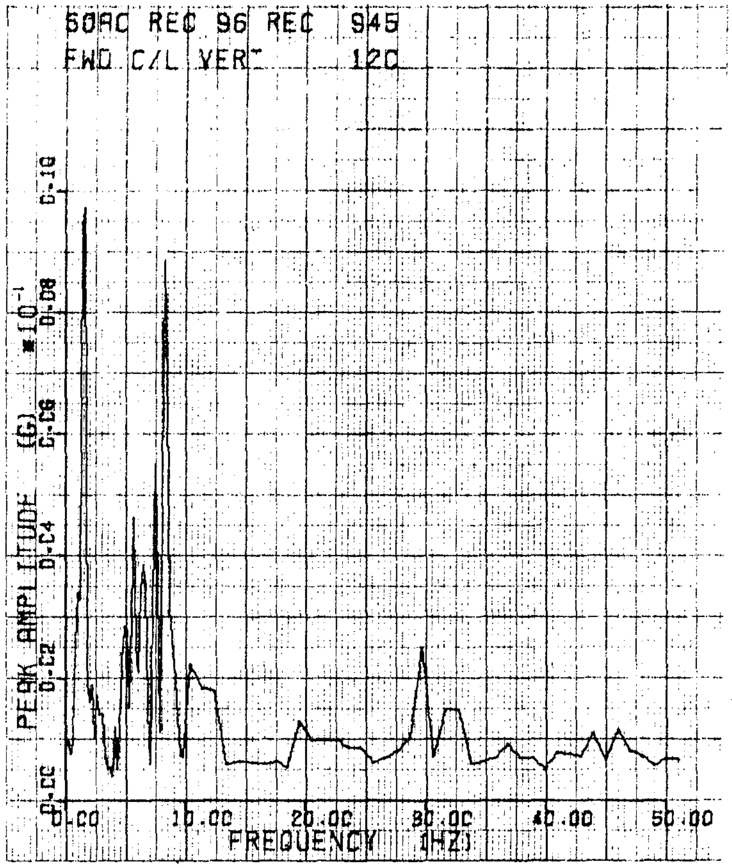
Figure B-22

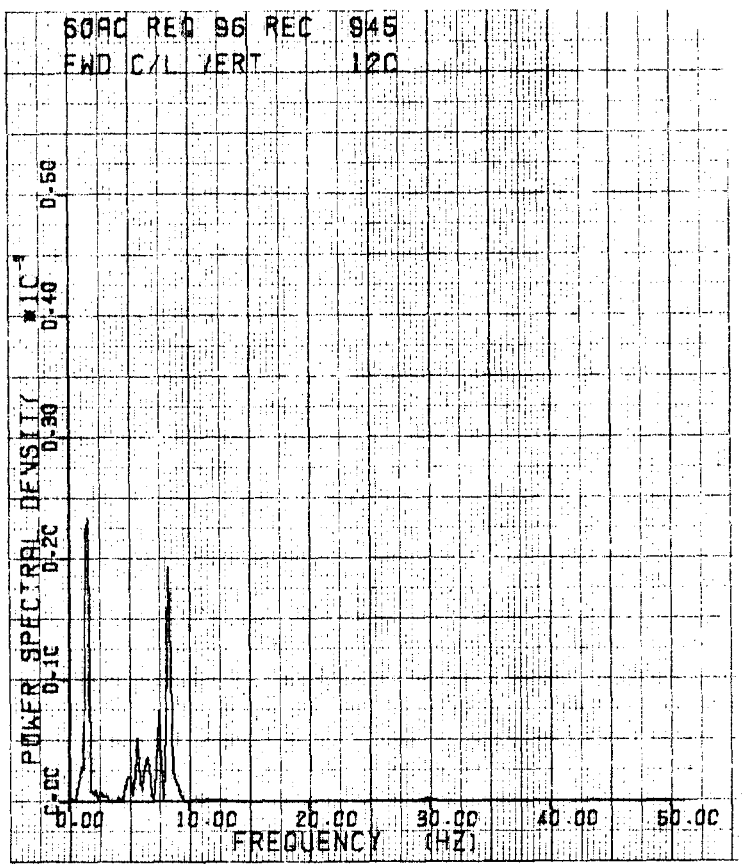




HIGH DENSITY CAR
90 KLB 3/29/74
35 MPH TRK SEC I

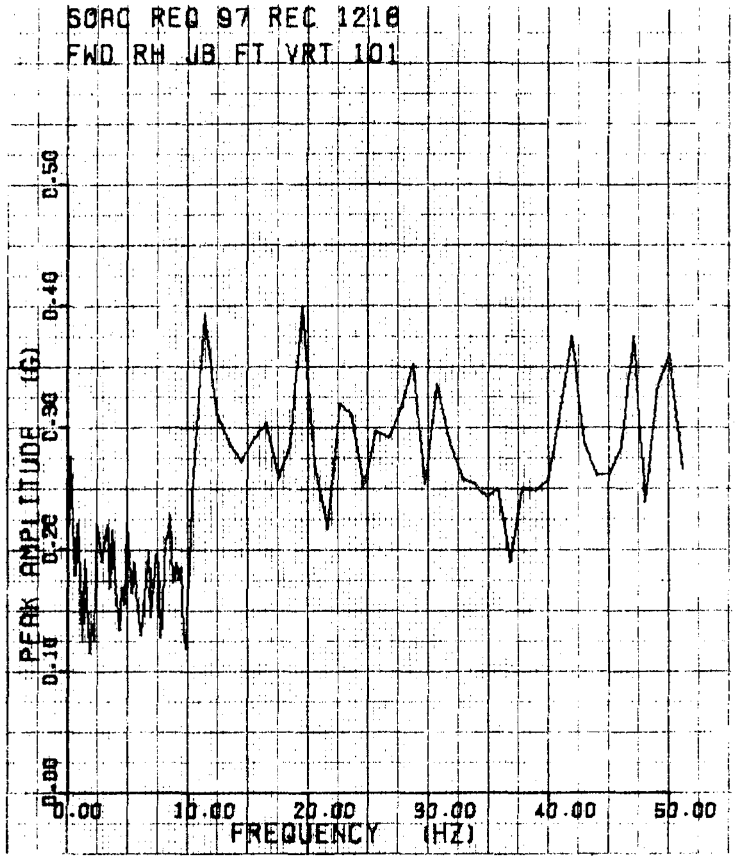
Figure B-23

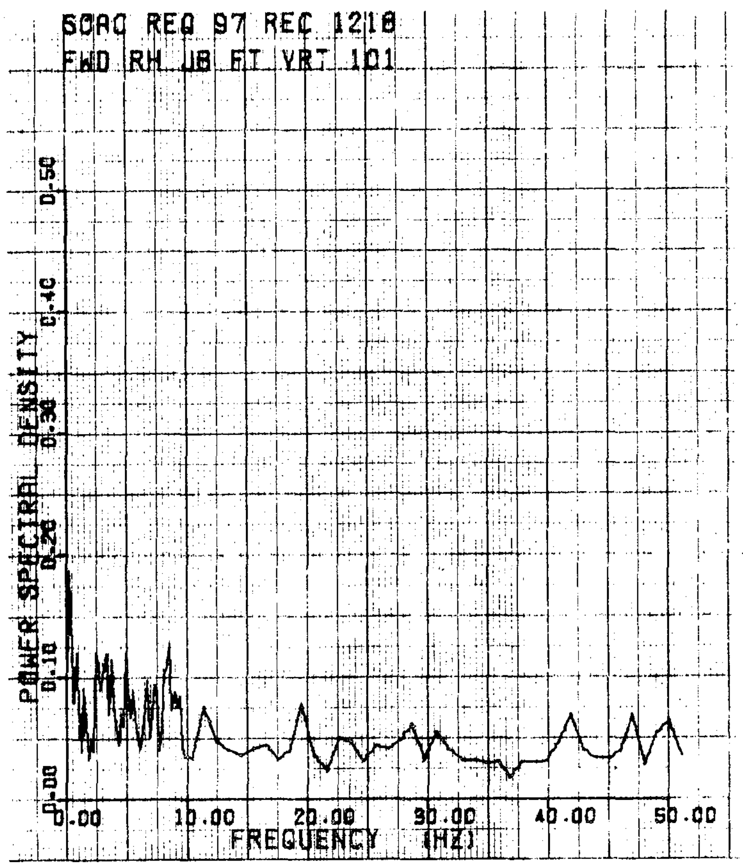




HIGH DENSITY CAR
90 KLB 3/29/74
35 MPH TRK SEC 1

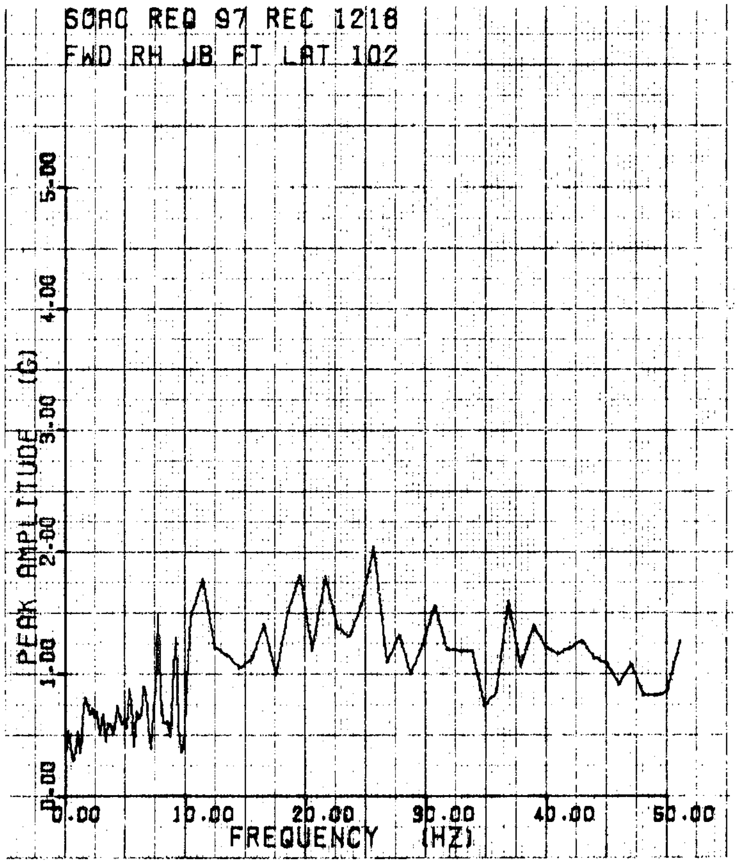
Figure B-24

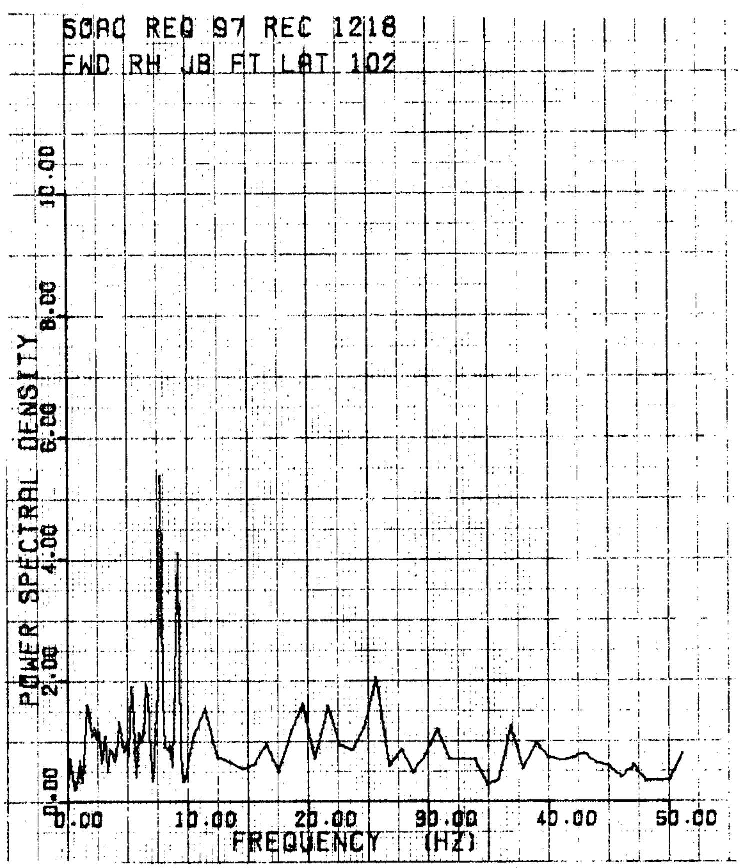




HIGH DENSITY CAR
90 KLB 3/29/74
43.2 MPH TRK SEC 1

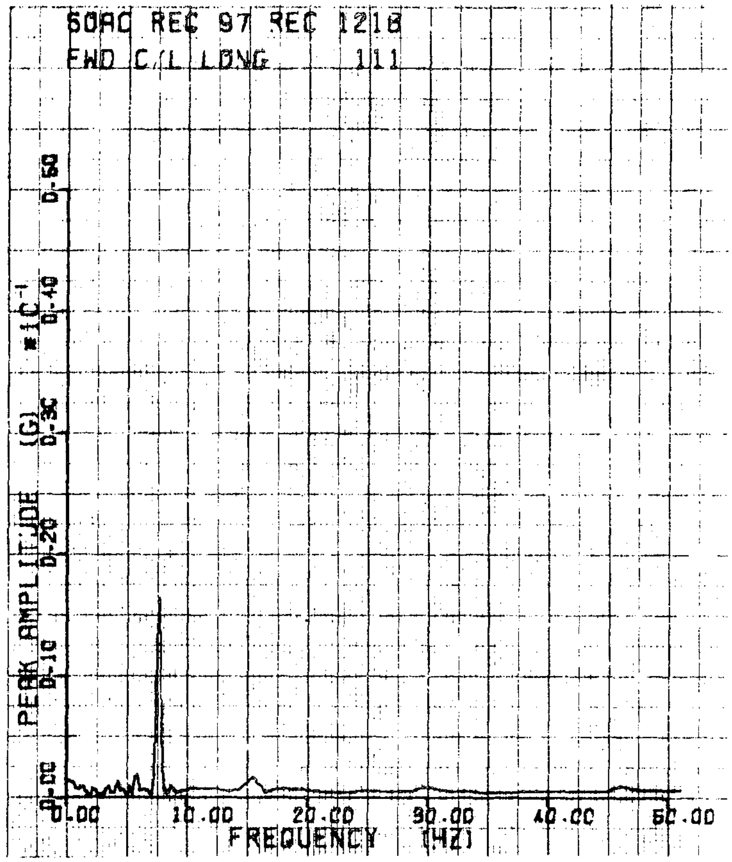
Figure B-25

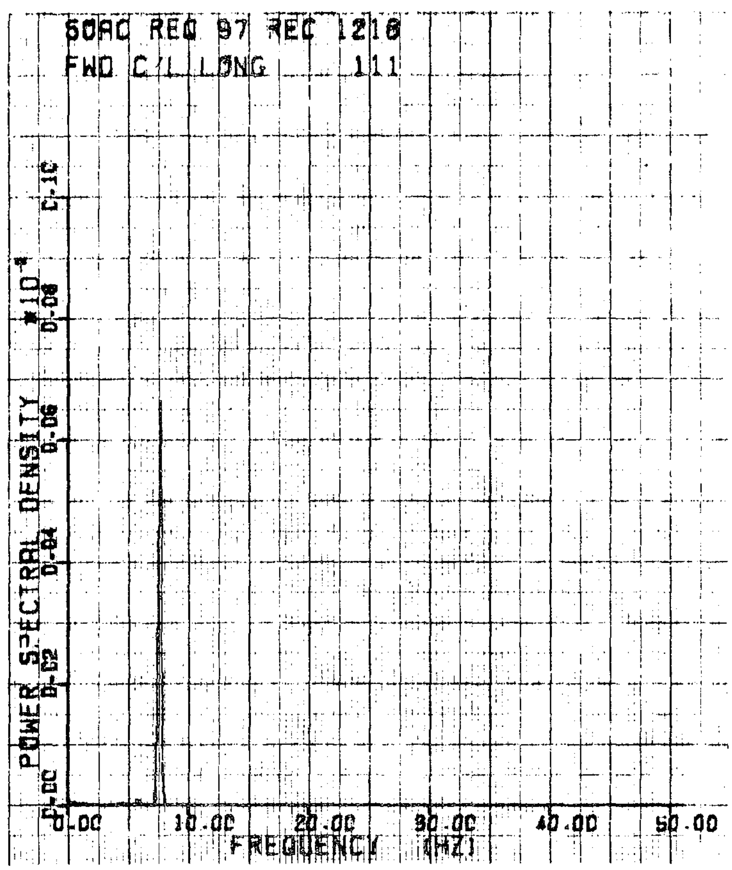




HIGH DENSITY CAR
90 KLB 3/29/74
43.2 MPH TRK SEC I

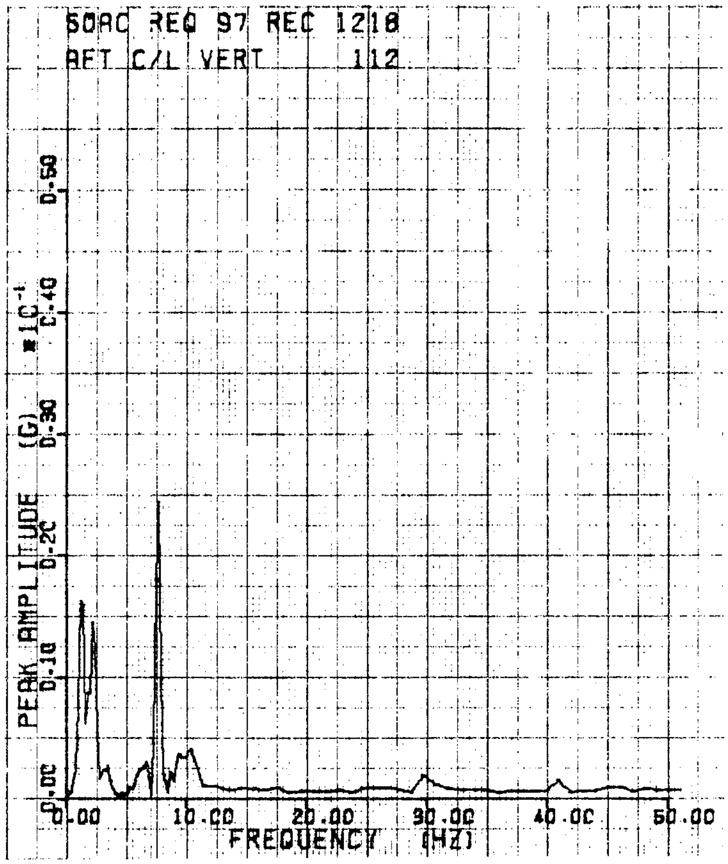
Figure B-26

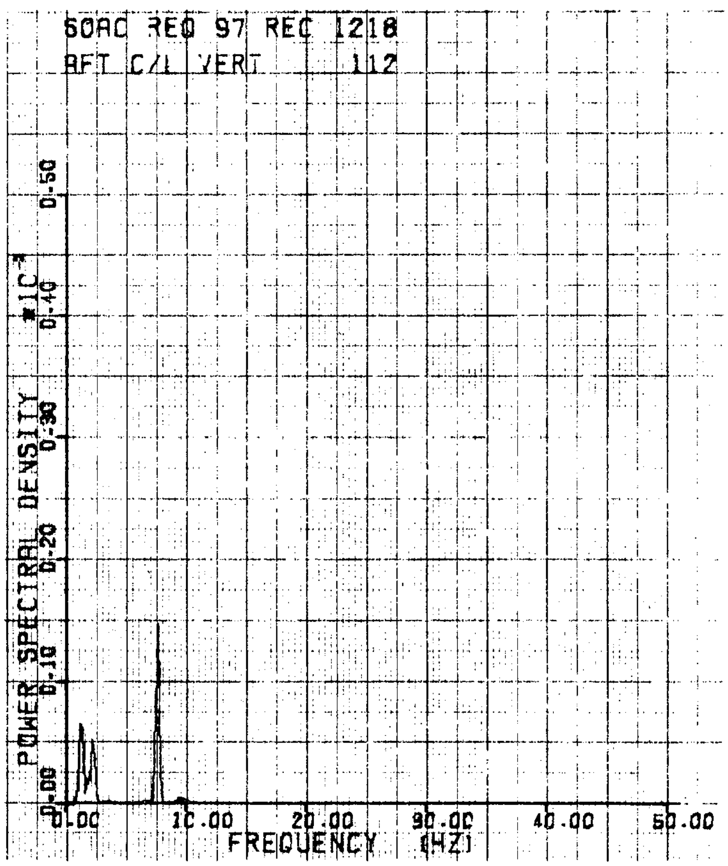




HIGH DENSITY CAR
90 KLB 3/29/74
43.2 MPH TRK SEC 1

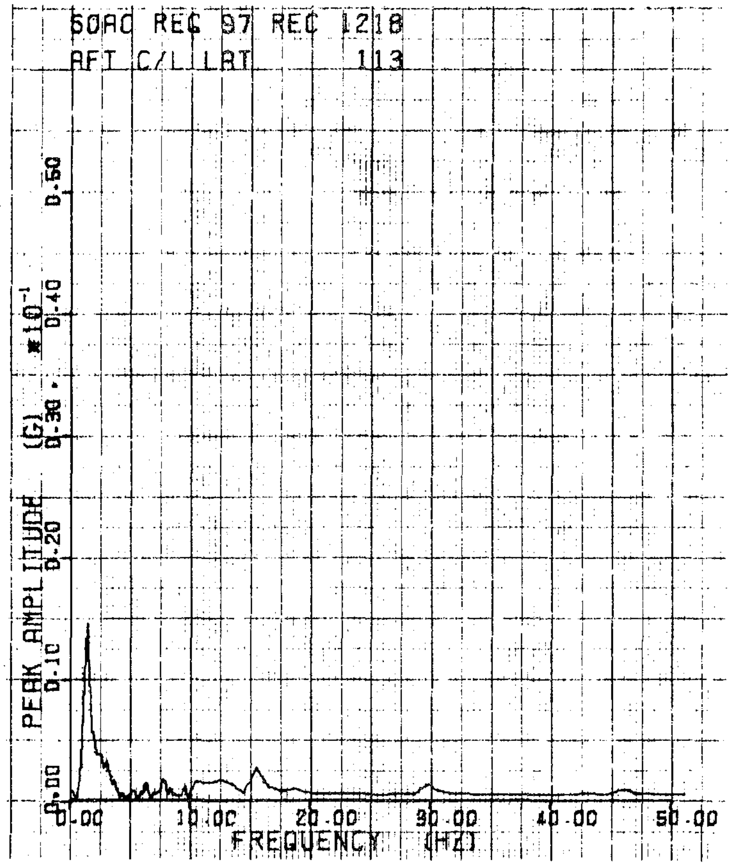
Figure B-27

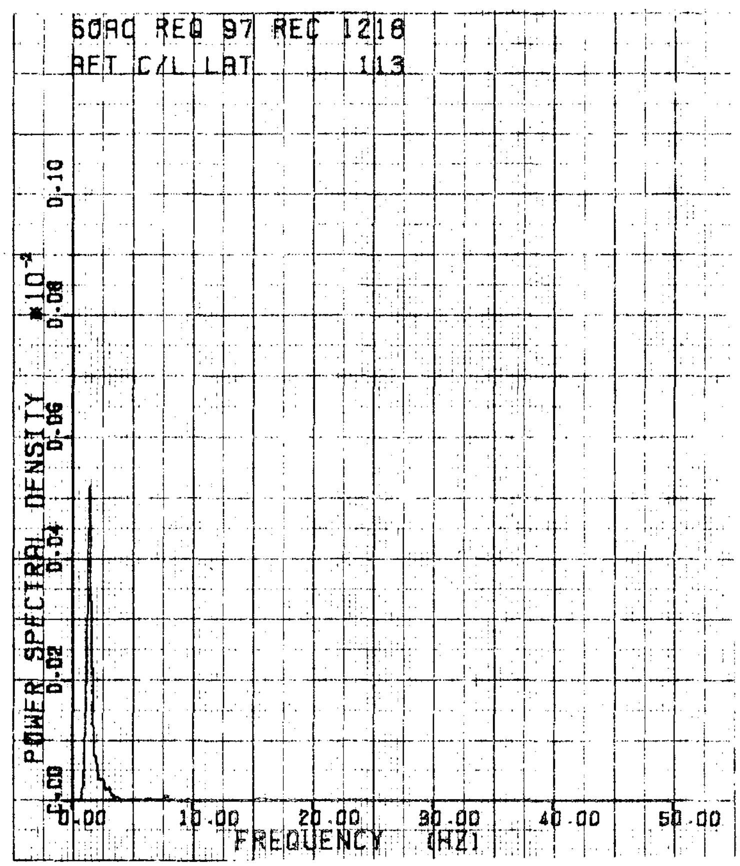




HIGH DENSITY CAR
90 KLB 3/29/74
43.2 MPH TRK SEC I

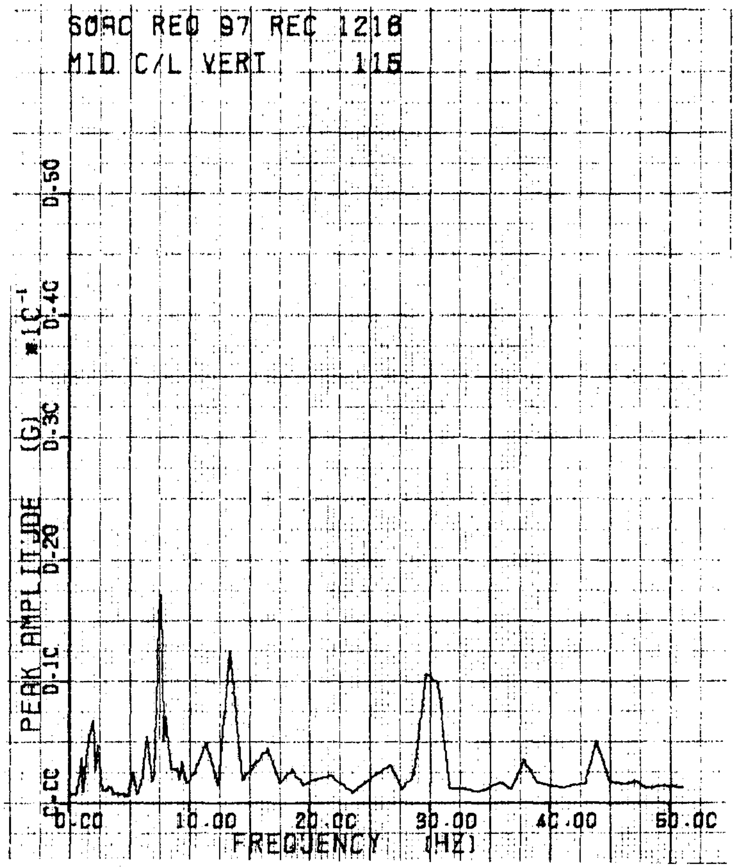
Figure B-28

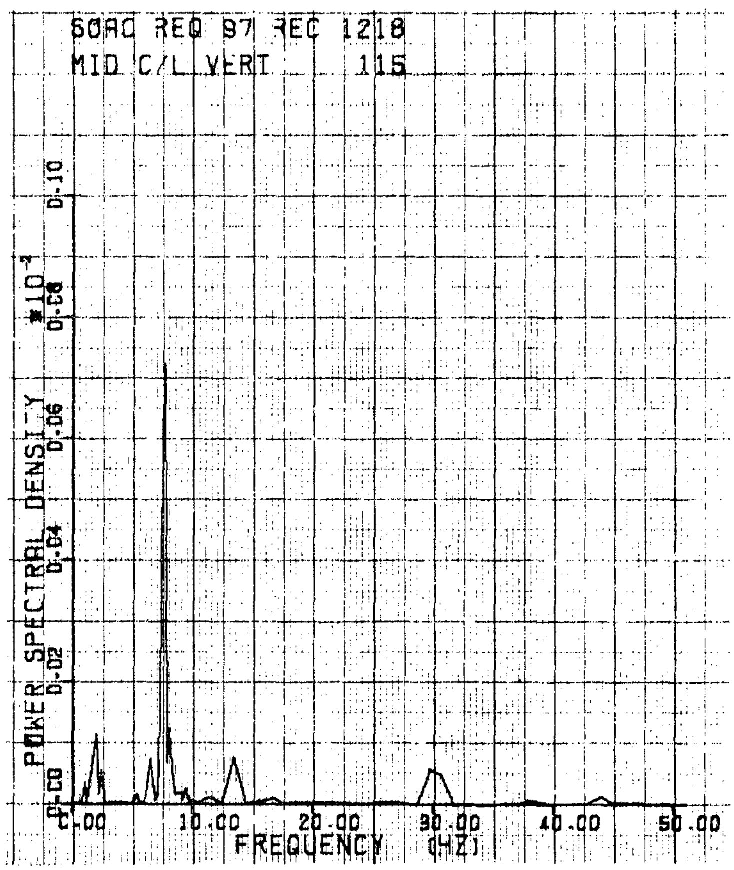




HIGH DENSITY CAR
90 KLB 3/29/74
43.2 MPH TRK SEC I

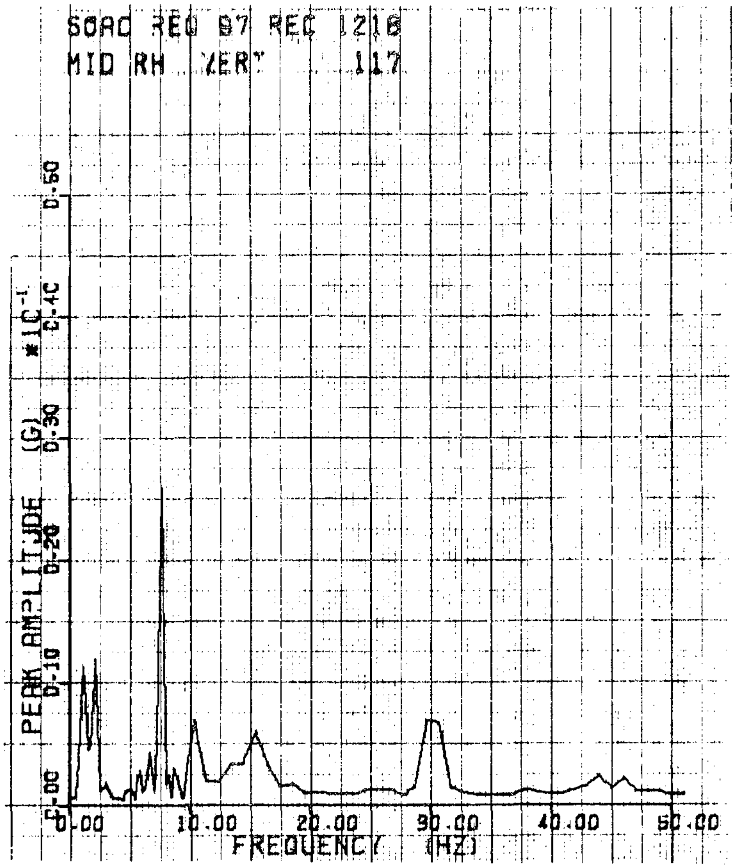
Figure B-29

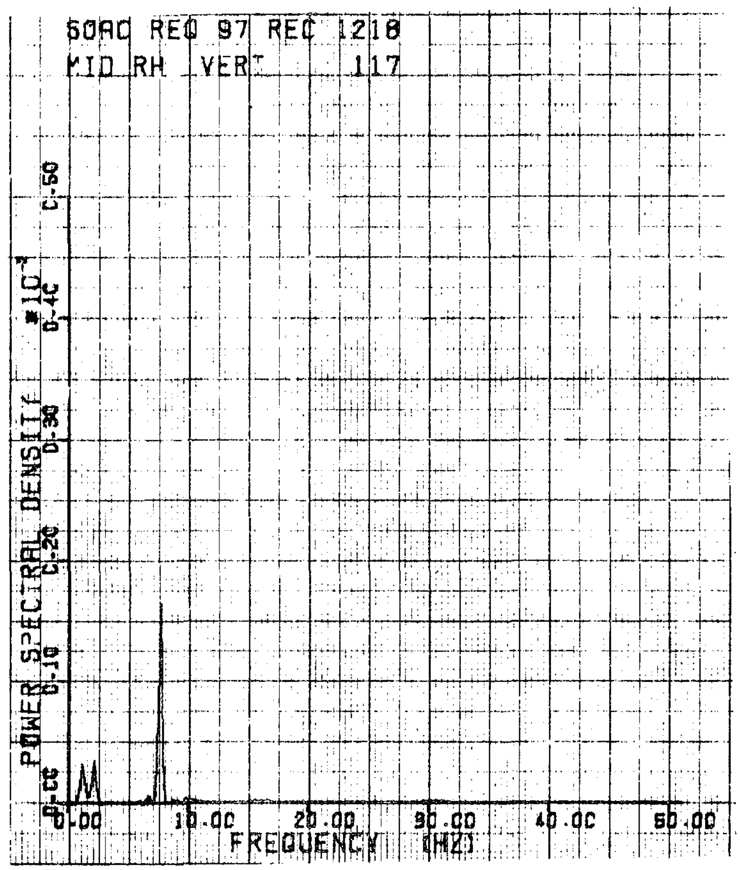




HIGH DENSITY CAR
90 KLB 3/29/74
43.2 MPH TRK SEC I

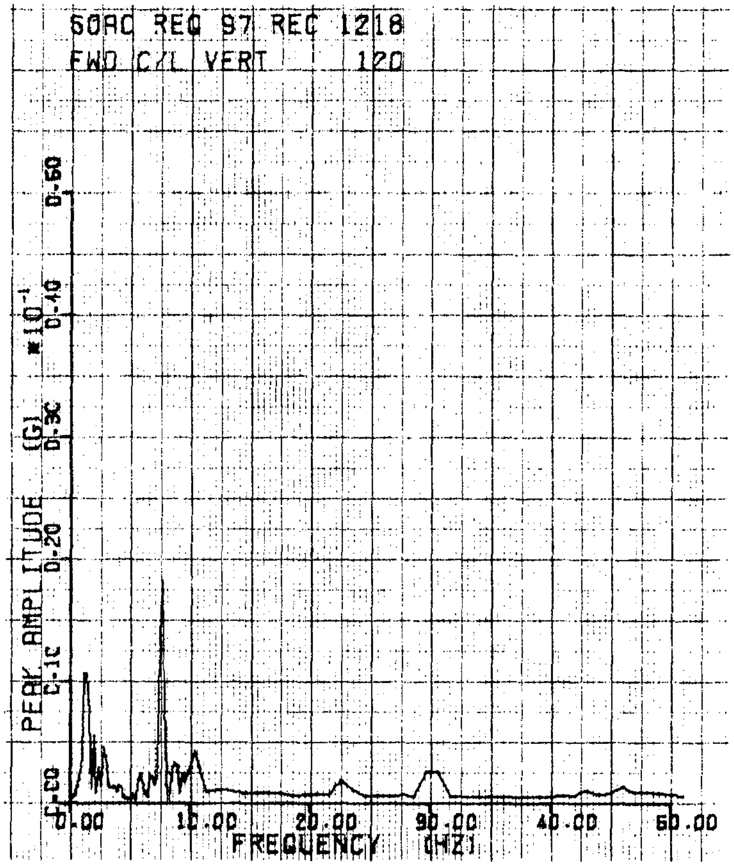
Figure B-30





HIGH DENSITY CAR
90 KLB 3/23/74
43.2 MPH TRK SEC I

Figure B-31


SOAC REQ 97 REC 1218
FWD C/L VERT 120
PEAK AMPLITUDE (G) *10⁻¹
0.00
0.10
0.20
0.30
0.40
0.50
0.00
10.00
20.00
30.00
40.00
50.00
FREQUENCY (HZ)

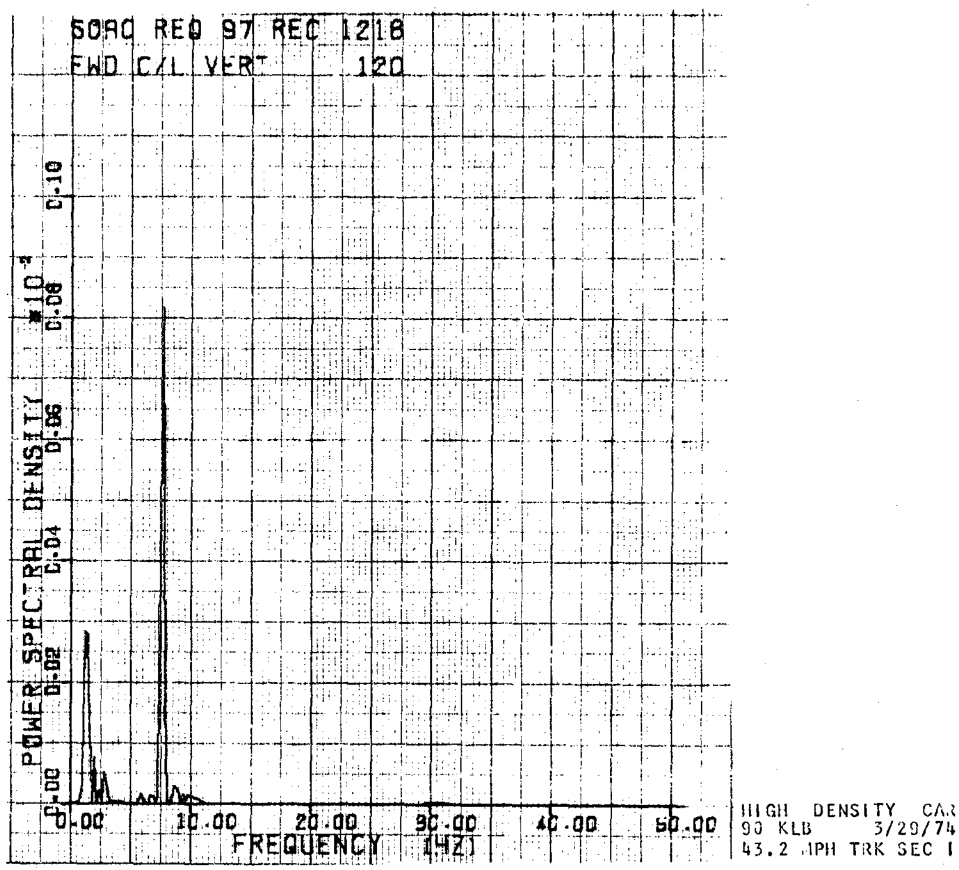
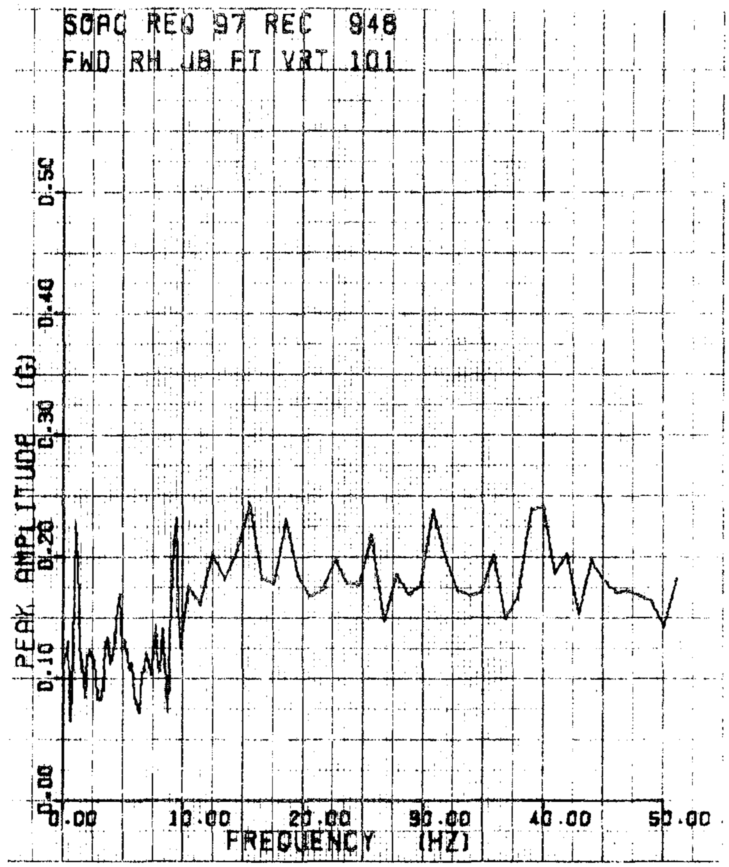
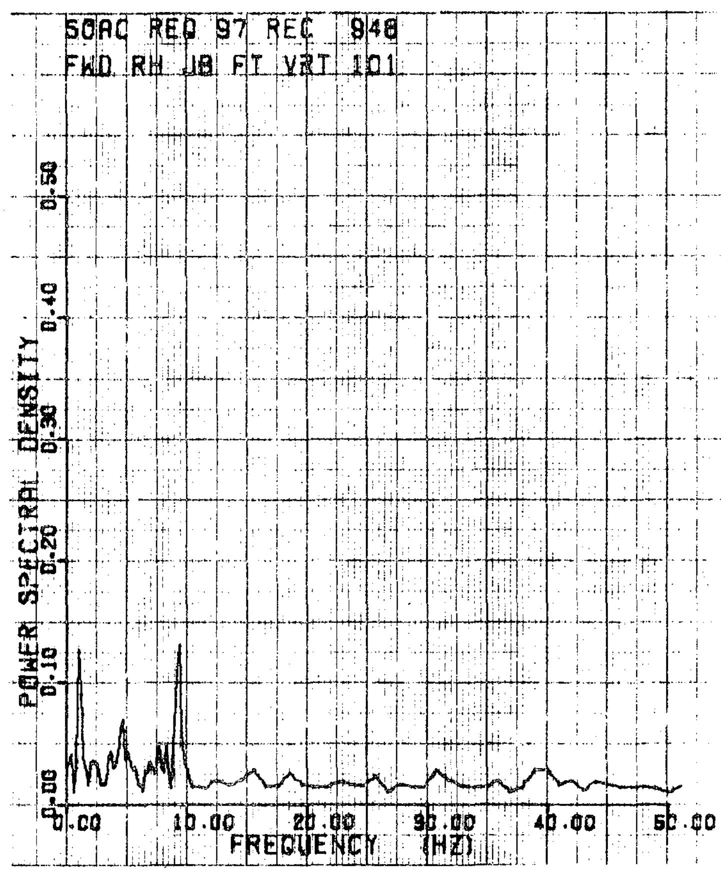

SOAC REQ 97 REC 1218
FWD C/L VERT 120
POWER SPECTRAL DENSITY *10⁻²
0.00
0.02
0.04
0.06
0.08
0.10
0.00
10.00
20.00
30.00
40.00
50.00
FREQUENCY (HZ)
HIGH DENSITY CAR
90 KLB 3/29/74
43.2 MPH TRK SEC I

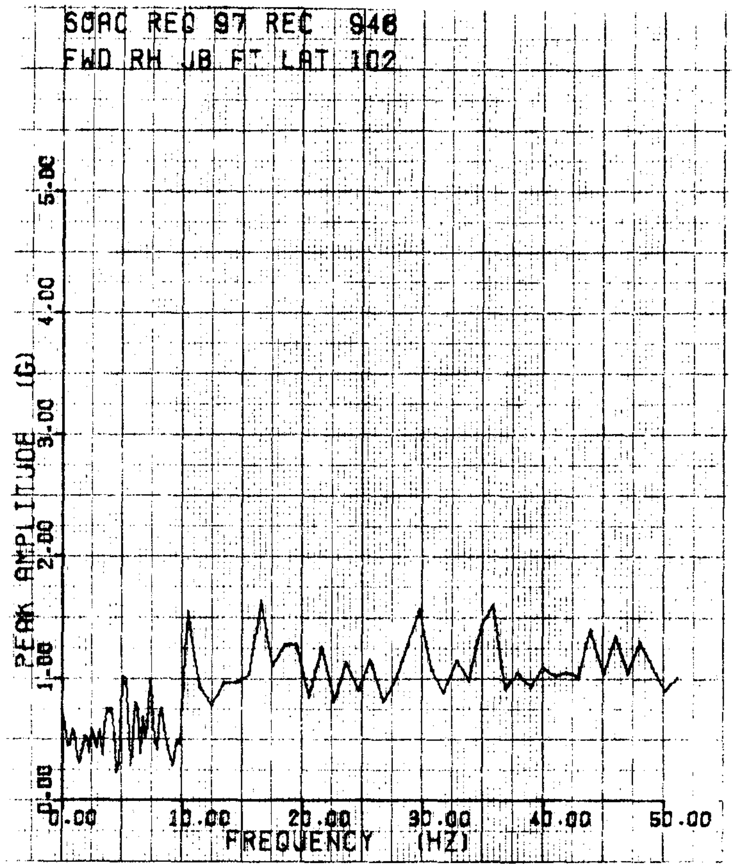
Figure B-32

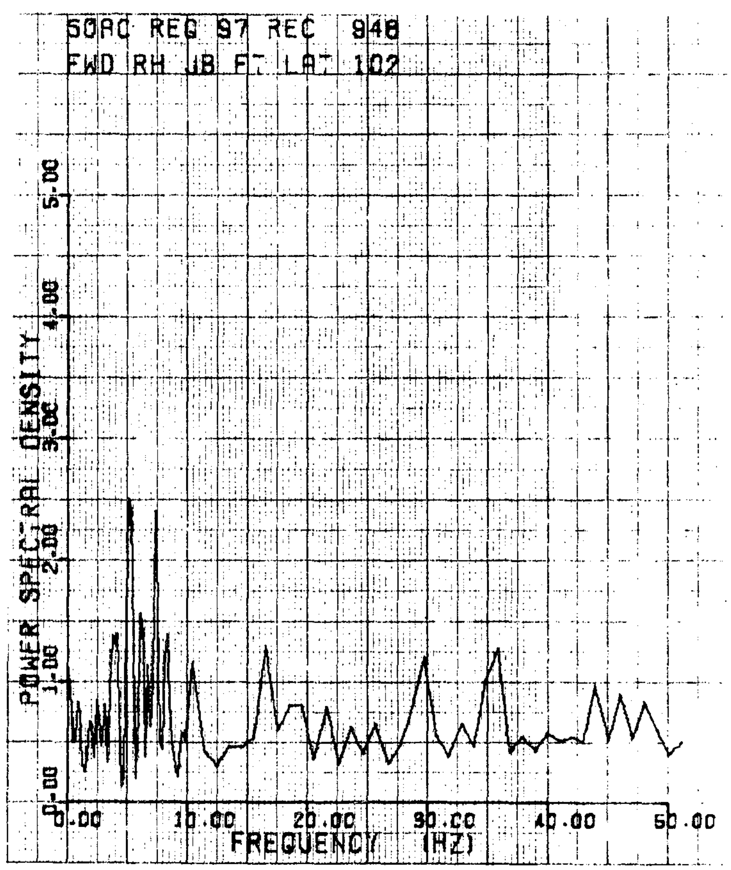




HIGH DENSITY CAR
90 KLB 3/29/74
45 MPH TRK SEC I

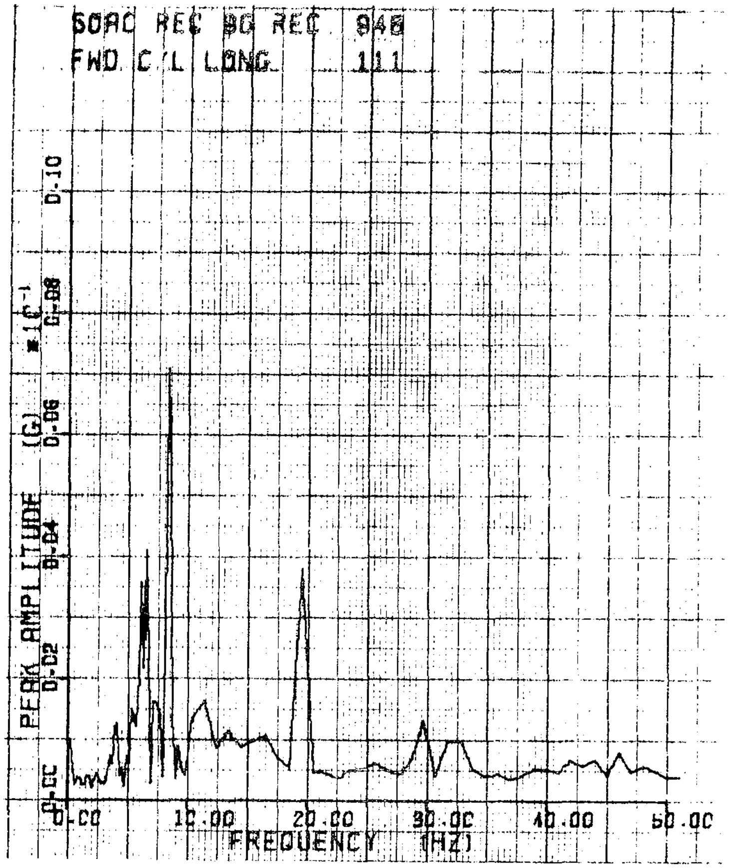
Figure B-33

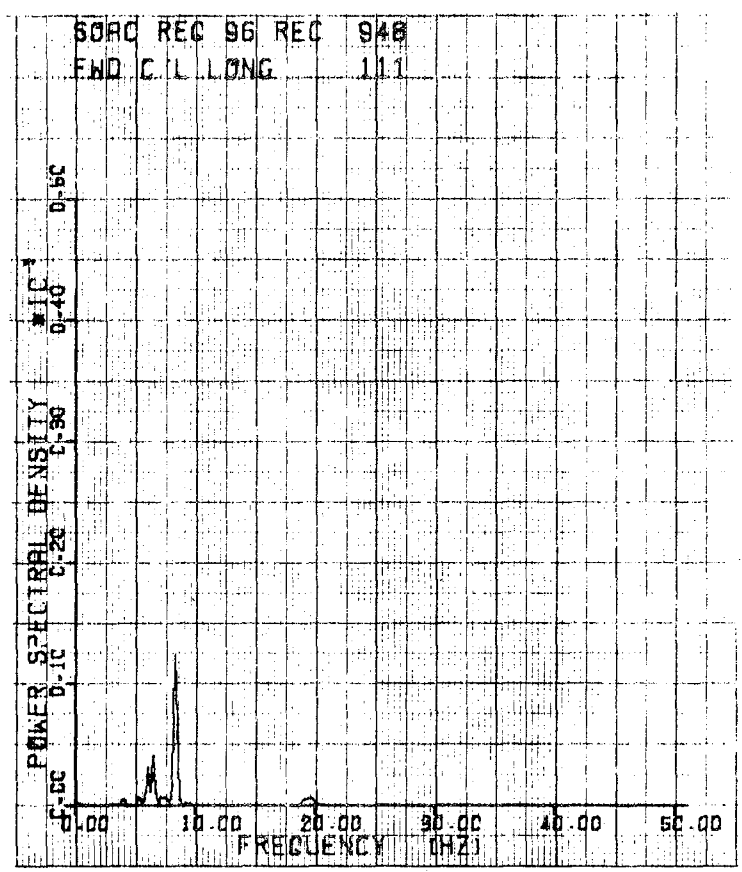




HIGH DENSITY CAR
90 KLB 3/29/74
45 MPH TRK SEC I

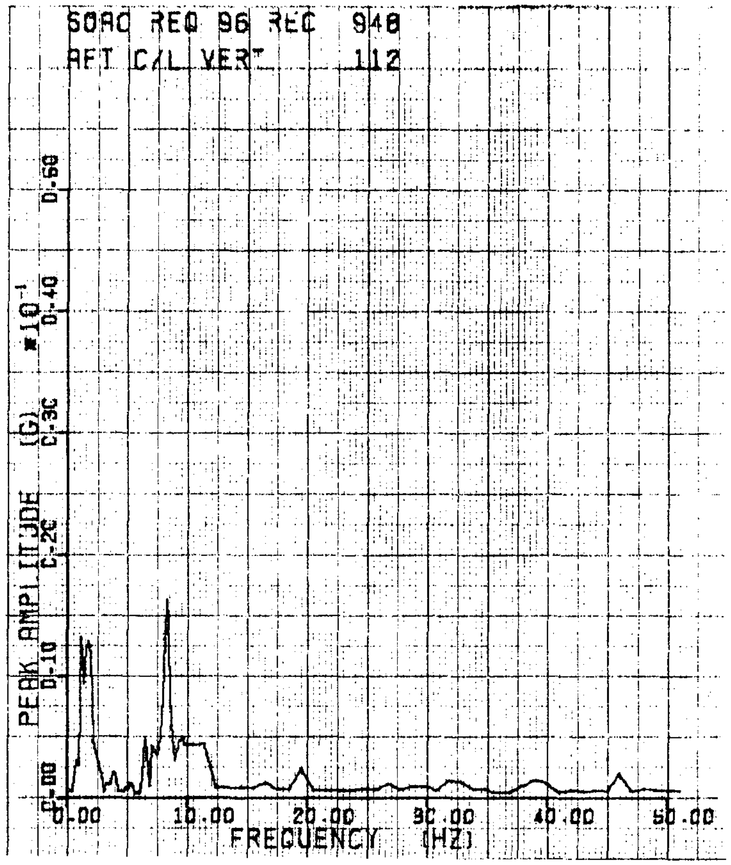
Figure B-34

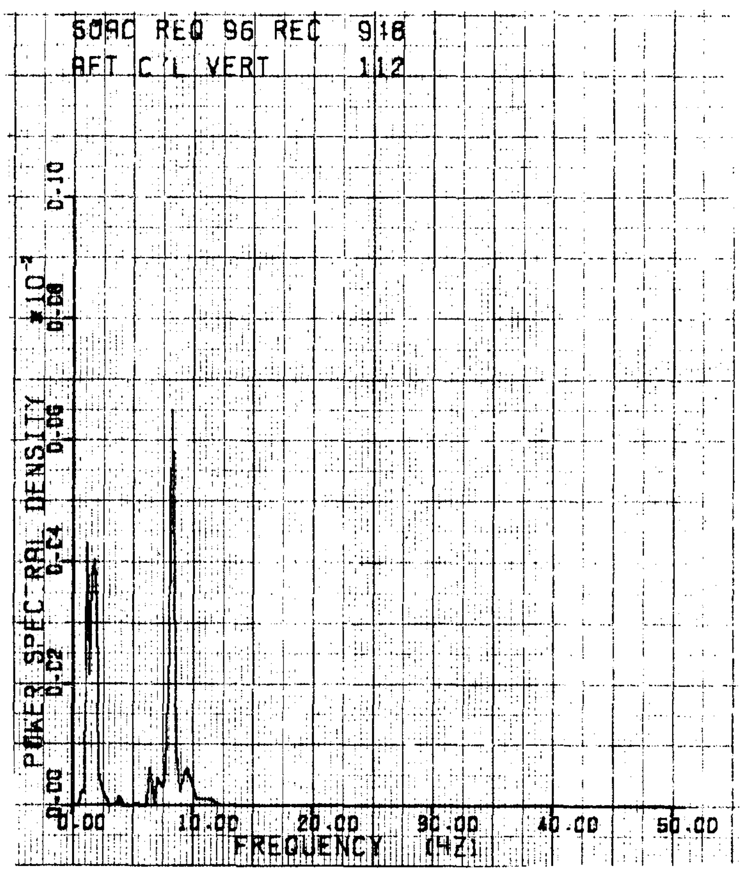




HIGH DENSITY CAR
30 KLB 3/29/74
45 MPH TRK SEC I

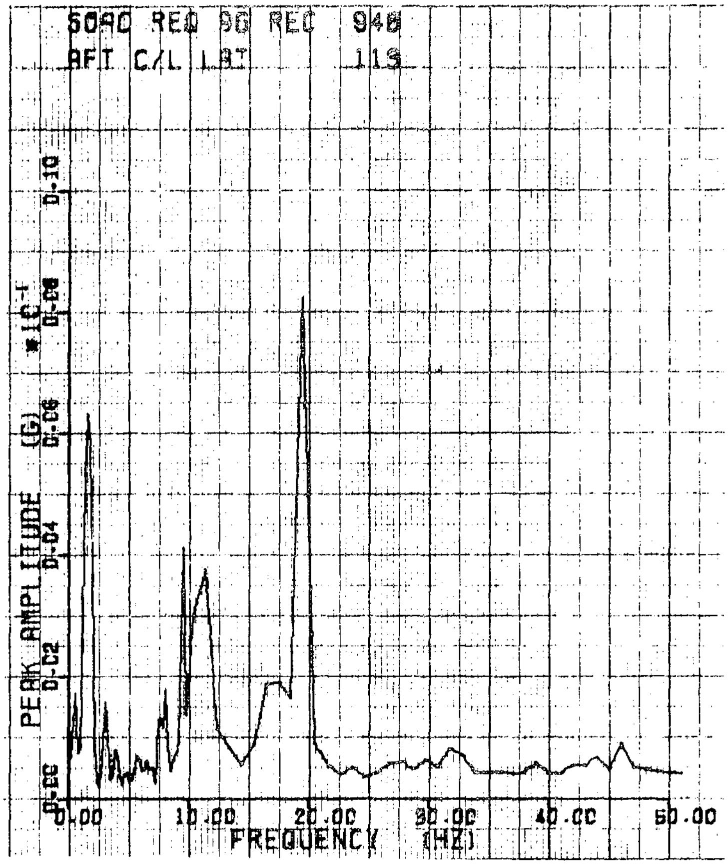
Figure B-35

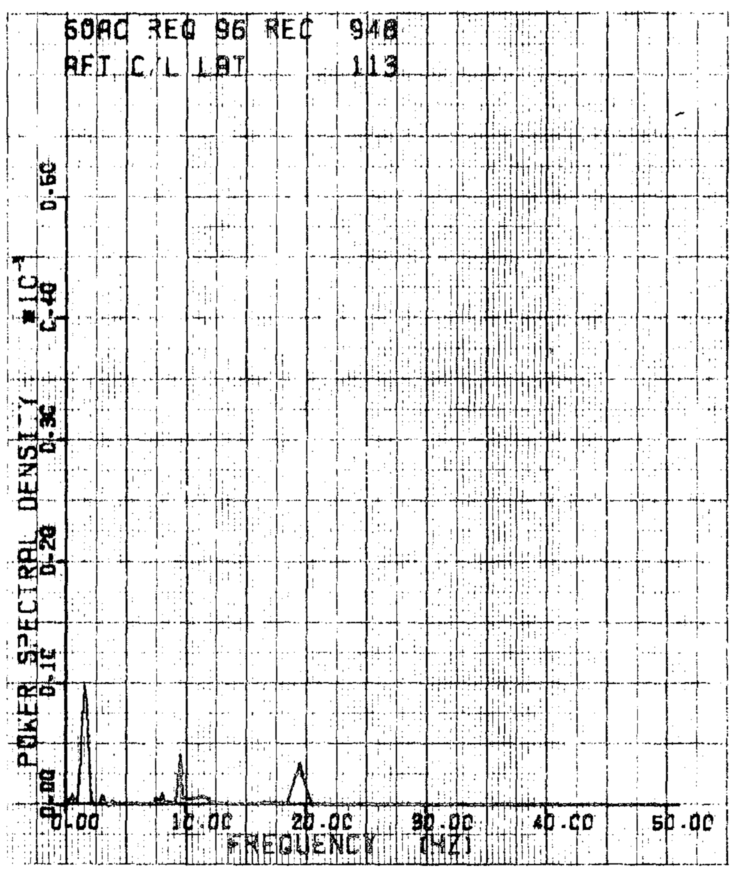




HIGH DENSITY CAR
90 KLB 5/29/74
45 MPH TRK SEC I

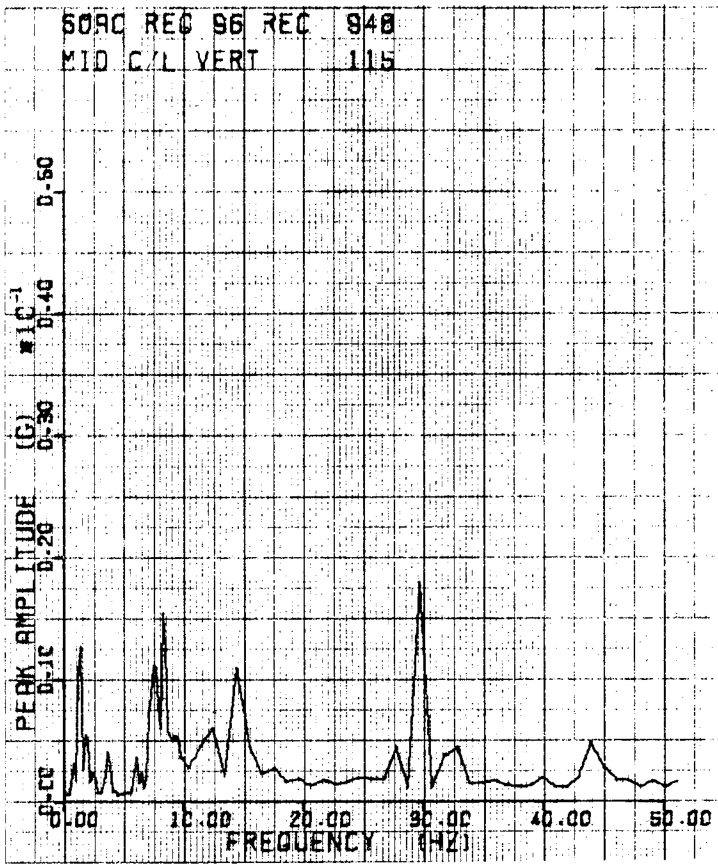
Figure B-36

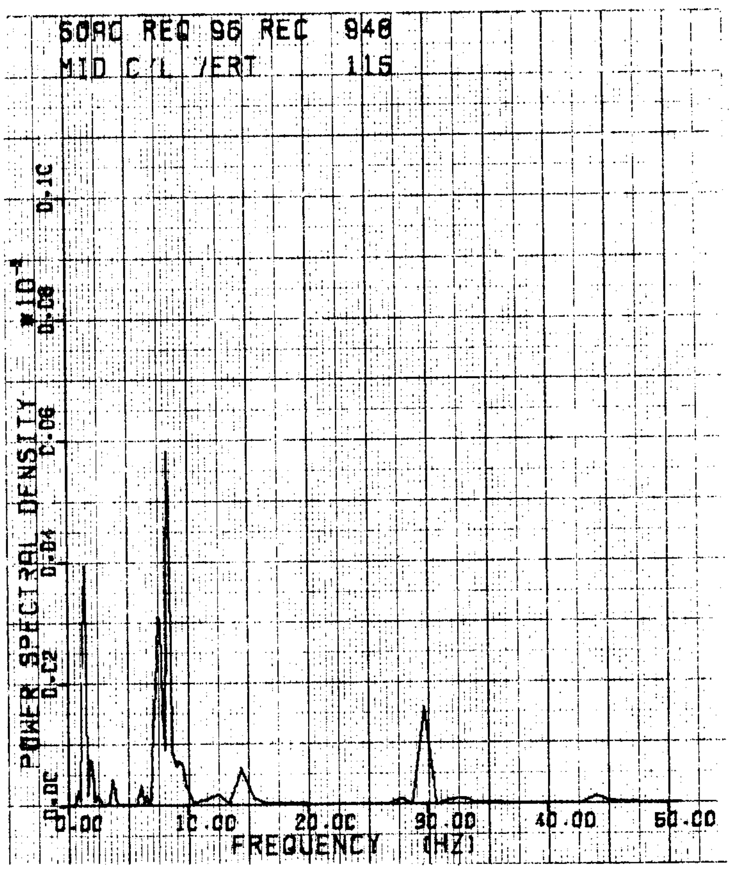




HIGH DENSITY CAR
90 KLB 5/29/74
45 MPH TRK SEC I

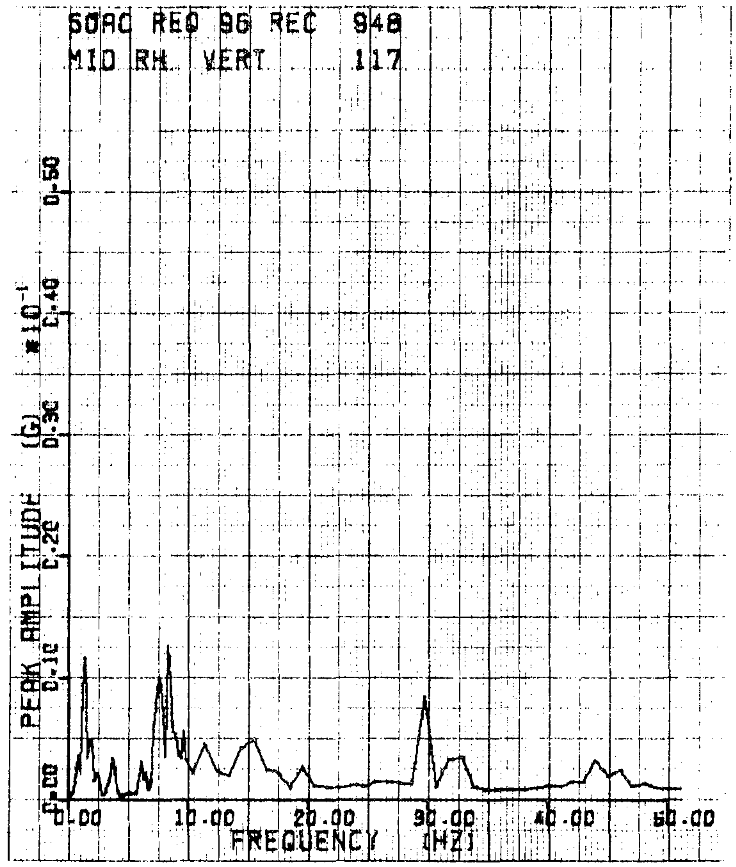
Figure B-37

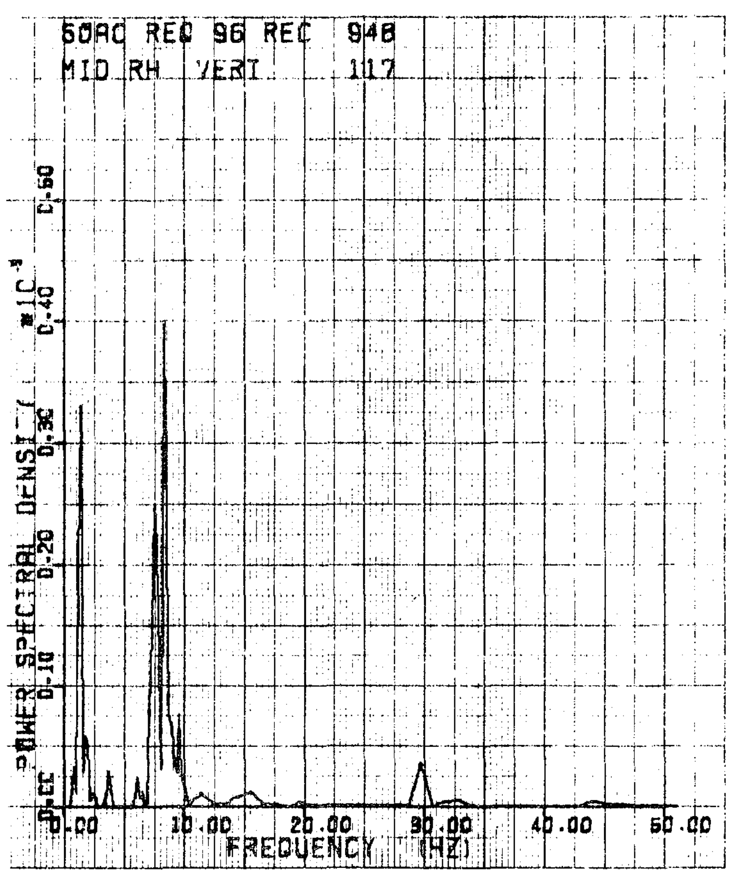




HIGH DENSITY CA!
90 KLB 3/20/74
45 MPH TRK SEC I

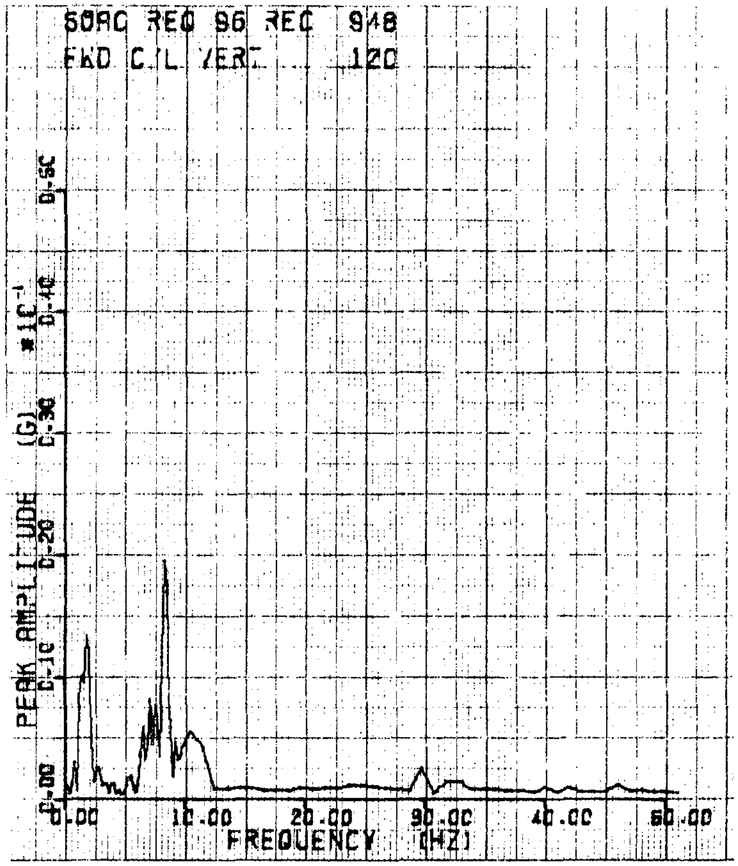
Figure B-38

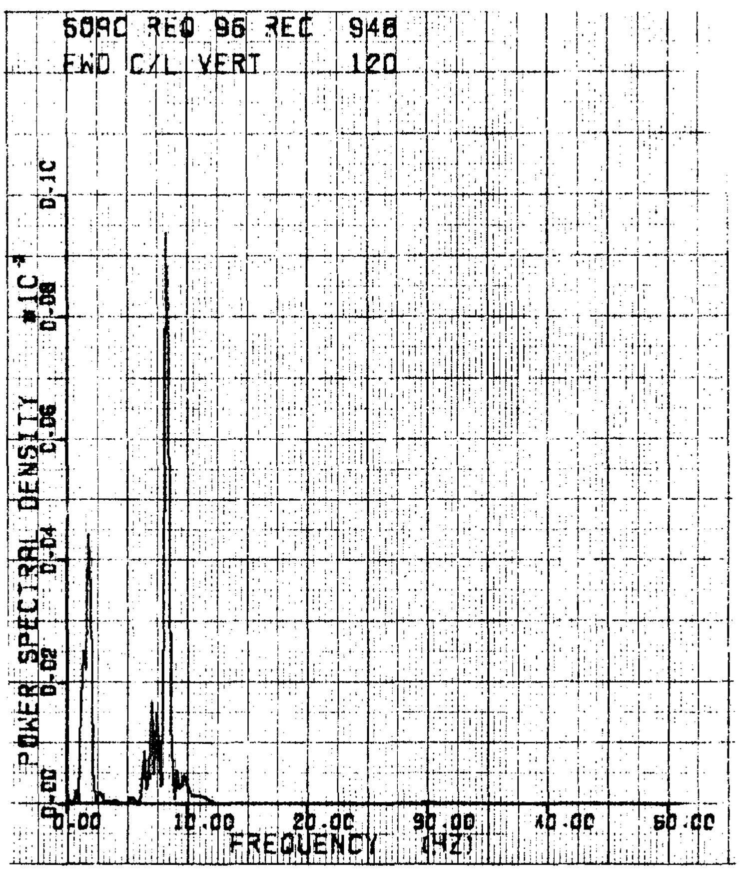




HIGH DENSITY CAR
90 KLB 3/29/74
45 MPH TRK SEC I

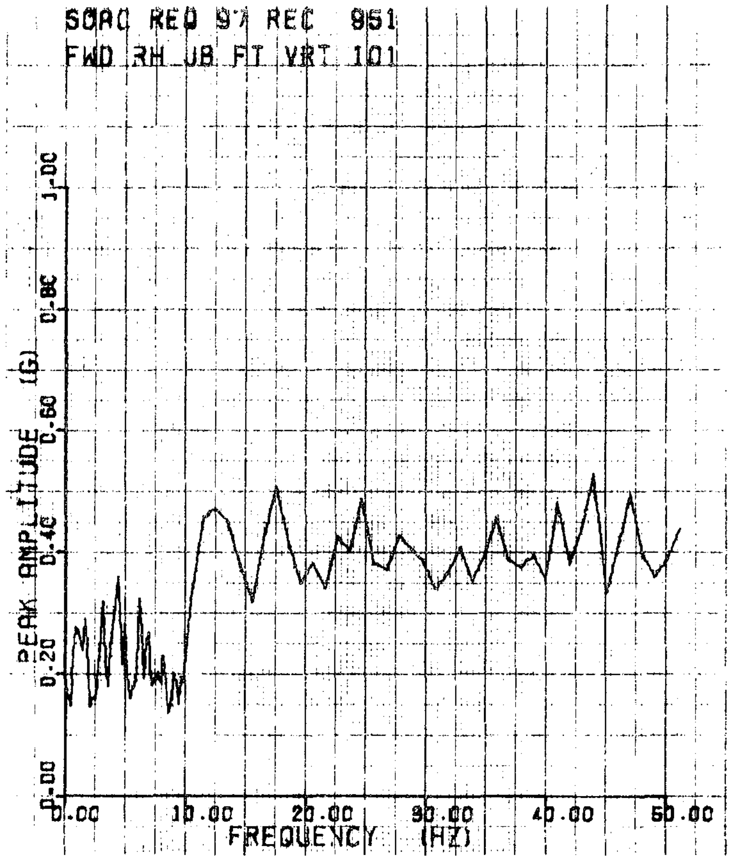
Figure B-39

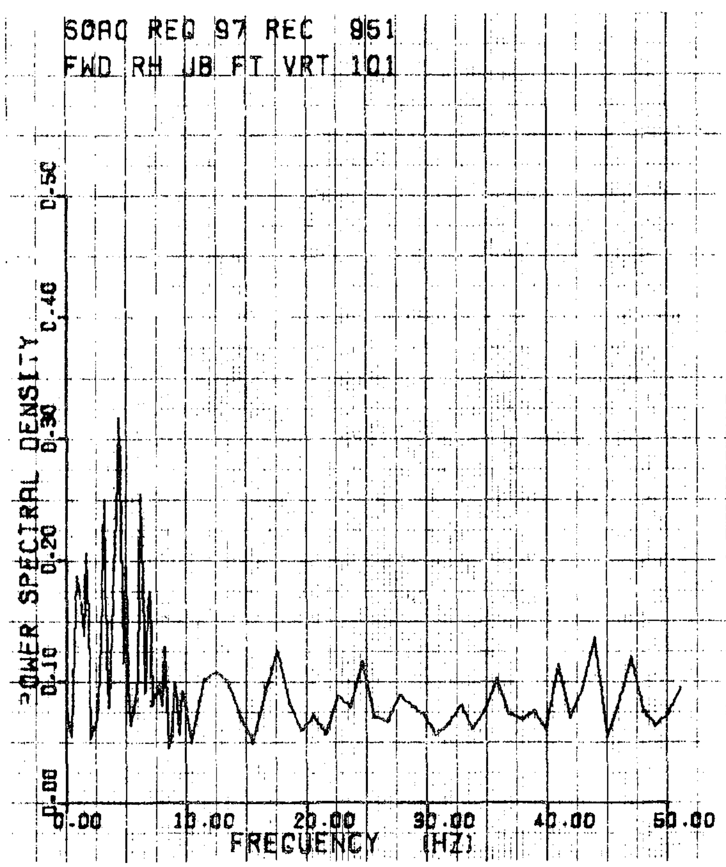




HIGH DENSITY CAR
90 KLB 3/20/74
45 MPH TRK SEC I

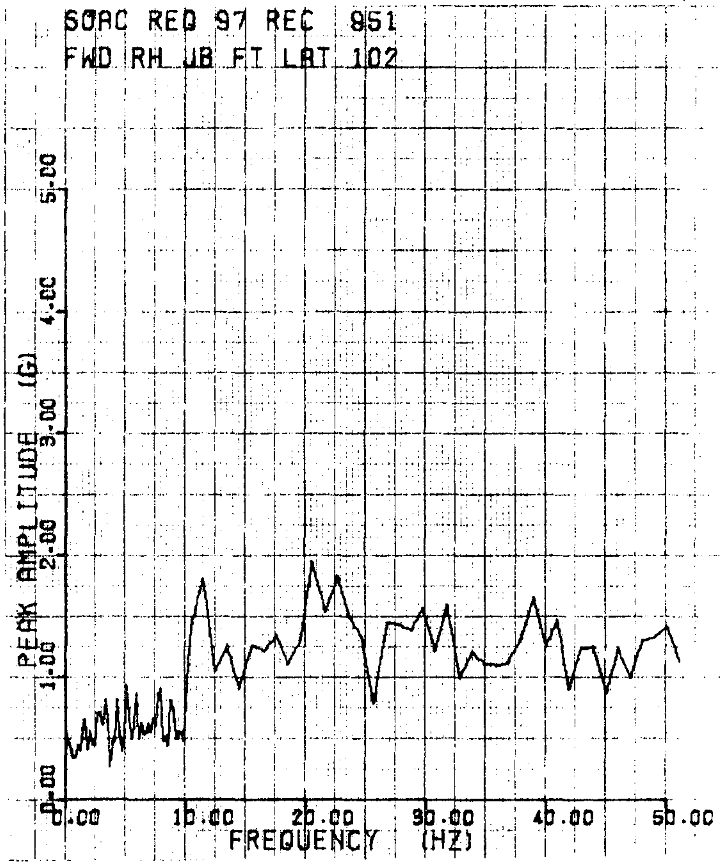
Figure B-40

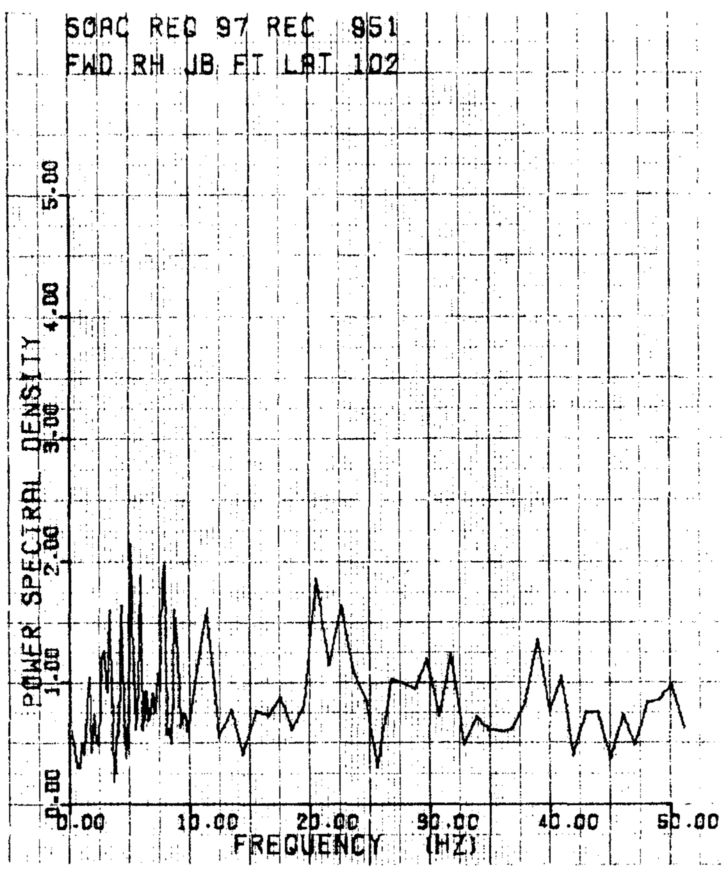




HIGH DENSITY CA
30 KLB 3/29/74
55 MPH TRK SEC I

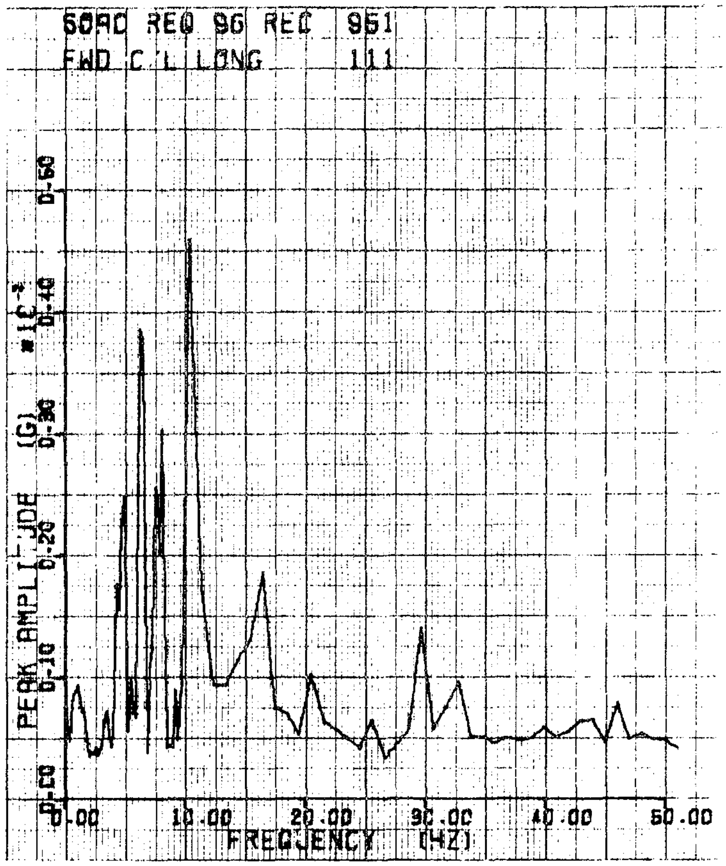
Figure B-41

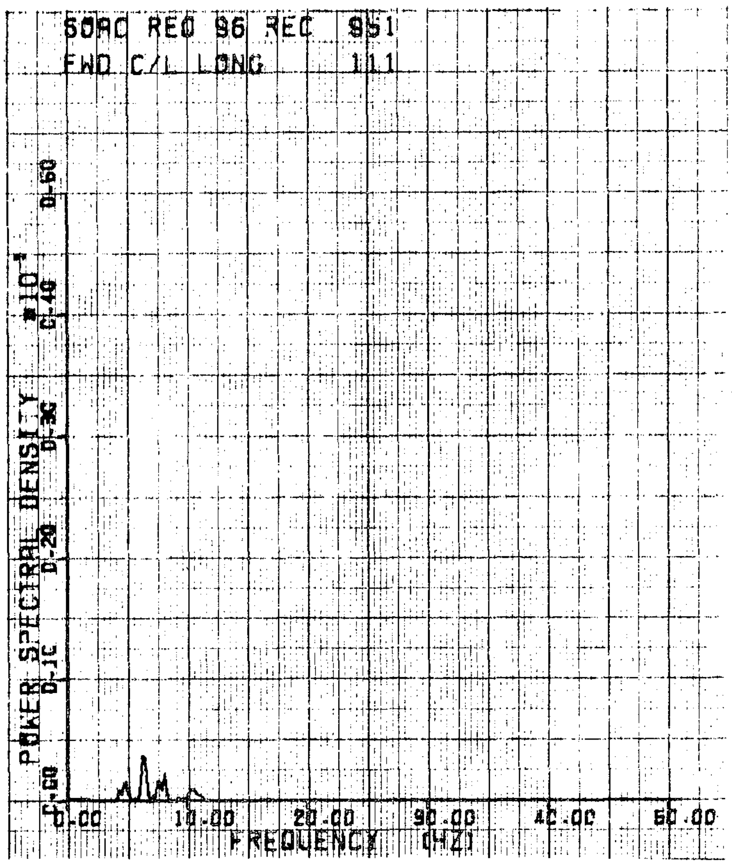




HIGH DENSITY CAR
90 KLB 3/29/74
55 MPH TRK SEC I

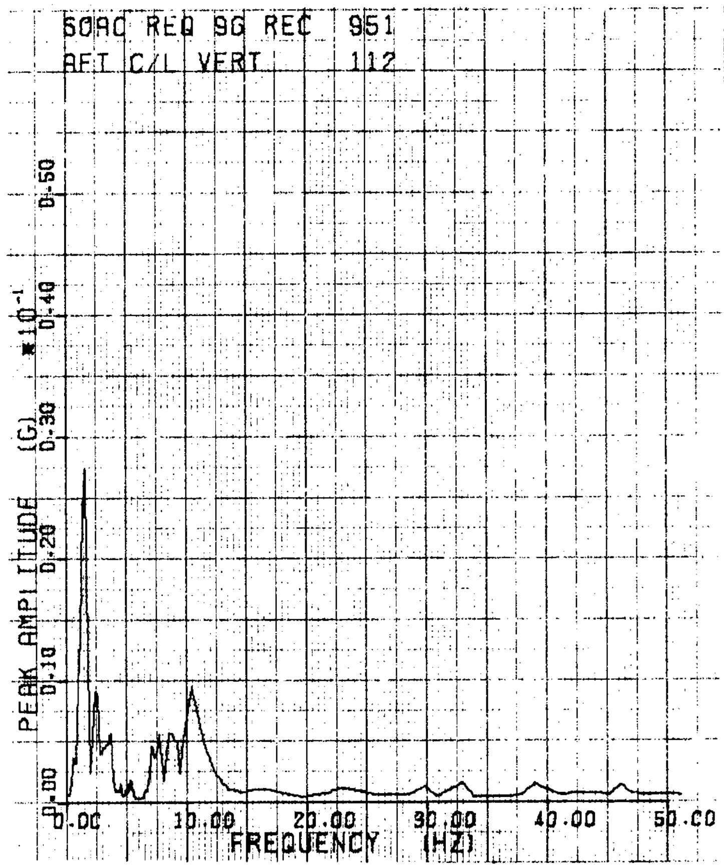
Figure B-42

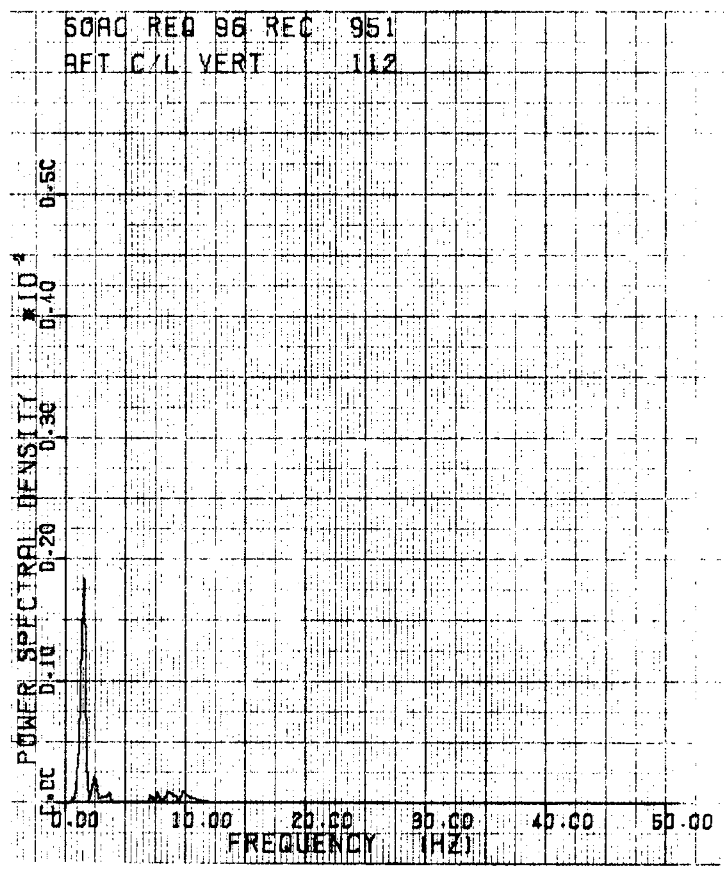




HIGH DENSITY CAR
90 KLB 3/29/74
55 MPH TRK SEC I

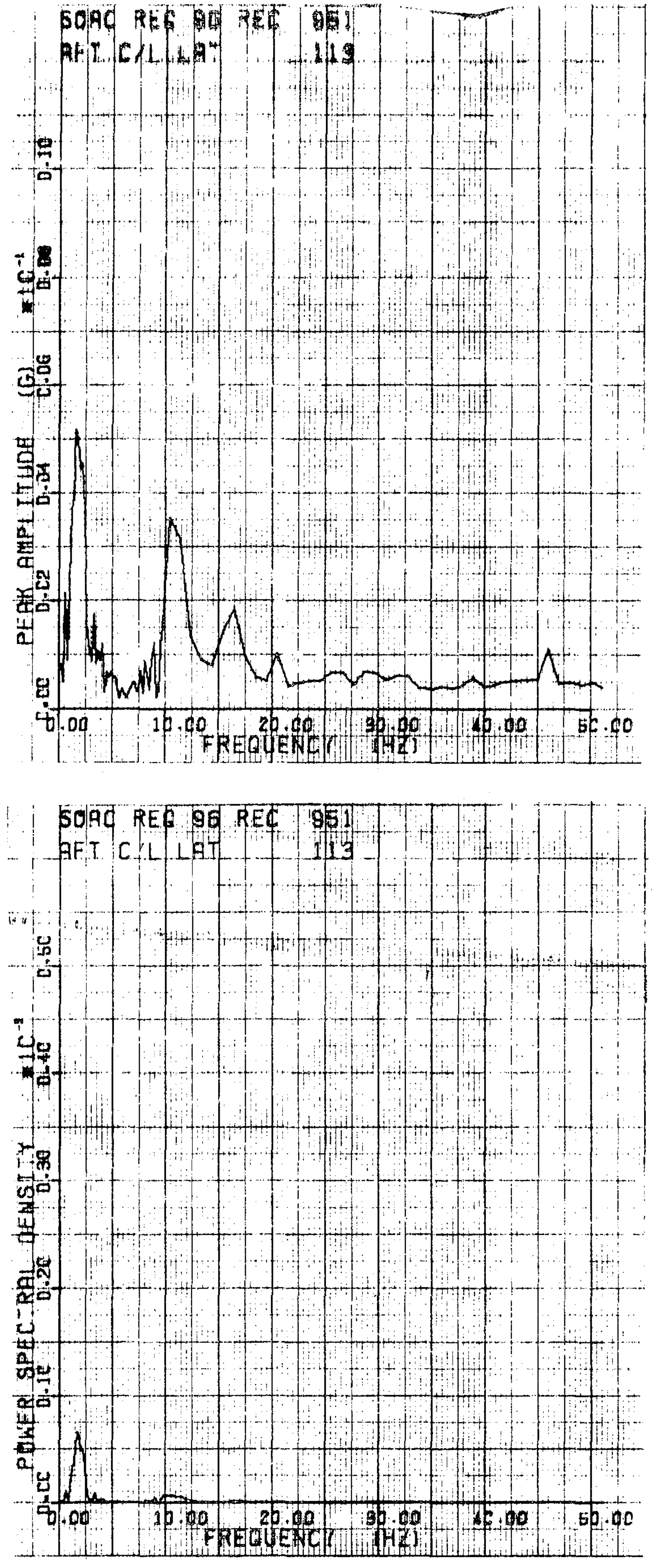
Figure B-43





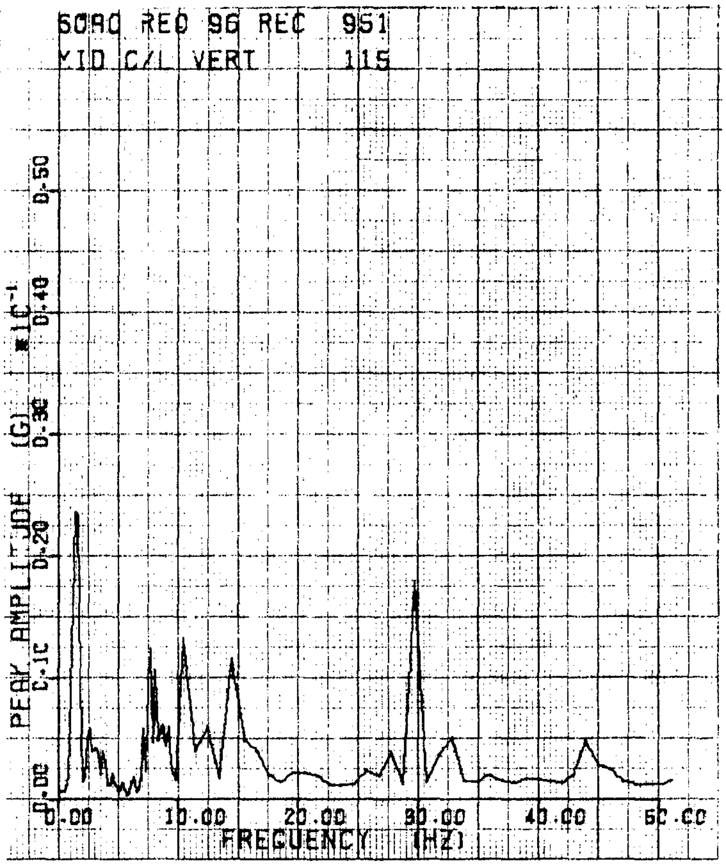
HIGH DENSITY CA
90 KLB 3/29/74
55 MPH TRK SEC I

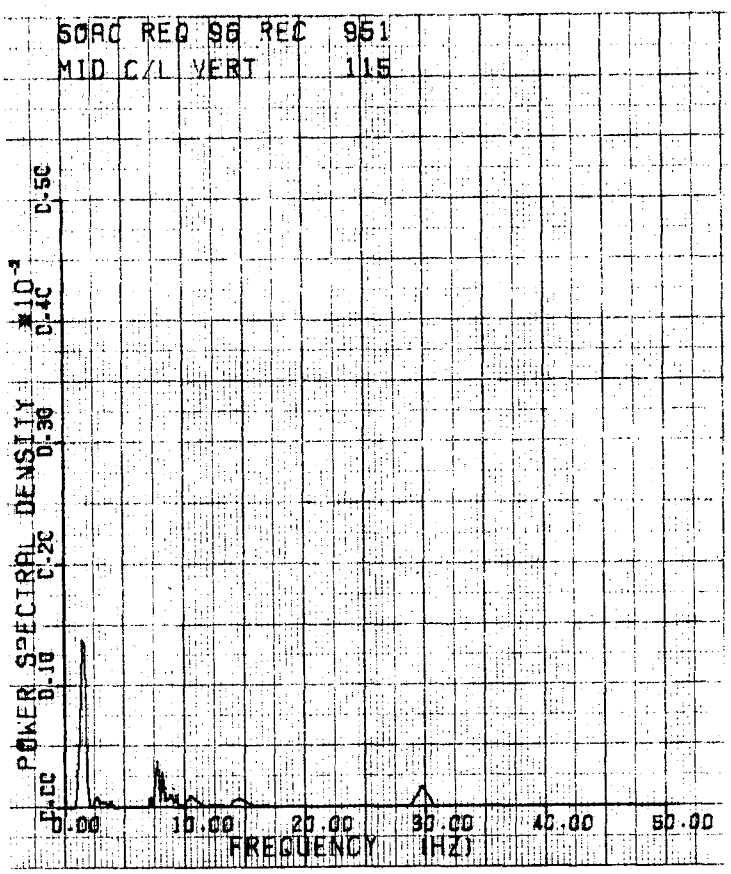
Figure B-44



HIGH DENSITY CAR
90 KLB 3/29/74
55 MPH TRK SEC I

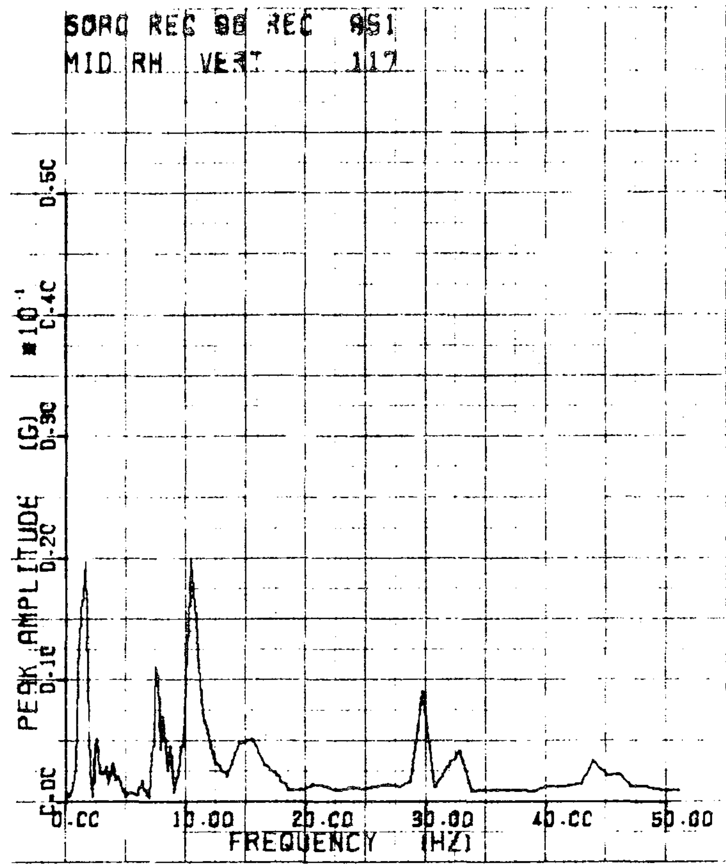
Figure B-45





HIGH DENSITY CAR
90 KLB 3/20/74
55 MPH TRK SEC I

Figure B-46


5090 REC 96 REC 951
MID RH VERT 117
PEAK AMPLITUDE (G) *10⁻¹
FREQUENCY (HZ)

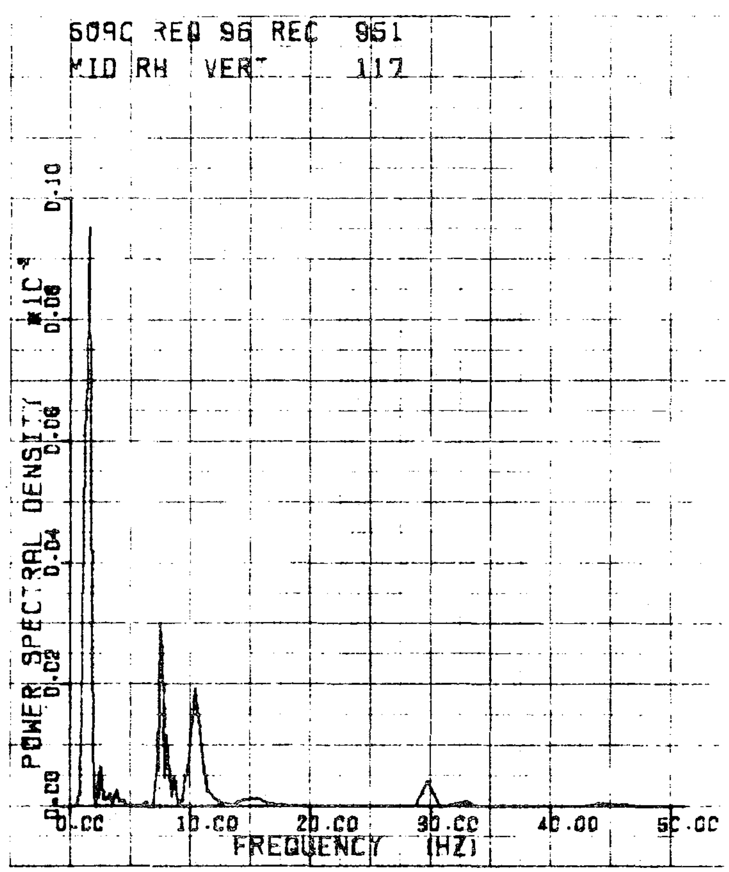
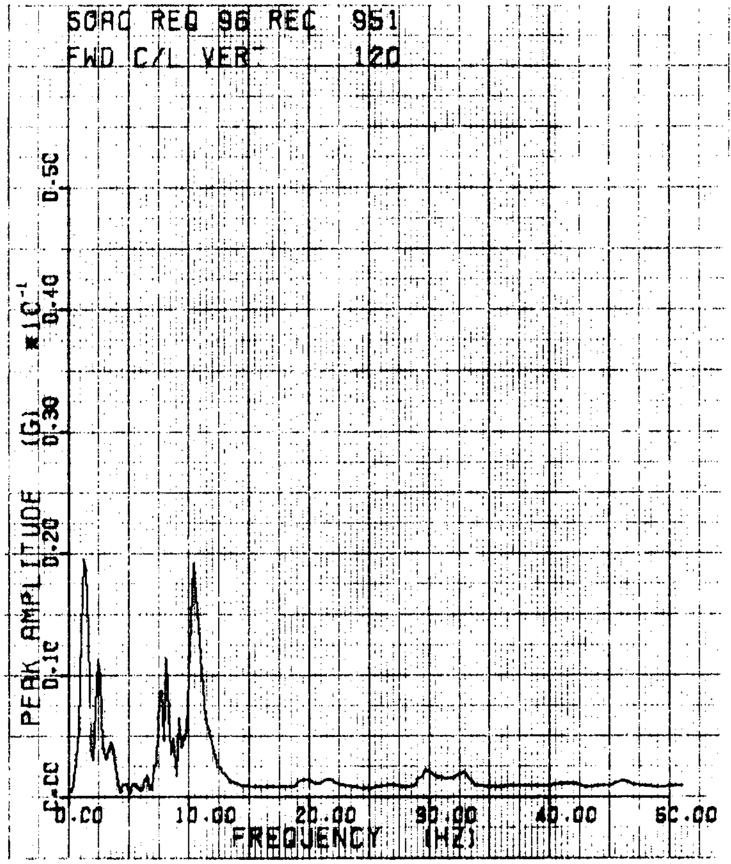
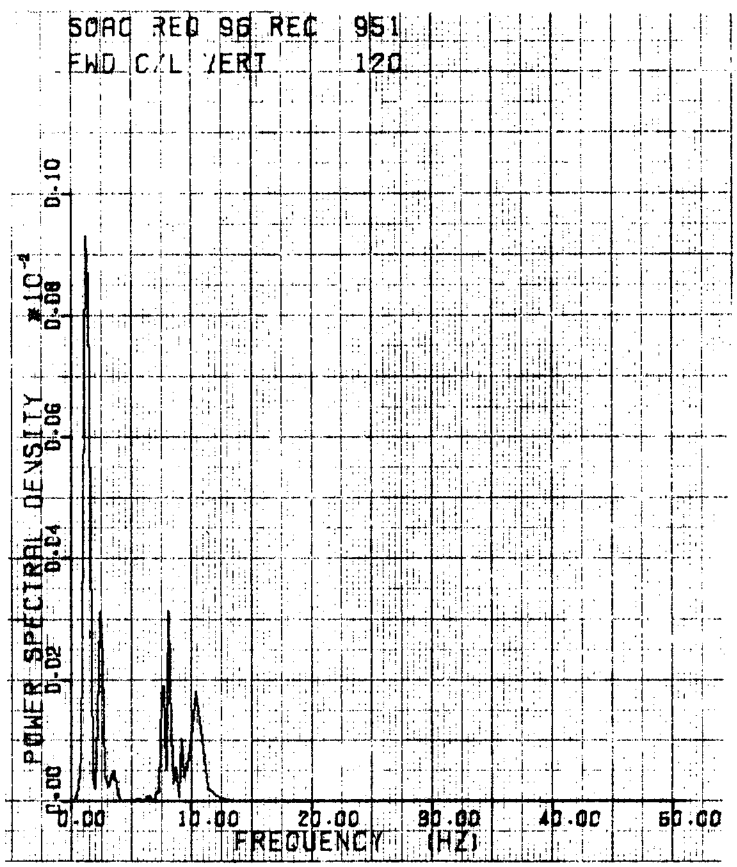

5090 REC 96 REC 951
MID RH VERT 117
POWER SPECTRAL DENSITY *10⁻²
FREQUENCY (HZ)

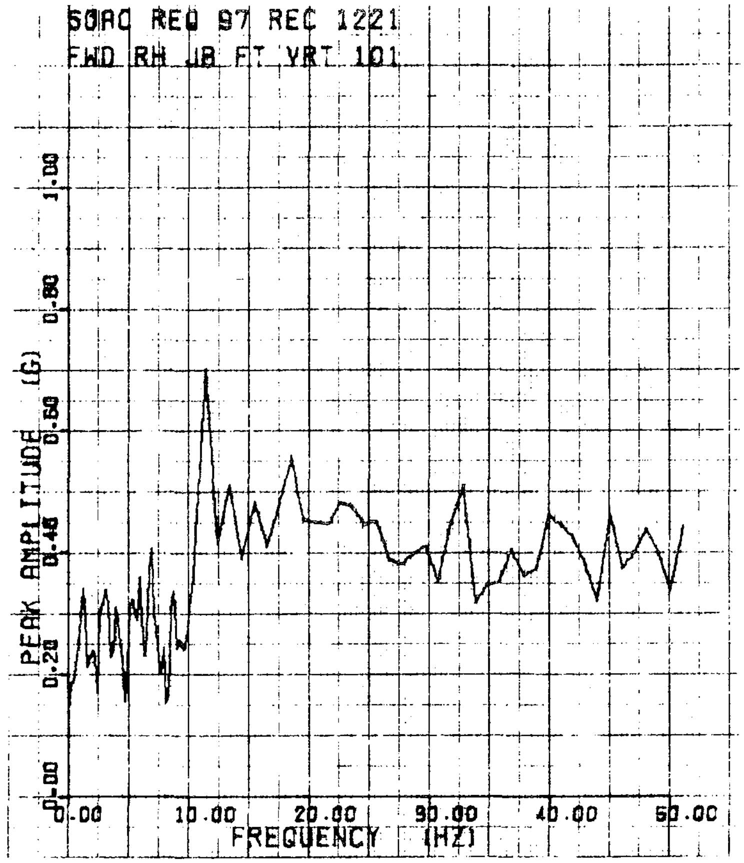
Figure B-47

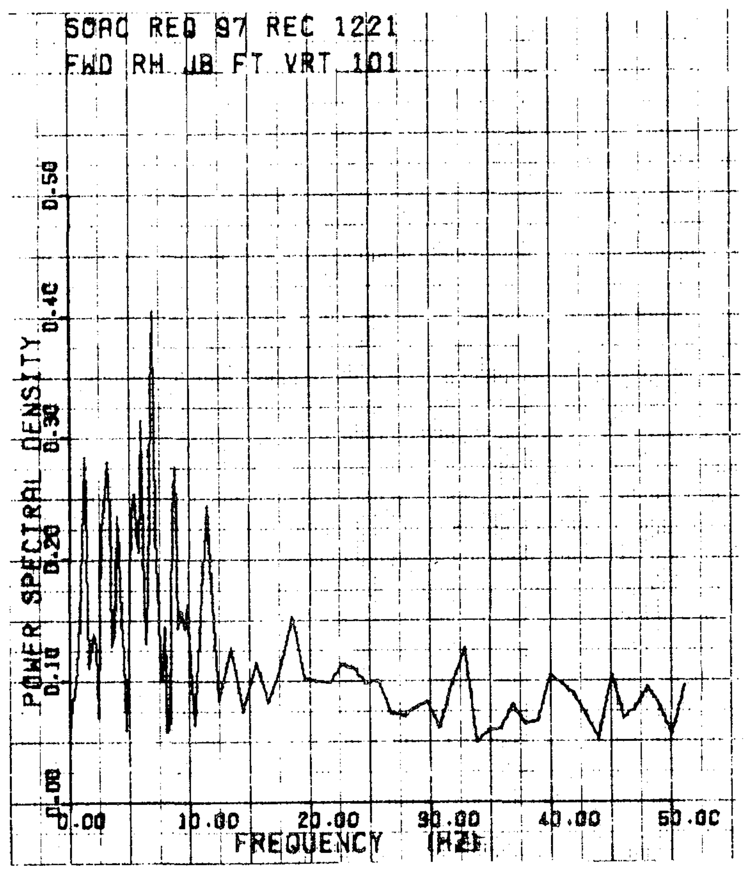




HIGH DENSITY CAR
90 KLB 3/29/74
55 MPH TRK SEC I

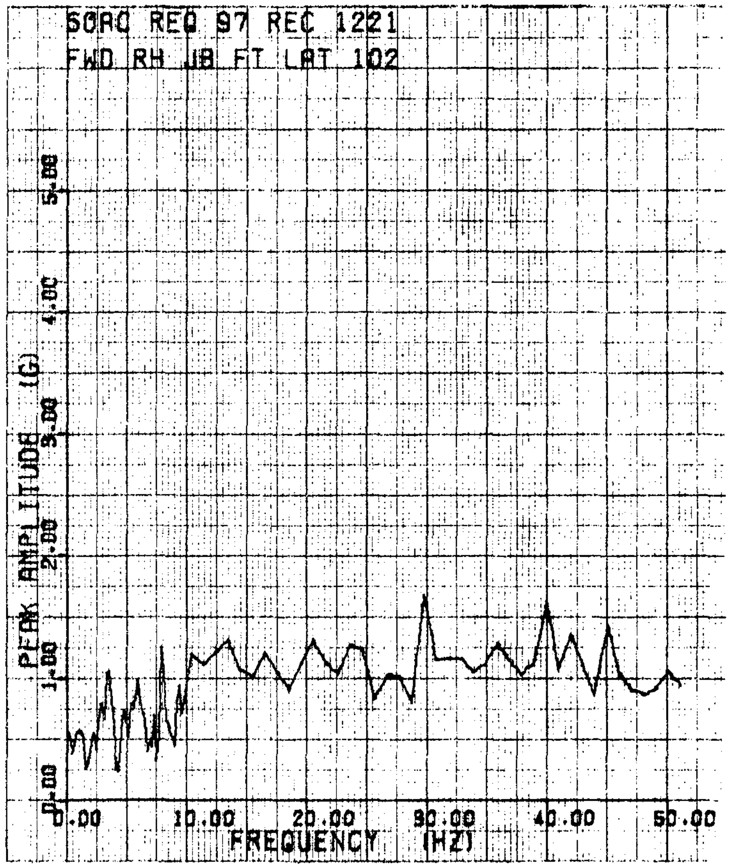
Figure B-48

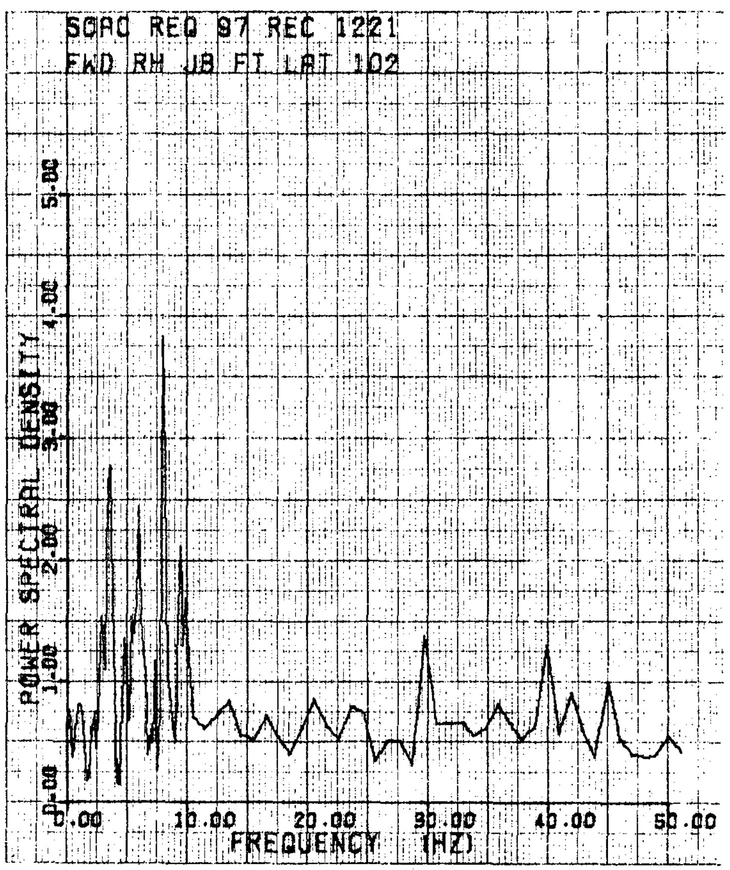




HIGH DENSITY CAR
90 KLB 3/29/74
56.0 MPH TRK SEC I

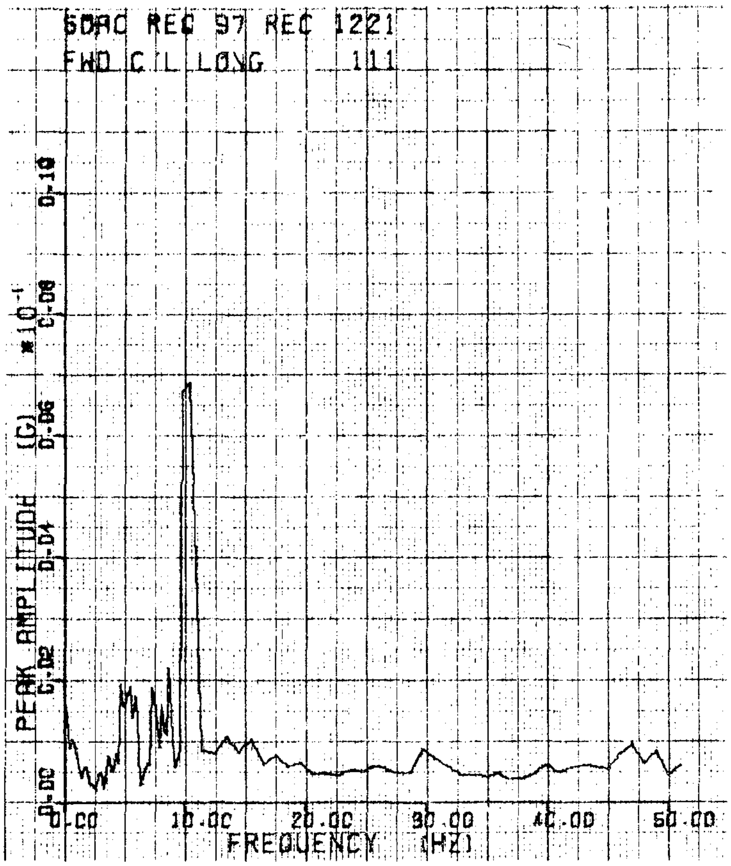
Figure B-49





HIGH DENSITY CAR
90 KLB 3/20/74
56.0 MPH TRK SEC 1

Figure B-50


SDRC REC 97 REC 1221
FWD C/L LONG 111
PEAK AMPLITUDE (G) *10⁻¹
0.00
0.02
0.04
0.06
0.08
0.10
0.00
10.00
20.00
30.00
40.00
50.00
FREQUENCY (HZ)

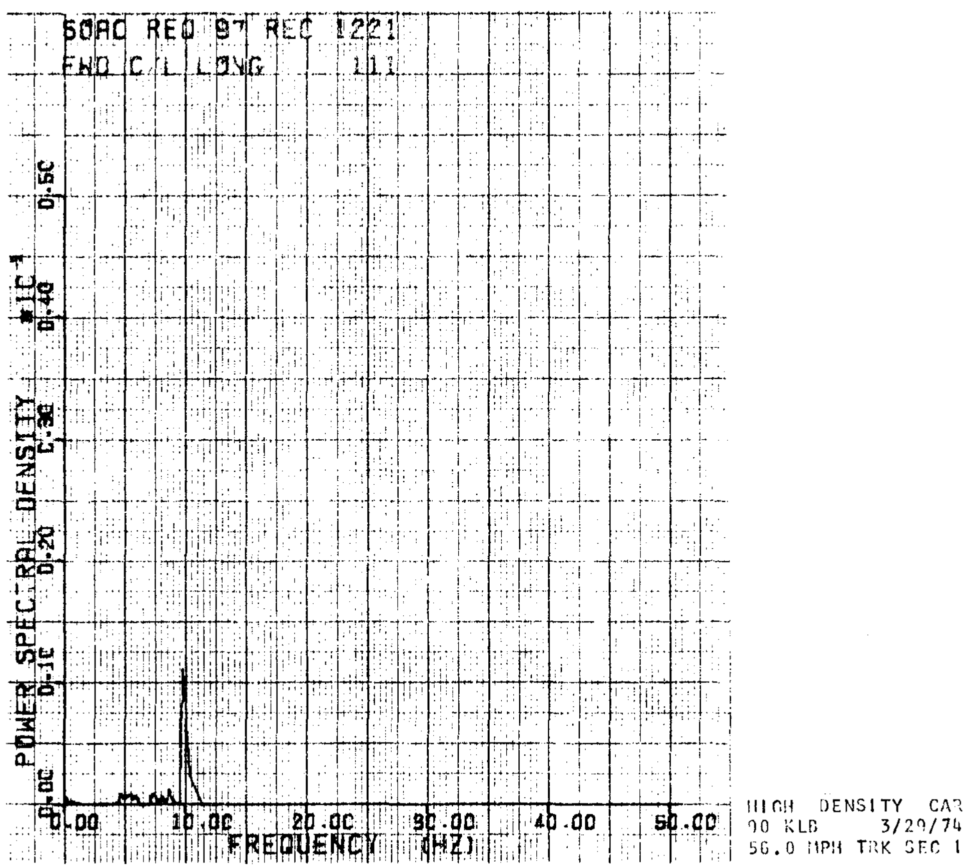
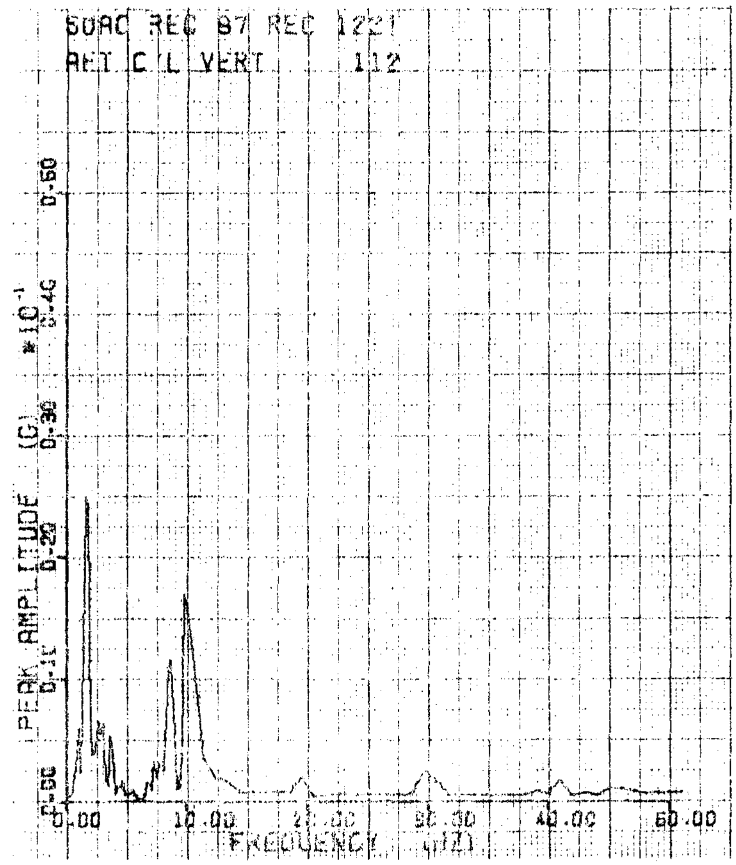
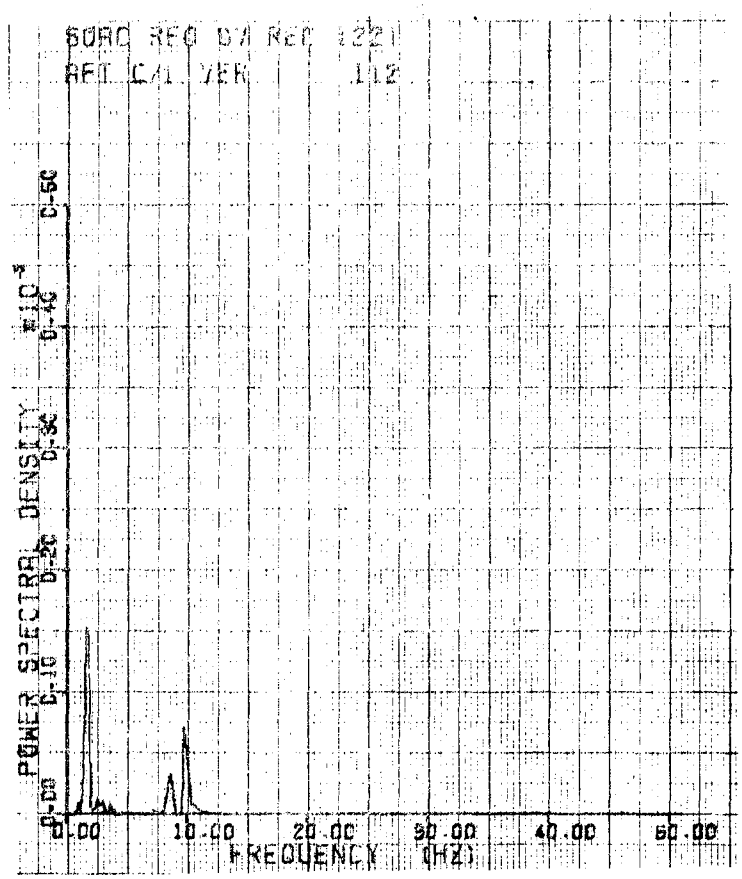

SDRC REC 97 REC 1221
FWD C/L LONG 111
POWER SPECTRAL DENSITY *10⁻¹
0.00
0.10
0.20
0.30
0.40
0.50
0.00
10.00
20.00
30.00
40.00
50.00
FREQUENCY (HZ)
HIGH DENSITY CAR
90 KLB 3/29/74
50.0 MPH TRK SEC 1

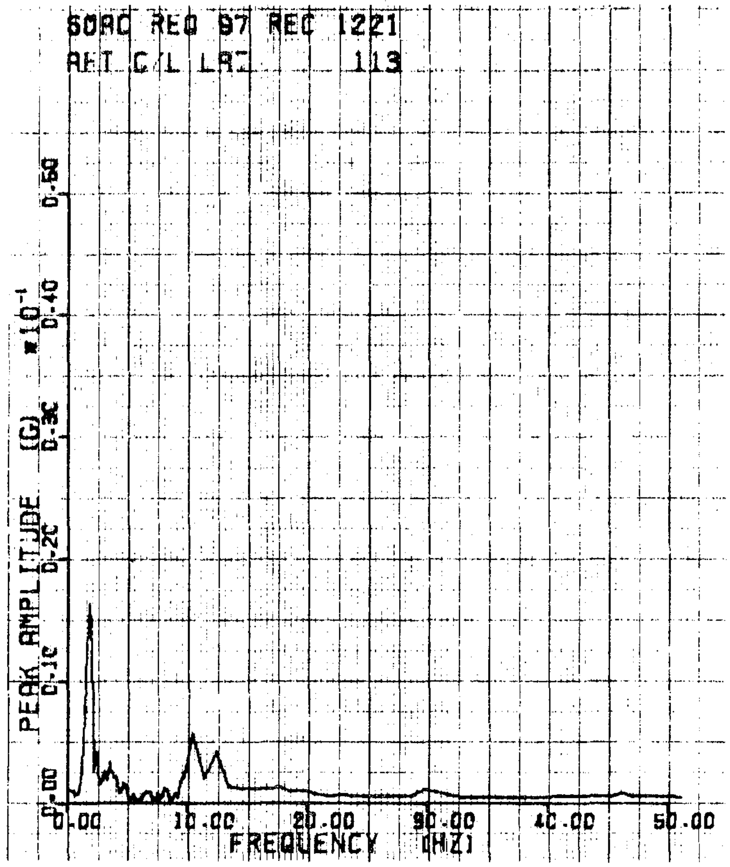
Figure B-51

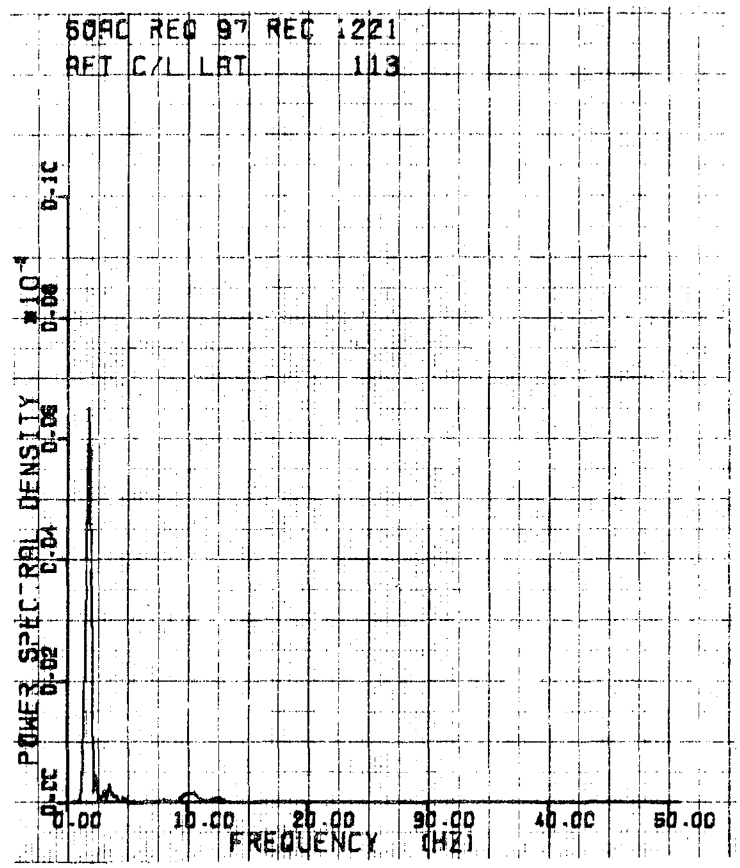




HIGH DENSITY CAR
30 KLB 3/29/74
56.0 MPH TRK SEC I

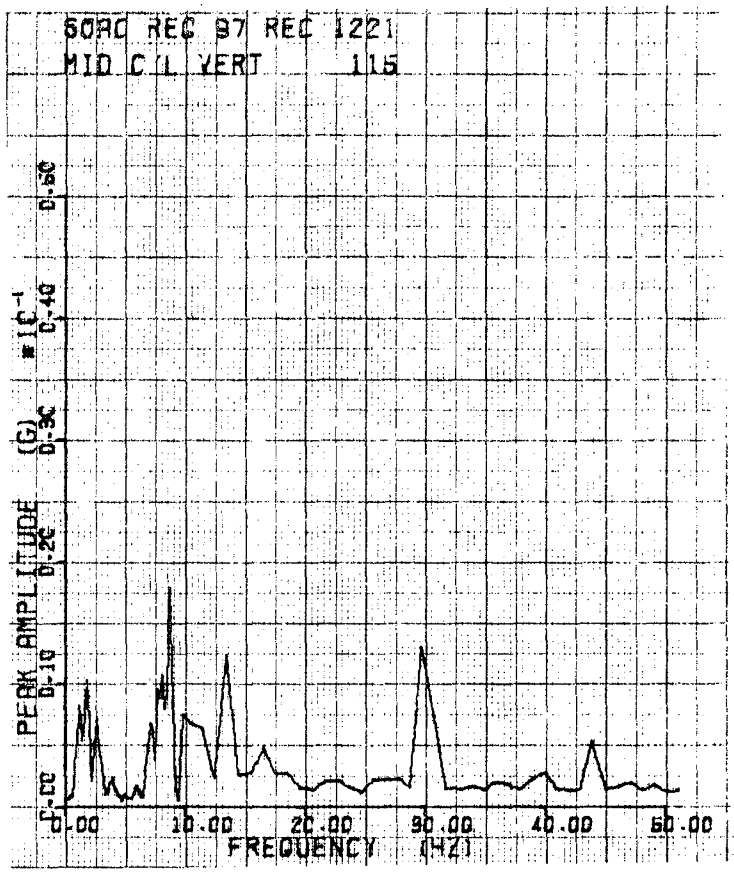
Figure B-52





HIGH DENSITY CAR
90 KLB 3/29/74
50.0 MPH TRK SEC I

Figure B-53


5ORC REC 97 REC 1221
MID C/L VERT 115
PEAK AMPLITUDE (G) *10^-1
0.00
0.10
0.20
0.30
0.40
0.50
0.00
10.00
20.00
30.00
40.00
50.00
FREQUENCY (HZ)

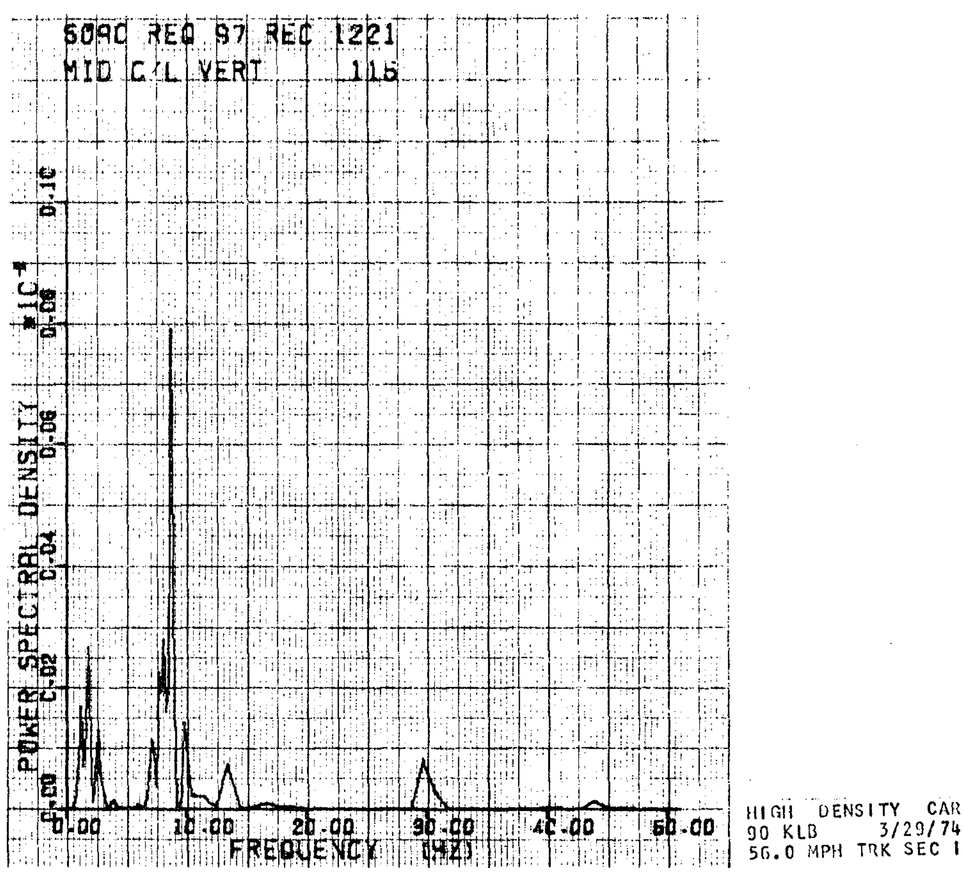
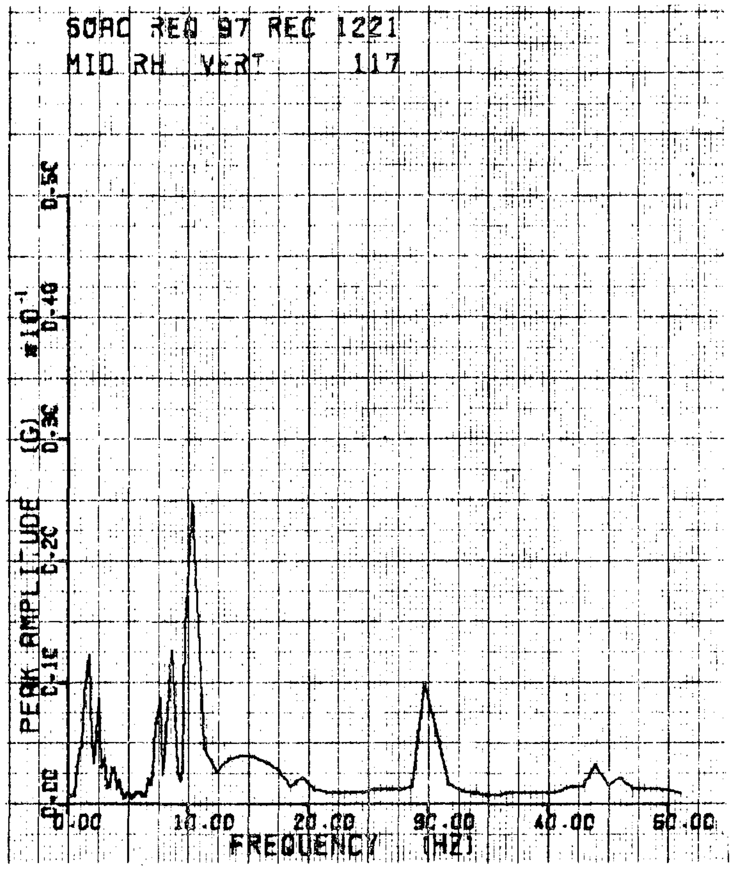
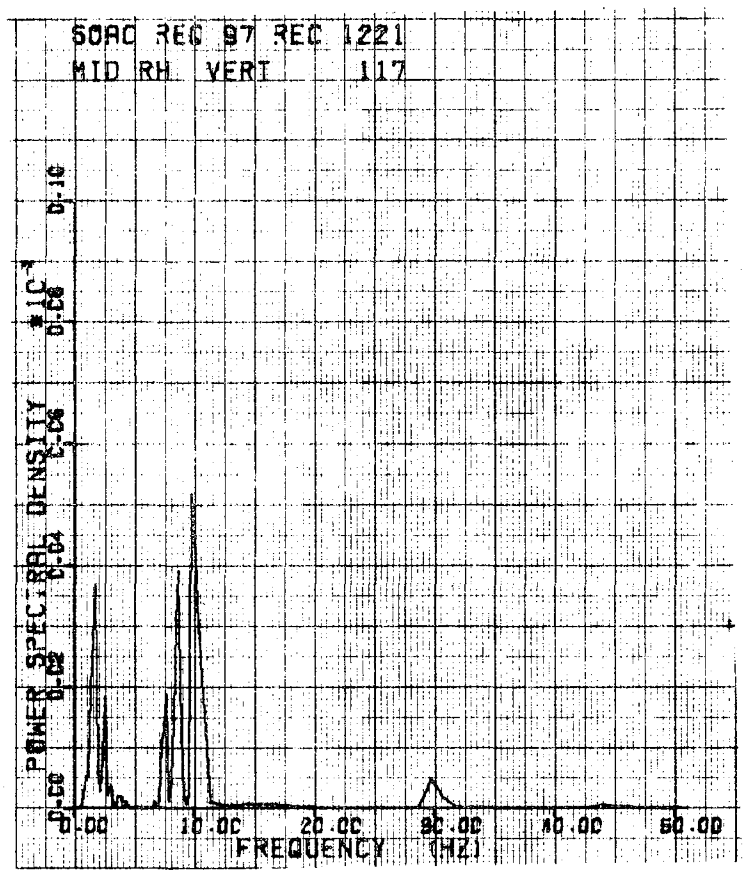

5ORC REQ 97 REC 1221
MID C/L VERT 115
POWER SPECTRAL DENSITY *10^-1
0.00
0.02
0.04
0.06
0.08
0.10
0.00
10.00
20.00
30.00
40.00
50.00
FREQUENCY (HZ)
HIGH DENSITY CAR
90 KLB 3/29/74
56.0 MPH TRK SEC I

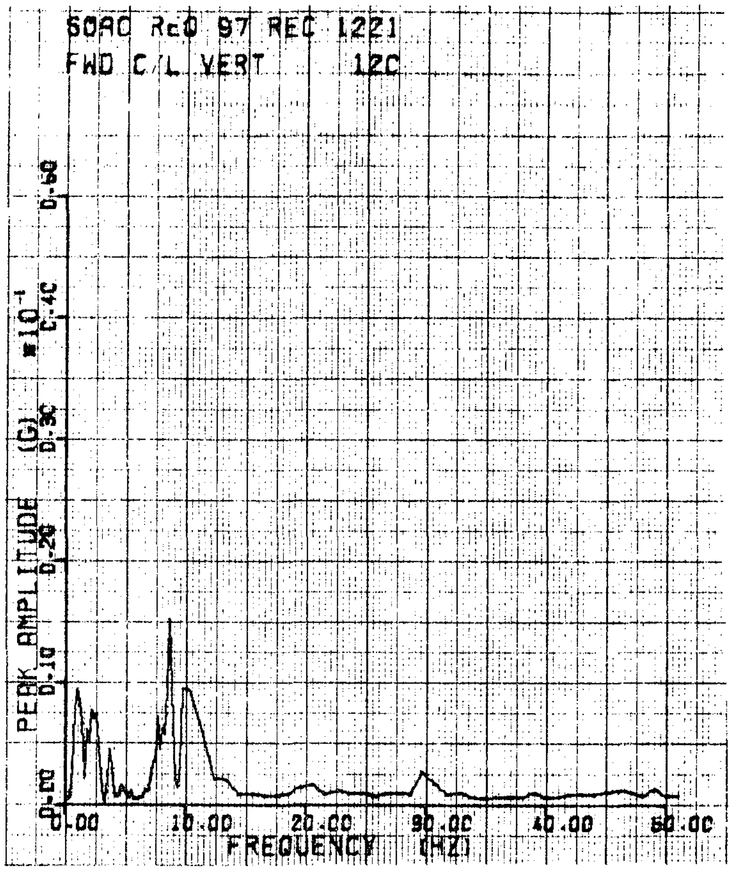
Figure B-54

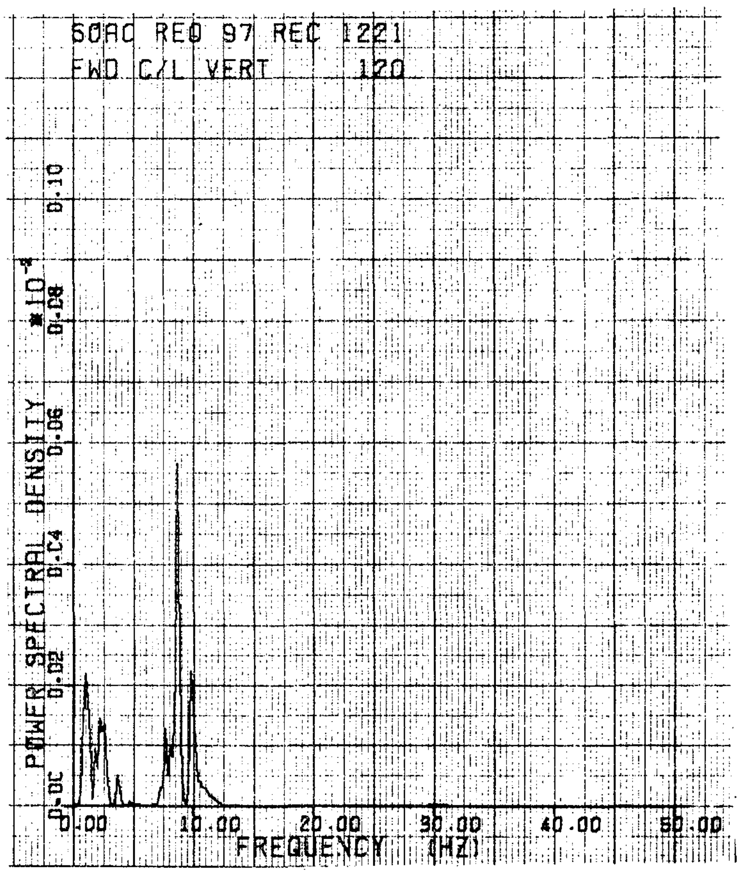




HIGH DENSITY CAR
90 KLB 3/29/74
56.0 MPH TRK SEC I

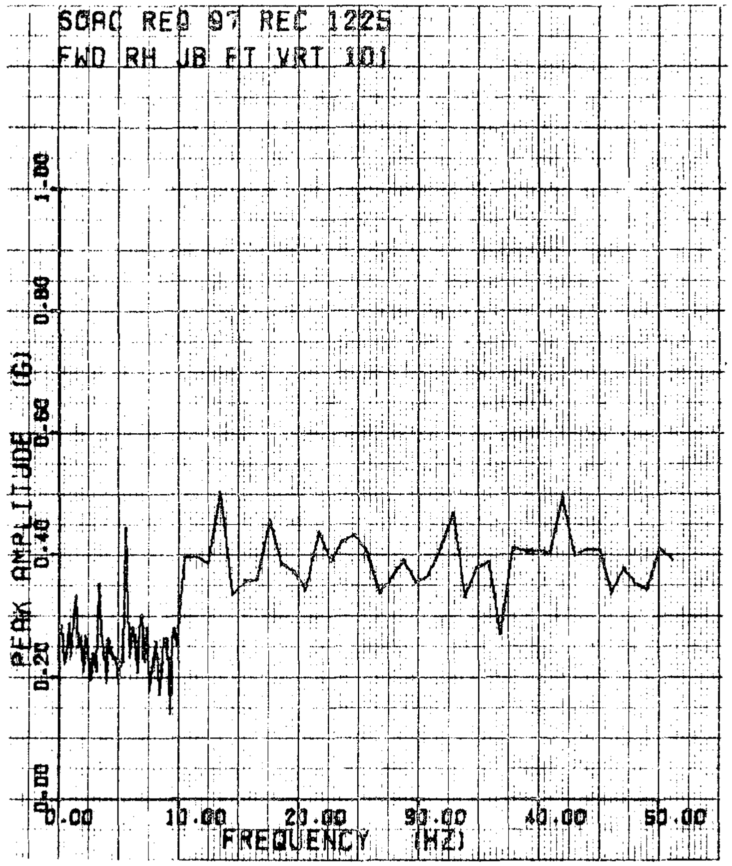
Figure B-55

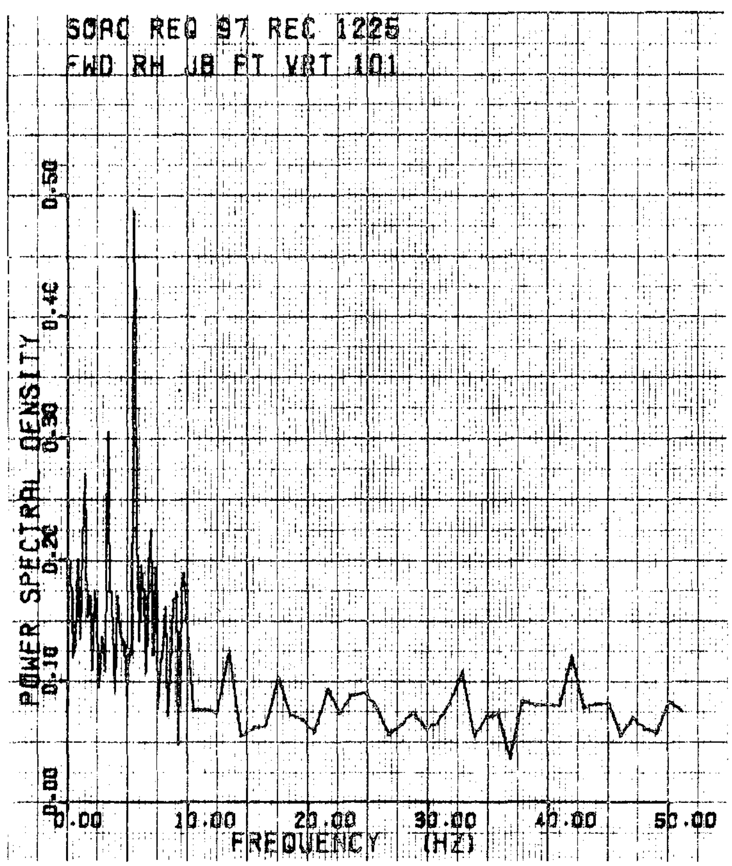




HIGH DENSITY CAR
90 KLB 3/29/74
56.0 MPH TRK SEC I

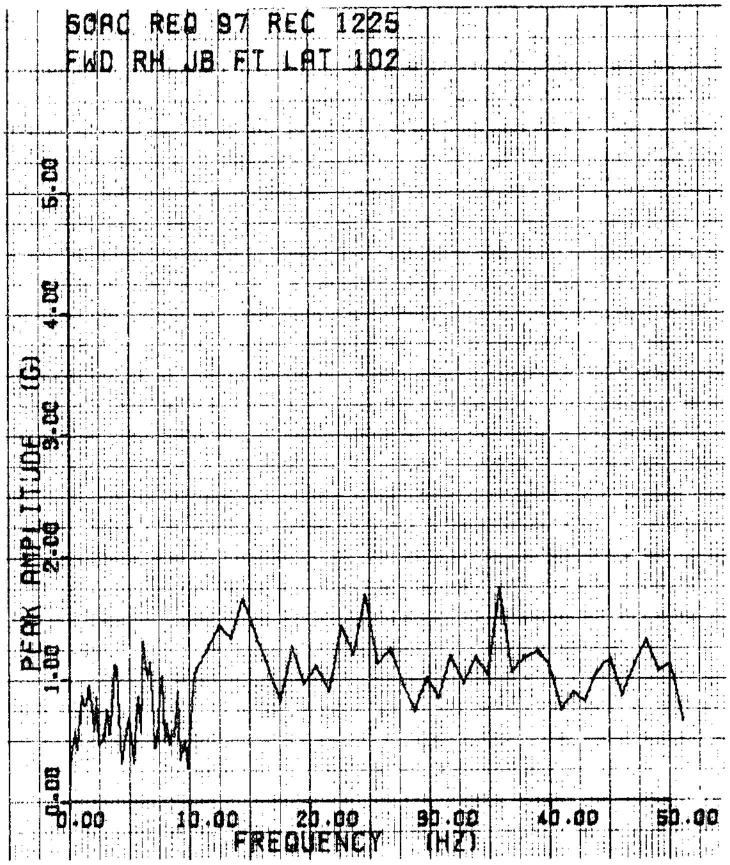
Figure B-56

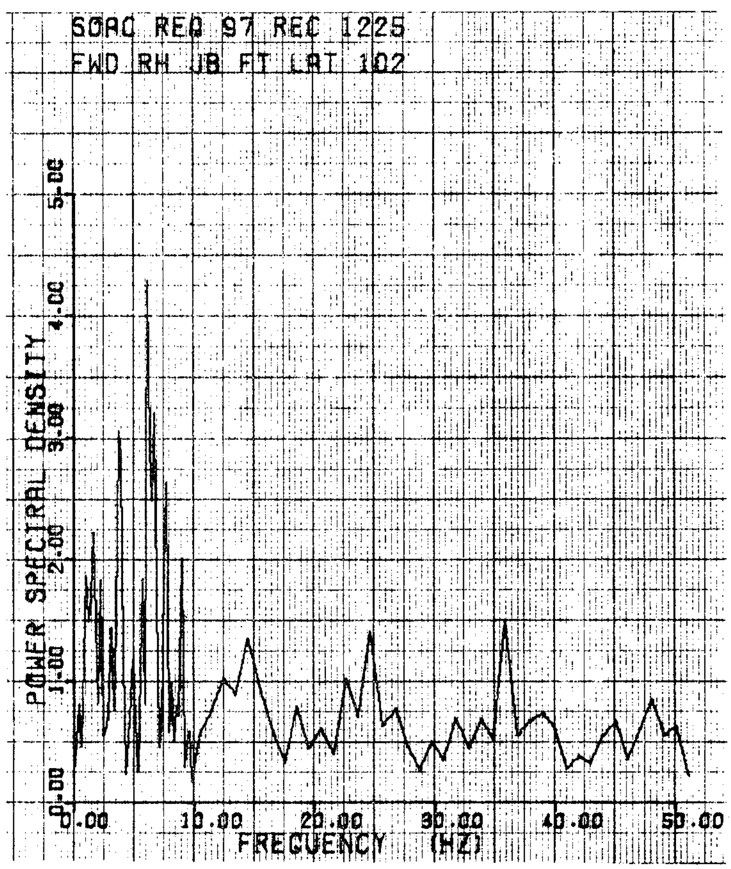




HIGH DENSITY CAR
90 KLB 3/29/74
67.2 MPH TRK SEC I

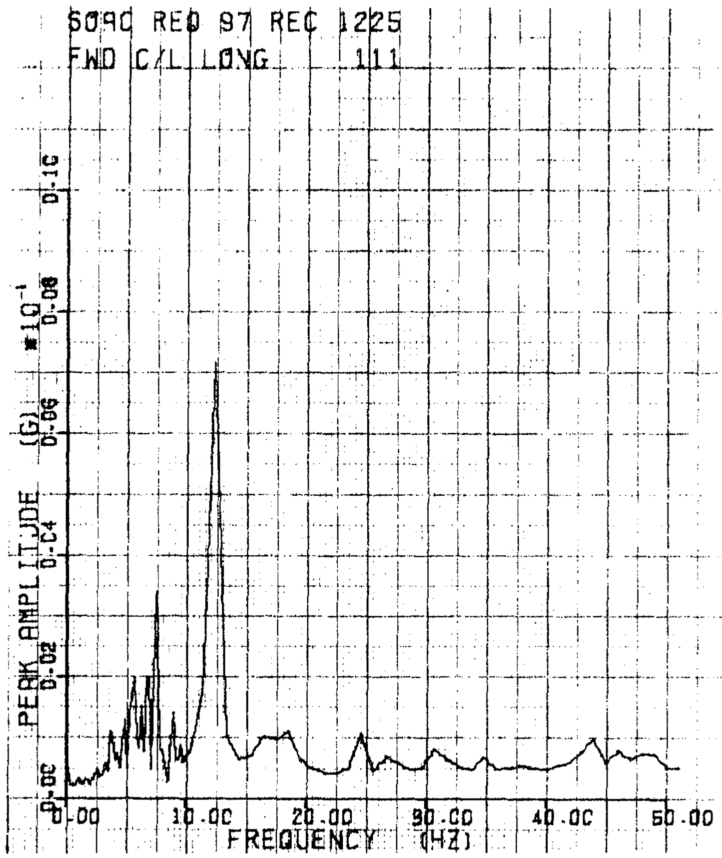
Figure B-57

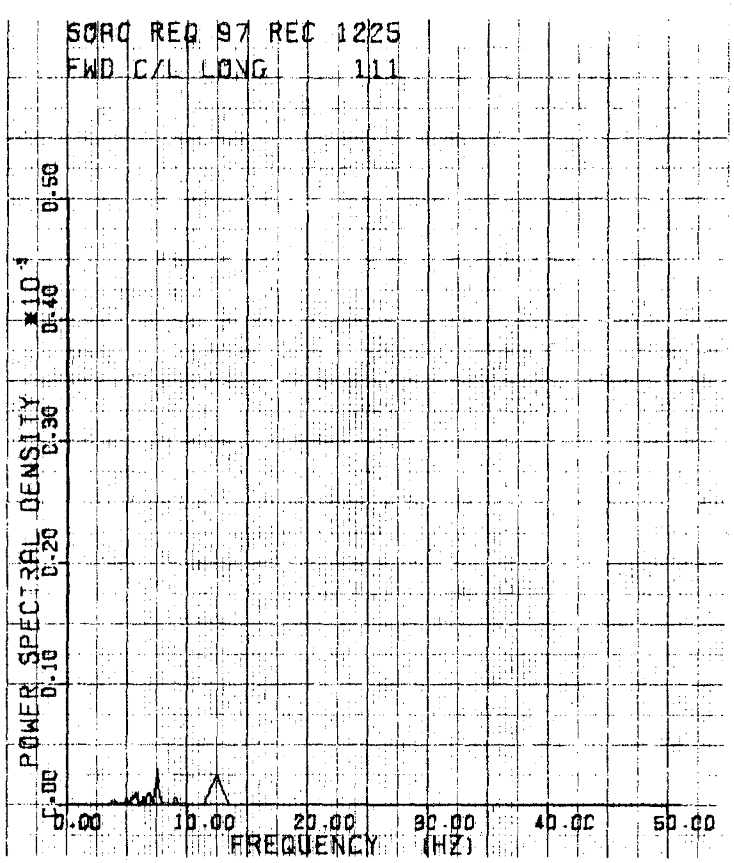




HIGH DENSITY CAR
90 KLB 3/29/74
67.2 MPH TRK SEC 1

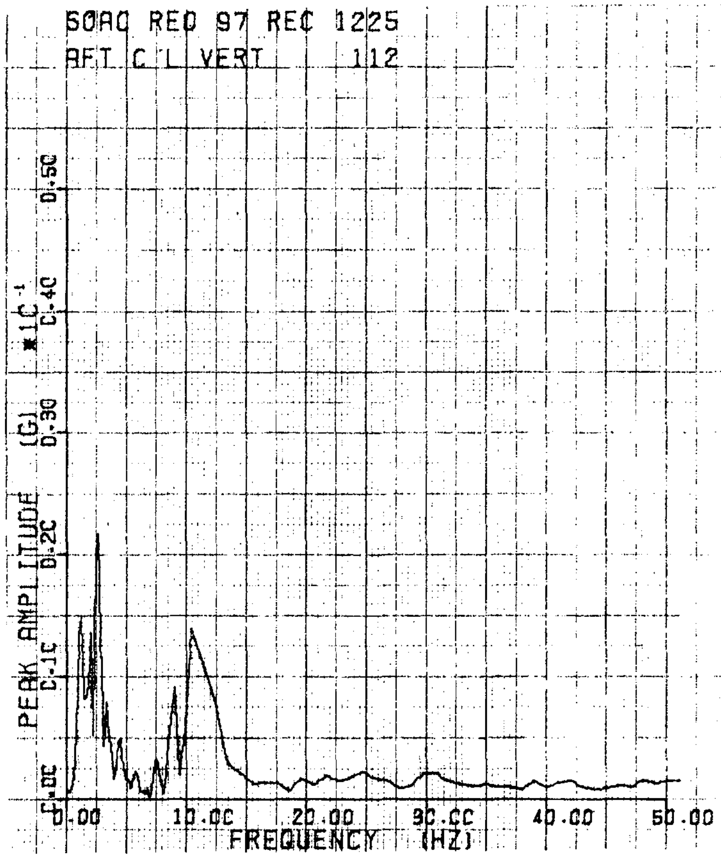
Figure B-58

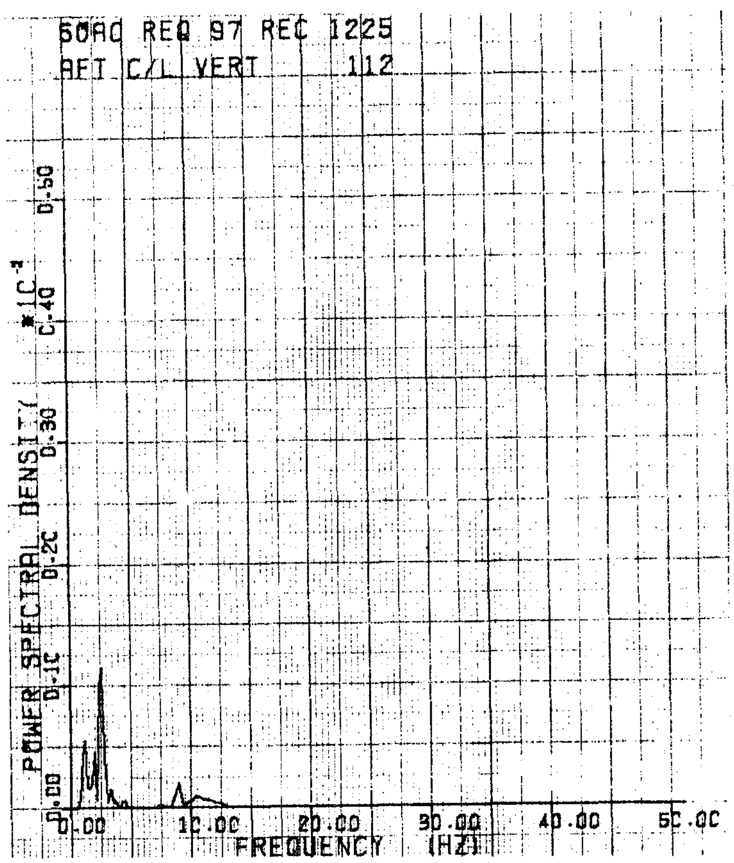




HIGH DENSITY CAR
90 KLB 3/29/74
67.2 MPH TRK SEC I

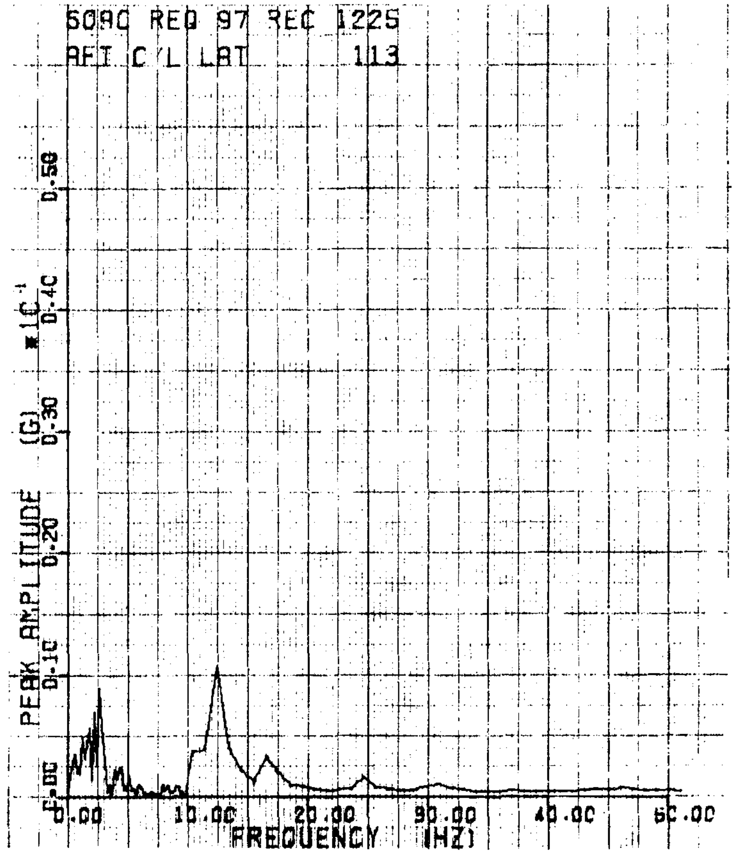
Figure B-59

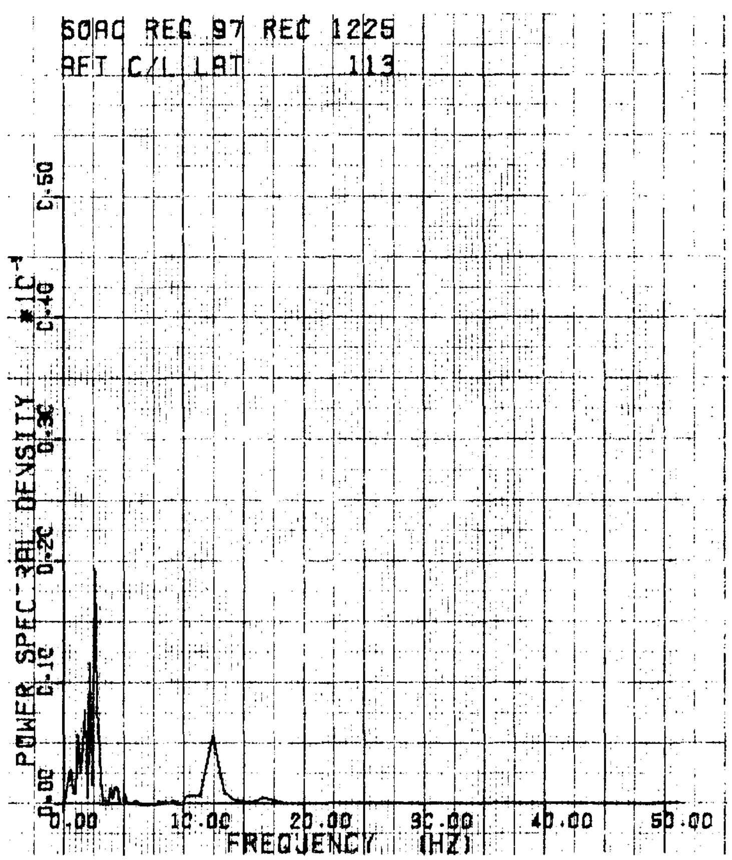




HIGH DENSITY CAR
90 KLB 3/29/74
67.2 MPH TRK SEC I

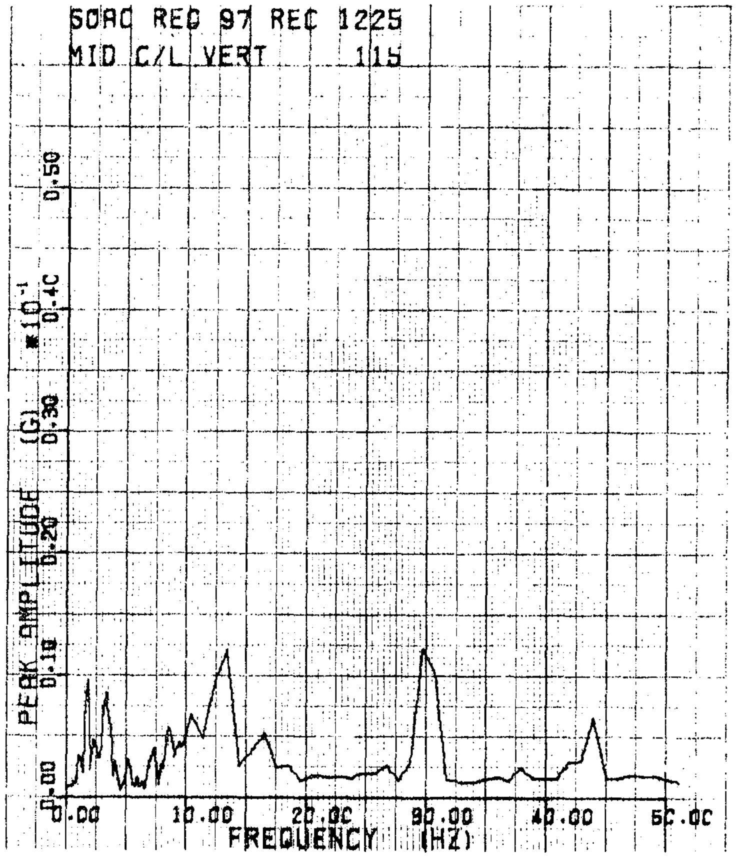
Figure B-60

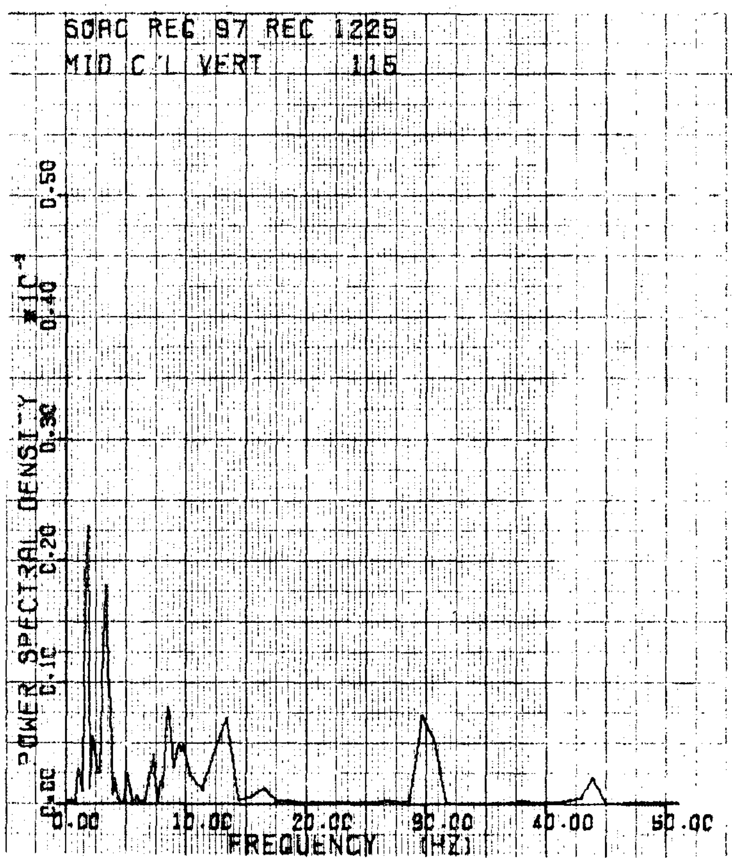




HIGH DENSITY CAR
90 KLB 3/29/74
67.2 MPH TRK SEC I

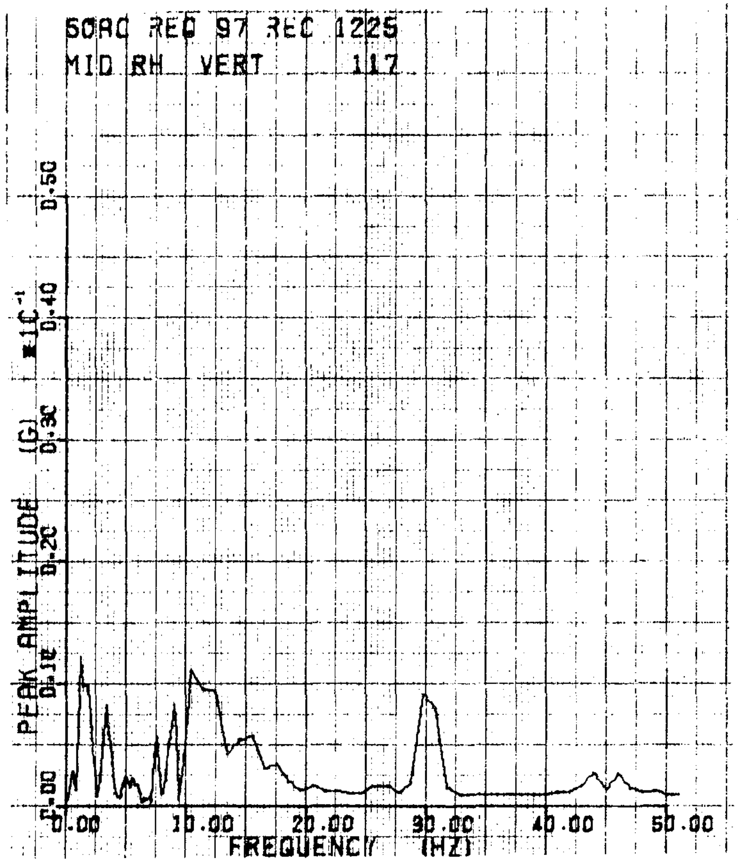
Figure B-61

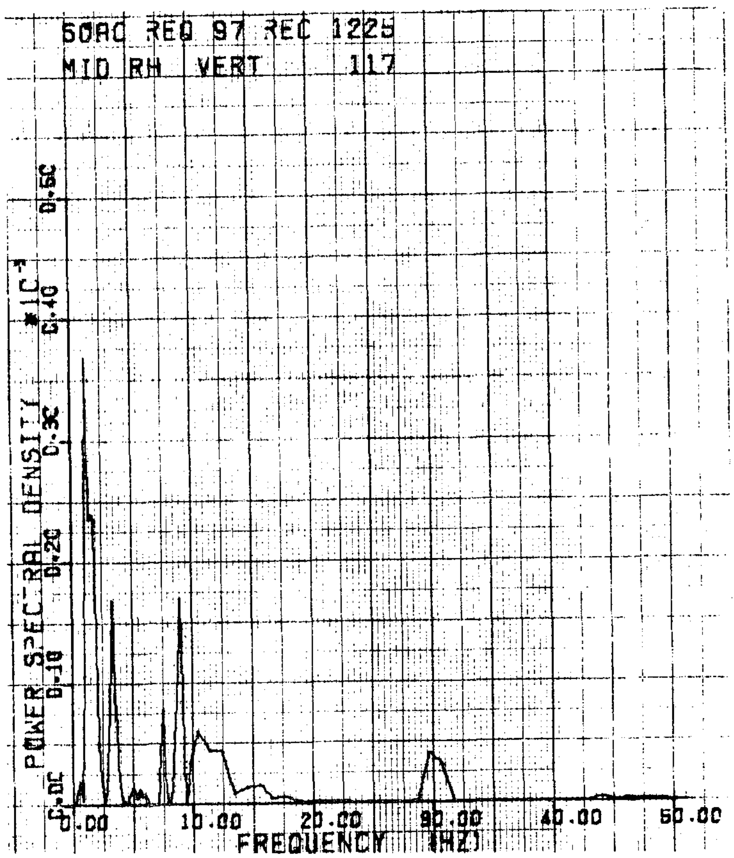




HIGH DENSITY CAR
90 KLB 3/29/74
67.2 MPH TRK SEC I

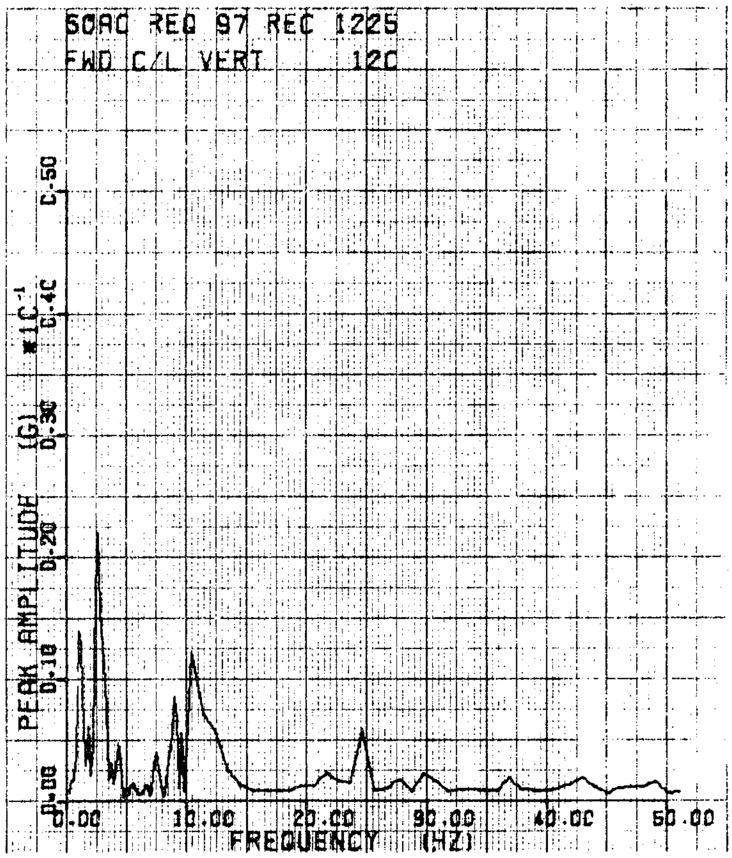
Figure B-62

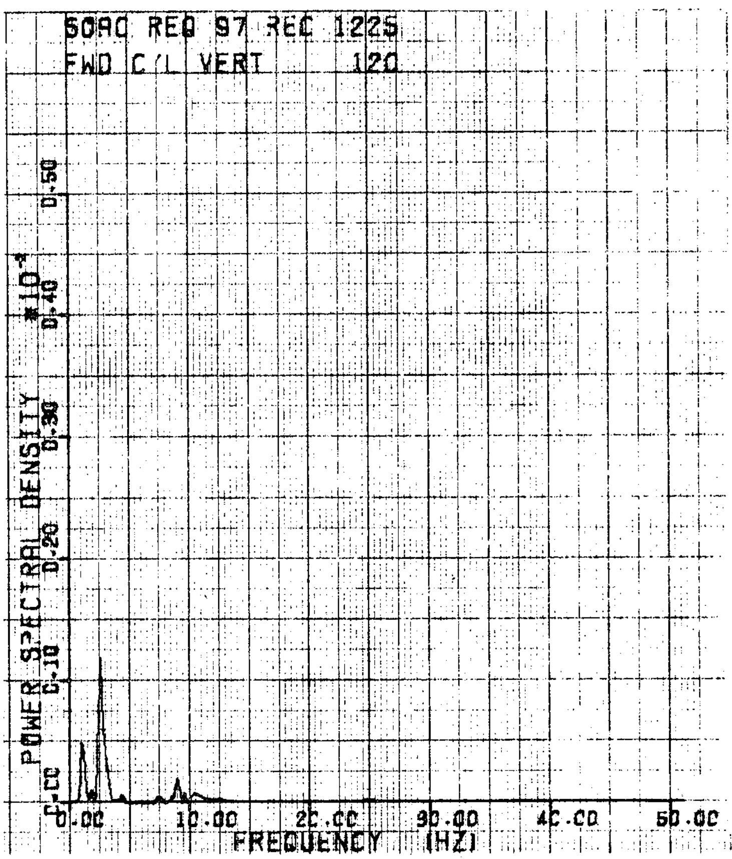




HIGH DENSITY CAR
3/29/74
67.2 SEC I

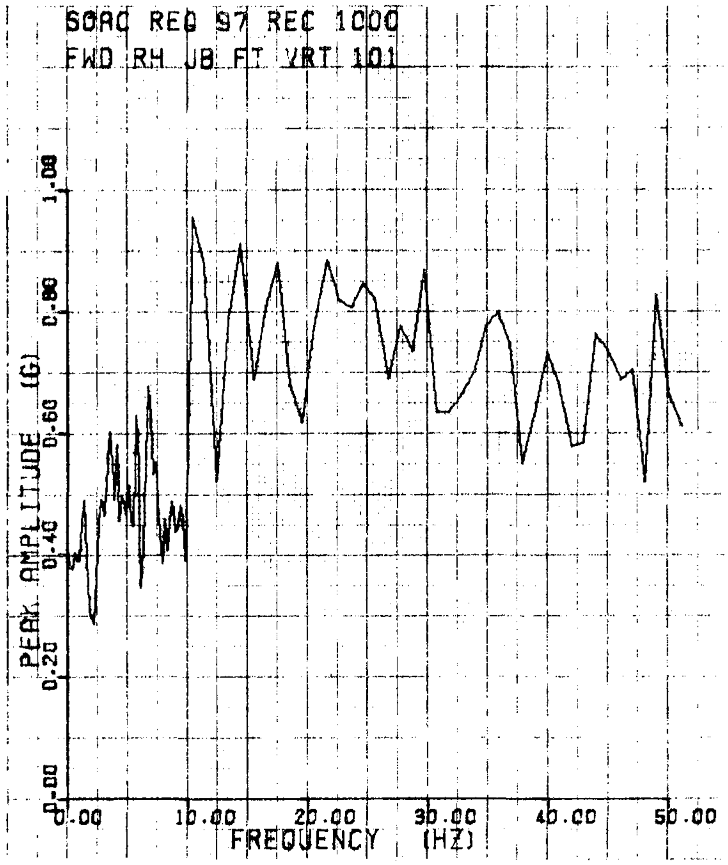
Figure B-63

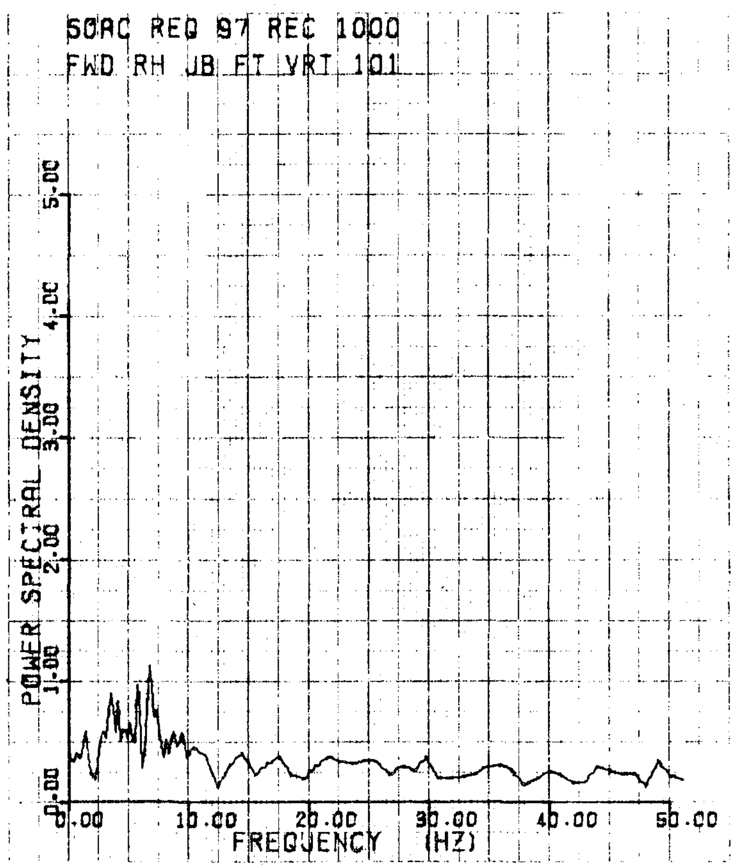




HIGH DENSITY CAR
70 KLB 3/20/74
67.2 MPH TRK SEC 1

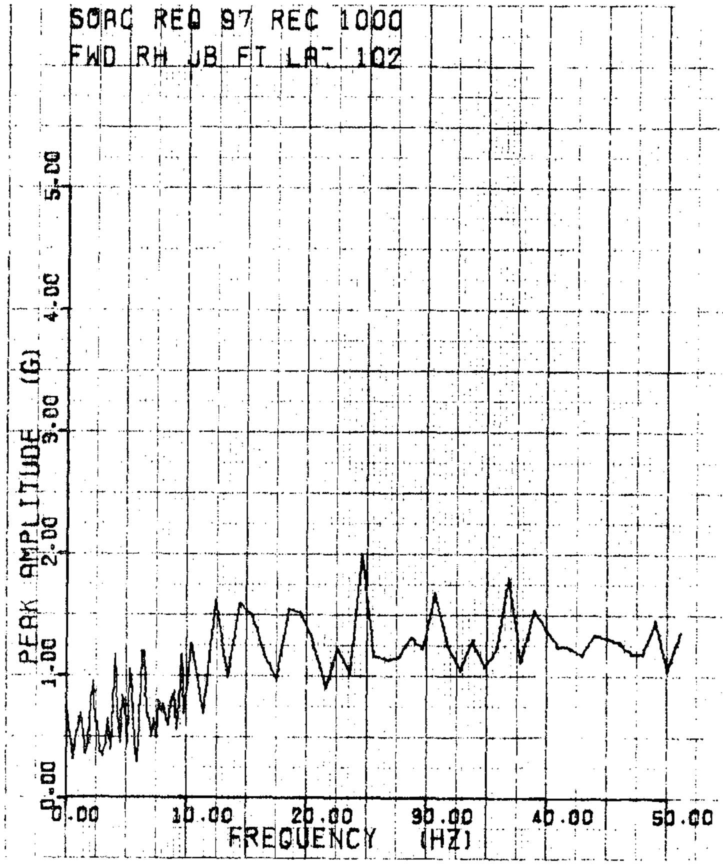
Figure B-64

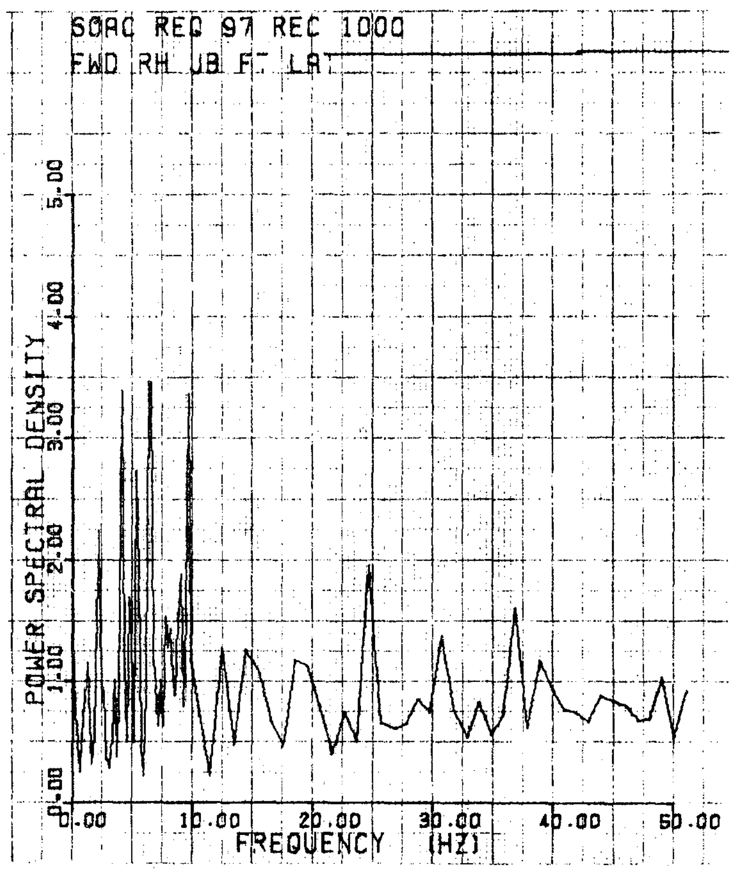




HIGH DENSITY CAR
90 KLB 3/29/74
80 MPH TRK SEC I

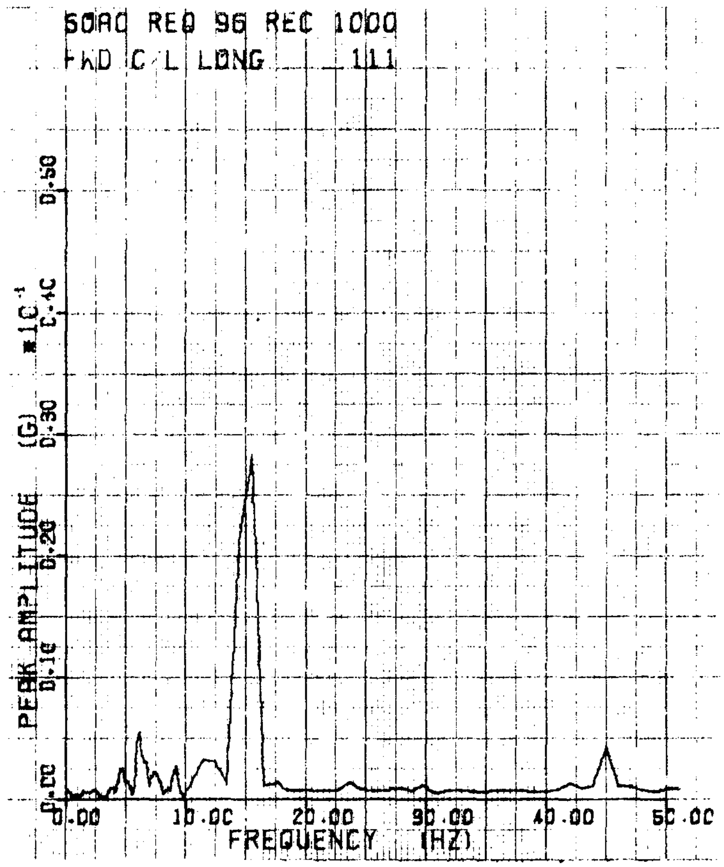
Figure B-65

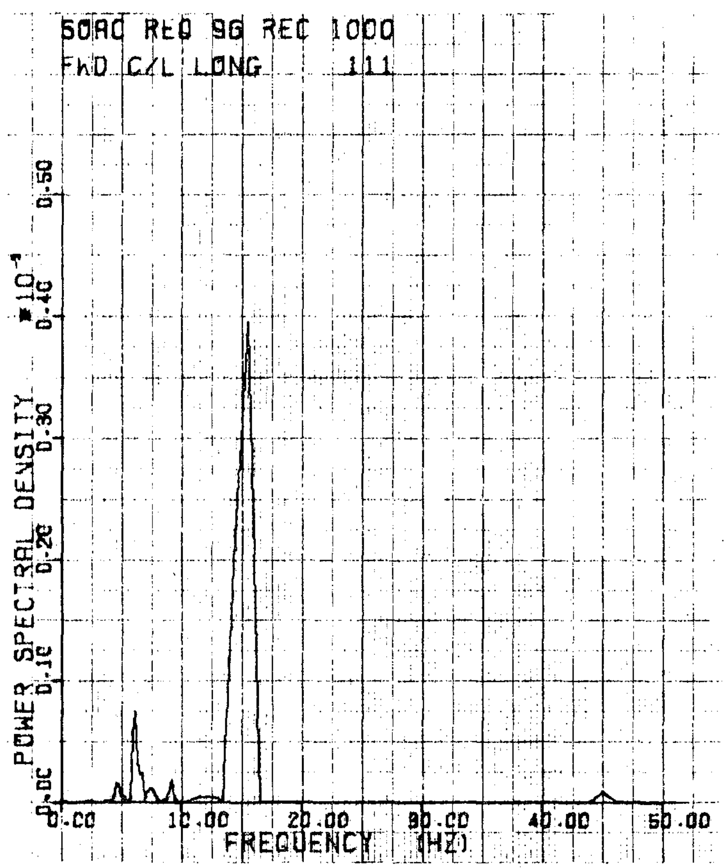




HIGH DENSITY CAR
90 KLB 3/29/74
80 MPH TRK SEC I

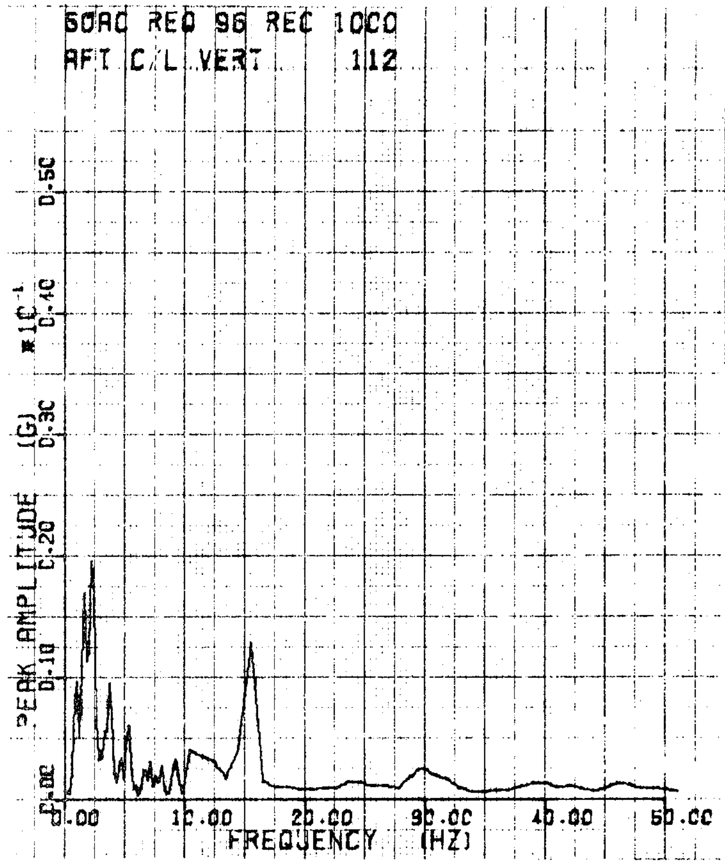
Figure B-66

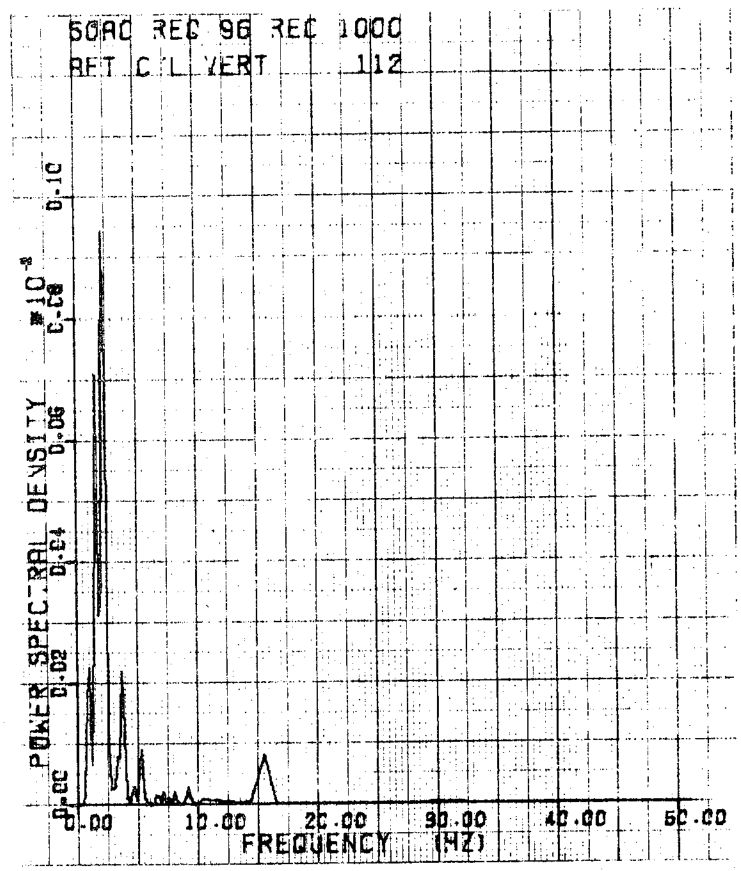




HIGH DENSITY CAR
90 KLB 3/29/74
80 MPH TRK SEC I

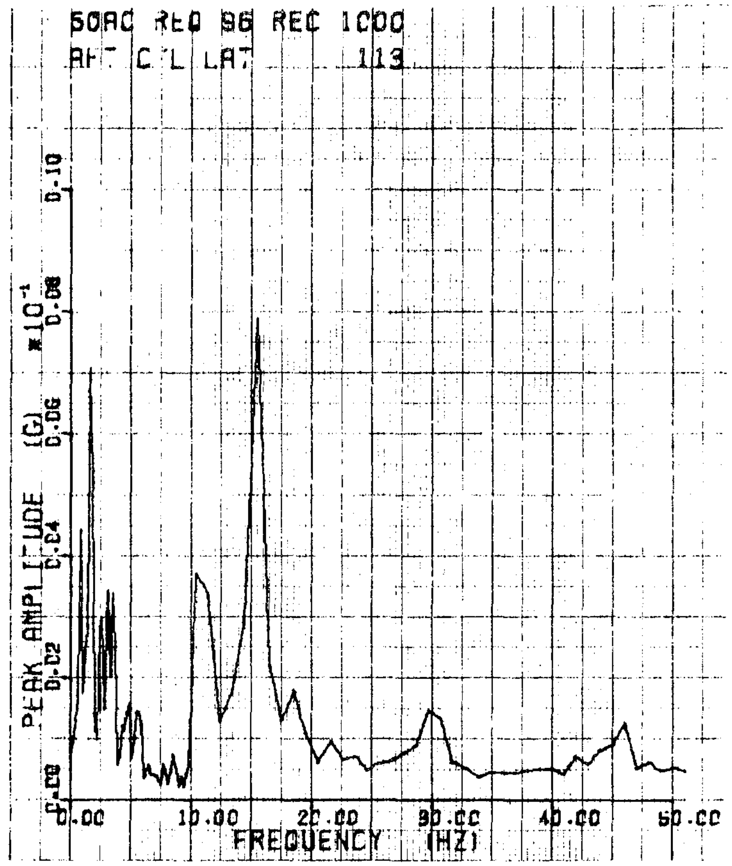
Figure B-67

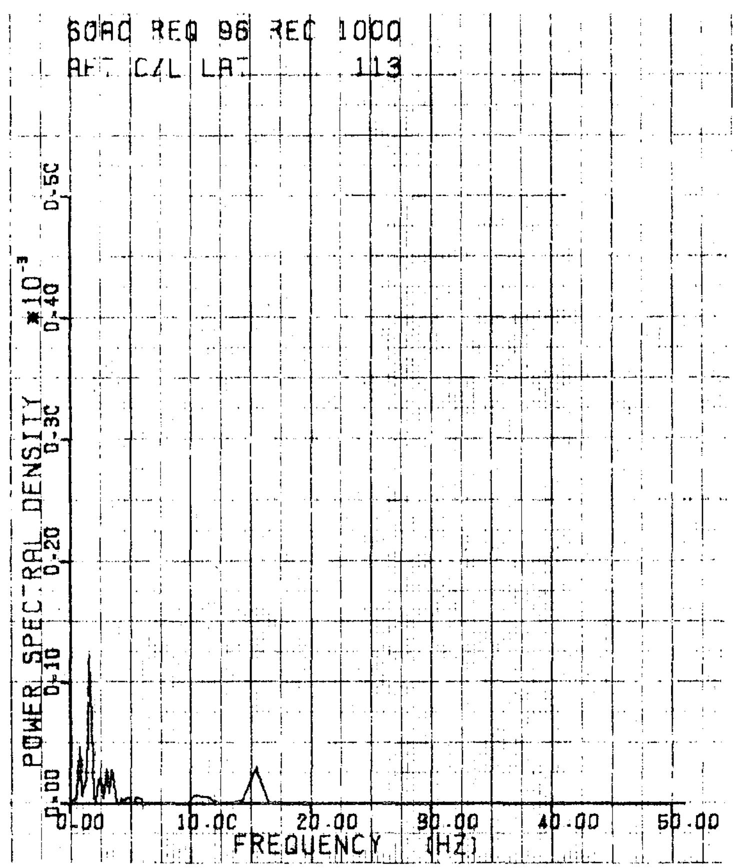




HIGH DENSITY CAR
30 KLB 3/29/74
60 MPH TRK SEC I

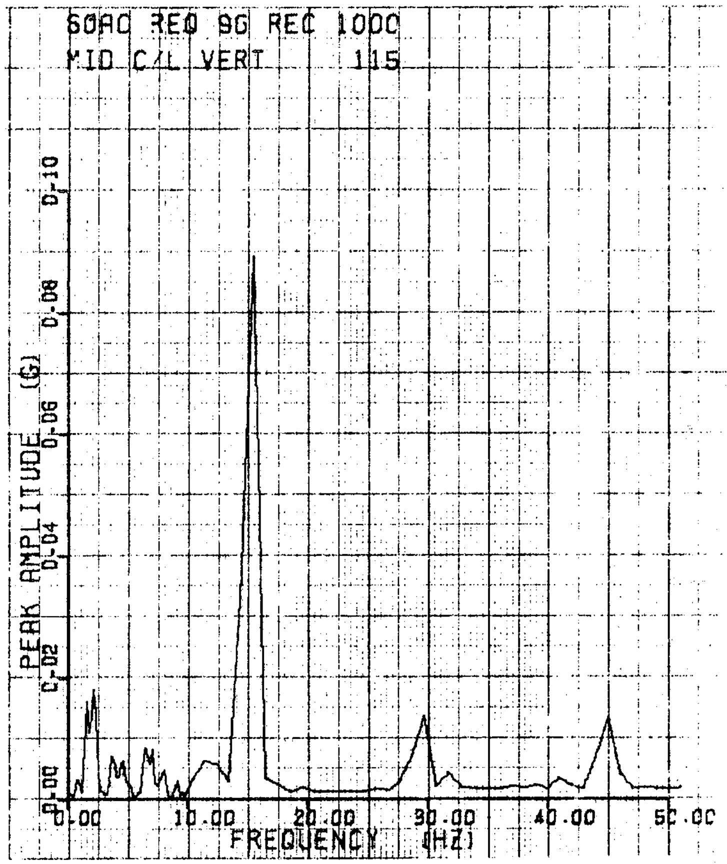
Figure B-68

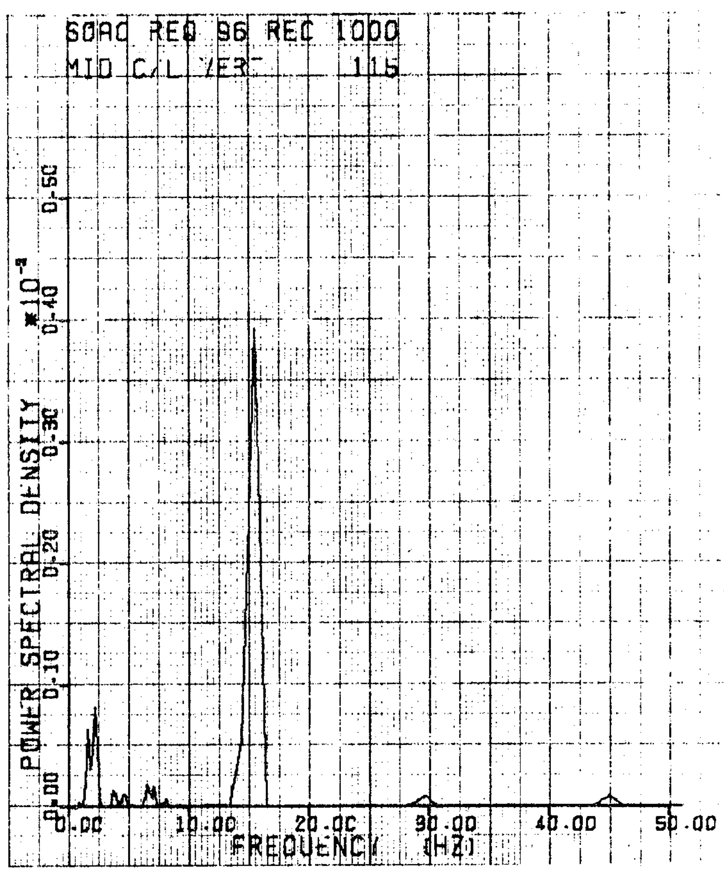




HIGH DENSITY CAR
5/29/74
TRK SEC 1

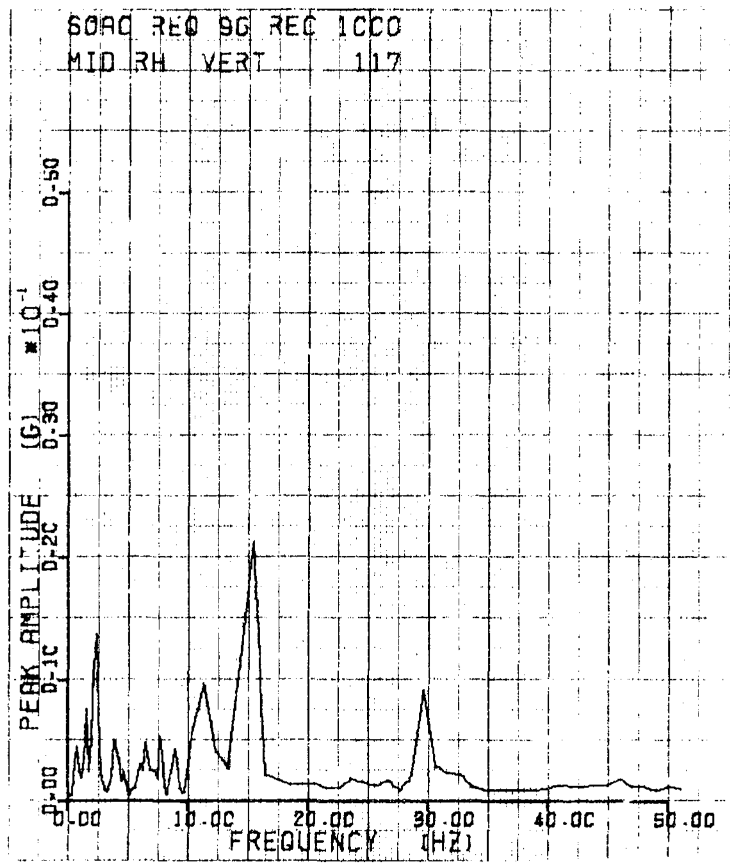
Figure B-69

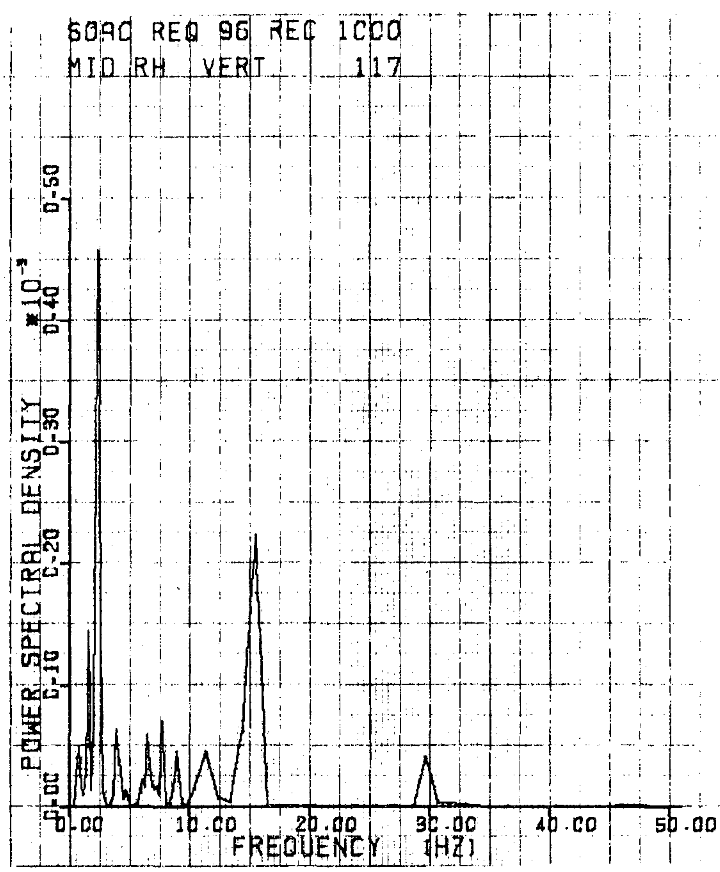




HIGH DENSITY CAR
30 KLB 3/29/74
80 MPH TRK SEC I

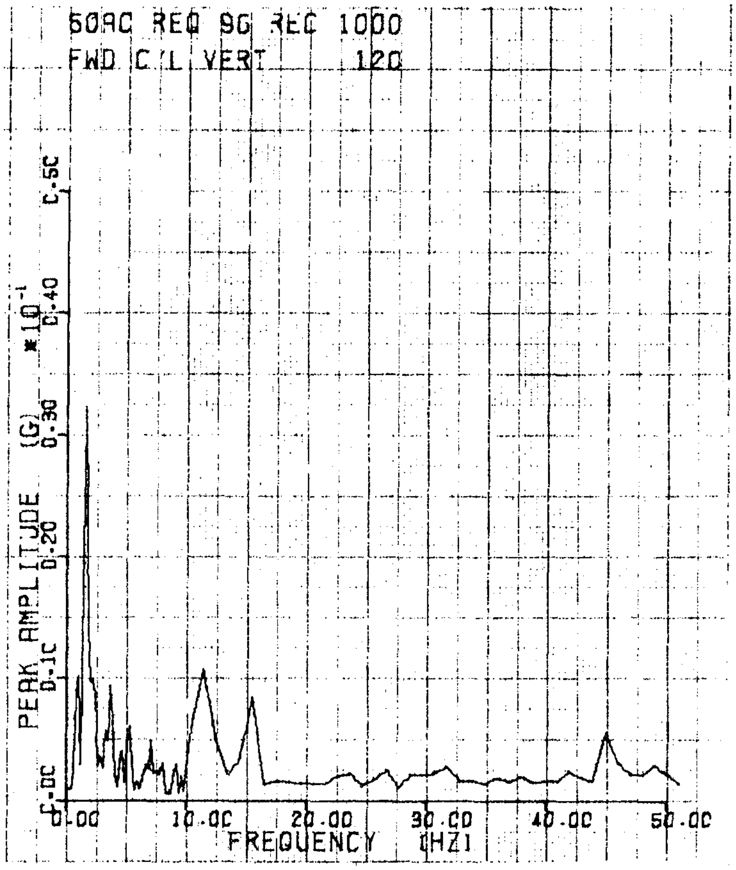
Figure B-70

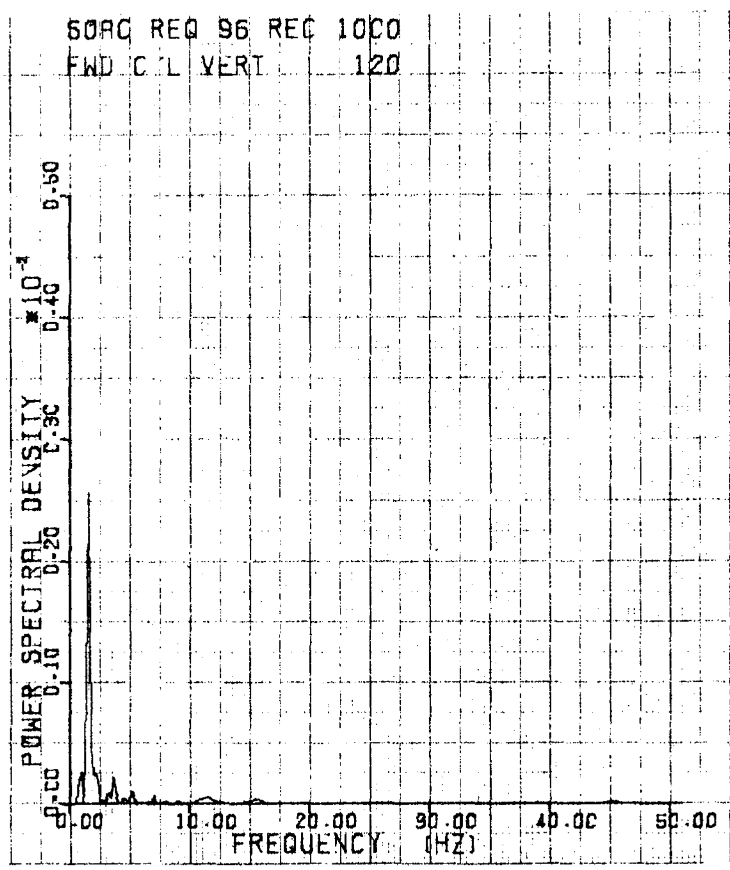




HIGH DENSITY CAR
00 KLB 3/20/74
80 MPH TRK SEC 1

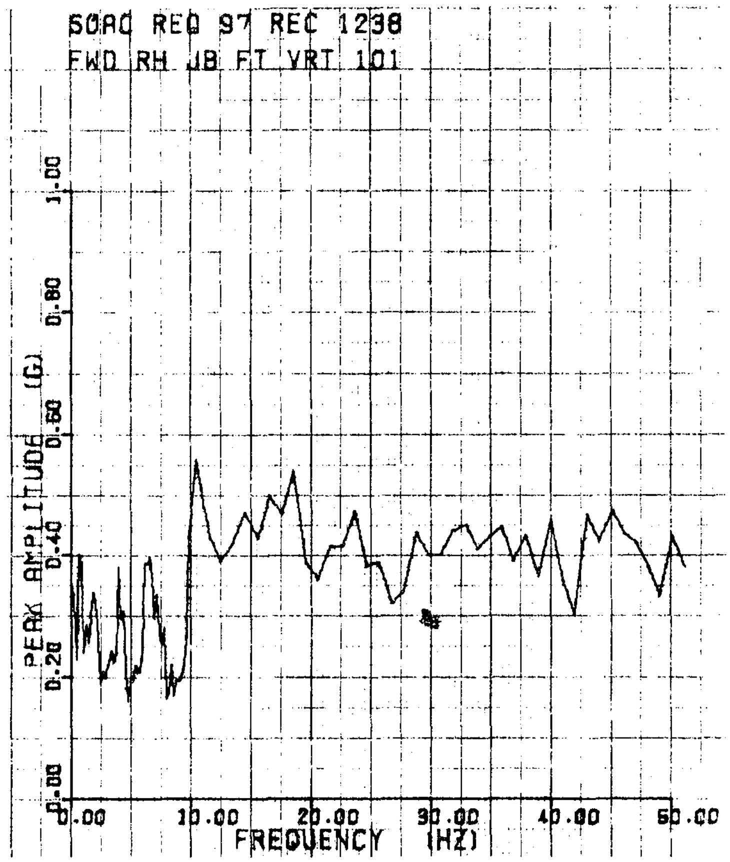
Figure B-71

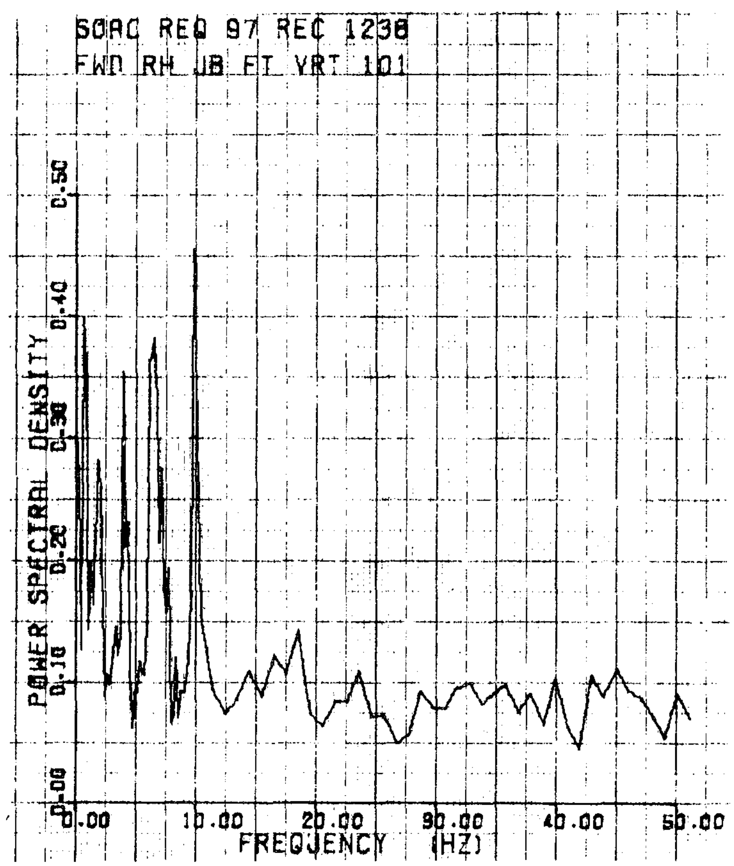




HIGH DENSITY CA
30 KLB 3/29/75
60 MPH TRK SEC I

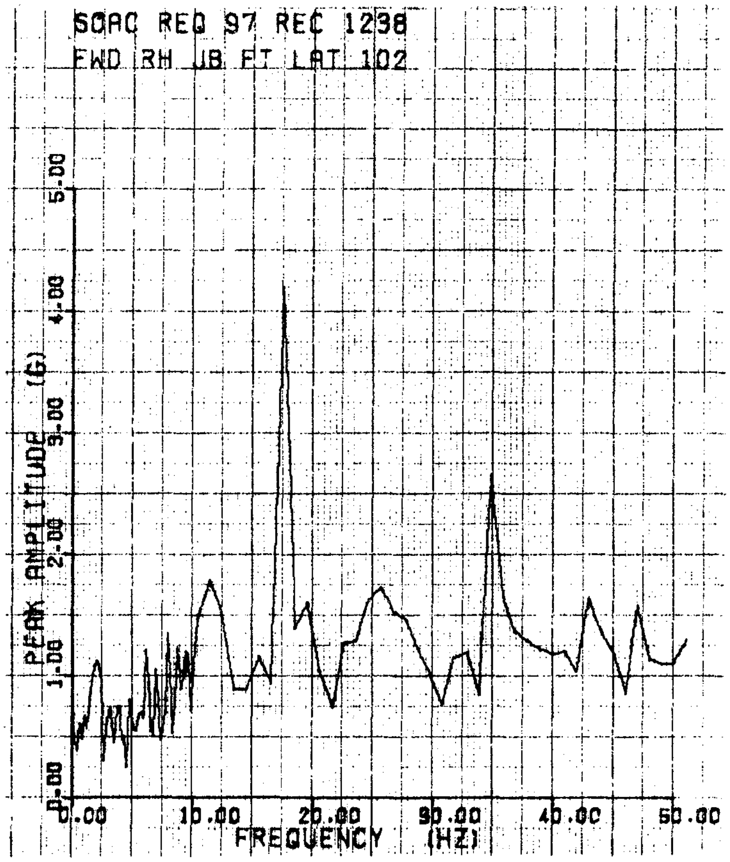
Figure B-72

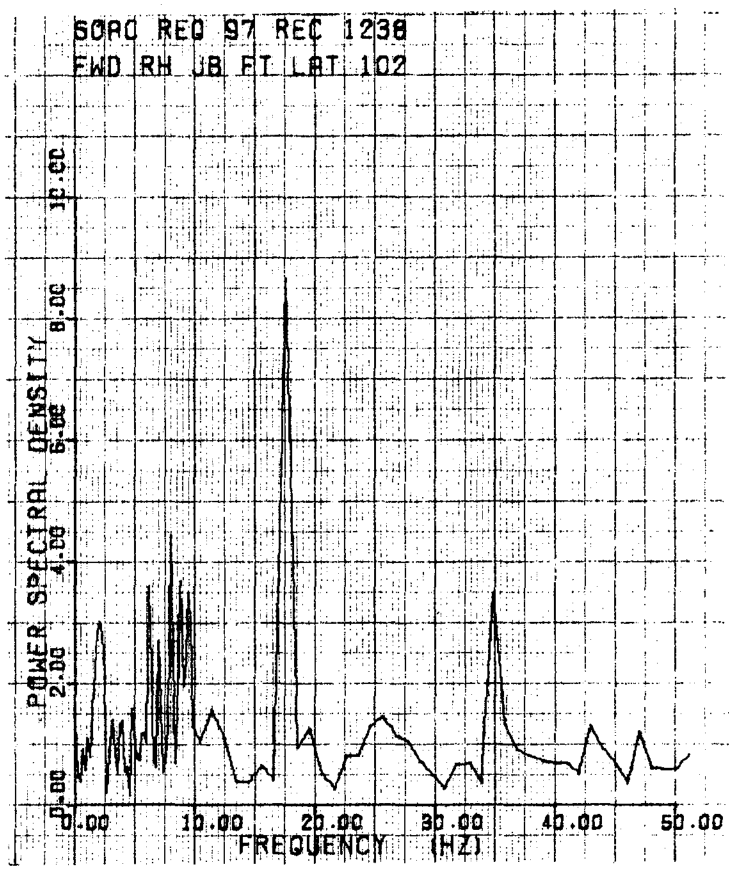




HIGH DENSITY CA?
90 KLB 3/29/74
94.4 MPH TRK SEC I

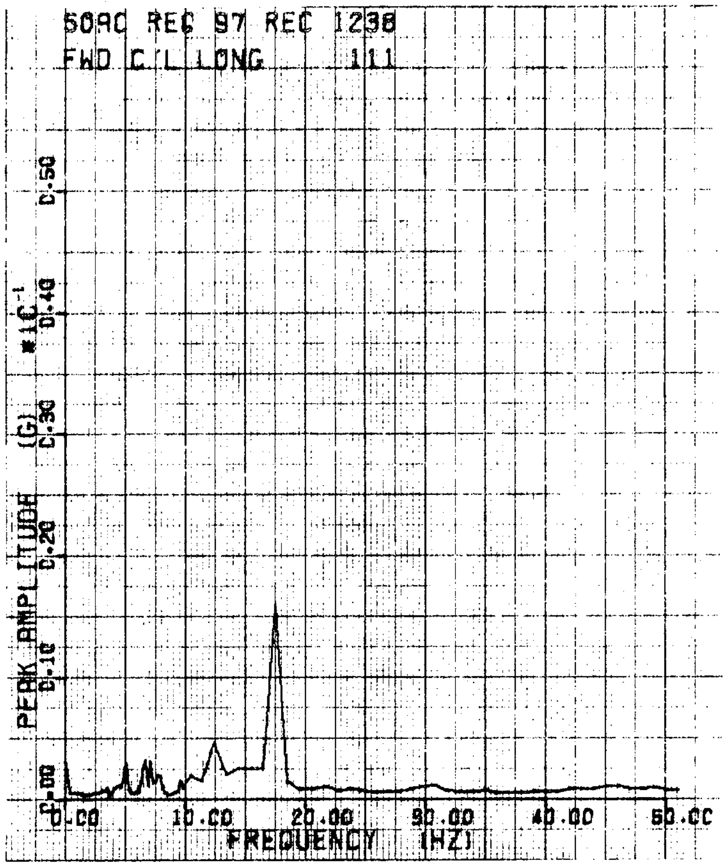
Figure B-73

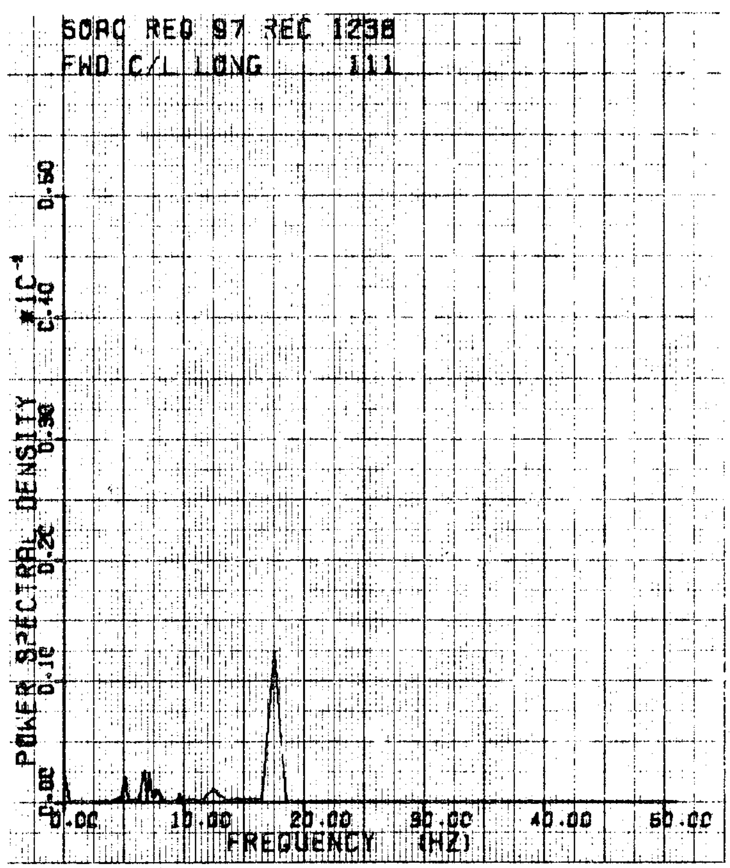




HIGH DENSITY CAR
90 KLB 3/29/74
94.4 MPH TRK SEC I

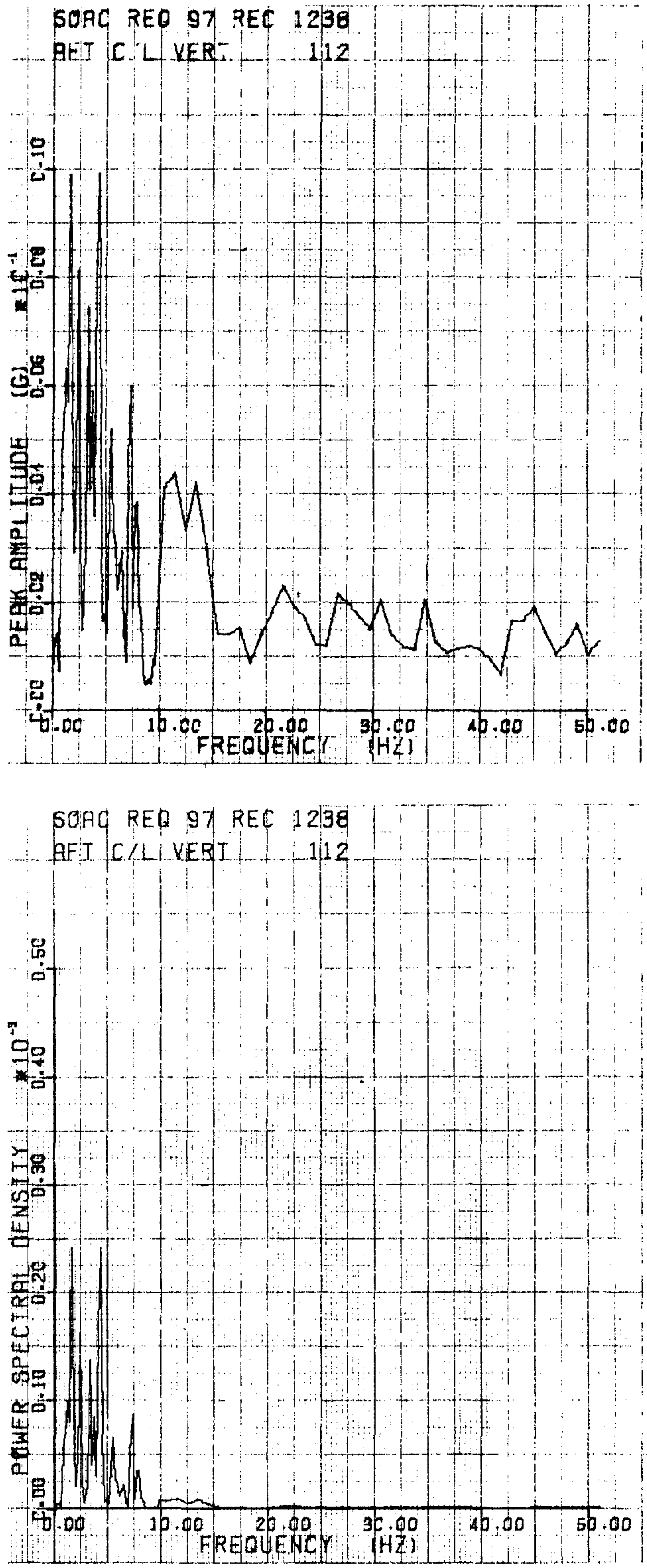
Figure B-74





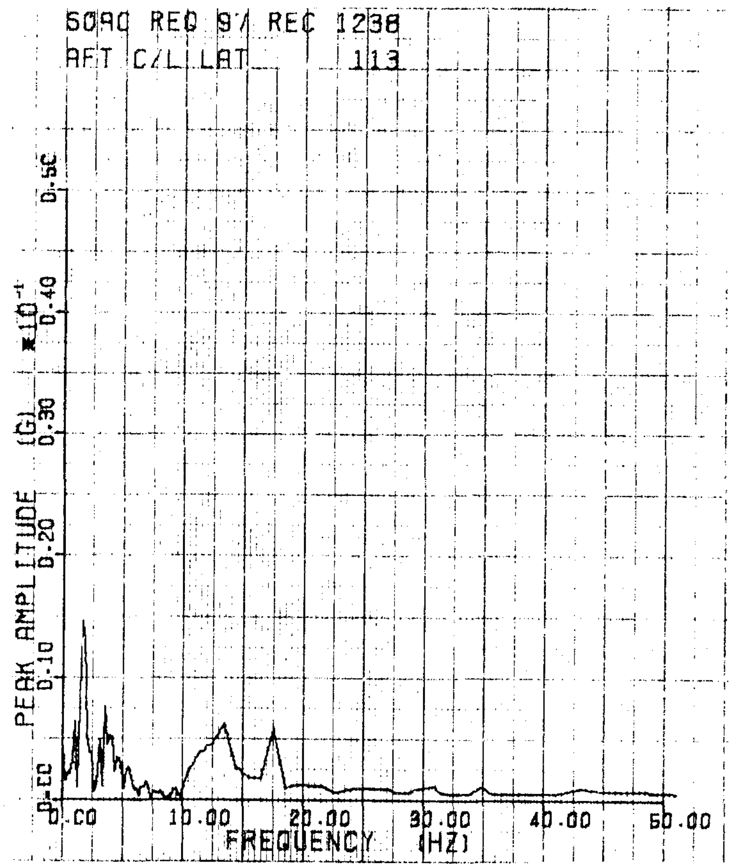
HIGH DENSITY CAR
90 KLB 3/29/74
94.4 MPH TRK SEC 1

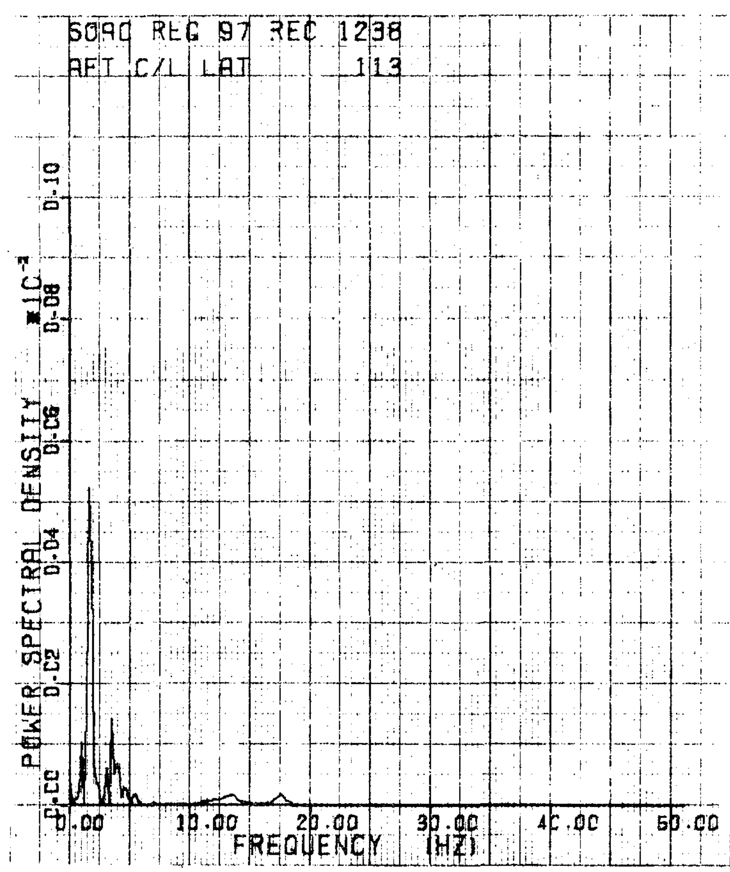
Figure B-75



HIGH DENSITY CAR
90 KLB 3/20/74
94.4 MPH TRK SEC 1

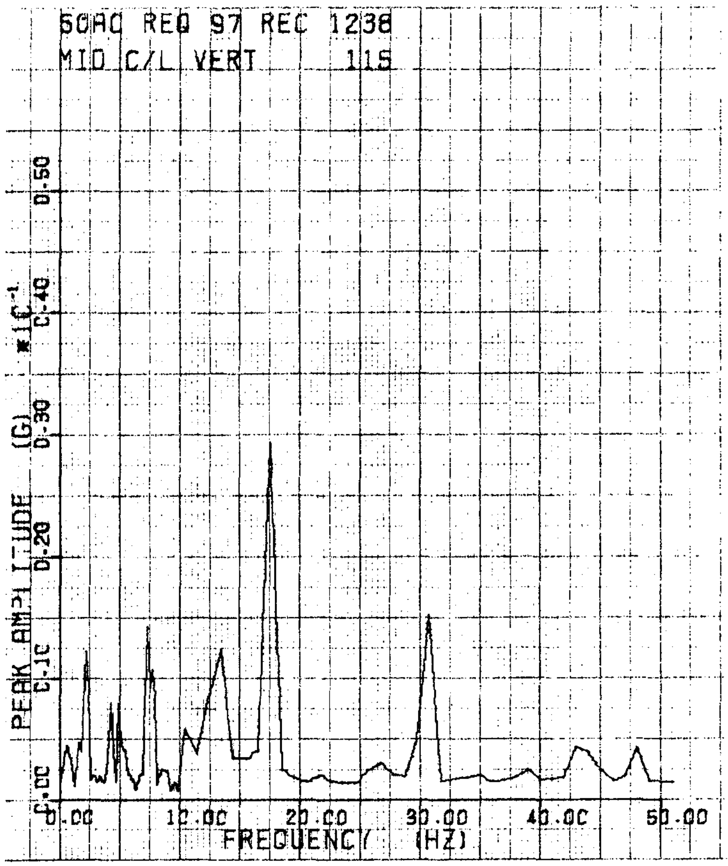
Figure B-76

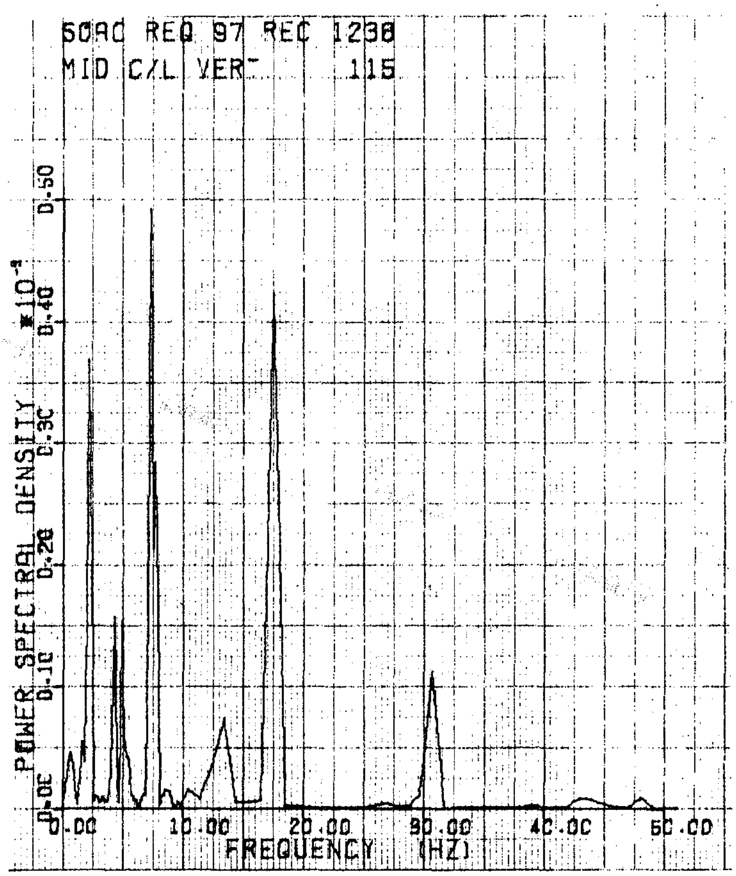




HIGH DENSITY CAR
90 KLB 5/29/74
34.4 MPH TRK SEC 1

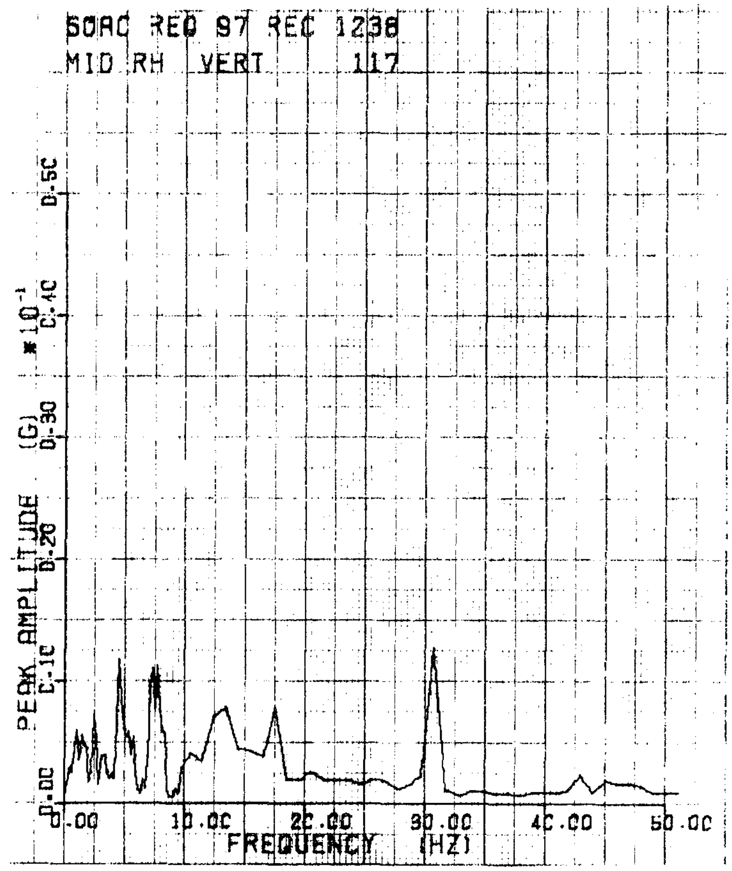
Figure B-77

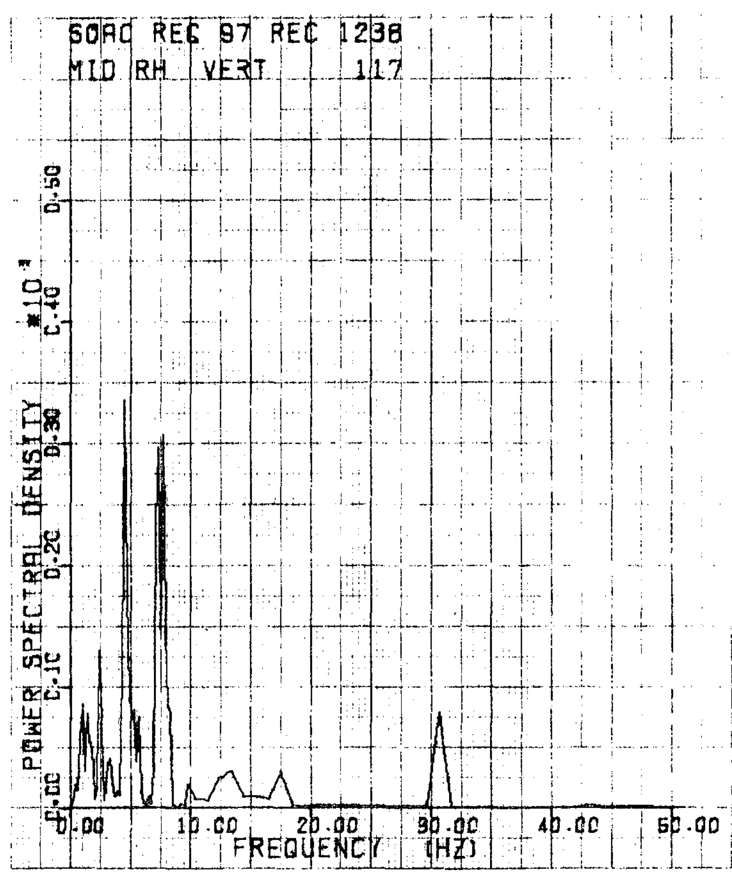




HIGH DENSITY CAR
90 KLB 3/29/74
94.4 MPH TRK SEC I

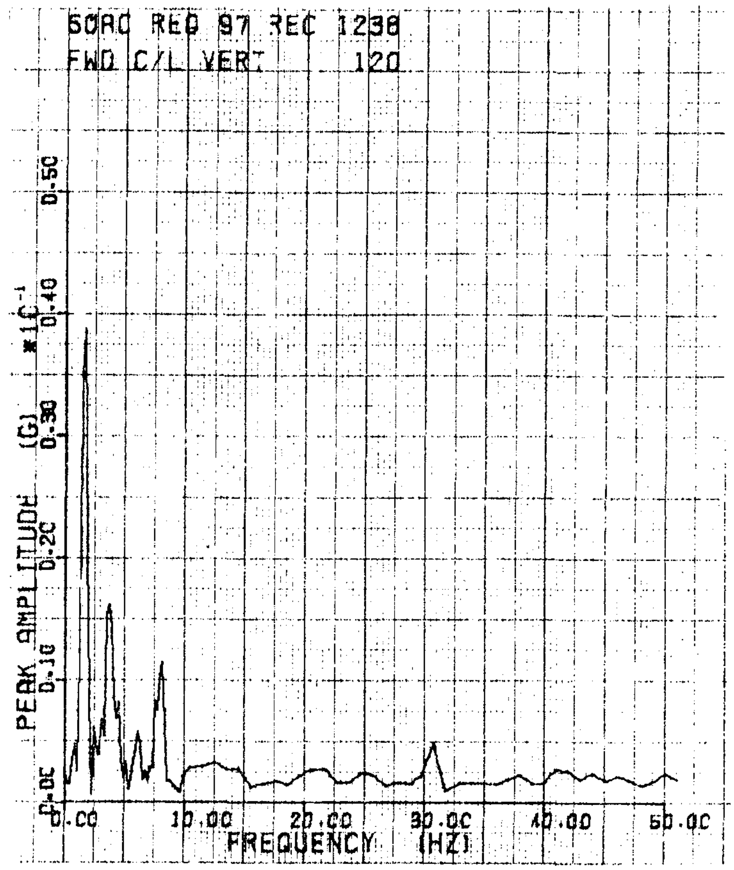
Figure B-78

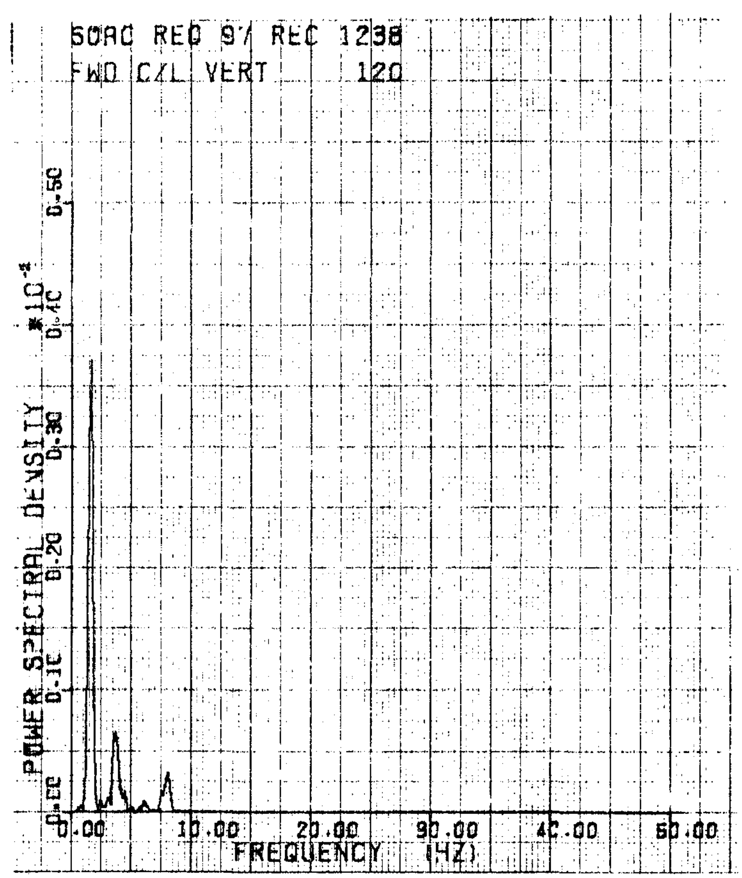




HIGH DENSITY CAR
90 KLB 3/29/74
94.4 MPH TRK SEC I

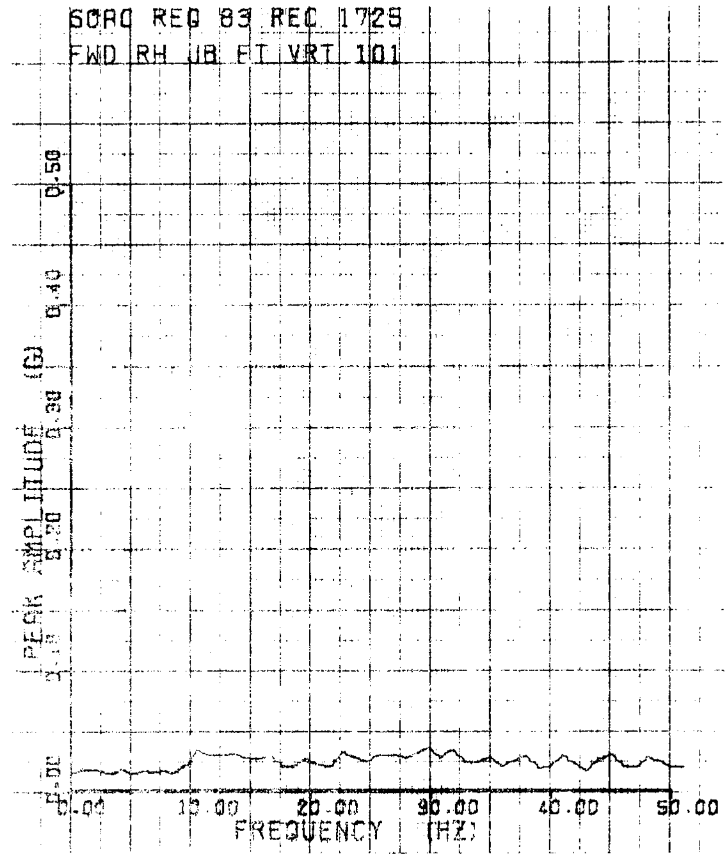
Figure B-79

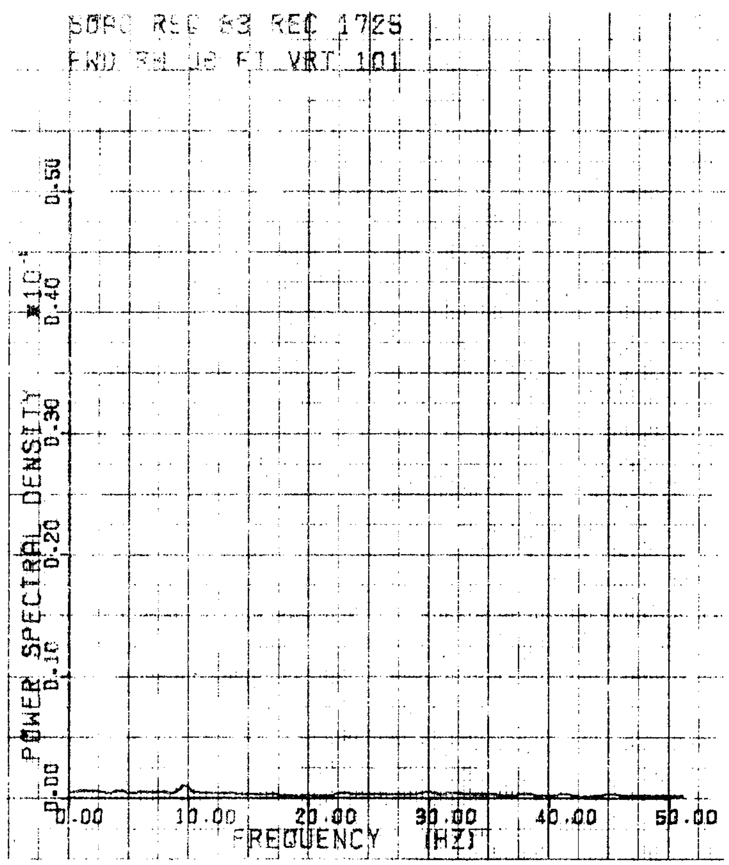




HIGH DENSITY CAR
00 KLB 3/29/74
04.4 MPH TRK SEC I

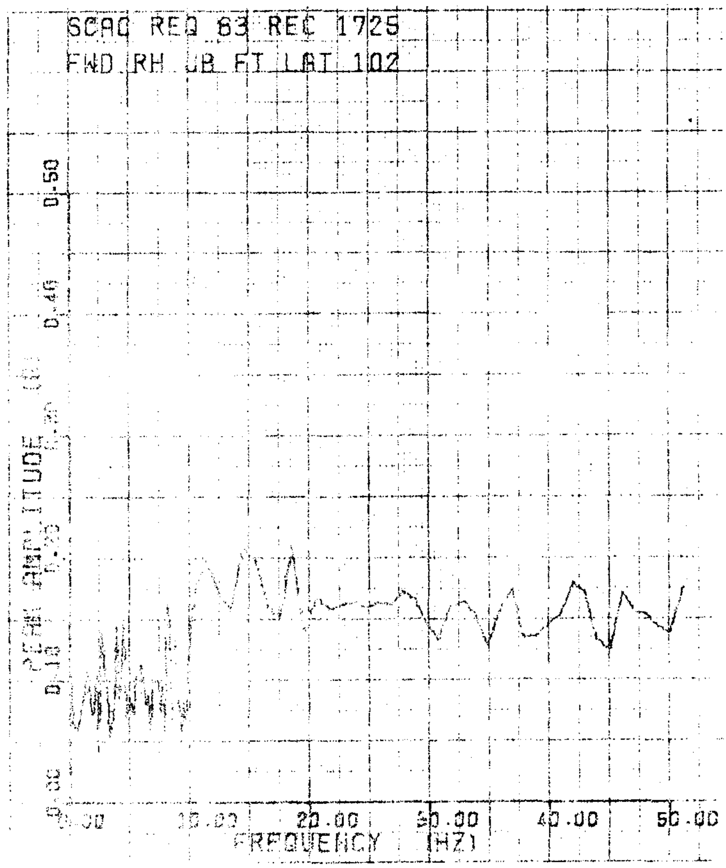
Figure B-80

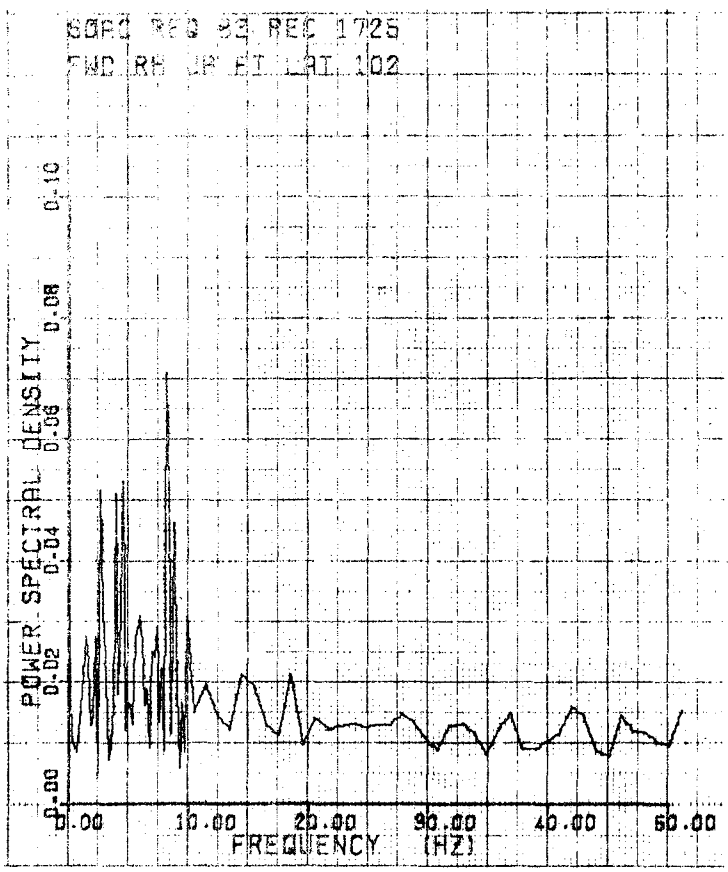




HIGH DENSITY CAR
105 KLB 3/20/74
20 MPH TRK SEC I

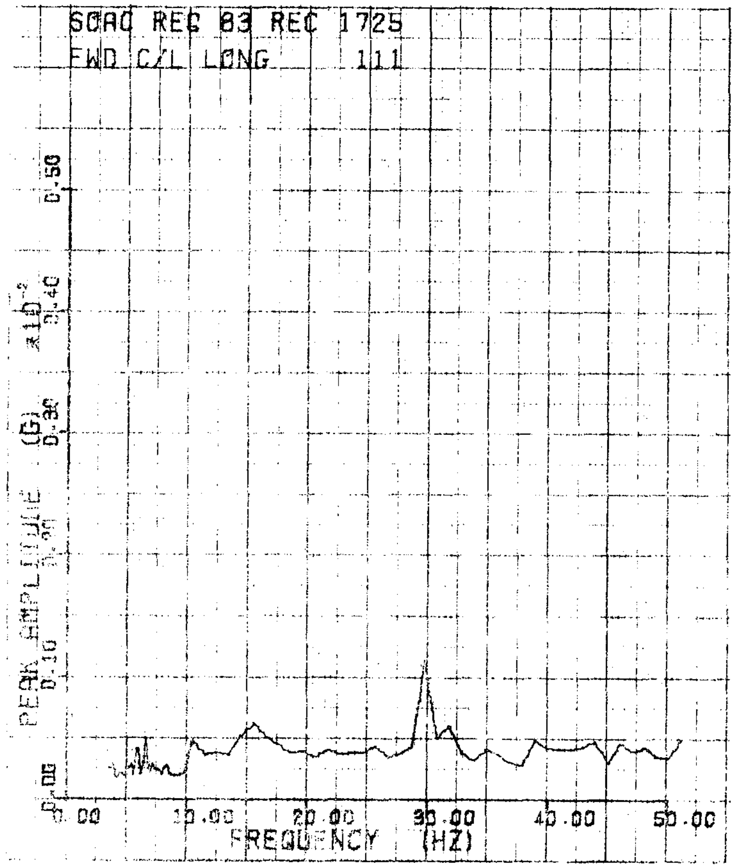
Figure B-81





HIGH DENSITY CAR
105 KLB 3/20/74
20 MPH TRK SEC 1

Figure B-82



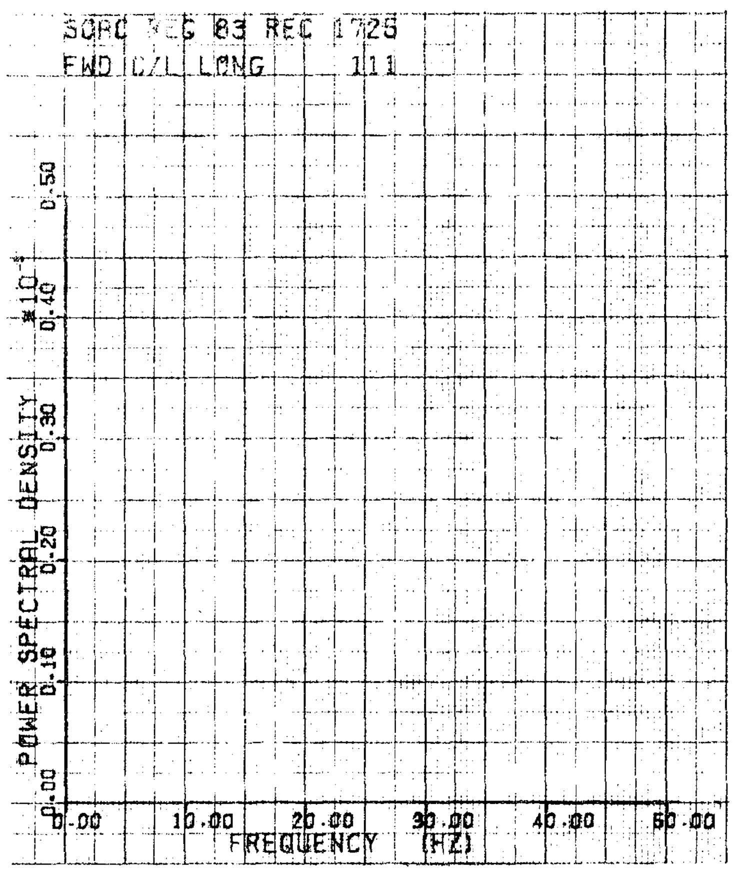
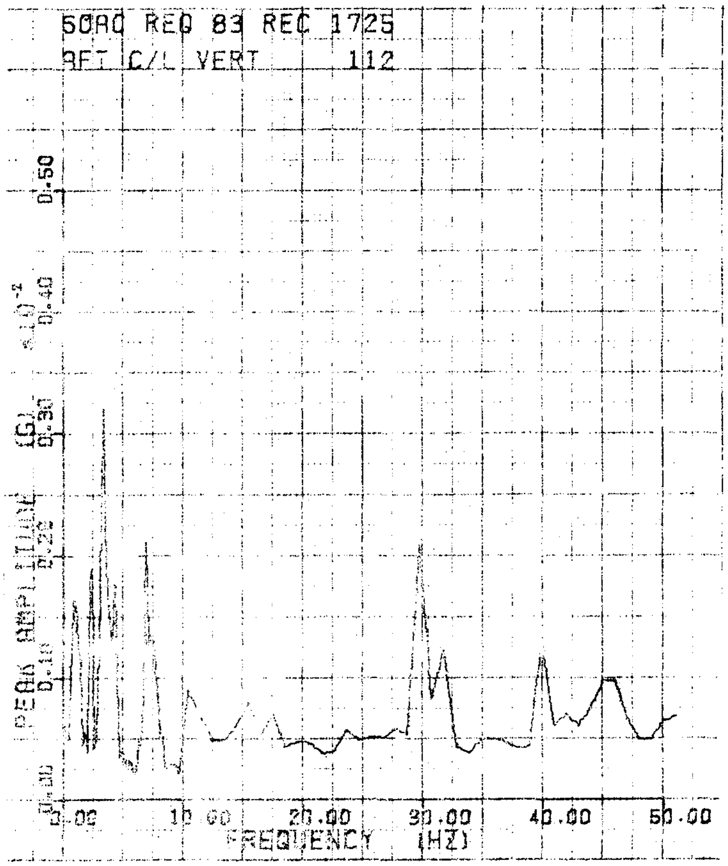
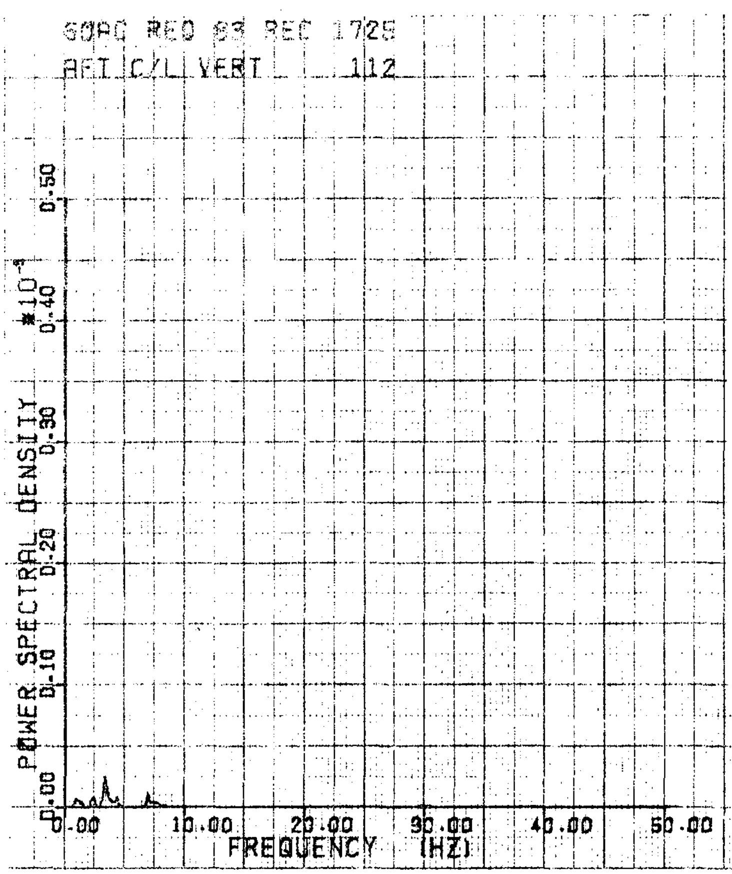


Figure B-83

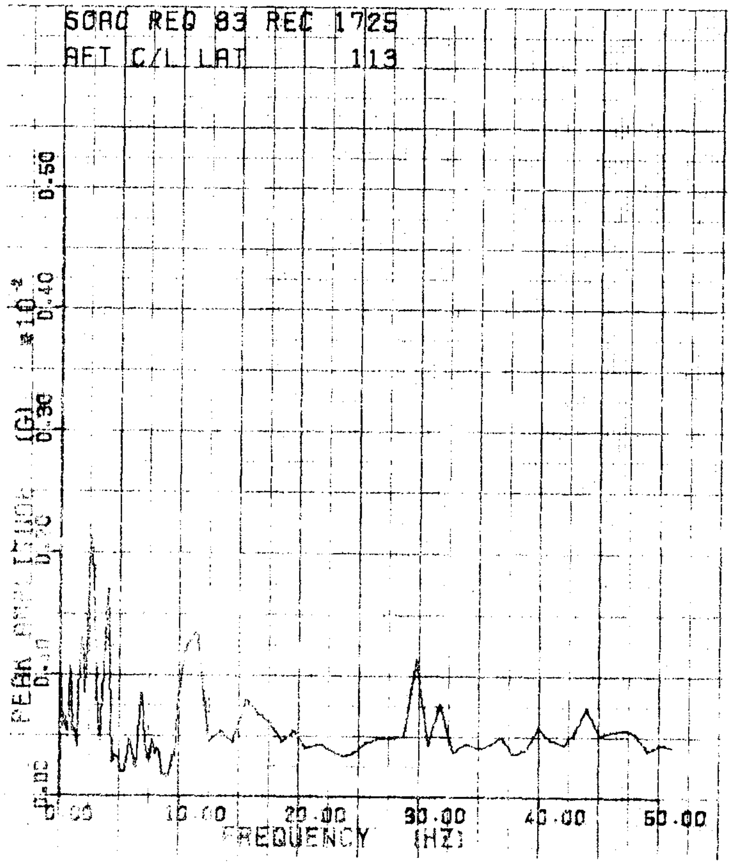
HIGH DENSITY CAR
20 MPH TRK SEC I





HIGH DENSITY CAR
105 KLB 3/20/74
20 MPH TRK SEC I

Figure B-84



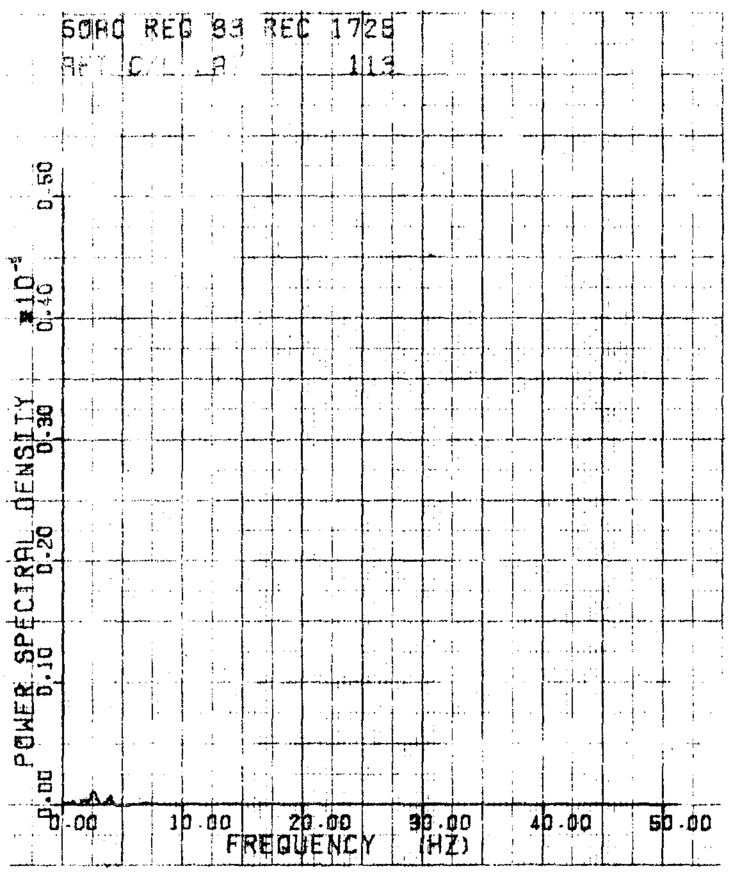
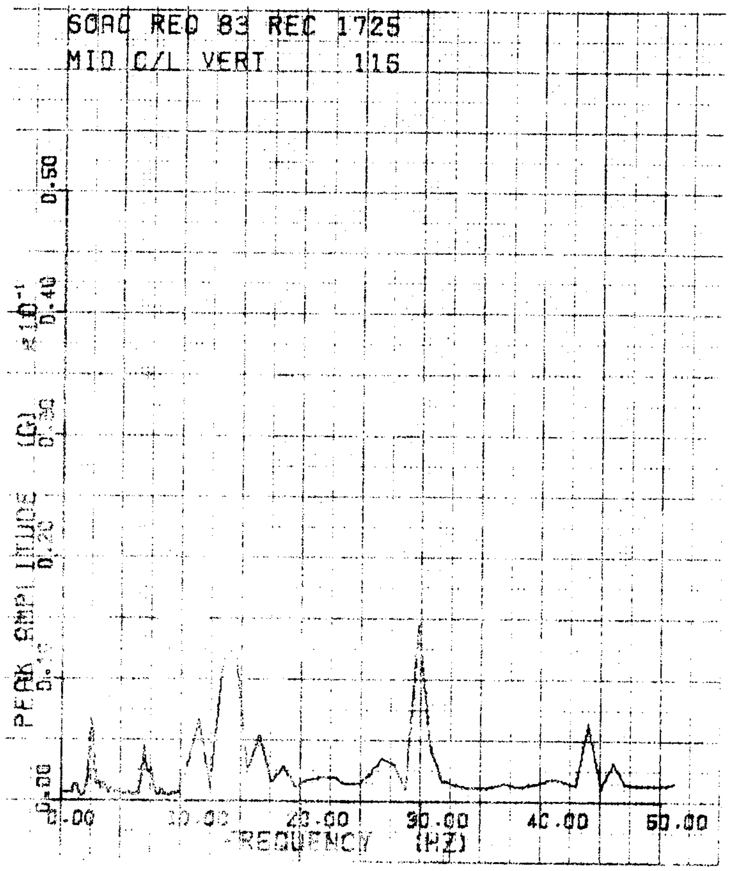


Figure B-85

HIGH DENSITY CAR
105 KLB 3/20/74
20 MPH TRK SEC 1



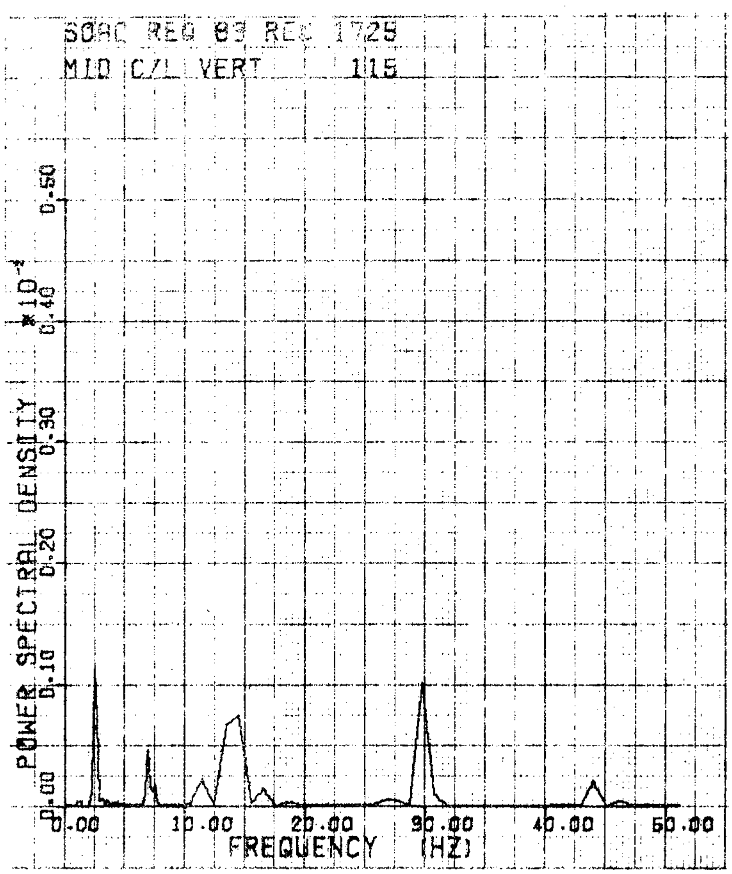
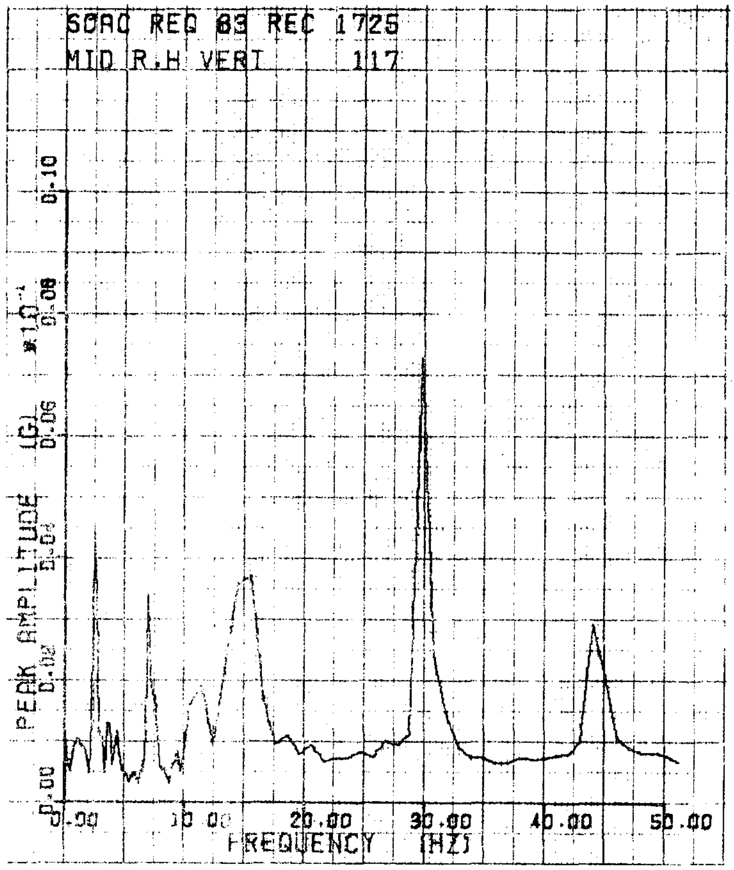
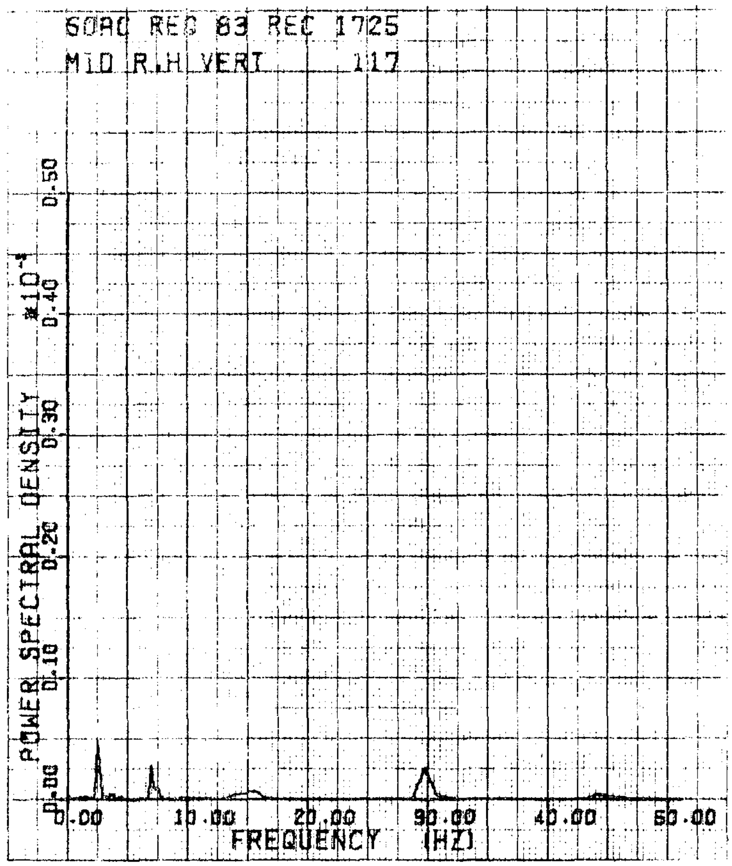


Figure B-86

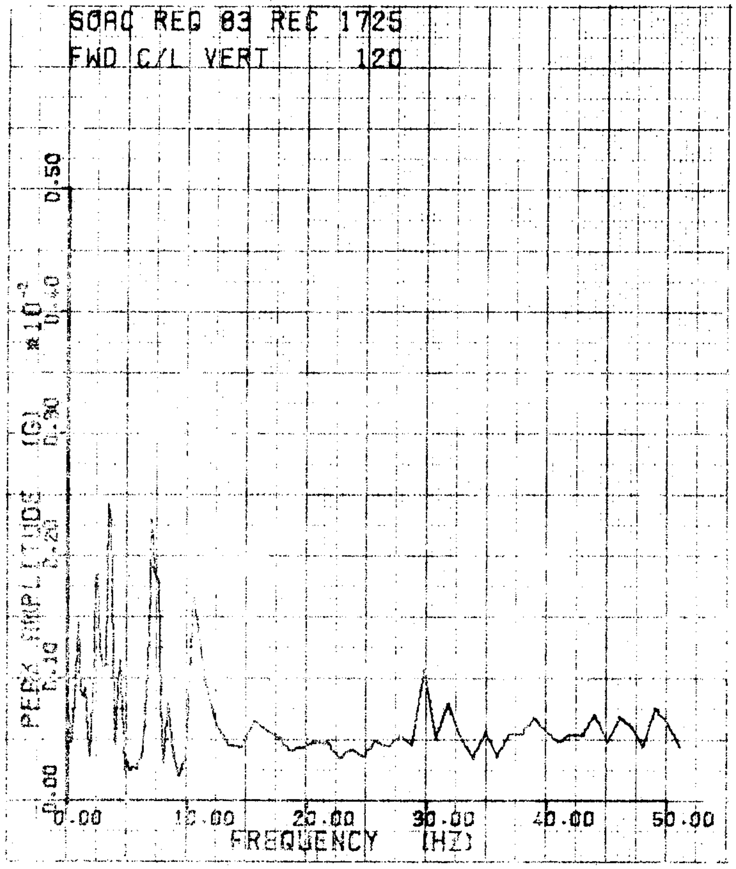
HIGH DENSITY CAR
105 KLB 3/20/74
20 MPH TRK SEC I

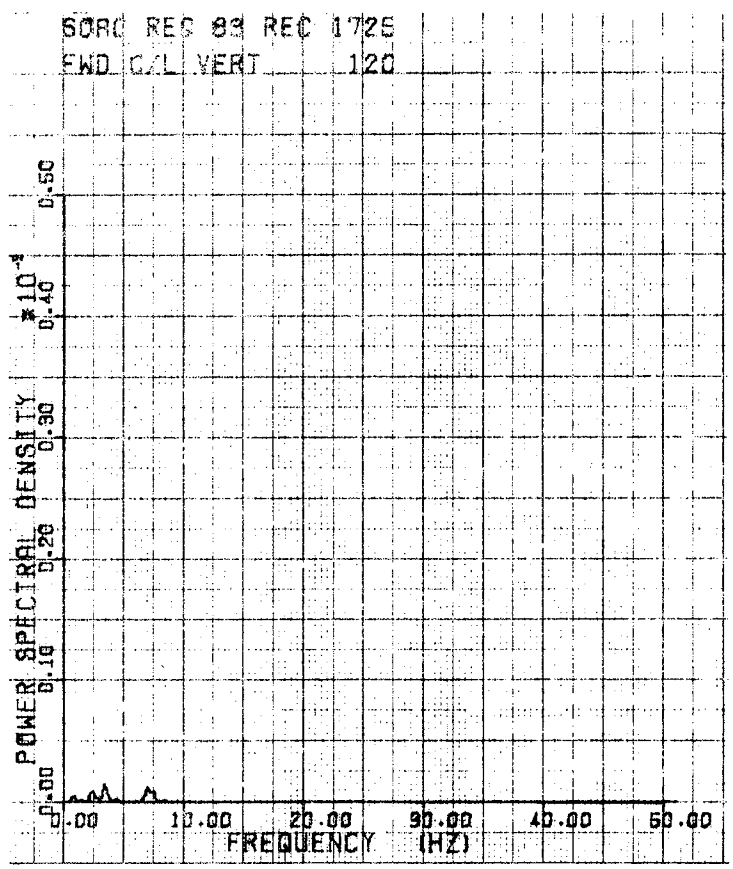




HIGH DENSITY CAR
105 KLB 3/20/74
20 MPH TRK SEC I

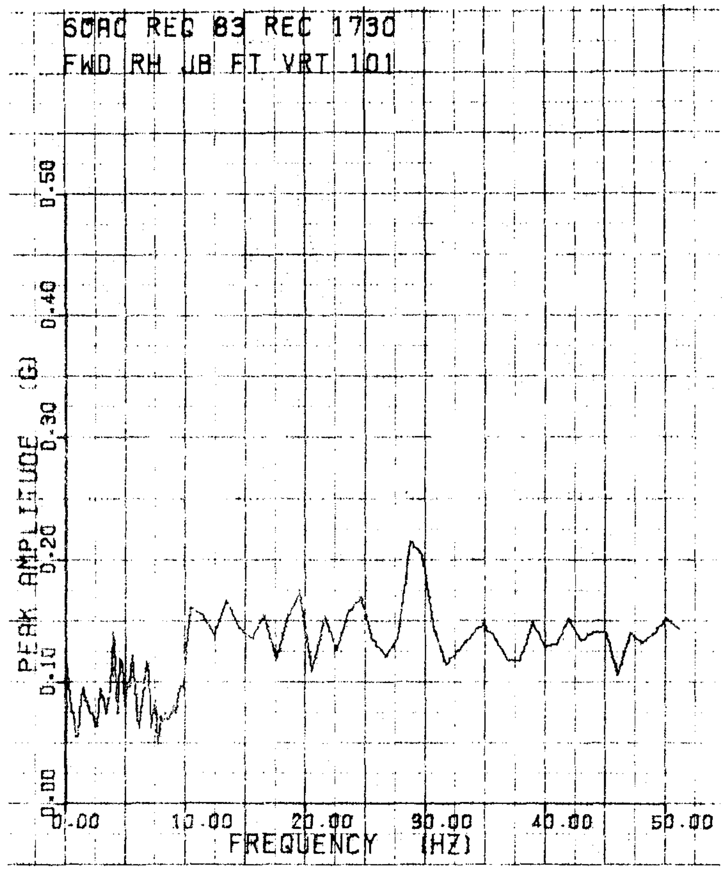
Figure B-87

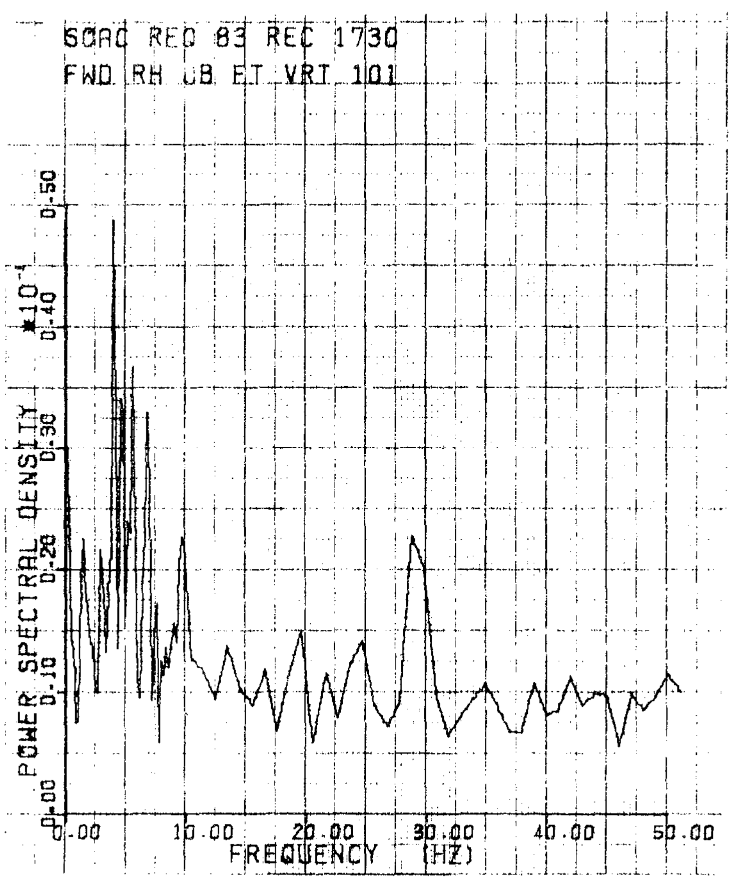




HIGH DENSITY CAR
105 KLB 3/20/74
20 MPH TRK SEC I

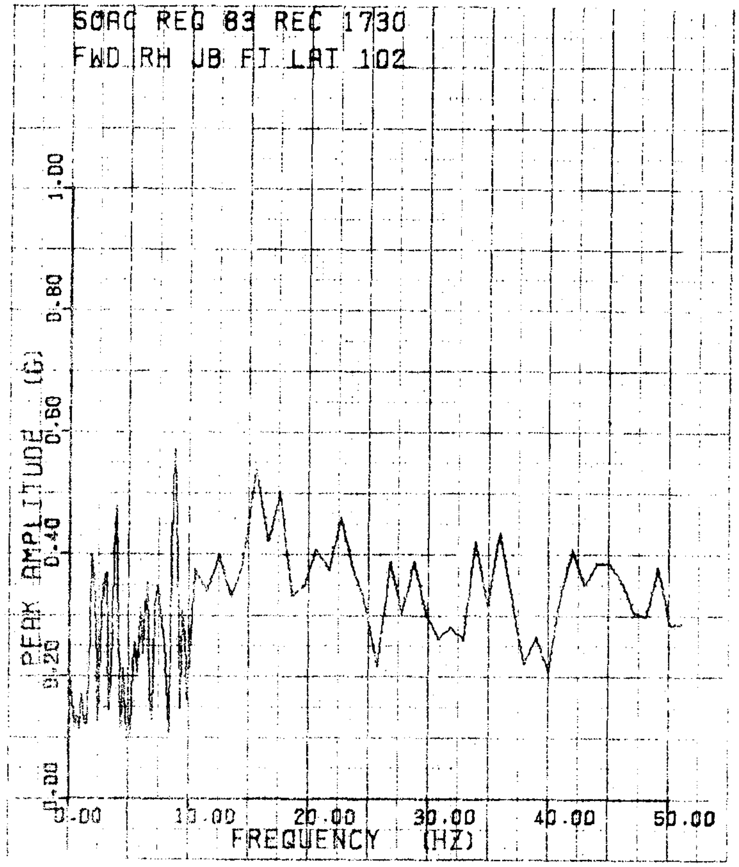
Figure B-88

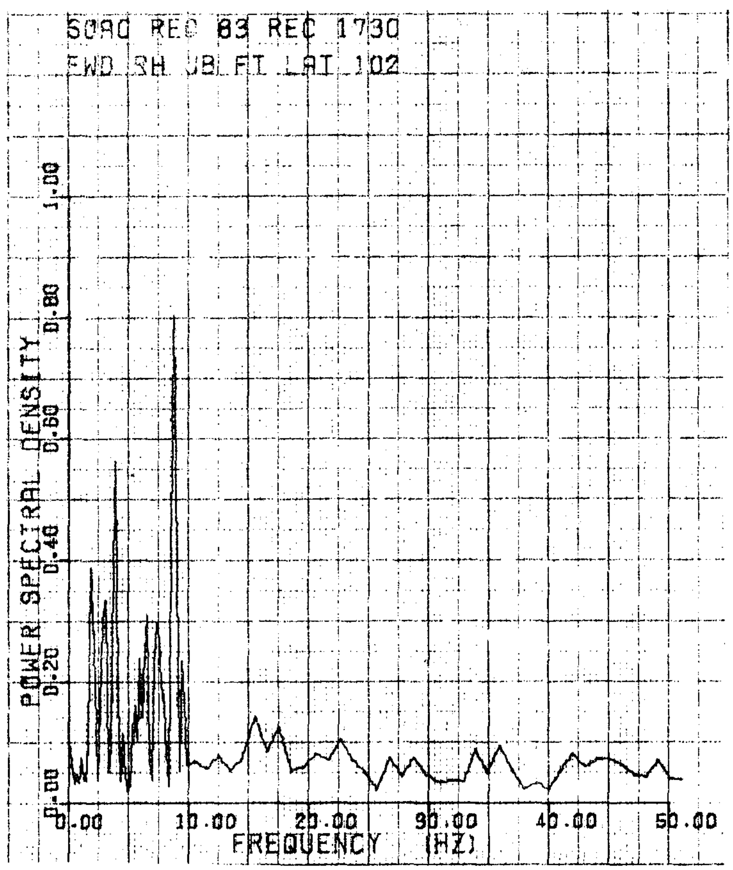




HIGH DENSITY CAR
105 KLB 3/20/74
35 MPH TRK SEC I

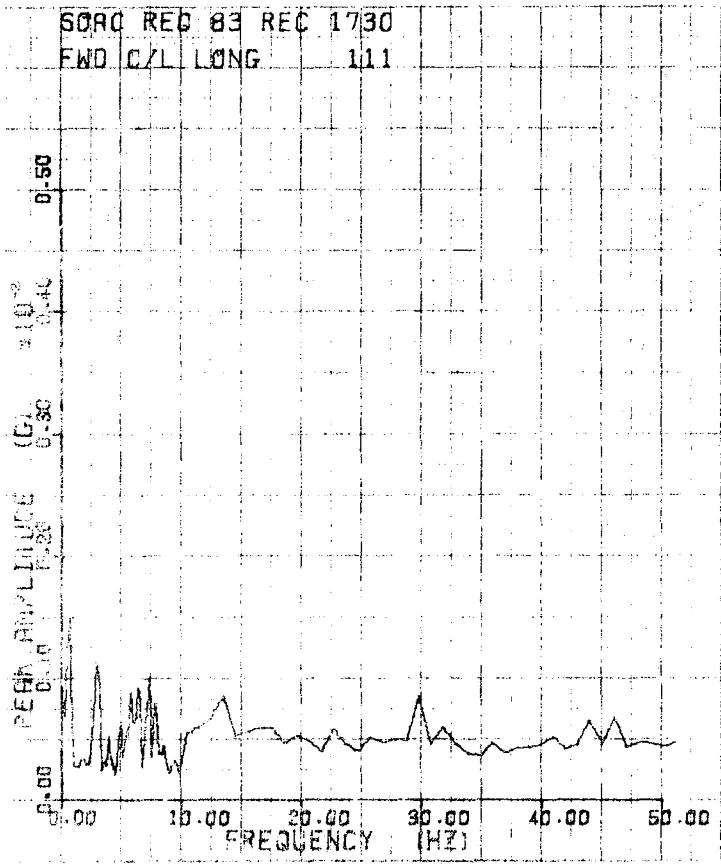
Figure B-89

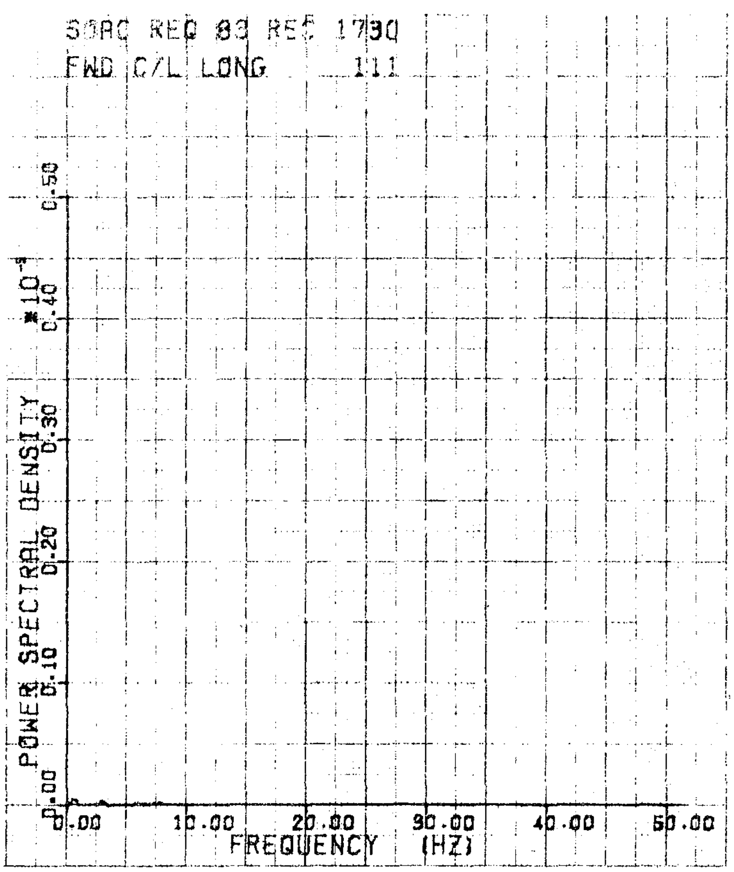




HIGH DENSITY CAR
105 KLB 3/20/74
35 MPH TRK SEC 1

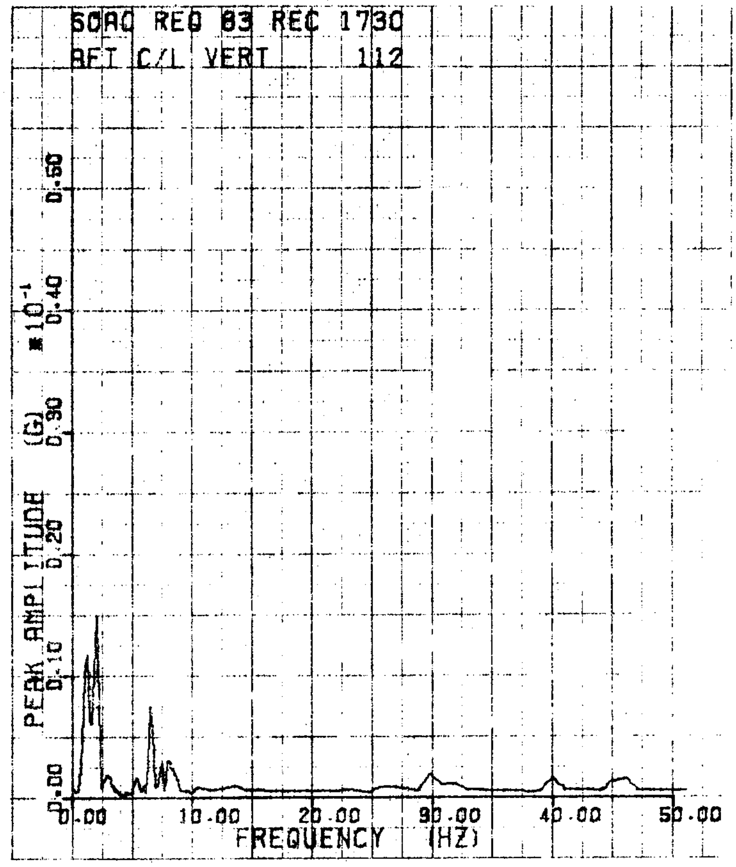
Figure B-90

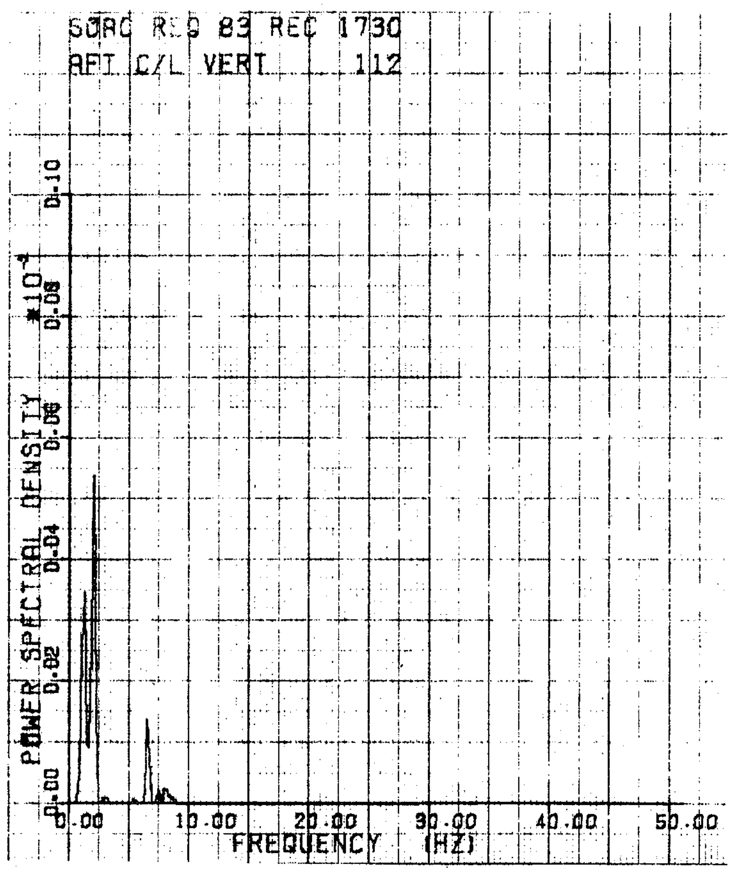




HIGH DENSITY CAR
105 KLB 3/20/74
35 MPH TRK SEC 1

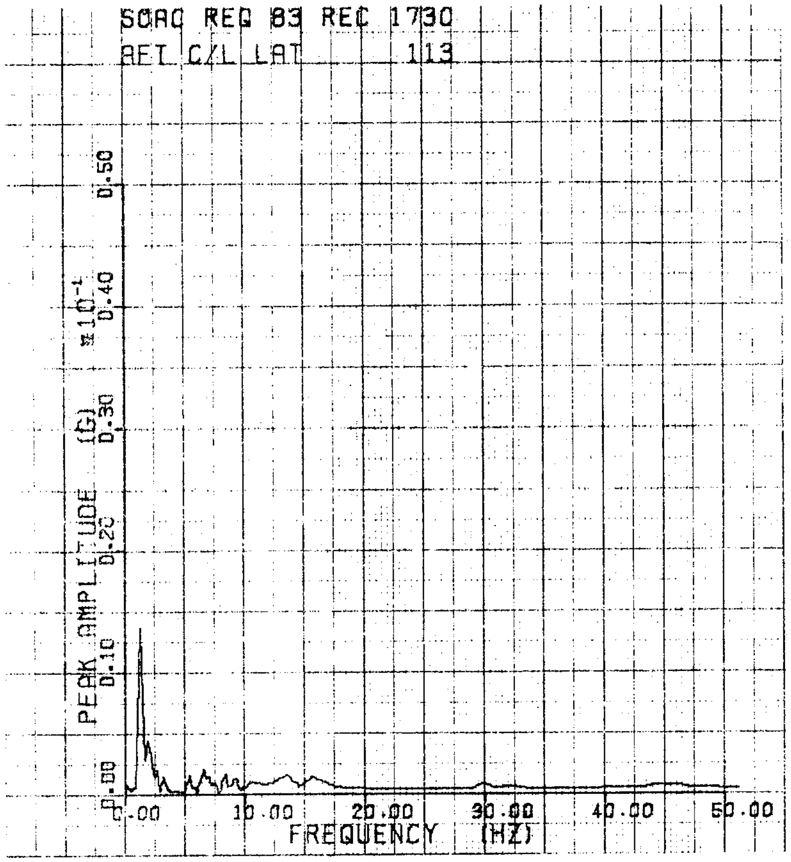
Figure B-91

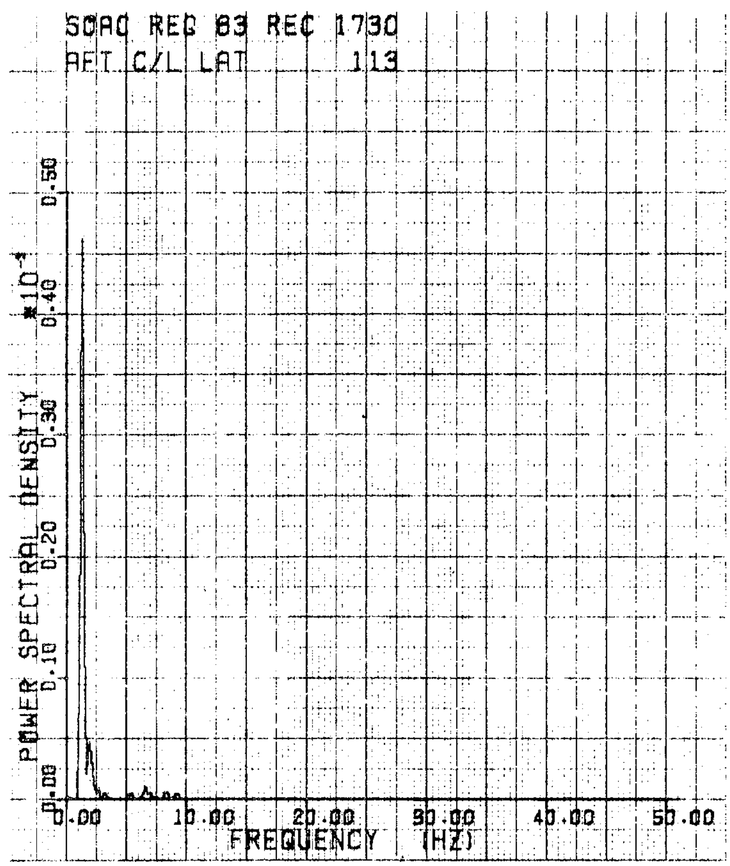




HIGH DENSITY CAR
105 KLB 3/20/74
35 MPH TRK SEC I

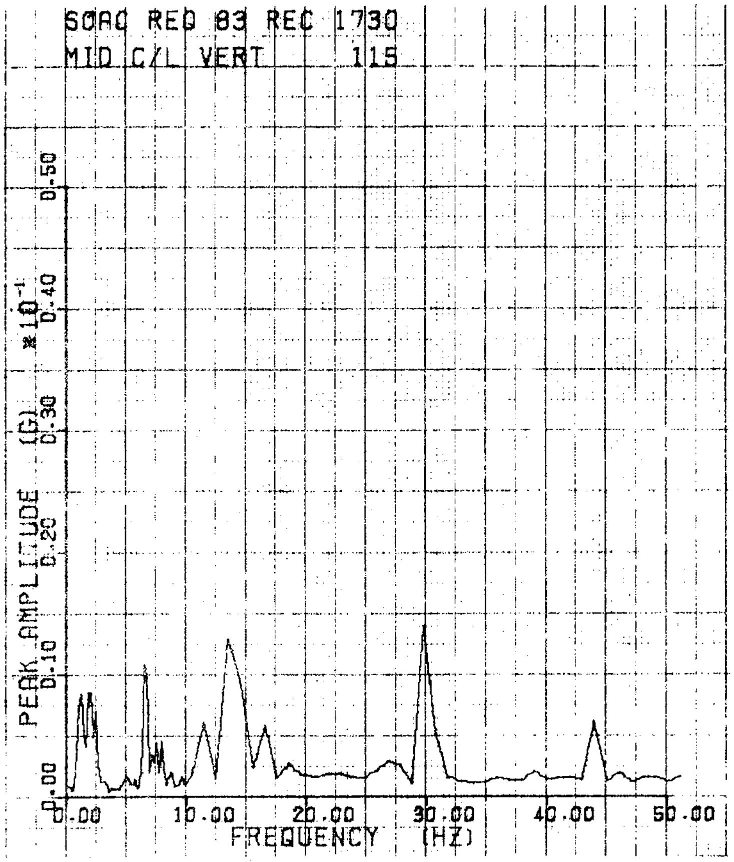
Figure B-92

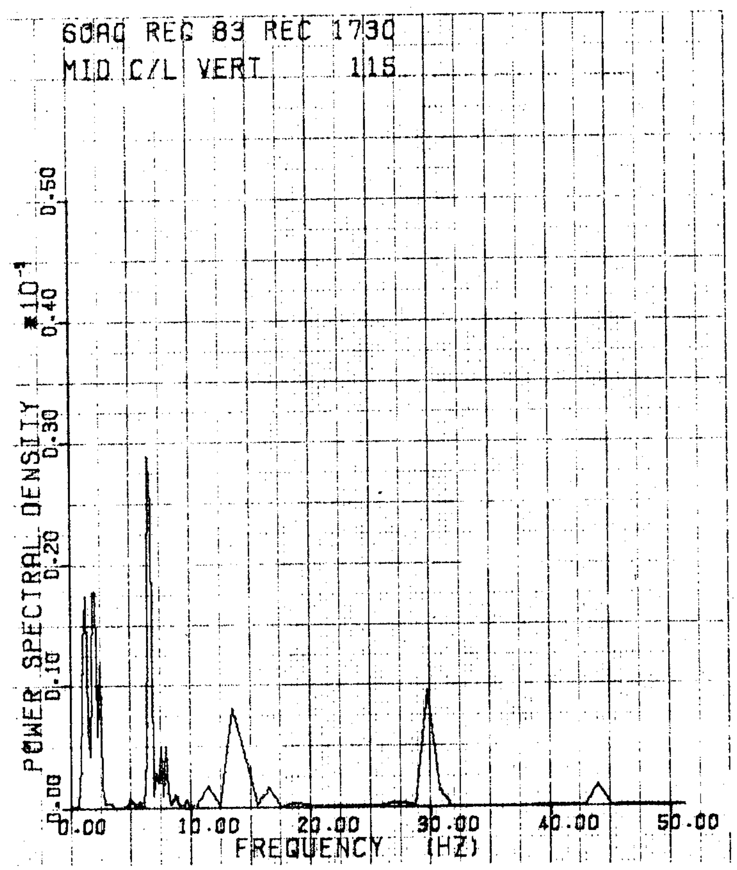




HIGH DENSITY CAR
105 KLB 3/20/74
35 MPH TRK SEC I

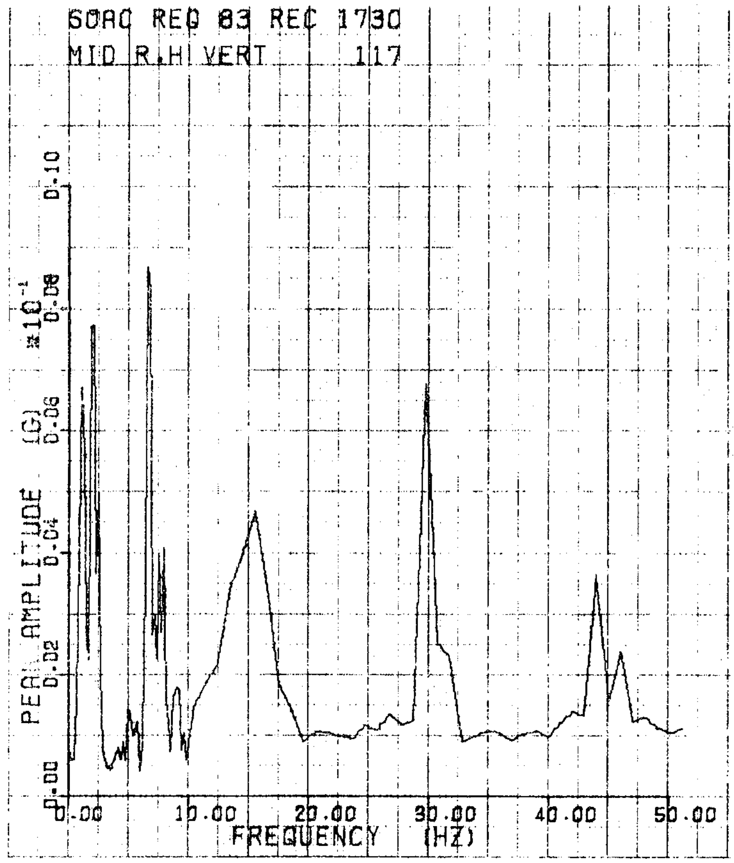
Figure B-93

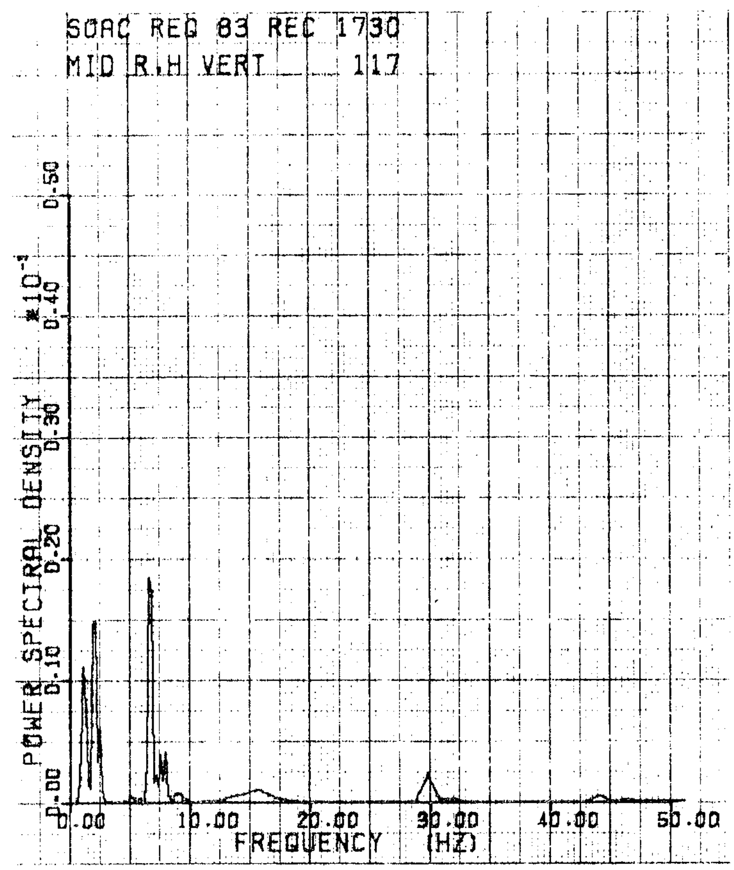




HIGH DENSITY CAR
105 KLB 3/20/74
35 MPH TPK SEC 1

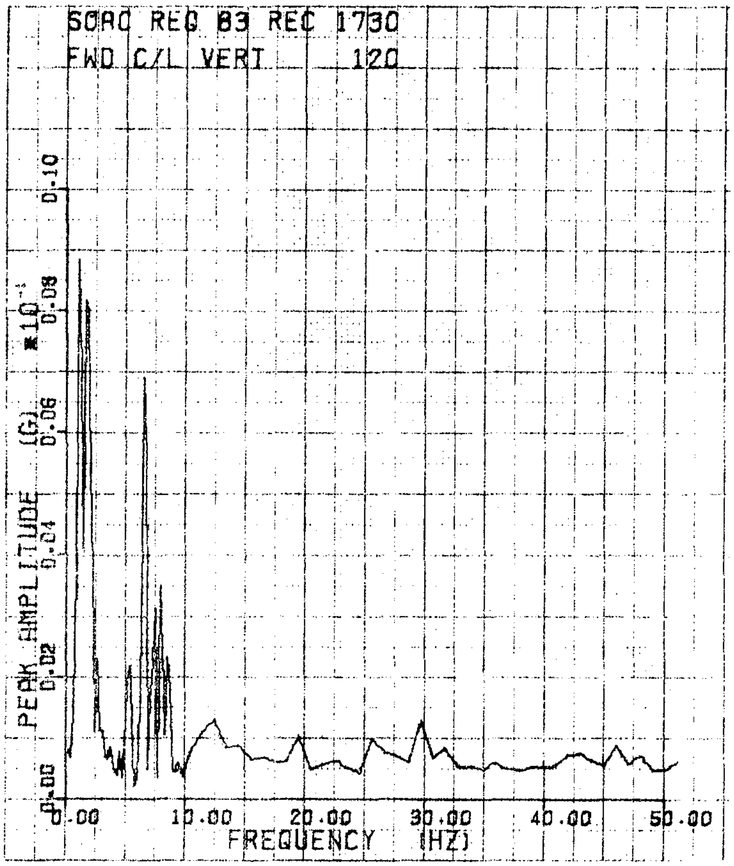
Figure B-94

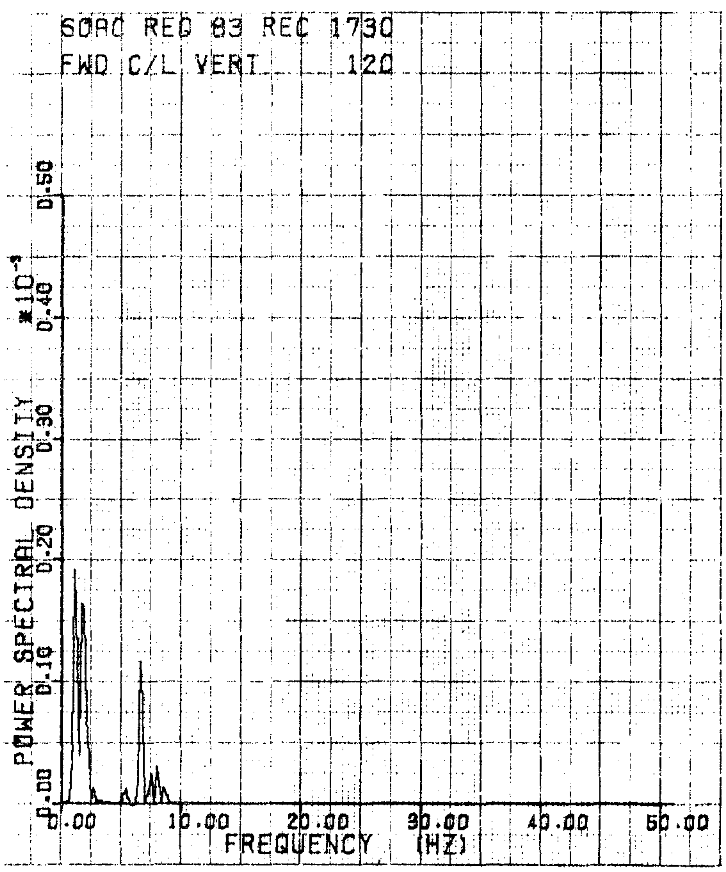




HIGH DENSITY CAR
105 KLB 3/20/74
35 MPH TRK SEC 1

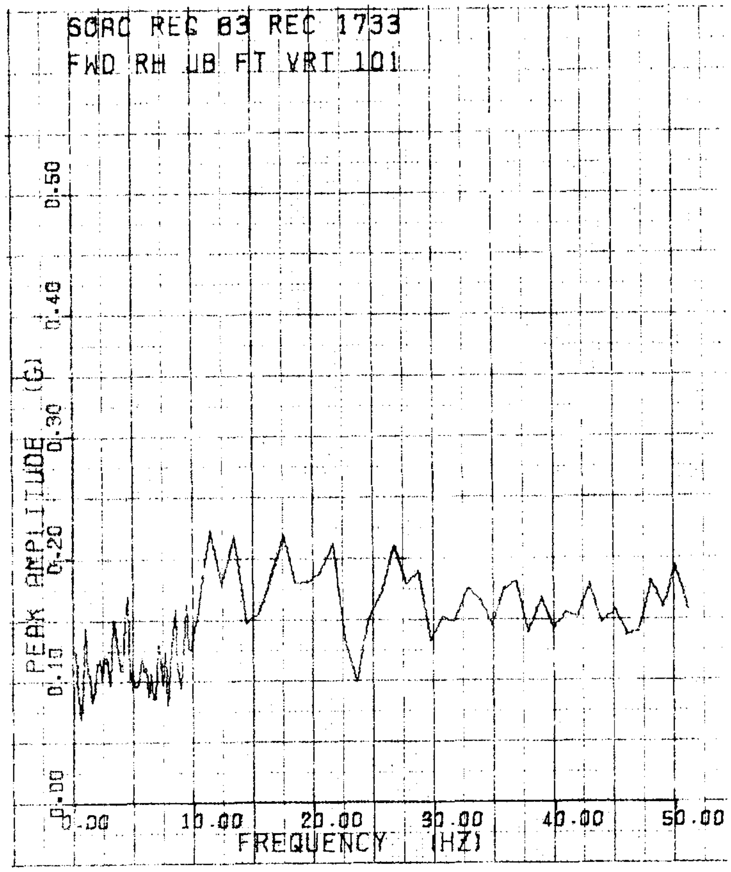
Figure B-95

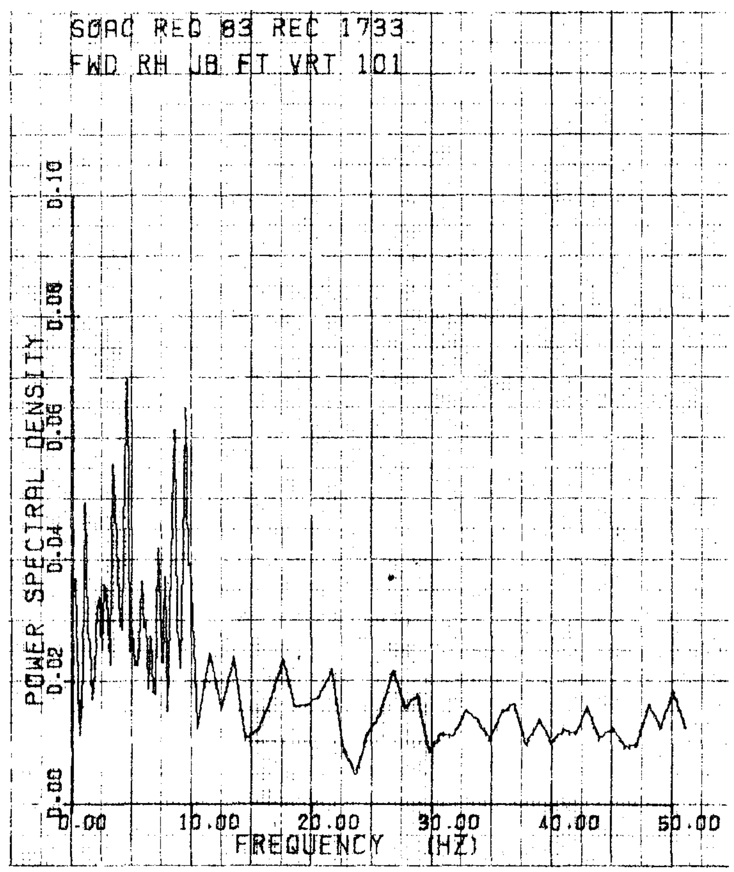




HIGH DENSITY CAR
105 KLB 3/20/74
35 MPH TRK SEC I

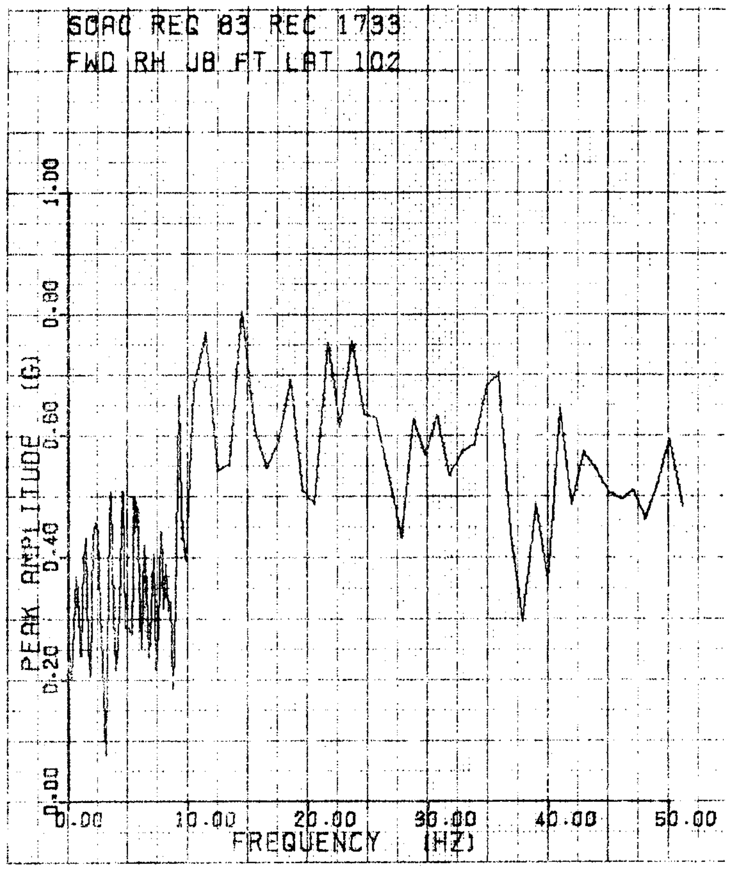
Figure B-96

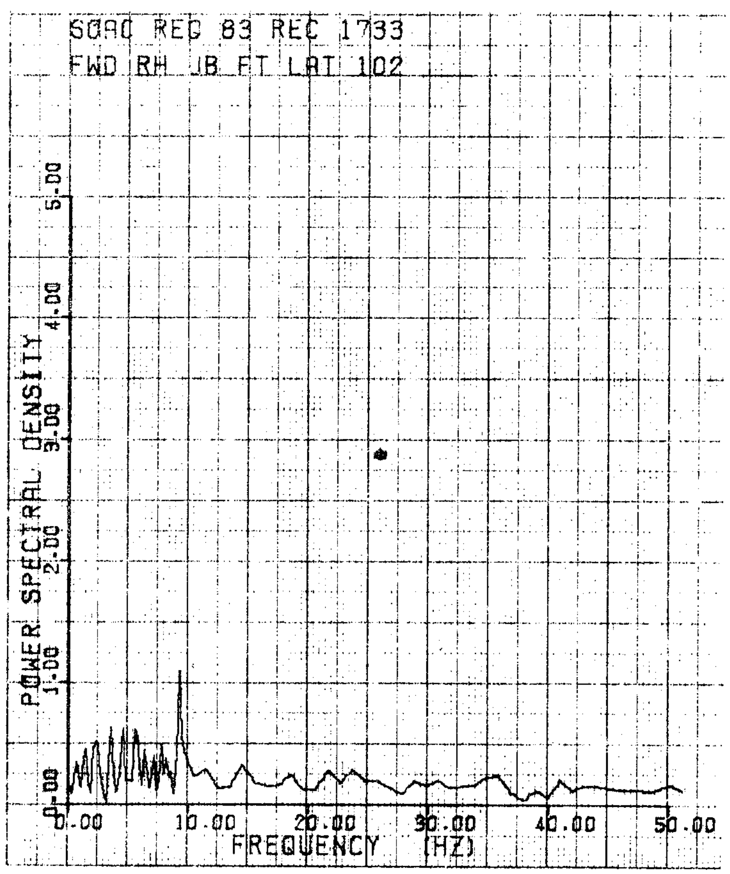




HIGH DENSITY CAR
105 KLB 3/20/74
45 MPH TRK SEC I

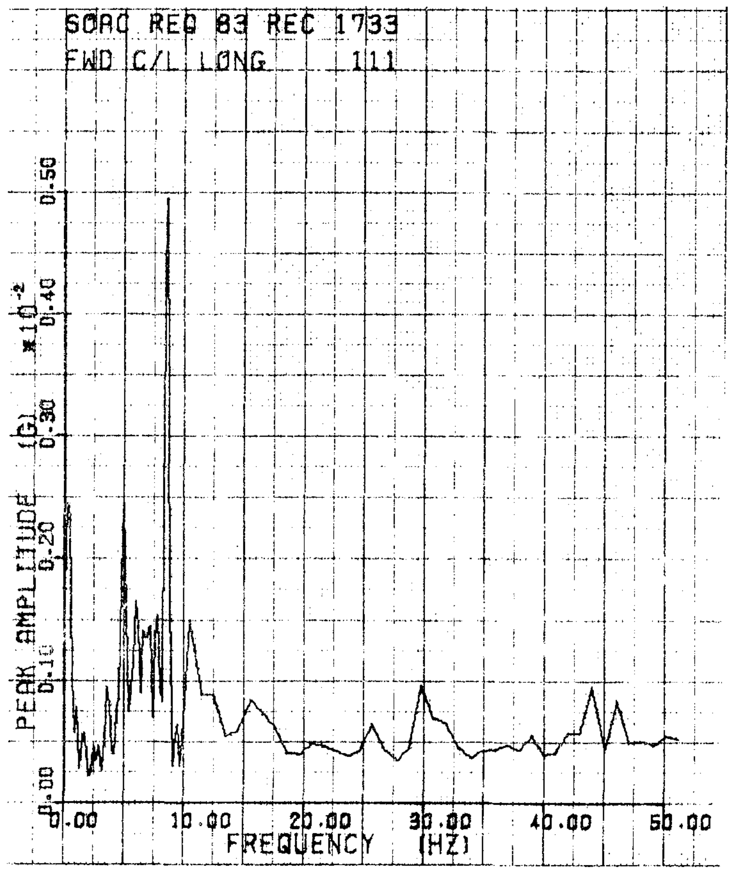
Figure B-97

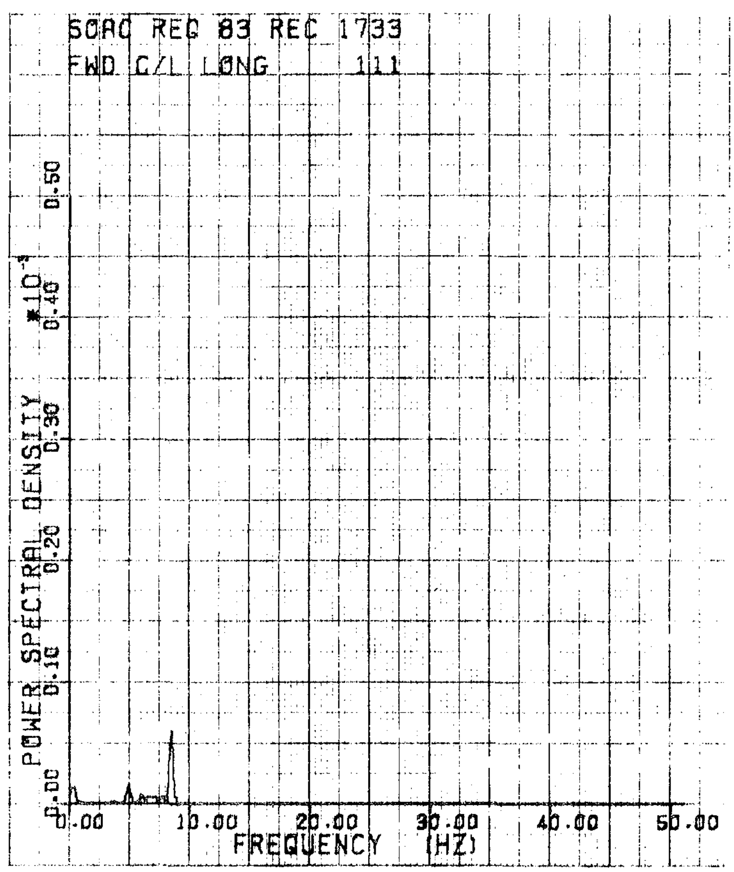




HIGH DENSITY CAR
105 KLB 3/20/74
45 MPH TRK SEC I

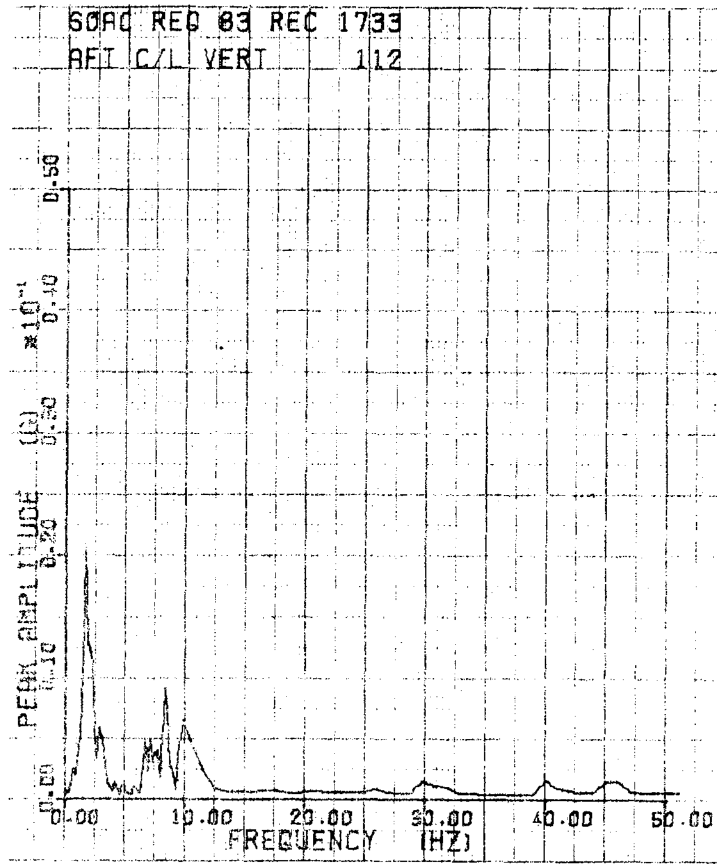
Figure B-98

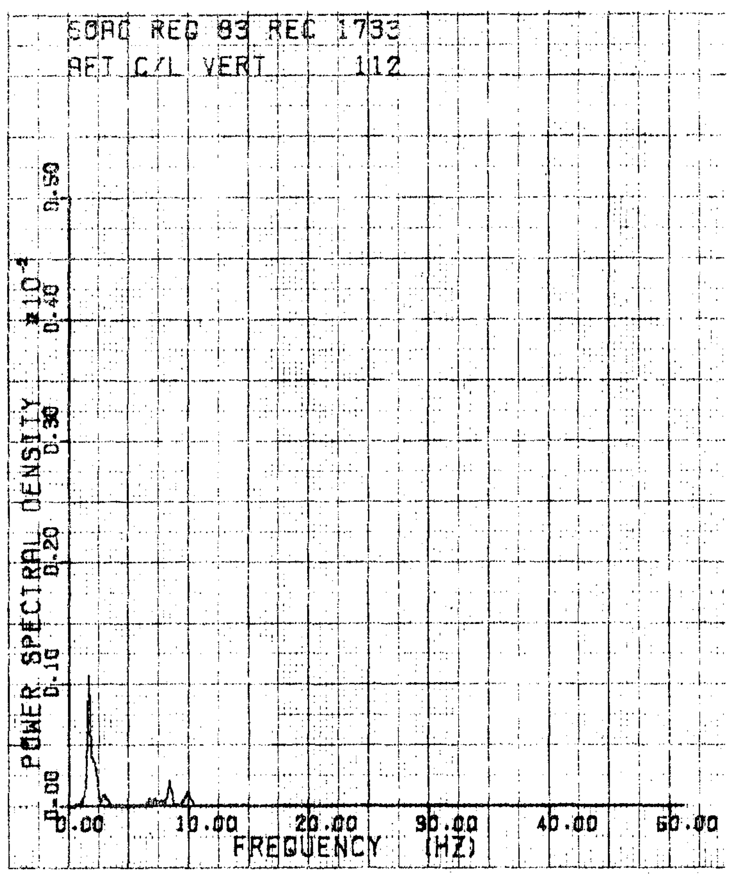




HIGH DENSITY CAR
105 KLB 3/20/74
45 MPH TRK SEC 1

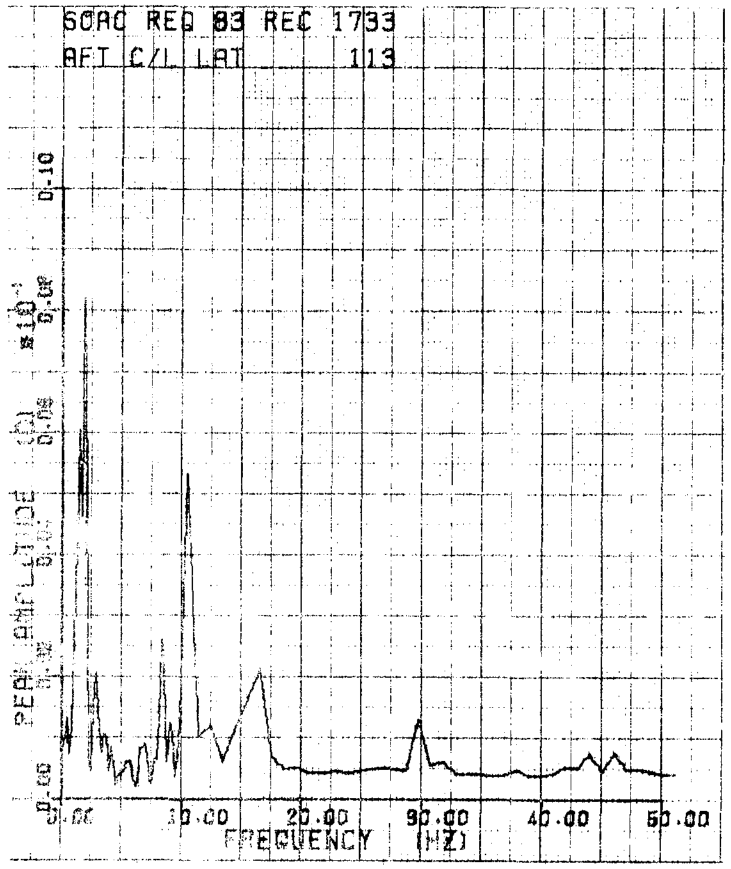
Figure B-99

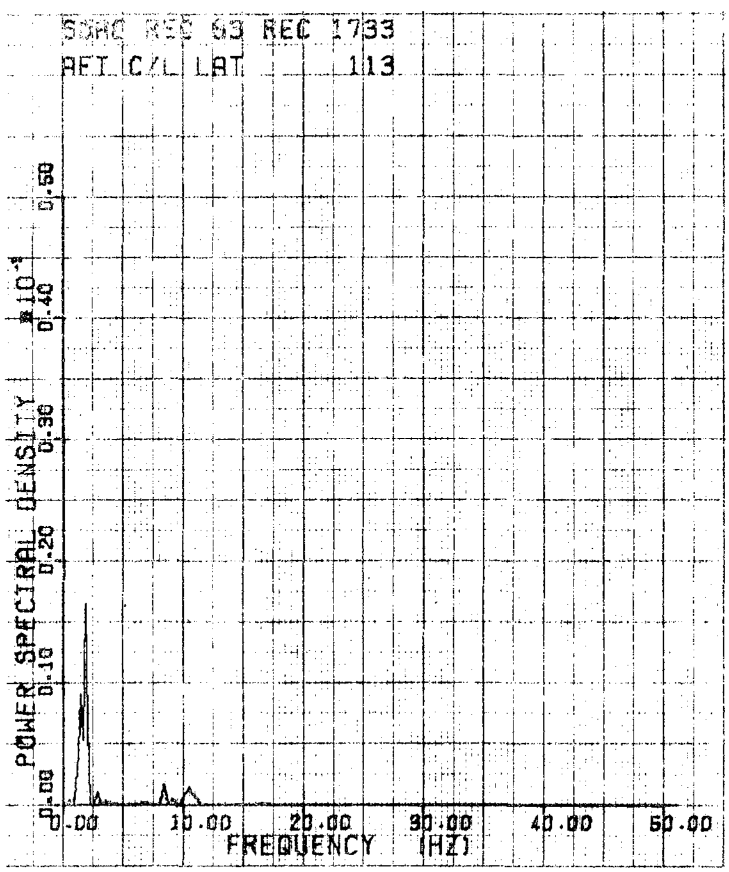




HIGH DENSITY CAR
105 KLB 3/20/74
45 MPH TRK SEC I

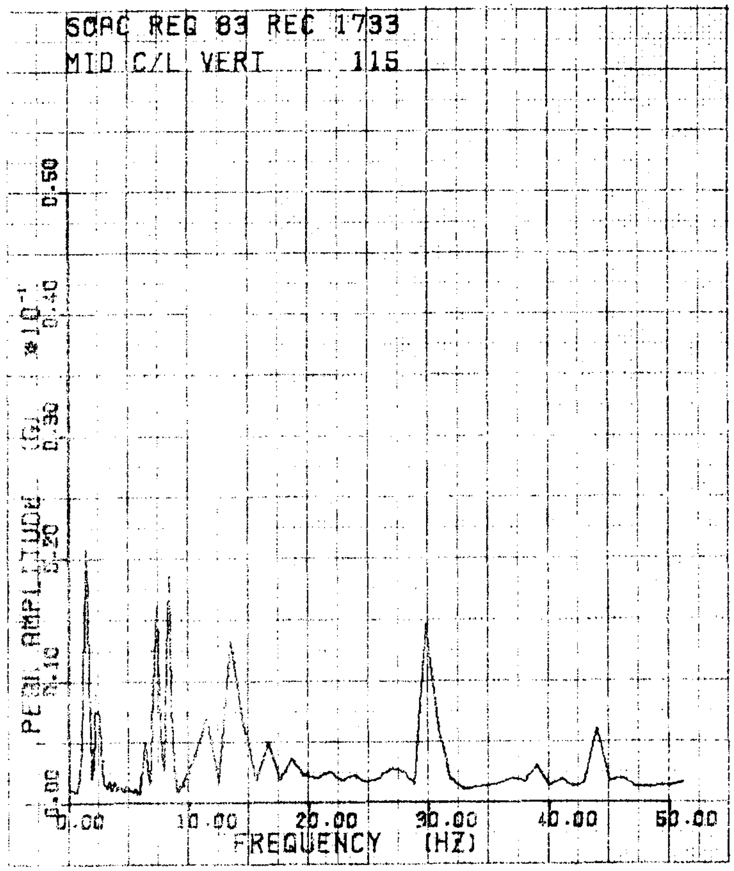
Figure B-100

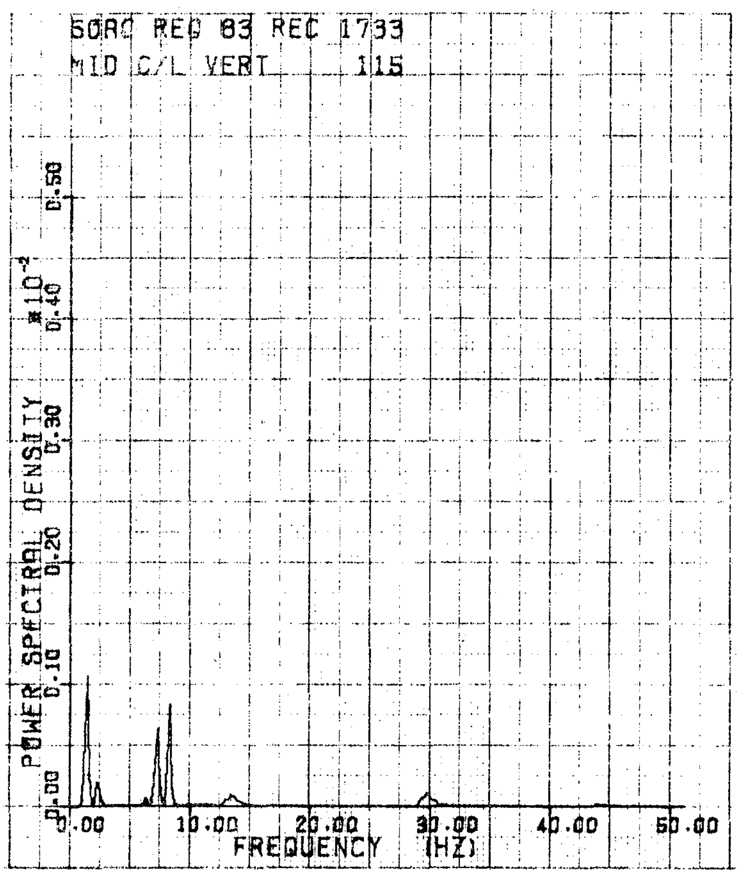




HIGH DENSITY CAR
105 KLB 3/20/74
45 MPH TRK SEC 1

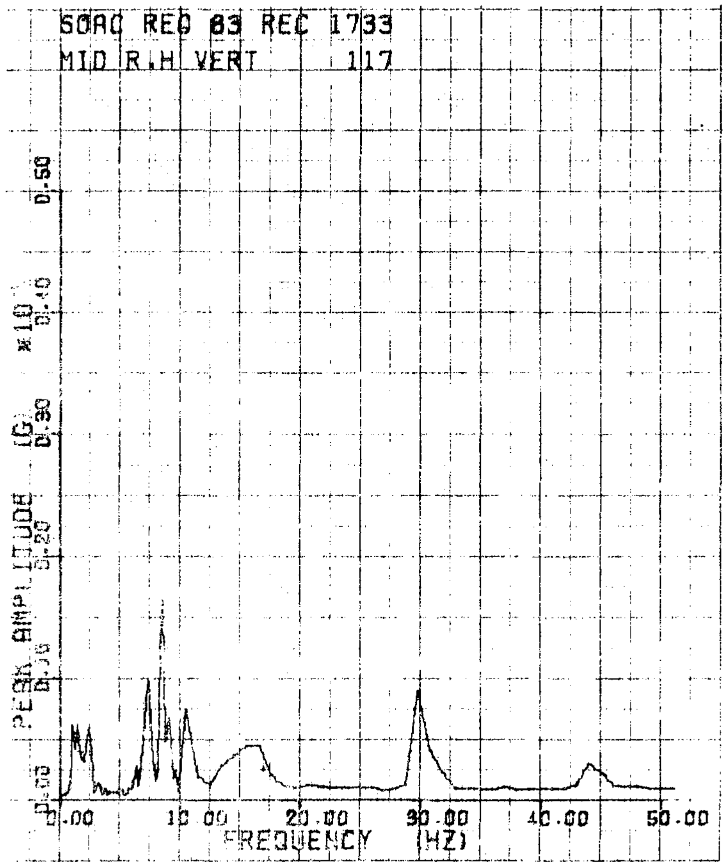
Figure B-101

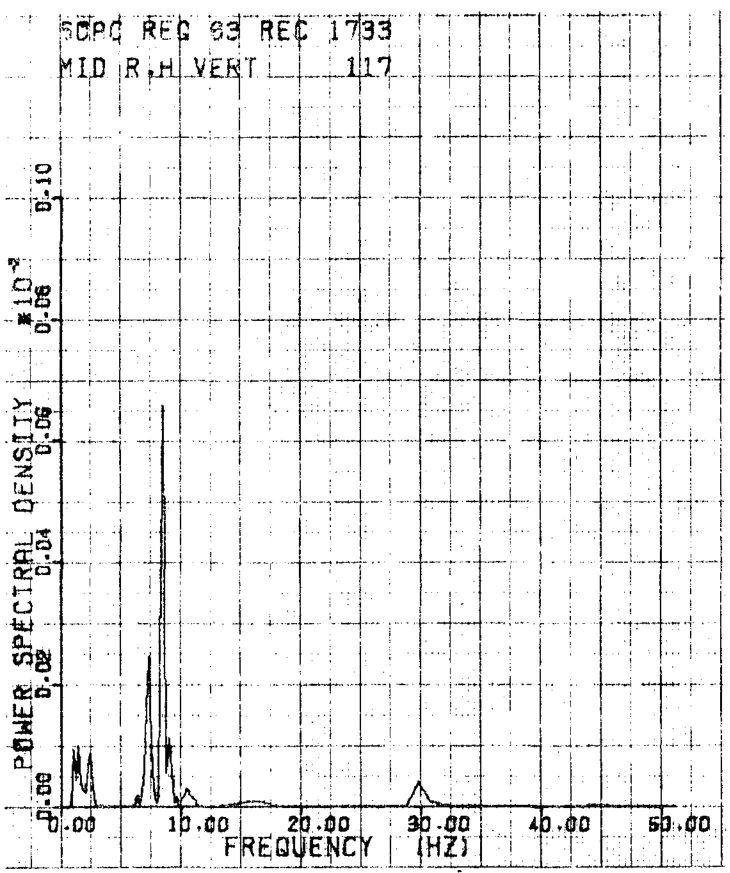




HIGH DENSITY CAR
105 KLB 3/20/74
45 MPH TRK SEC I

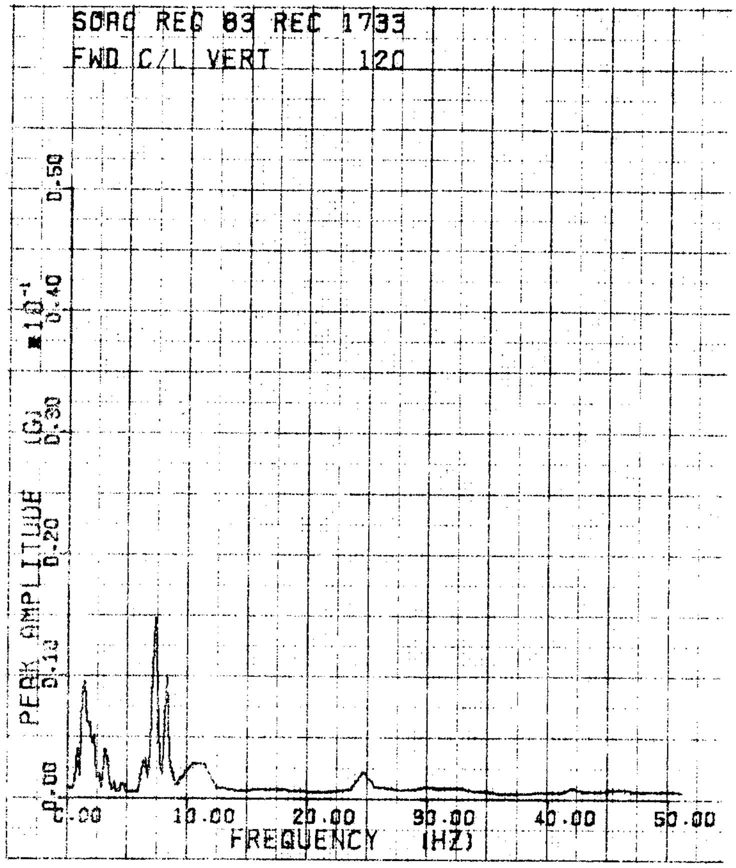
Figure B-102

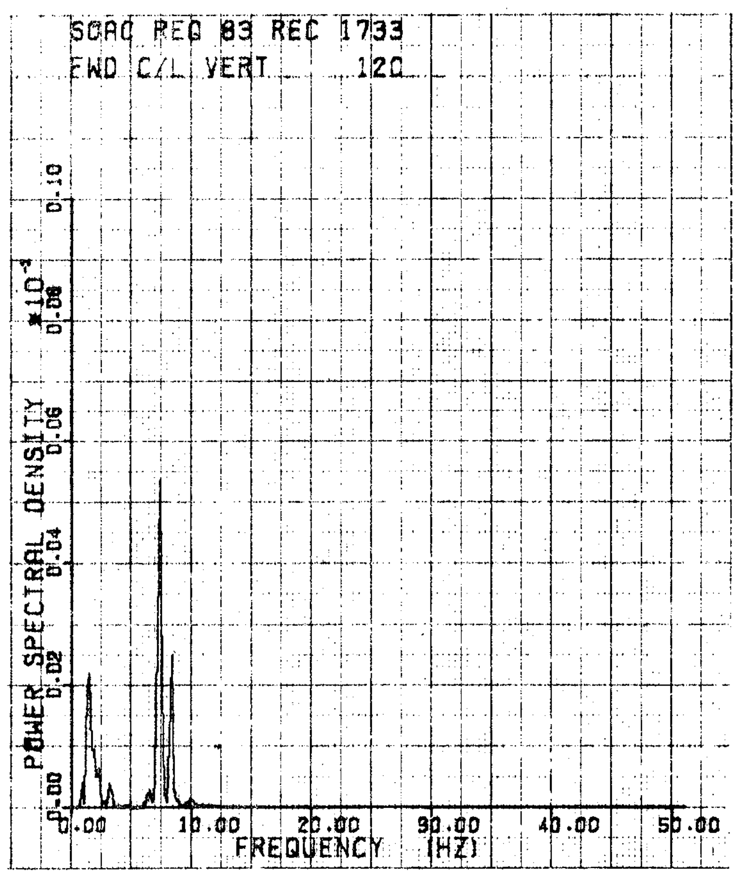




HIGH DENSITY CAR
105 KLB 3/20/74
45 MPH TRK SEC 1

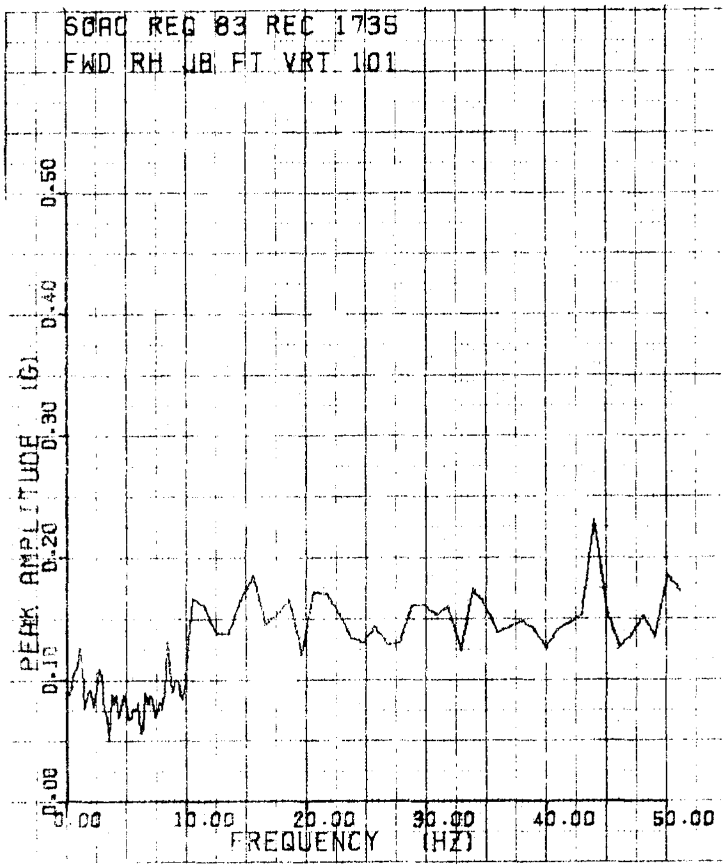
Figure B-103

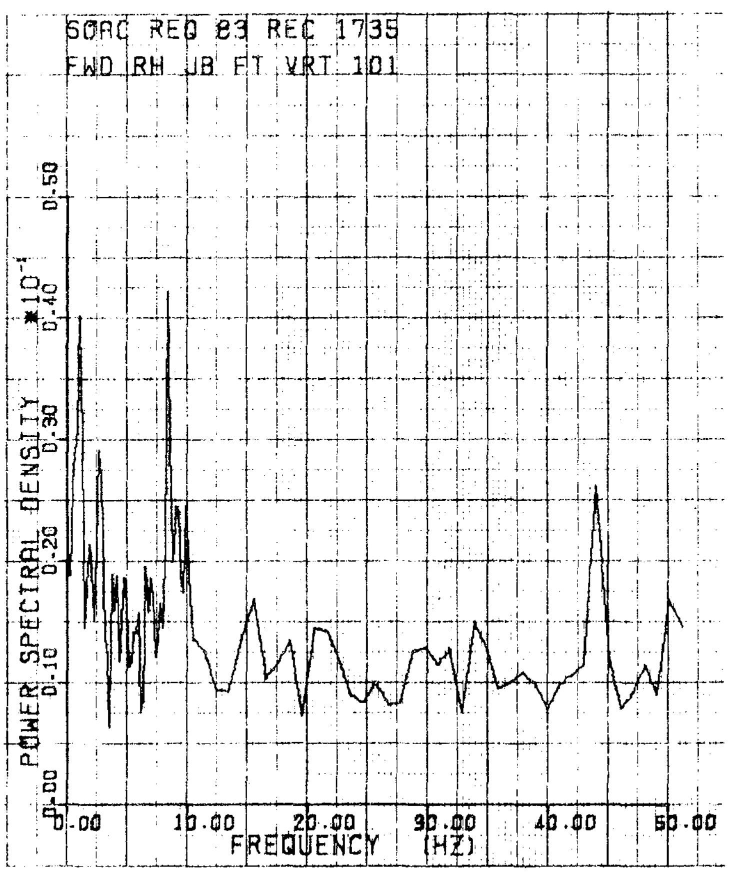




HIGH DENSITY CAR
105 KLB 3/20/74
45 MPH TRK SEC I

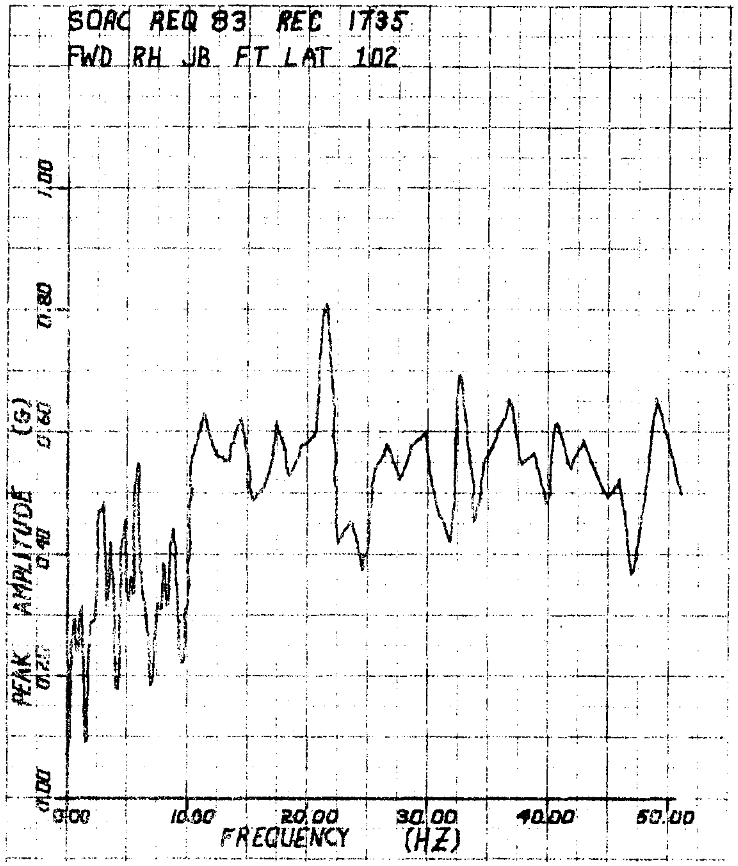
Figure B-104

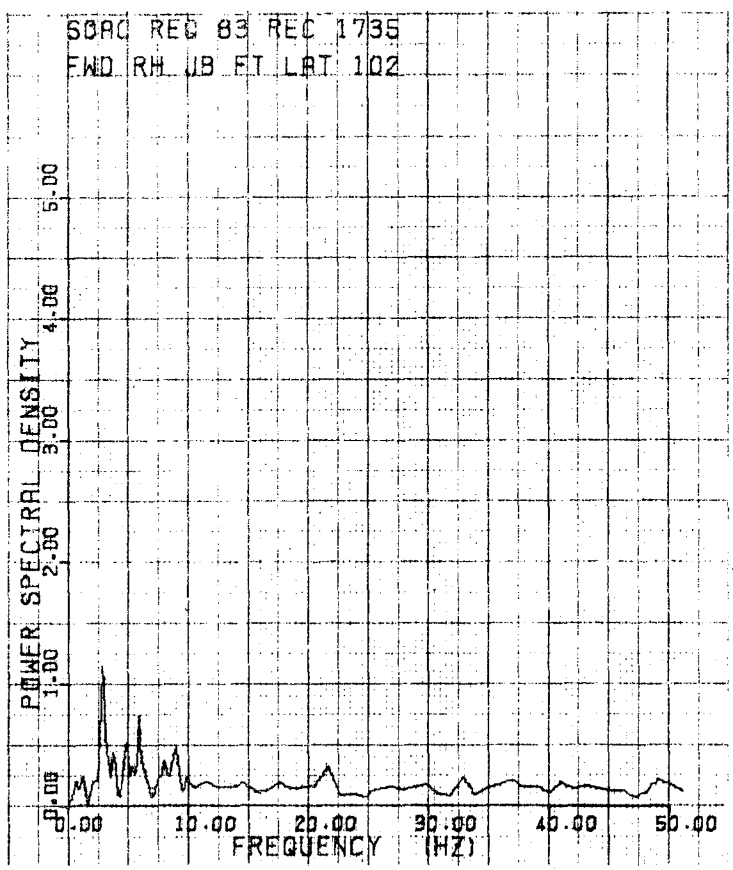




HIGH DENSITY CAR
105 KLB 3/20/74
55 MPH TRK SEC 1

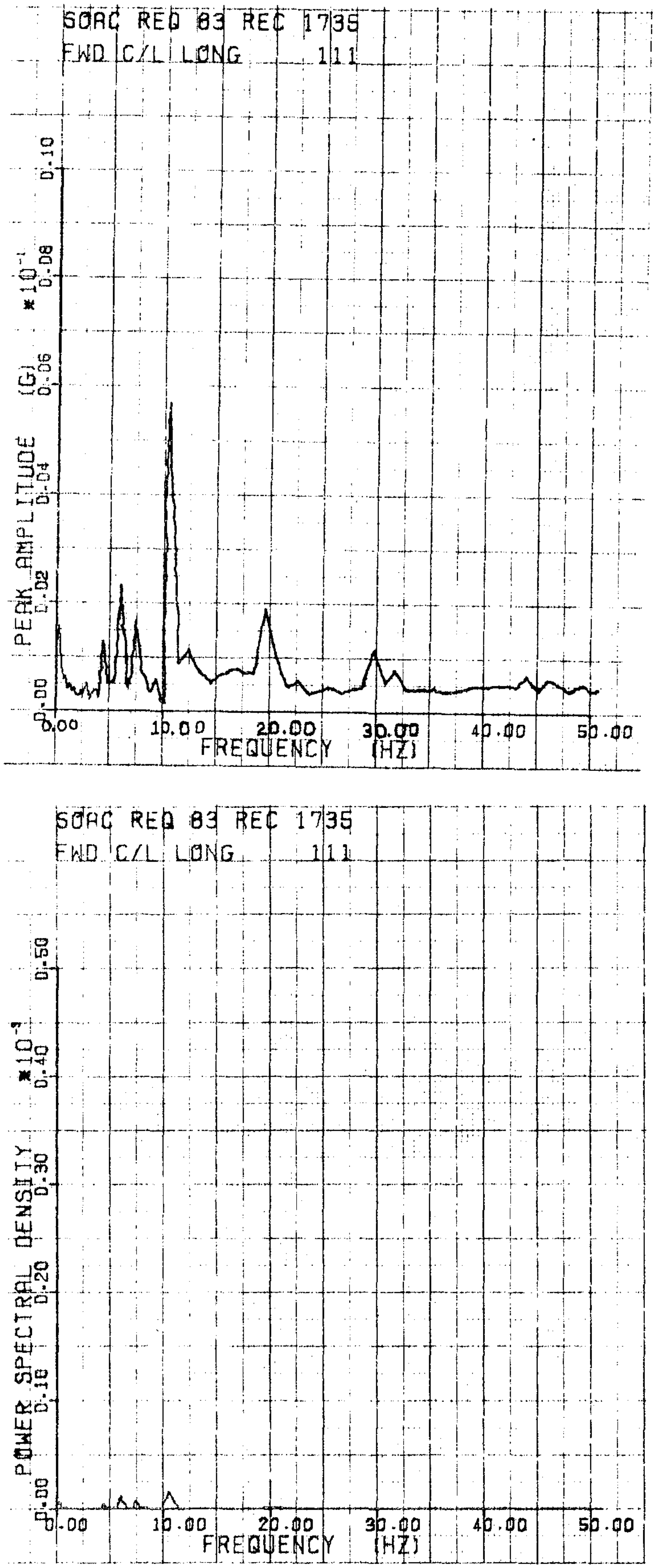
Figure B-105





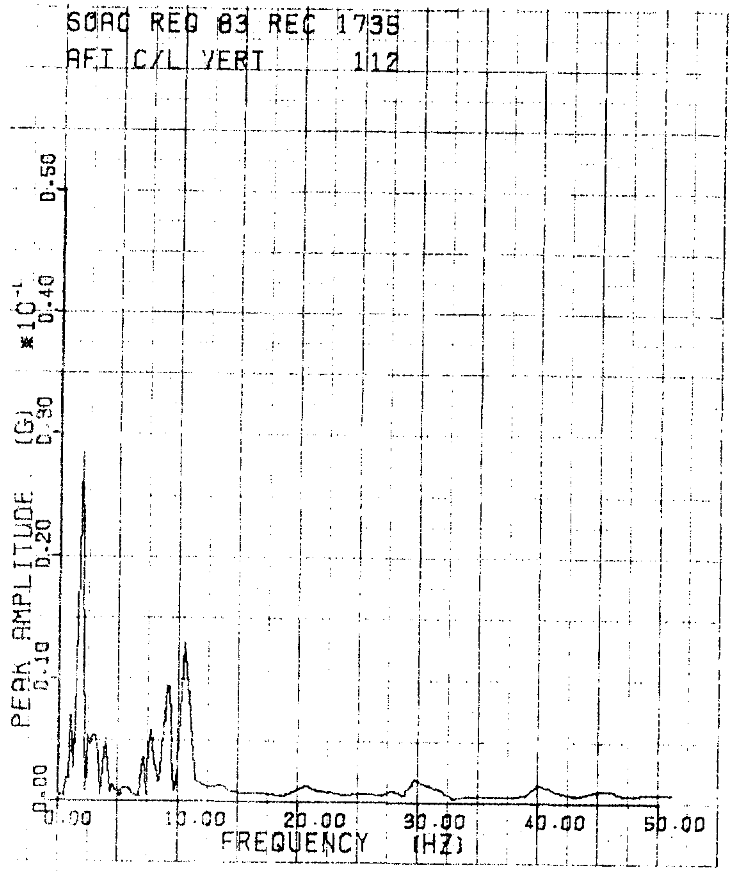
HIGH DENSITY CAR
105 KLB 3/20/74
55 MPH TRK SEC I

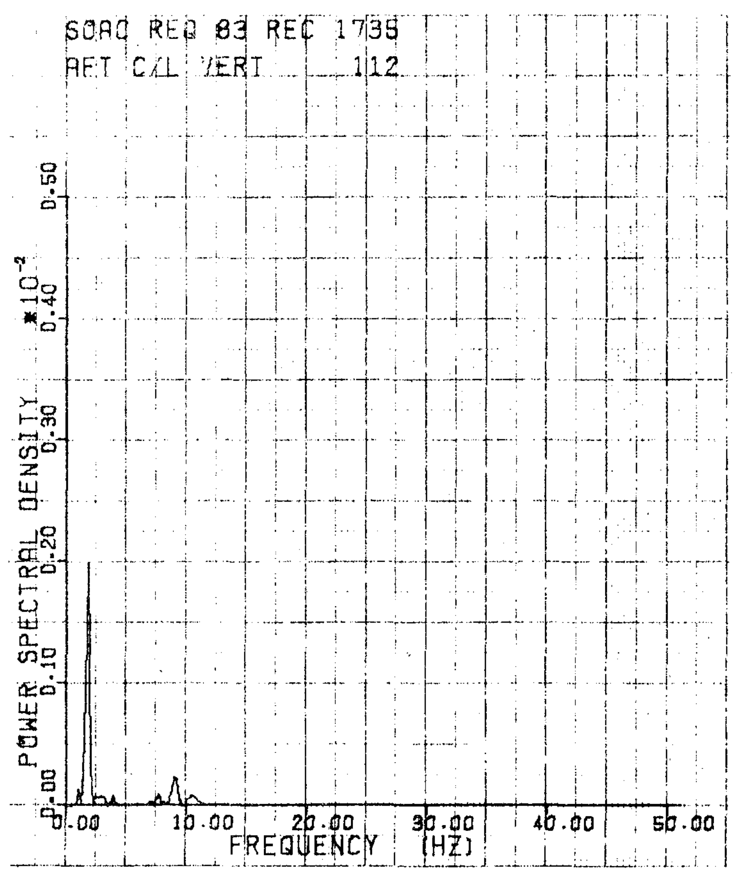
Figure B-106



HIGH DENSITY CAR
105 KLB 3/20/74
45 MPH TRK SEC I

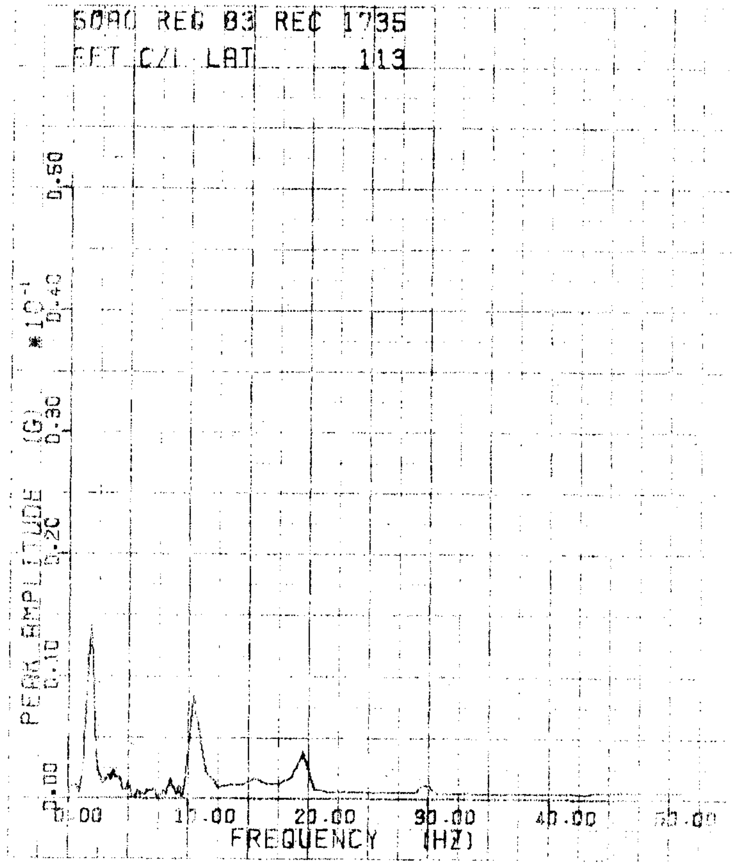
Figure B-107

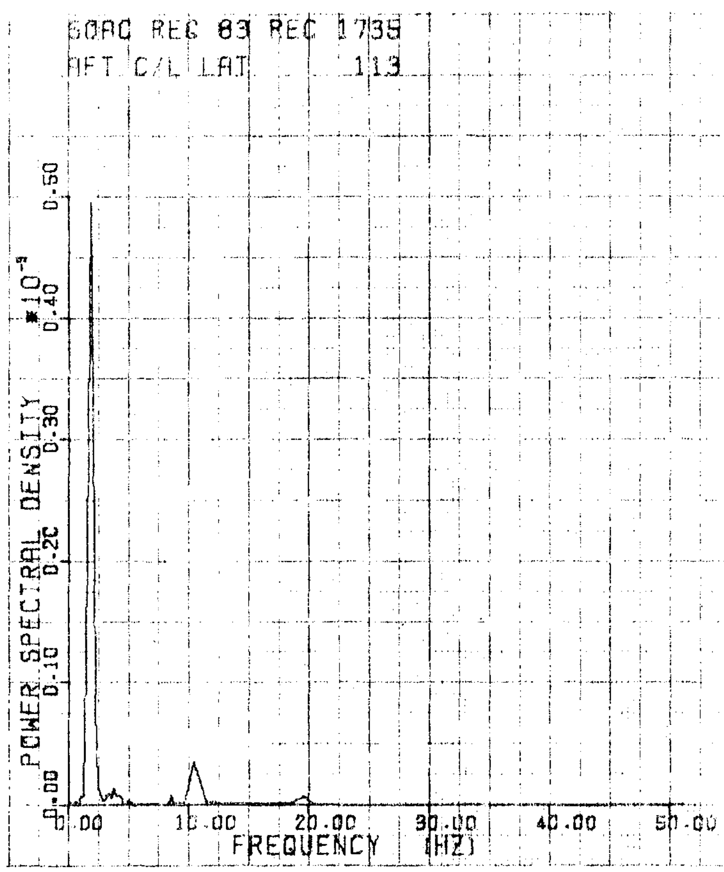




HIGH DENSITY CAR
105 KLB 3/20/74
55 MPH TRK SEC 1

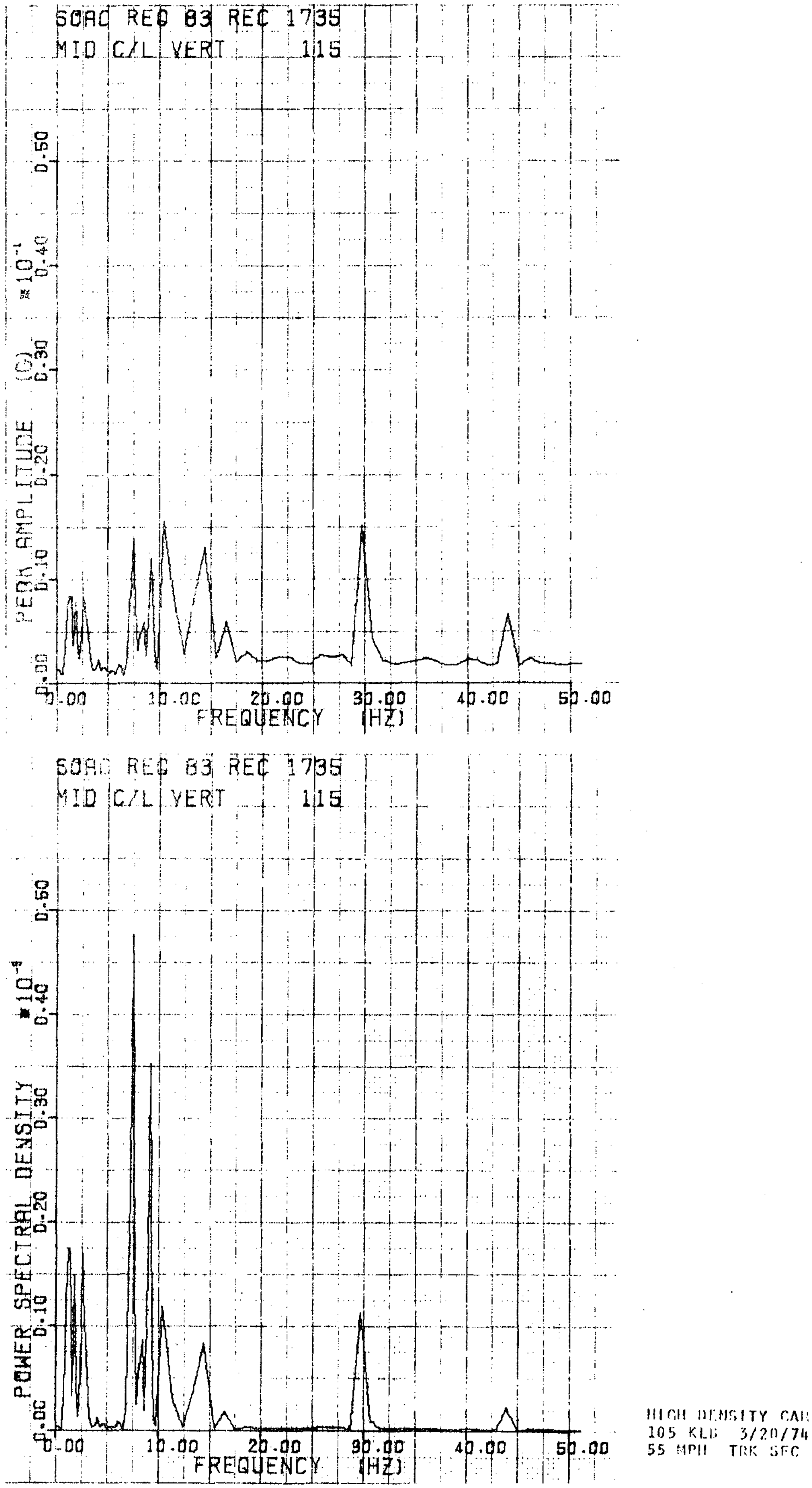
Figure B-108





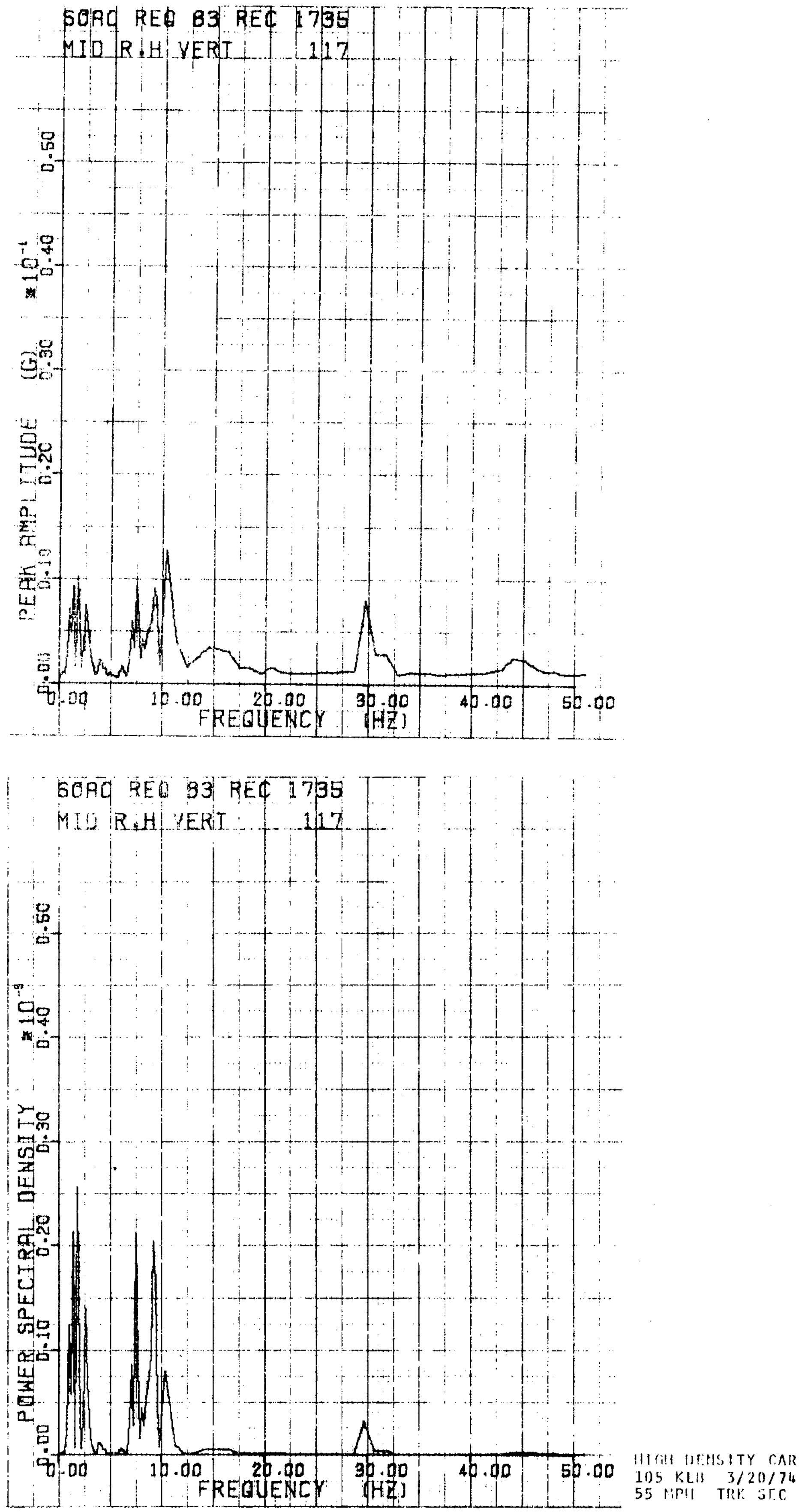
HIGH DENSITY CAR
105 KLB 3/20/74
55 MPH TRK SEC 1

Figure B-109



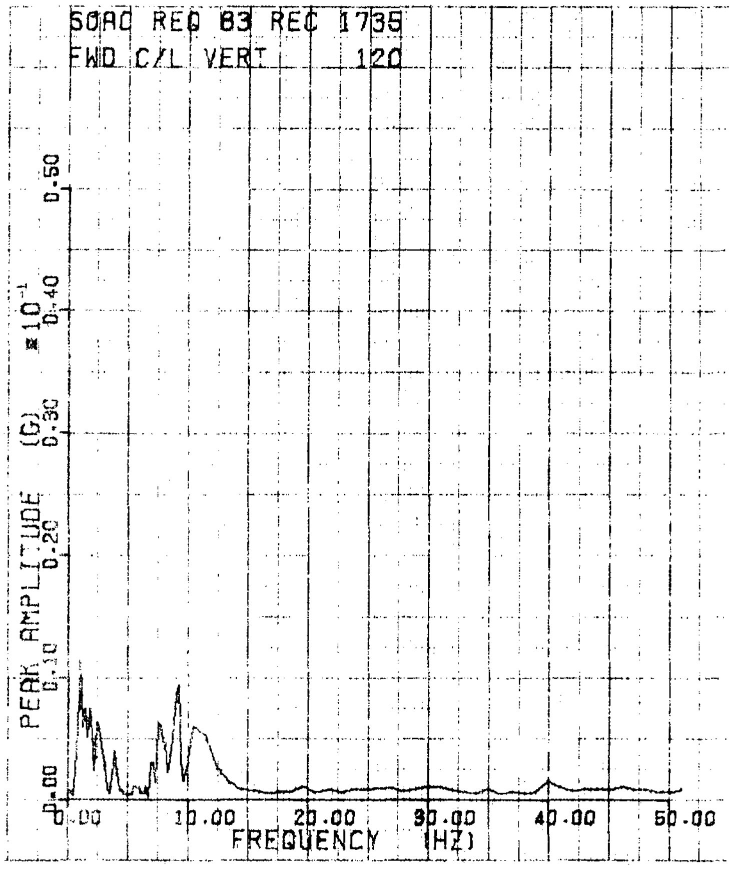
SOAC REC 83 REC 1735
MID C/L VERT 115
PEAK AMPLITUDE (G) *10⁻¹
0.00
0.10
0.20
0.30
0.40
0.50
0.00
10.00
20.00
30.00
40.00
50.00
FREQUENCY (HZ)
SOAC REC 83 REC 1735
MID C/L VERT 115
POWER SPECTRAL DENSITY *10⁻⁴
0.00
0.10
0.20
0.30
0.40
0.50
0.00
10.00
20.00
30.00
40.00
50.00
FREQUENCY (HZ)
HIGH DENSITY CAR
105 KLB 3/20/74
55 MPH TRK SEC I

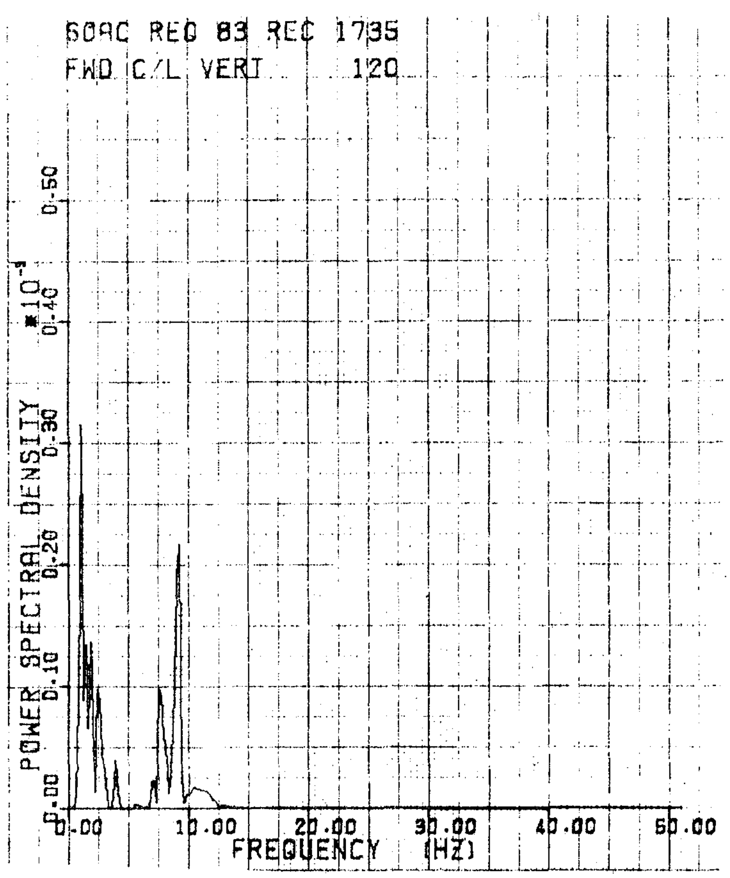
Figure B-110



SOAC REQ 83 REC 1735
MID R.H VERT 117
PEAK AMPLITUDE (G) *10⁻¹
0.00
0.10
0.20
0.30
0.40
0.50
0.00
10.00
20.00
30.00
40.00
50.00
FREQUENCY (HZ)
SOAC REQ 83 REC 1735
MID R.H VERT 117
POWER SPECTRAL DENSITY *10⁻³
0.00
0.10
0.20
0.30
0.40
0.50
0.00
10.00
20.00
30.00
40.00
50.00
FREQUENCY (HZ)
HIGH DENSITY CAR
105 KLB 3/20/74
55 MPH TRK SEC 1

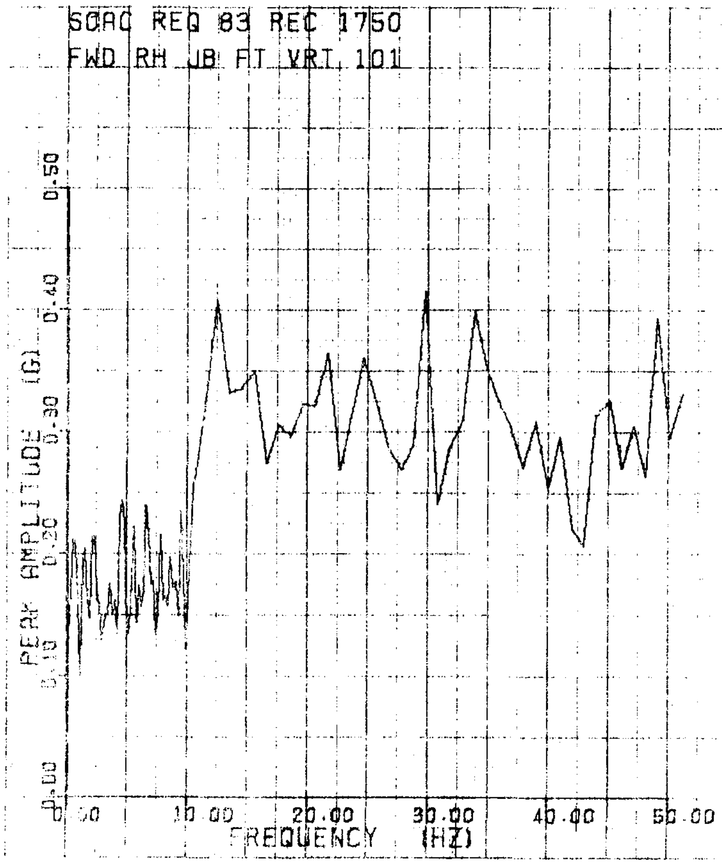
Figure B-111

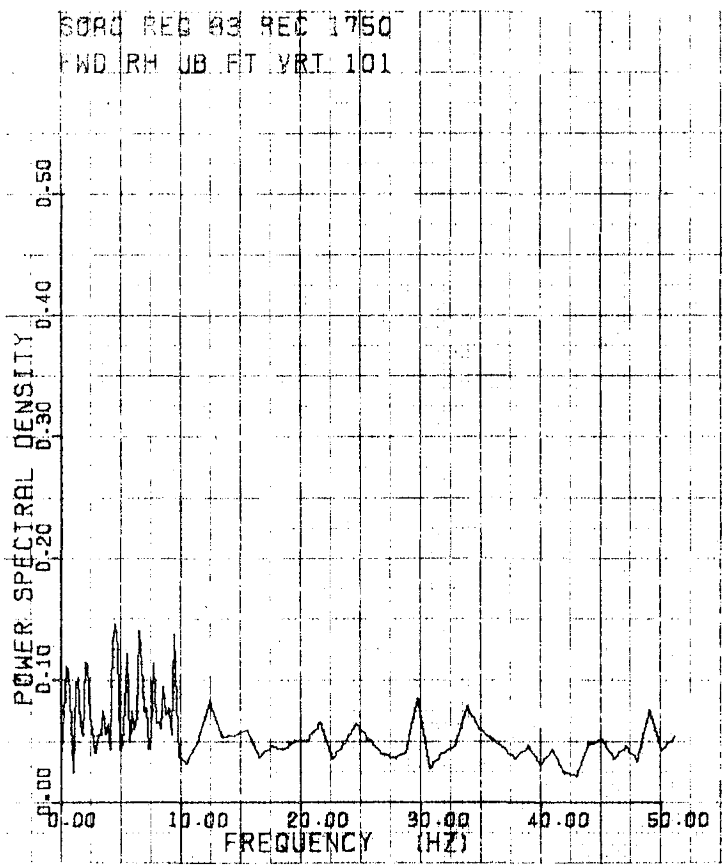




HIGH DENSITY CAR
105 KIP 3/20/74
55 MPH TRK SEC 1

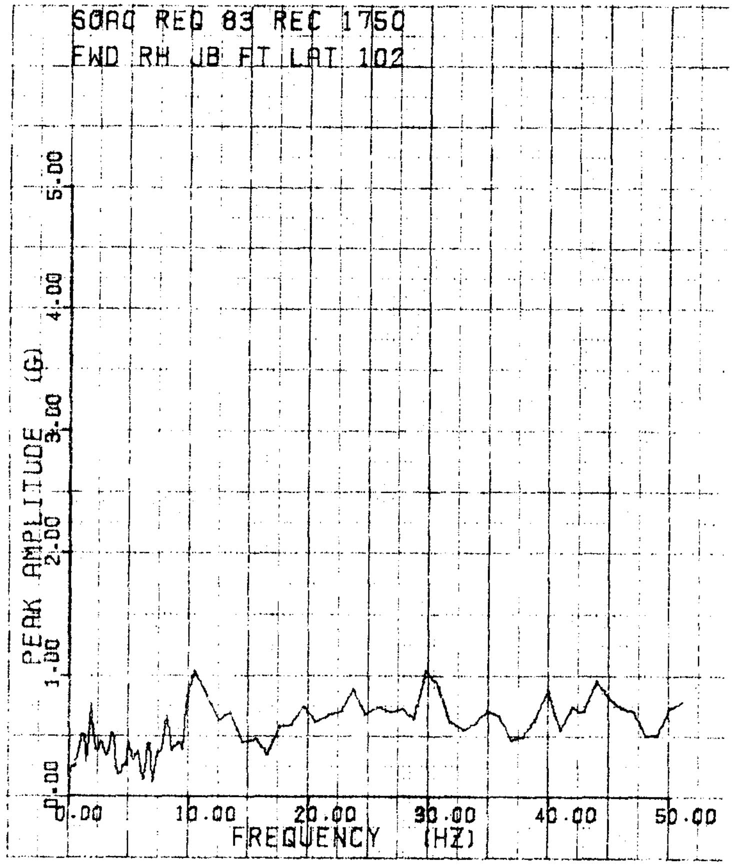
Figure B-112

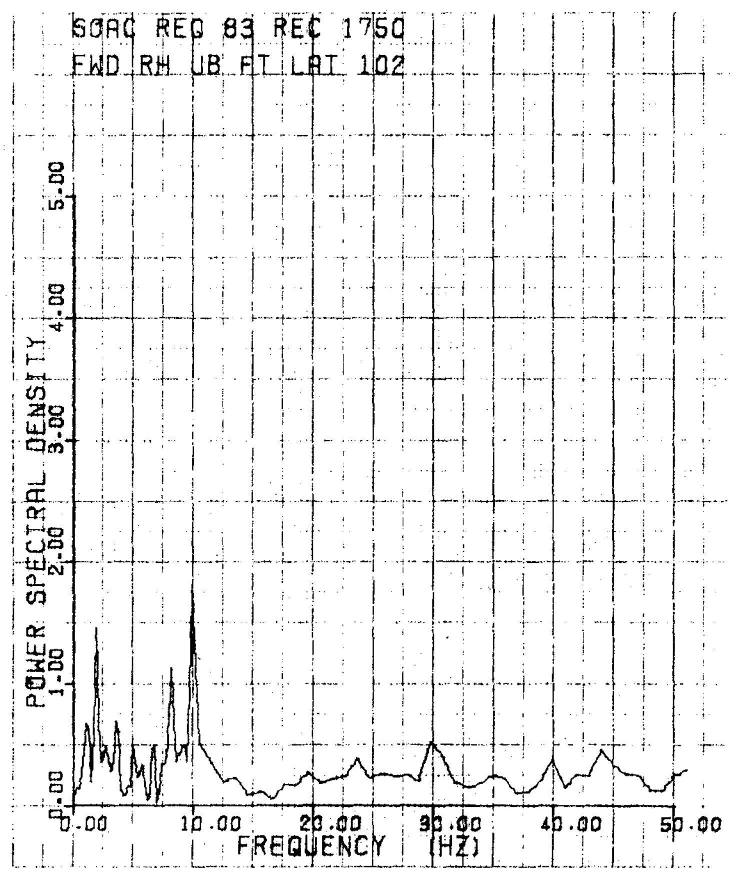




HIGH DENSITY CAR
105 KLB 3/20/74
80 MPH TRK SEC I

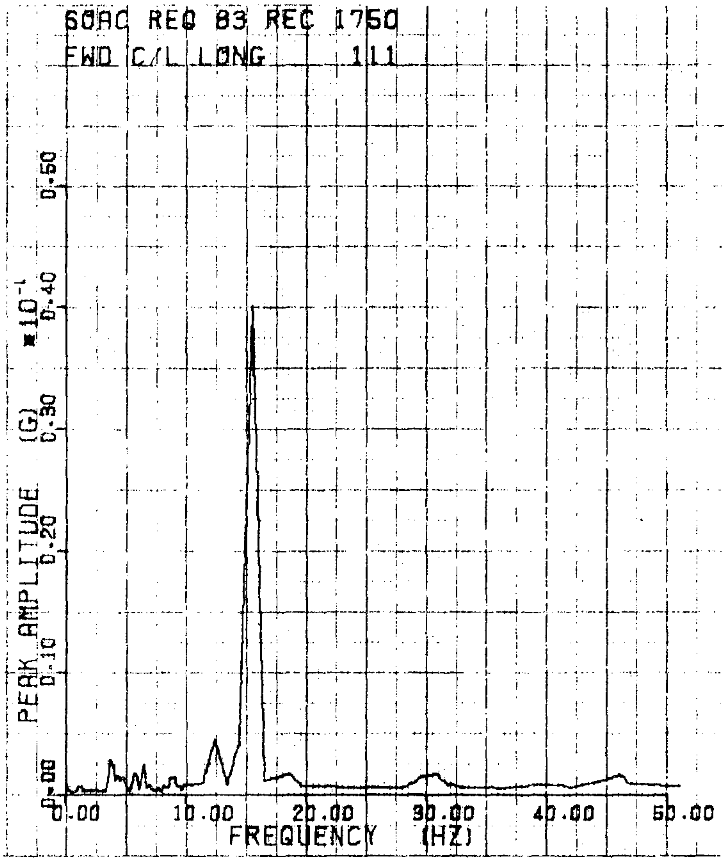
Figure B-113

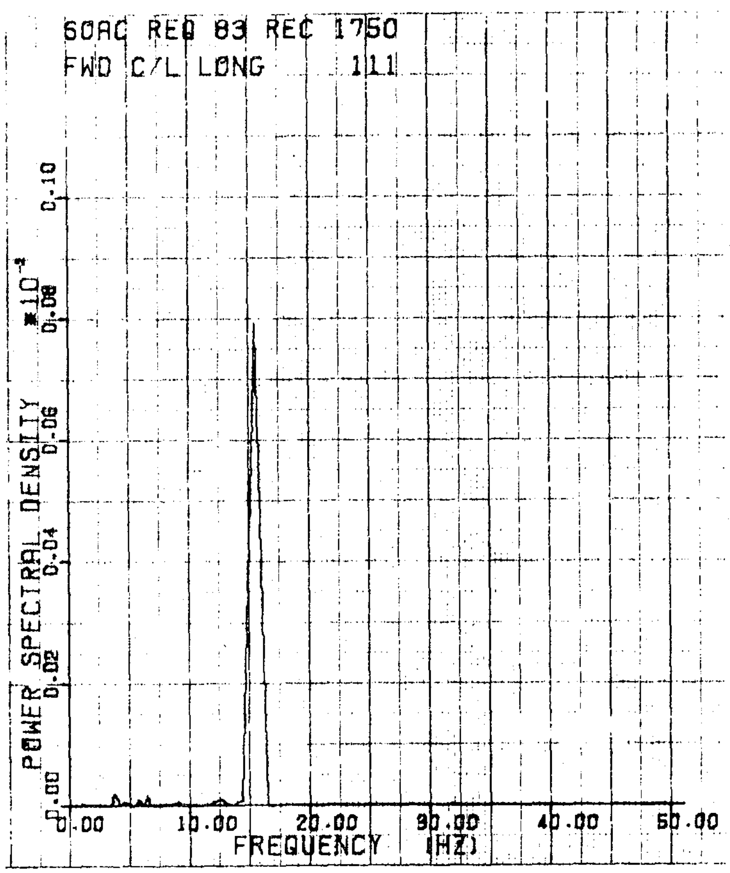




HIGH DENSITY CAR
105 KLB 3/20/74
30 MPH TRE SEC I

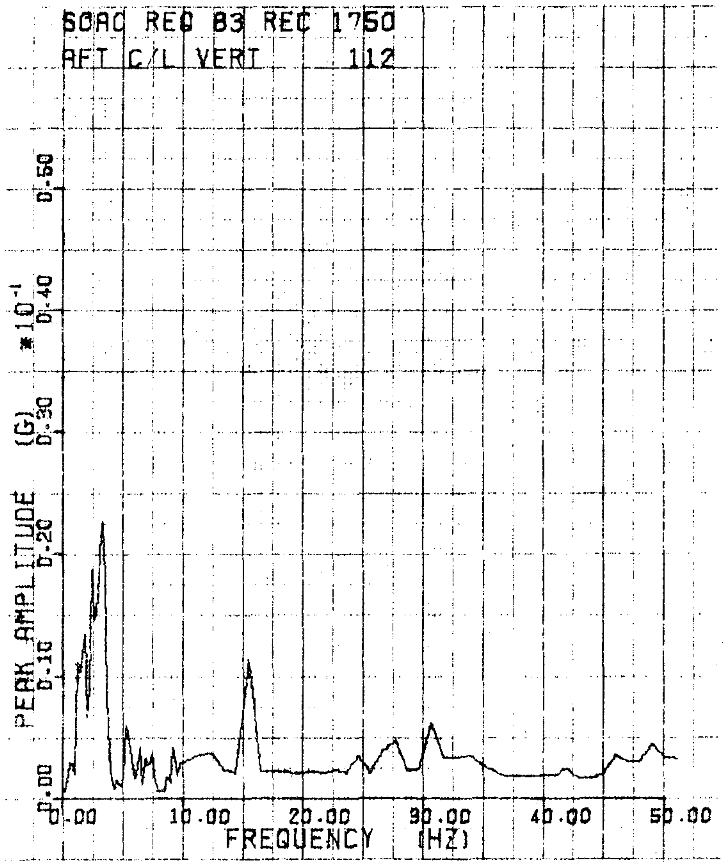
Figure B-114

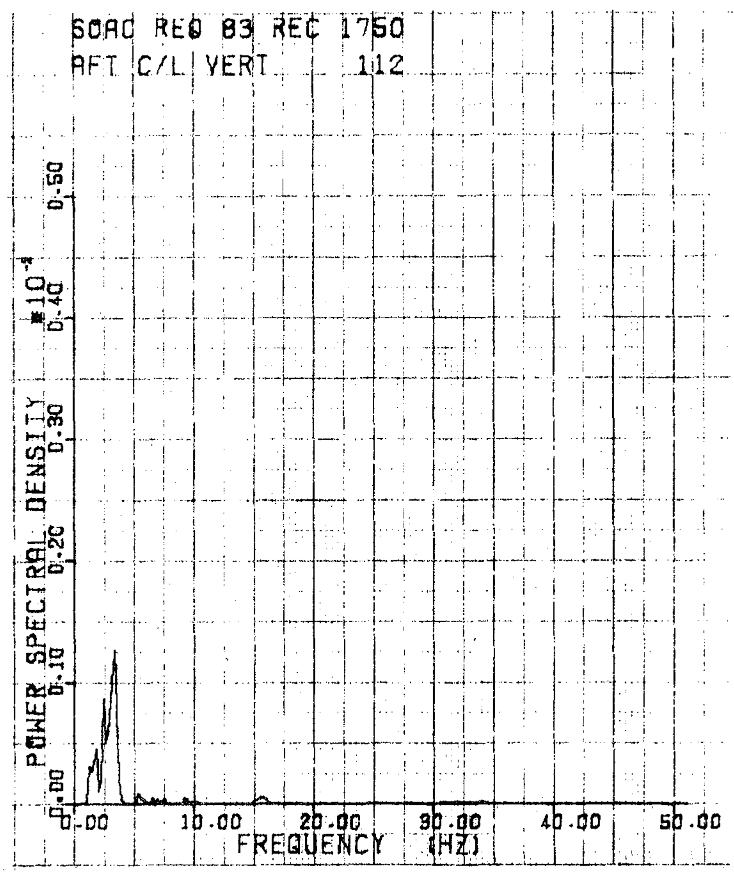




HIGH DENSITY CAR
105 KLB 3/20/74
80 MPH TRK SEC 1

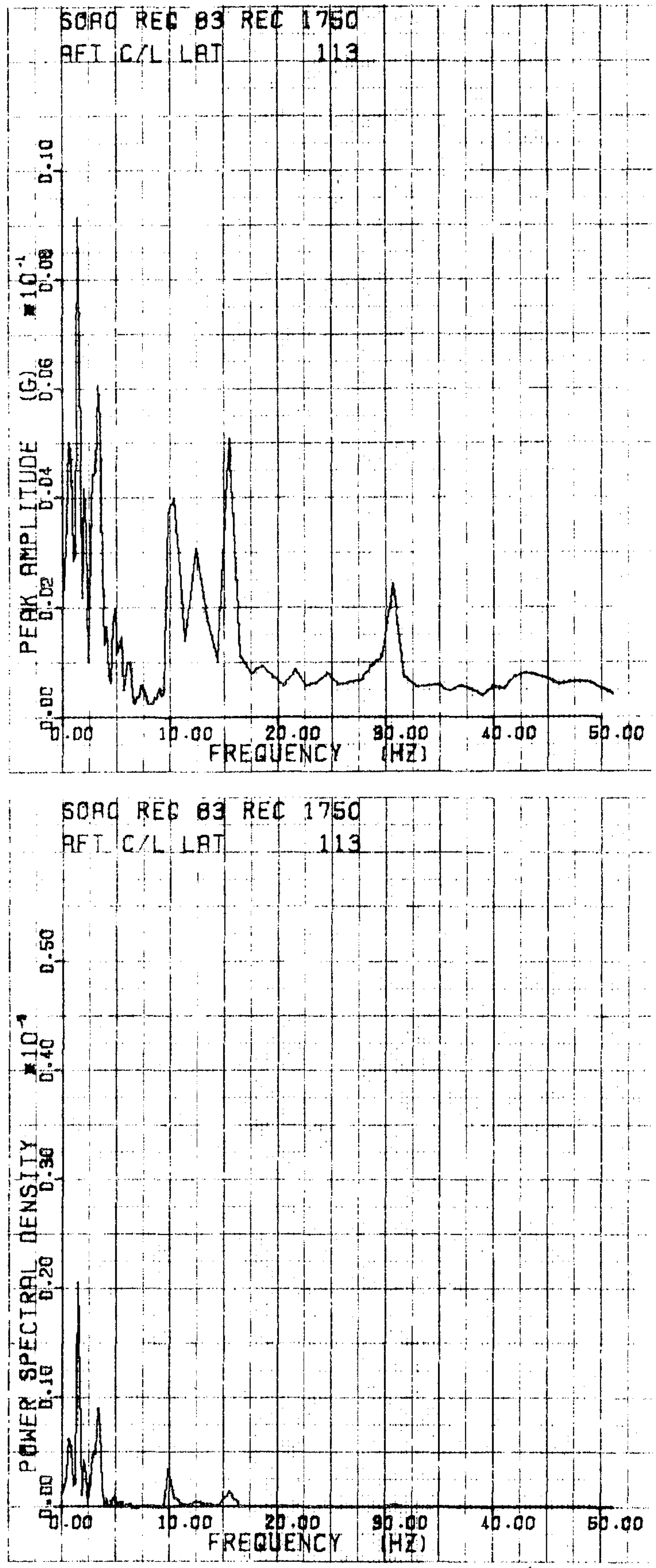
Figure B-115





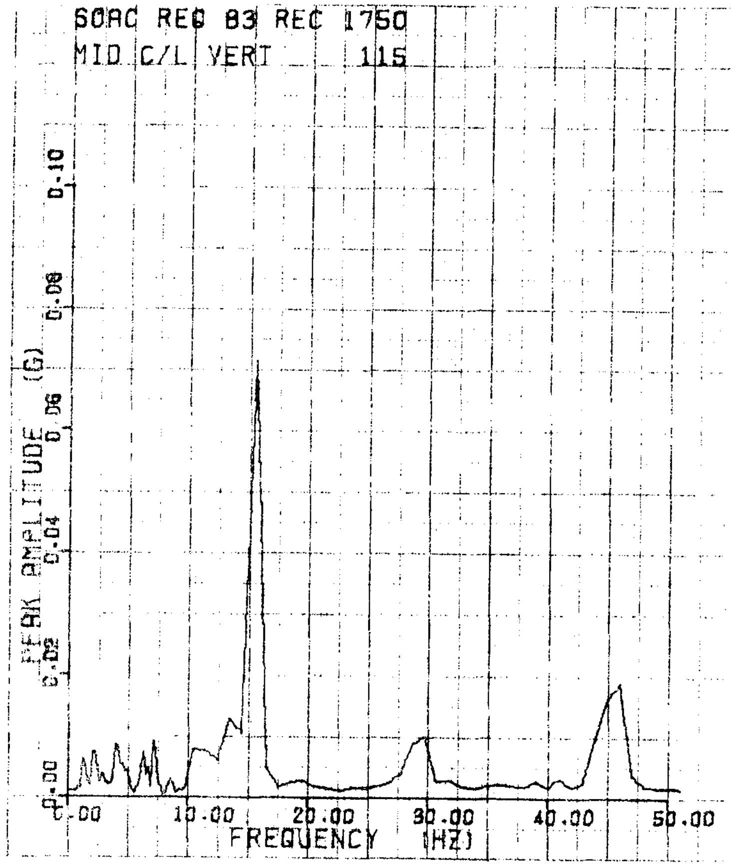
HIGH DENSITY CAR
105 KLB 3/20/74
80 MPH TRK SEC I

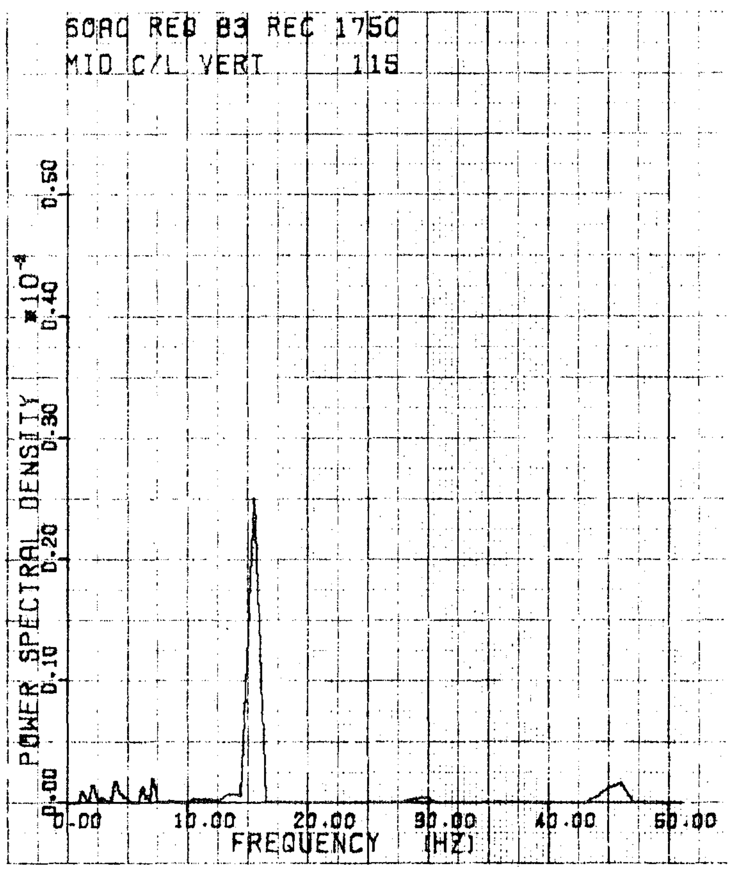
Figure B-116



HIGH DENSITY CAR
105 KLB 3/20/74
80 MPH TRK SEC I

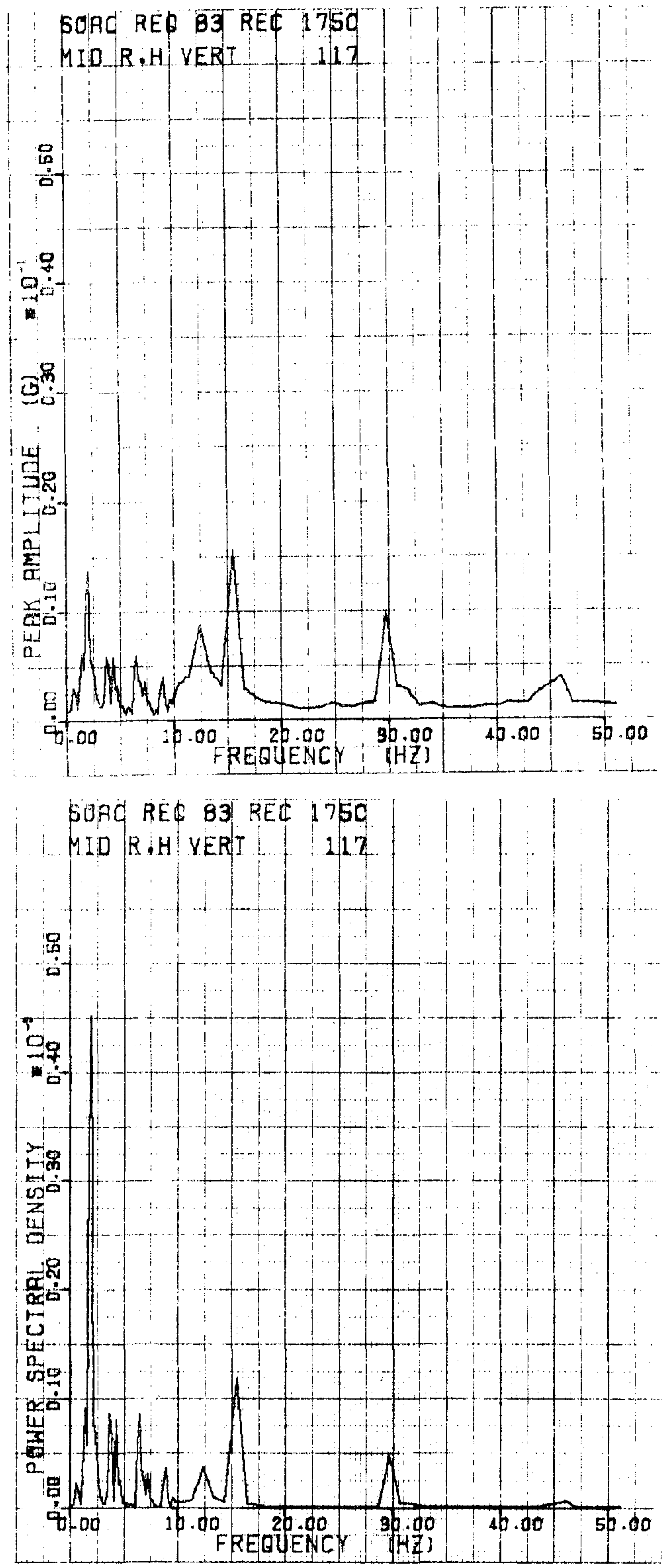
Figure B-117





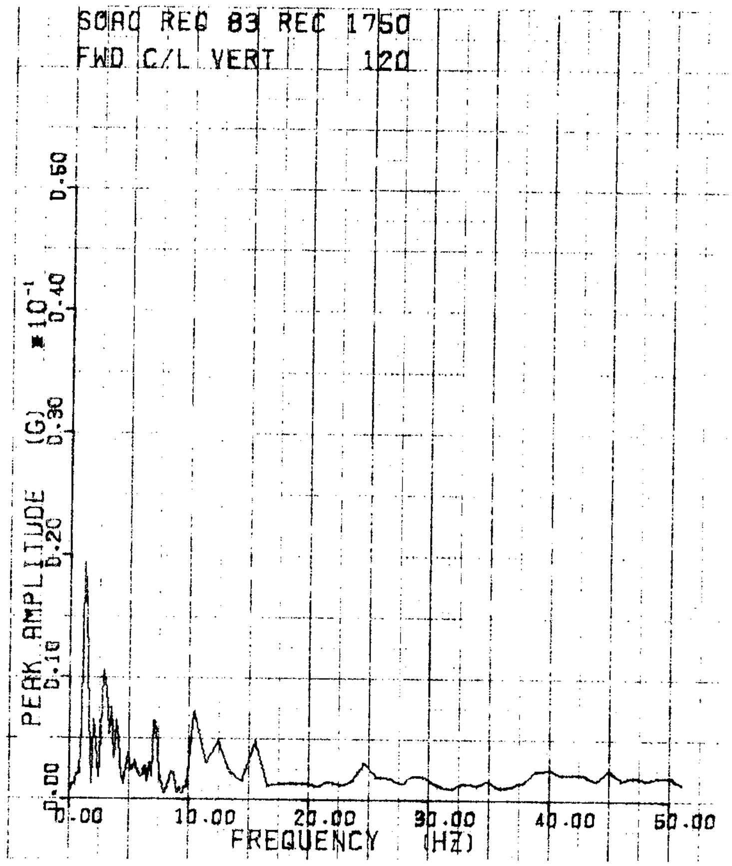
HIGH DENSITY CAR
105 KLB 3/20/74
80 MPH TRK SEC I

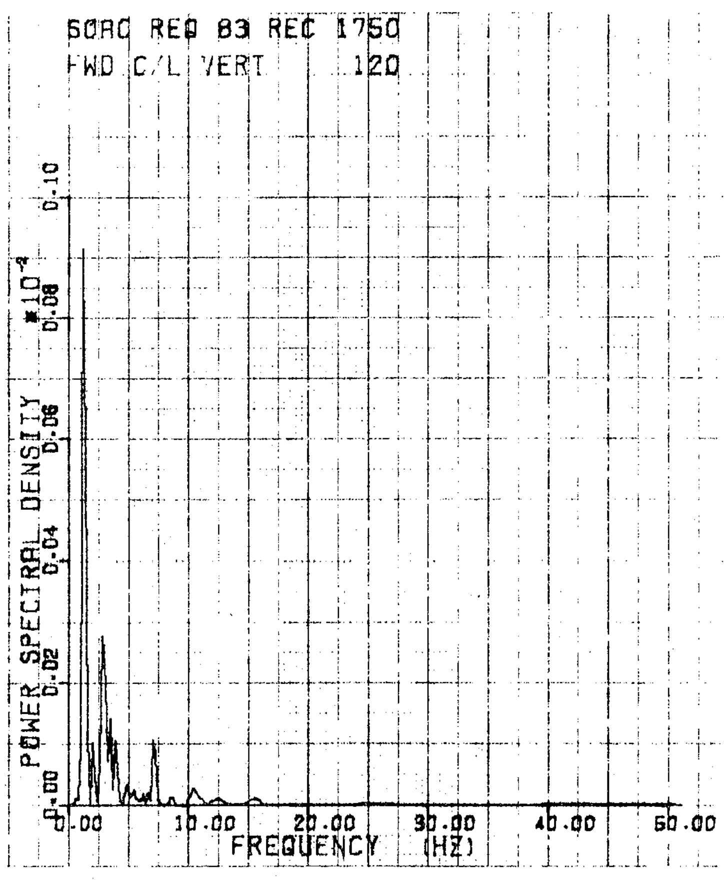
Figure B-118



HIGH DENSITY CAR
105 KLB 3/20/74
80 MPH TEK SEC I

Figure B-119





HIGH DENSITY CAR
105 KLB 3/20/74
80 MPH TRK SEC I

Figure B-120

APPENDIX C
REPORT OF INVENTIONS

After a diligent review of the work performed under this contract, it was determined that no new innovation, discovery, improvement or invention was made.