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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 IV. NOISE TESTS

Boeing Vertol Company

Prepared for:

Urban Mass Transportation Administration
Transportation Systems Center

January 1975

PREFACE

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

The report is presented in six volumes. Volume I is a description of the program and a summary of the test results. Volumes II through V are organized to technical disciplines, as follows: Volume II, Performance; Volume III, Ride Quality; this volume, Volume IV, Noise; and Volume V, Structures, Voltage, and Radio Frequency Interference. Volume VI contains a description of the SOAC Instrumentation System used for Performance, Ride Quality and Structural testing.

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16. Abstract

This six-volume report presents the technical methodology, data samples, and results of tests conducted on the SOAC on the Rail Transit Test Track at the High Speed Ground Test Center in Pueblo, Colorado during the period April to July 1973. The UMTA-sponsored Urban Rail Supporting Technology Program, for which TSC is Systems Manager, emphasizes three major development task areas: facilities, technology and test program. Test program development comprises three sub-areas: vehicle testing, ways and structures testing and track geometry measurement. The objective of the SOAC program is to demonstrate the current state-of-the-art in rail rapid transit vehicle technology, with passenger convenience and operating efficiency as primary goals. The objectives of the Engineering Test program are to provide a set of SOAC engineering data and to further develop the methodology for providing transit vehicle comparisons. These objectives were met with the presentation of the test results in this report and the incorporation of refinement to the testing methodology into the General Vehicle Test Plan, GSP-064. In this series, Vol. I contains a description of the SOAC test program and vehicle, and a summary of the test results; Vol. II, Performance Test data; Vol. III, Ride Quality Test data; Vol. IV, Noise Test data; Vol. V, Structural, Voltage, and Radio Frequency Interference Test data; and Vol. VI a description of the Instrumentation System used for performance, ride quality and structural testing.

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Section 1

INTERIOR NOISE

1.1 SUMMARY

Test Sequence

Table 1-1 is a log of Interior Noise Test Run Numbers and basic test configuration.

TABLE 1-1. INTERIOR NOISE SURVEY TEST RUN LOG

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

Test Procedures

Detailed test procedures are as contained in SOAC ENGINEERING TEST PROGRAM TEST PROCEDURES (Reference 1*).

Objective

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

*Reference 1. SOAC ENGINEERING PROGRAM TEST PROCEDURES, D174-10023-1, Boeing Vertol Company, Philadelphia, Pa., July 1973.

Status

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

1.2 TEST DESCRIPTION

A portable microphone/recorder data system was used to survey a large number of locations throughout the car. The types of surveys performed were as follows:

a. Equipment noise
b. Speed effect
c. Repeat runs
d. Track construction effect
e. Interior survey
f. Weight effect
g. Absorption test
h. Power condition effect
i. Resilient wheels

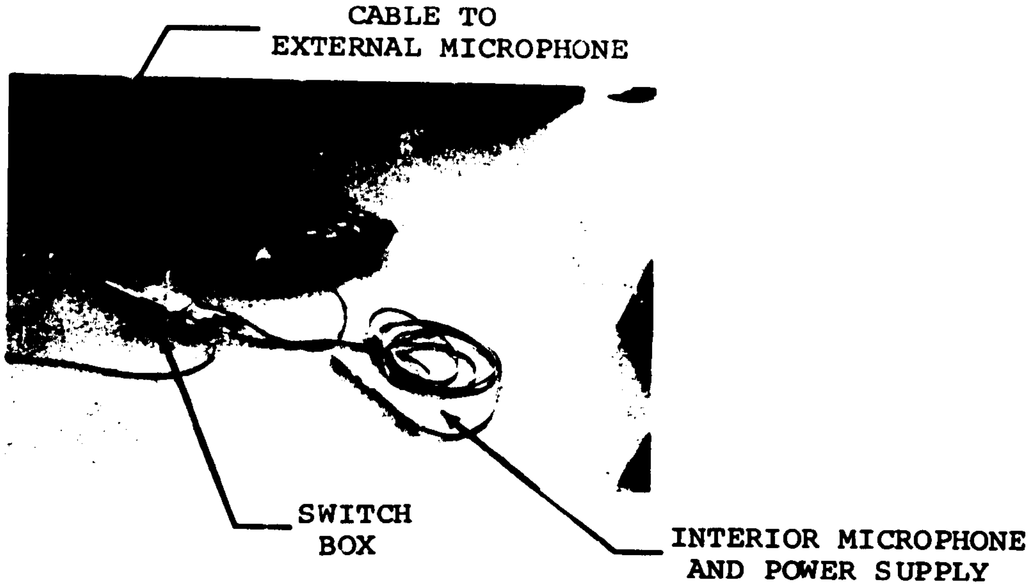
Sound measurements were made in a manner which allowed a complete time history of each measured sound signal to be retained on magnetic tape. Subsequent data reduction included standard "A" weighted noise levels, 1/3-octave band analysis, and narrow band spectrum analysis for selected data points (Figures 1-1 and 1-2).

1.3 INSTRUMENTATION

1.3.1 Field Measurement Equipment

The instrumentation used for measurement of noise levels consisted of a 1-inch condenser microphone with battery operated cathode-follower and a 1/4-inch, single-channel tape recorder. Table 1-2 lists the specific items of equipment by manufacturer, model and serial number. For interior measurements, the tape recorder/microphone pair was operated as a portable unit. An accelerometer was used for structure-borne noise measurements. The recorder was operated at a tape speed of 7-1/2 ips to achieve a good frequency response characteristic. A gain/attentuation system consisting of 10 dB incremental steps was incorporated into the recorder to maintain accuracy of the system (Figure 1-3).

INTERIOR/EXTERIOR NOISE RECORDING EQUIPMENT



STRUCTURE-BORNE NOISE RECORDING EQUIPMENT

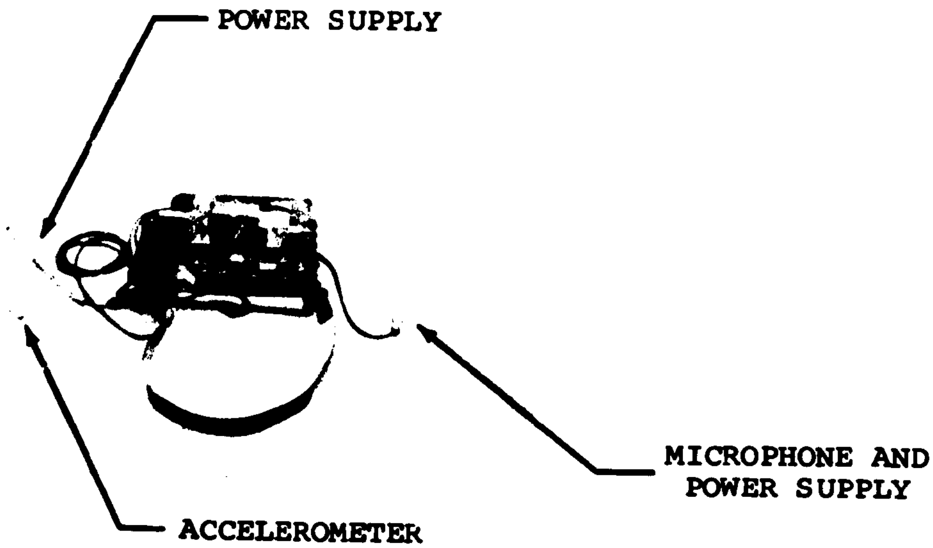


Figure 1–1. Instrumentation for Interior Noise Measurement

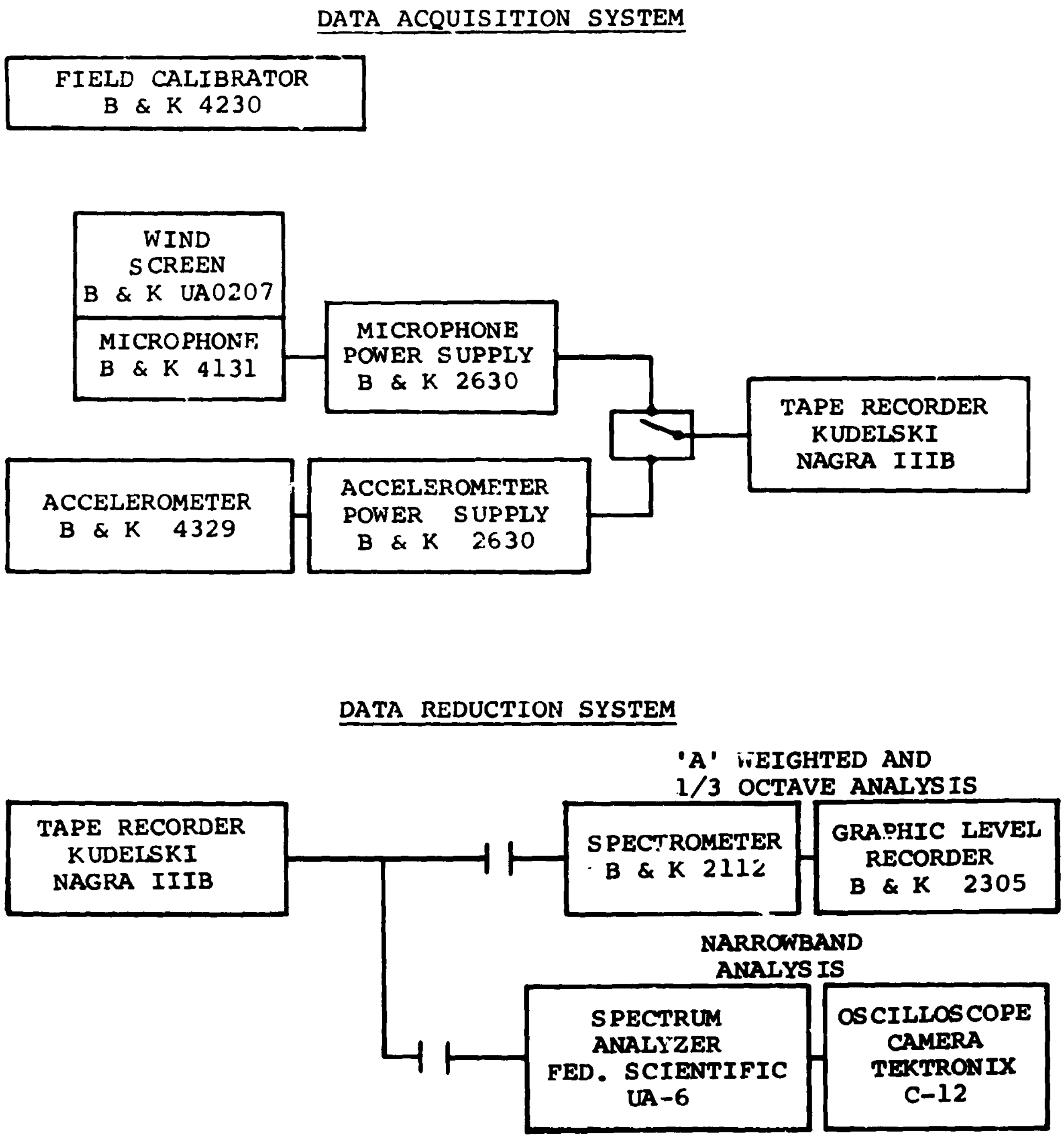


Figure 1–2. Block Diagrams for Noise Measurement Data Acquisition and Reduction Systems

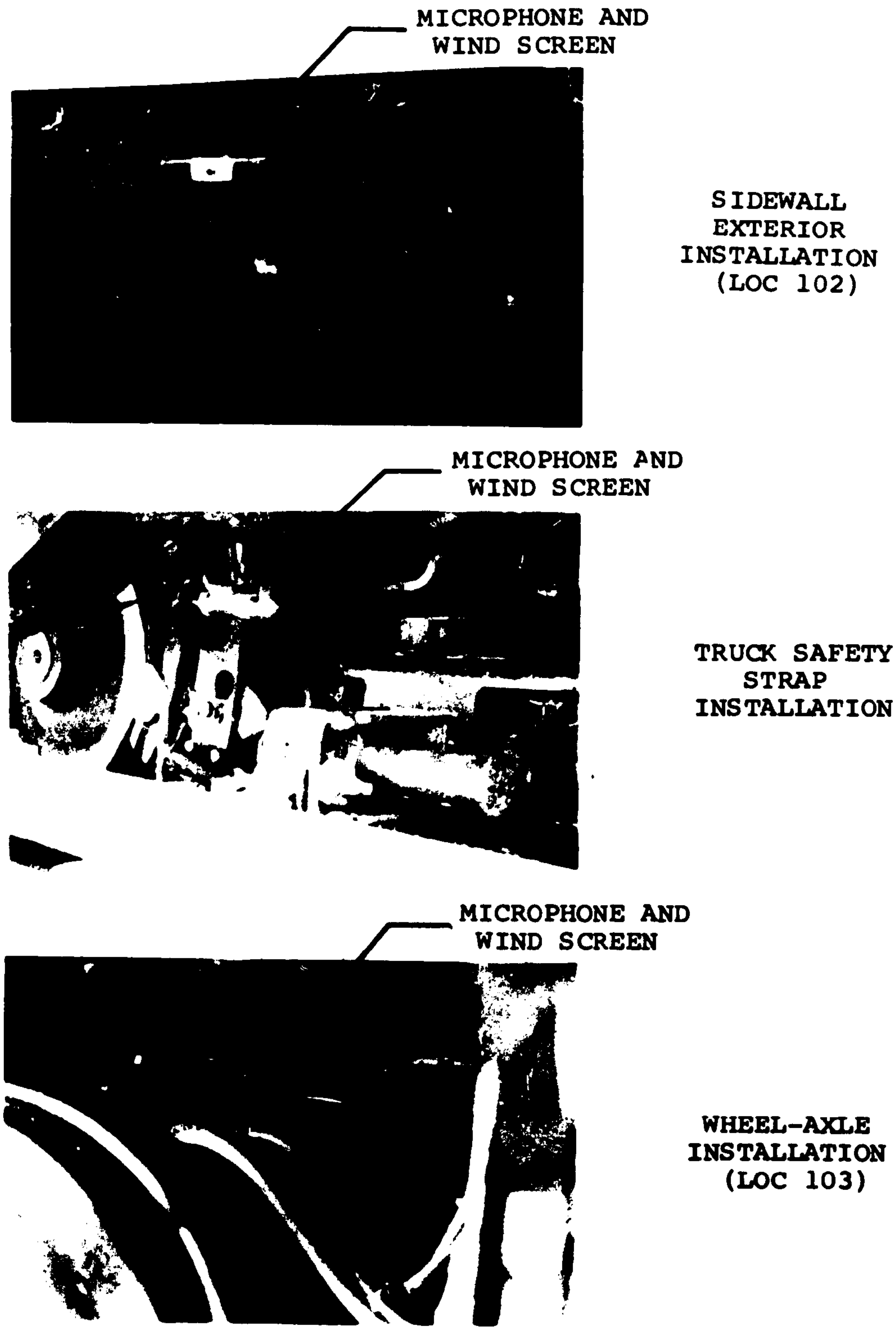


Figure 1–3. On-Car Microphone Installations

TABLE 1-2. ON-CAR NOISE MEASUREMENT INSTRUMENTATION

Item	Manufacturer	Model	Serial No.
1. Tape Recorder	Kudelski	NAGRA III	PHO 67-10290
2. Tape Recorder	Kudelski	NAGRA III	PHO 67-10441
3. Microphone, 1-inch	B&K	4131	73624
4. Power Supply	B&K	2630	168943
5. Microphone	B&K	4131	205686
6. Power Supply	B&K	2630	87607
7. Calibrator	B&K	4230	396443
8. Accelerometer	B&K	4329	86112

1.3.2 Calibration

The recorder was calibrated prior to testing using a swept-frequency sinusoidal insert voltage over the range 20 Hz to 20 kHz at a level of 100 mv. The input signal was applied at the cathode follower and recorded on magnetic tape and played back on the same recorder to produce the frequency response curve shown in Figure 1-4. Microphone response, does not change system accuracy over the frequency range of 2 to 15 kHz.

During the test period, a known signal (94 dB at 1000 Hz) was recorded on each tape to establish system sensitivity and establish a reference level.

1.3.3 System Accuracy

a. The frequency response of each microphone to a sinusoidal wave of constant amplitude lies within the limits of 10 Hz to 14 kHz linear, ±1 dB for sound pressure levels in the range from 50 to 120 dB.

b. Each complete assembly of noise measurement and recording equipment (including cables) had an electrical frequency response linearity of withing ±2 dB from 50 Hz to 10 kHz for a range of signal voltage levels corresponding to input sound levels of 50 dB to 120 dB at the microphone sensor.

c. The total harmonic distortion of the sound sensing microphone equipment did not exceed 1 percent over the measurement dynamic range.

d. The total harmonic distortion of the assembled noise measurement and recording equipment did not exceed 4 percent over the measurement dynamic range.

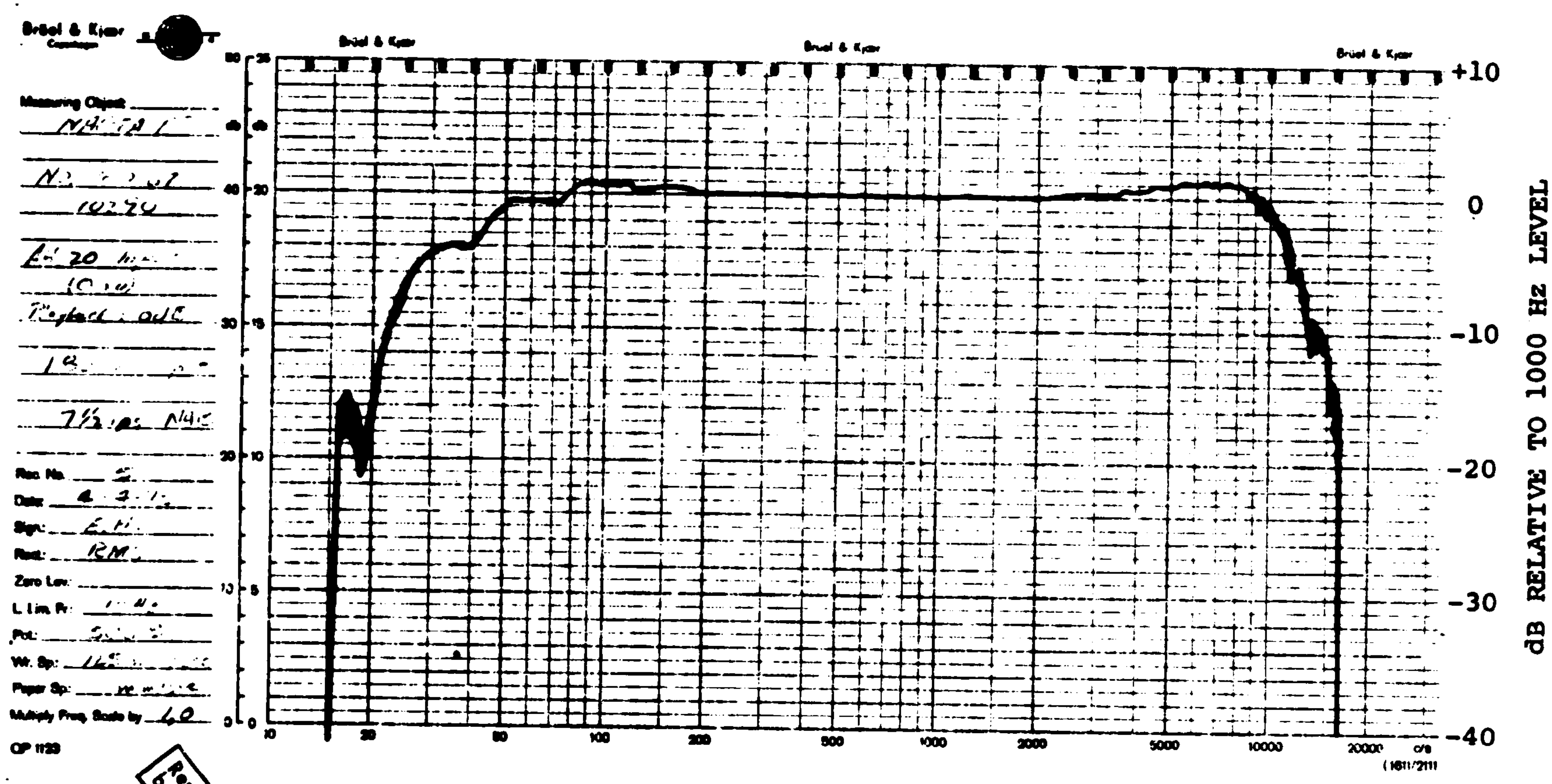


Figure 1—4. System Frequency Response

1.4 TEST PROCEDURES

Tests were conducted under ambient conditions during which winds of 10 to 15 mph occurred. Temperatures were between 55 to 75°F, and a clear and dry atmosphere existed. For interior measurements, no distinction was made between the directions of car operation after a preliminary investigation revealed there was no change in noise level for dBA weighting. Data obtained when nearby objects were passed (e.g., the locomotive and diesel generators used for the power source, or special trackwork such as turnouts) were not reported. The microphone was positioned so that it was not shielded from the source by the person taking the data or any other person or object. The car was occupied by only those persons required for the test, generally less than four. For the baseline survey the microphone was positioned at the height of a seated passenger. Other heights were surveyed at specific locations within the car.

Measurement positions for the interior noise survey are shown in Figure 1-5. Detailed testing procedures employed are as follows:

Pre-test

a. Ballast car to required weight (AW ____).

b. Set-up, calibrate instruments.

c. Proceed to test zone.

1.4.1 Equipment Noise Survey, Interior

The purpose of this sequence of tests is to determine interior noise level effects of cycling various items of car equipment.

a. Position one SOAC car on the transit loop near station location 170, with all equipment turned off.

b. Set-up and calibrate the recording system per previously described procedures.

c. Position the microphone at ear level at car location 49 (see Figure 1-5).

d. Start the recorder, identify the test point and record gain level by voice.

e. Record approximatley 15 seconds of noise data for this record.

f. Stop recorder and enter recorder number on a log sheet.

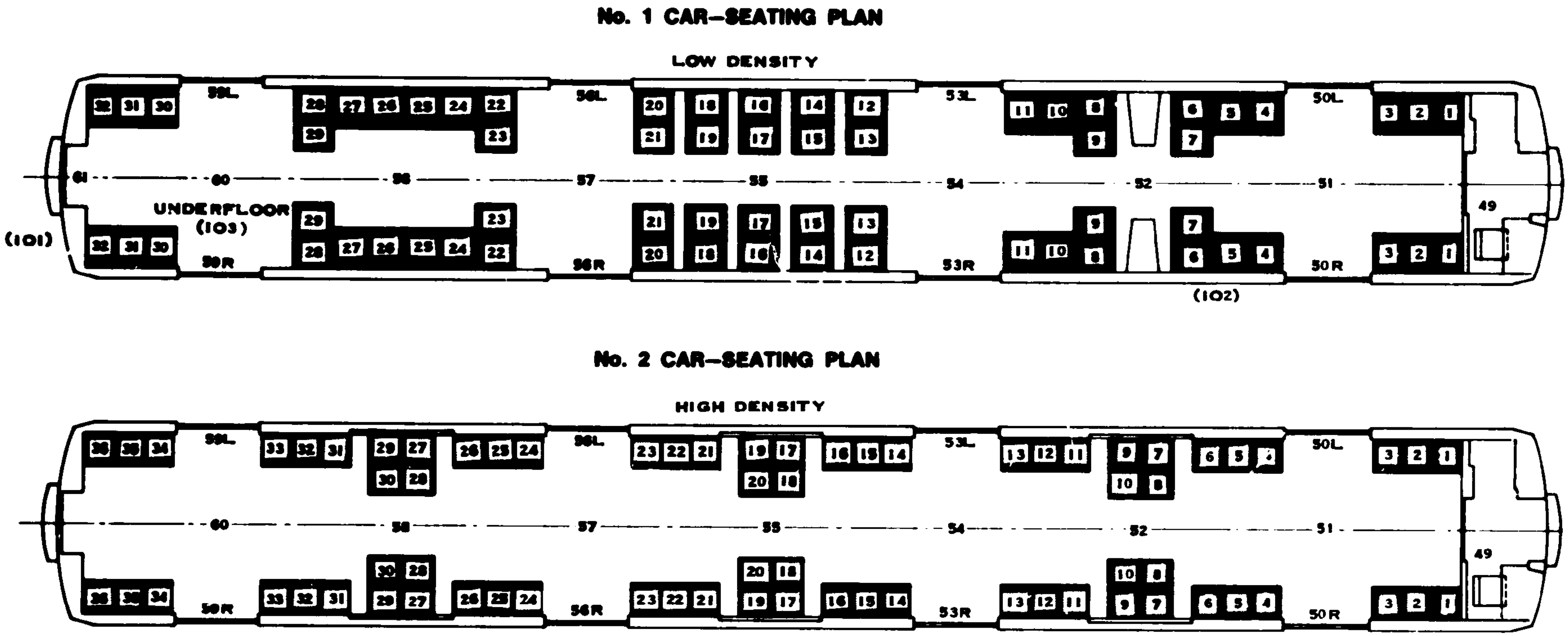


Figure 1–5. Interior Noise Measurement Positions

g. Repeat steps c through f for the three remaining car locations: 51, 55 and 60.

h. Turn on car lighting system and repeat steps c through g.

i. Turn on air conditioning system and repeat steps c through g.

j. Cycle doors open and closed while recording data, repeating steps c through g.

k. With doors open, and while recording data, vent the brakeline, repeating steps c through g.

1.4.2 Effect of Track Section

The purpose of this sequence of tests is to determine the effect of track sections on interior noise.

a. Operate the car around the transit loop at 50 mph. The car will be at 90,000 pounds or the empty weight; the air conditioning system will be on.

b. The car operator will announce the entrance into and departure from all track sections.

c. Set-up and calibrate the recording system per previously described procedures.

d. For each of the track sections and required car location, identify the test point and record gain level on the recorder by voice. Obtain a continuous record of noise around the test loop and enter record number on a log sheet. The microphone should be positioned at ear level of a seated passenger for these test points.

1.4.3 Speed Effect

The purpose of this sequence of tests is to determine the effect of speed on interior noise. This sequence will be performed on each of the SOAC cars at two different weights (90,000 and 105,000 pounds).

a. Operate the SOAC car through track Section I at a steady speed. The air conditioning system will be on.

b. The car operator will announce the entering and leaving of this section.

c. For each speed and car location required, identify the test point and record gain level on the recorder by voice. Obtain 15 seconds of data, and enter the record number on a log sheet. The microphone should be positioned at the ear level of a seated passenger for these test points.

1.4.4 Survey of Interior Noise

The purpose of this sequence of tests is to determine the noise levels throughout the car by a detail survey of passenger locations. This sequence will be performed on each of the SOAC cars, at the light weight (90,000 pounds) only.

a. Operate the SOAC through Track Section I at the required speed. The air conditioning system will be on.

b. The car operator will announce the entering and leaving of Track Section I.

c. Set-up and calibrate the recording system per previously described procedures.

d. For each speed and car location required, identify the test point and record amplifier gain level on the recorder by voice, obtain 15 seconds of data, and enter the record number and record gain level on a log sheet. The microphone should be positioned at the car level of a seated passenger for these test points.

1.4.5 Structure Borne Noise

The purpose of this sequence of tests is to determine the distribution of the noise of the car body structure. This sequence will be performed on Car No. 2 at one car weight (90,000 pounds).

a. Operate the SOAC car through Track Section I at required speeds. The air conditioning system will be on.

b. The car operator will announce the entering and leaving of this track section.

c. Set up and calibrate the recording system per previously described procedures.

d. For each speed and car location required, identify the test point and record gain level on the recorder by voice, obtain 15 seconds of accelerometer data, and enter the record number in a log sheet. The accelerometer should be positioned on double-backed pressure-sensitive tape.

1.4.6 Coasting Car Noise Levels

The purpose of this sequence of tests is to determine the contribution of wheel/rail noise to the interior acoustic environment of the car. This sequence will be performed on Car No. 1 at one car weight (90,000 pounds).

a. Operate the SOAC car through Track Section IV at the required speed, in a coasting mode. All car systems not required for car operation will be off.

b. The car operator will announce the entering and leaving of this track section.

c. Set-up and calibrate the recording system per previously described procedures.

d. For each speed and car location required, identify the test point and record gain level on the recorder by voice, obtain a minimum of 15 seconds of data, and enter the record number and record gain level in a log sheet.

1.4.7 Absorption Test

The purpose of this sequence is to determine the acoustic absorption in the interiors of both SOAC cars (in an empty configuration). Devices which produce impulse type sounds (similar to the sound of exploding balloons, for example) will be used for this test.

a. Position the car in an area which has a low ambient noise level.

b. Explode at least three balloons at each required location, identify the test point, record gain level on the recorder, and enter on a log sheet. The microphone should be approximately three feet from the balloon for each record, and should be midway between floor and ceiling.

1.4.8 Resilient Wheels - Interior Noise Survey

The purpose of this sequence of tests is to determine the effect of resilient wheels on the interior noise of the SOAC car. This sequence will be performed on each of the SOAC cars at 90,000 and 105,000 pounds. The car configuration for the resilient wheel tests will be identical with that for the noise survey with the steel wheels.

a. Operate the SOAC car through each track section and speed as required. The air conditioning system will be on.

b. For the data taken at steady speed around the test loop, the car operator will announce the entering and leaving of this track section.

c. Set-up and calibrate the recording system per previously described procedures.

d. For each speed and car location required, identify the test point and record gain level on the recorder by voice, obtain at least 15 seconds of data, and enter the record number in a log sheet. The microphone should be positioned at the ear level of a seated passenger for these test points.

1.5 DATA

The basic analysis of all data recorded during the program consists of a frequency analysis using an "A" weighting network and is presented in Table 1-3. Selected data points have also been analyzed using 1/3-octave band filters (preferred frequencies) and these are presented in Figures 1-6 through 1-29. All data reported has been converted to sound pressure levels referenced to 2.0×10^{-5} N/M^2. Analysis of the structure borne noise has been made using "A" weighting and the levels reported are in dBA relative to 1g rms.

Where narrow band components required identification, data was analyzed with a digital analyzer (Federal Scientific UA-6 Spectrum Analyzer). Data from this analysis is presented in the form of oscilloscope photographs in Figures 1-30 through 1-41.

During the testing all systems were operating. Some equipment normally cycles as part of its operating mode, such as the brake air compressor and the air conditioner compressor. When these systems cycled to their 'off' mode, a small variation in interior noise level occurred. No correction has been applied to the data to account for this.

TABLE 1-3. ON-CAR NOISE DATA

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	FIGURE NUMBER
1	Effect of Track Constr.	90,000	Steel-Flats	I	50	55	13-B-1,2	35	68	
				II	50	55		41	69	
				III	50	55		40	69.5	1-32
				IV	50	55		38	68.5	
				V	50	55		37	67.5	
				VI	50	55		36	68	
			Trued	I	50	55	13-B-9	317	67	
				II	50	55		318	67	
				III	50	55		319	67	
			Resilient	I	50	55	13-B-18	567	65	
				II	50	55		566	65	
				III	50	55		565	65	
				IV	50	55		564	65	
				V	50	55		563	62.5	
				VI	50	55		562	64.5	
		105,000	Resilient	I	50	55	13-B-20	618	61.5	
				II	50	55		617	62	
				III	50	55		616	62	
				IV	50	55		615	63.5	
				V	50	55		614	63	
				VI	50	55		613	62.5	
2	Effect of Track Constr.	105,000	Resilient	I	50	55	13-B-21	638	62.5	
				II	50	55		639	64	
				III	50	55		640	64.5	
				IV	50	55		641	64	
				V	50	55		642	64.5	
				VI	50	55		643	64	

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	FIGURE NUMBER
1	Equip. Noise, All Systems Off	90,000	Steel-Flats	I	0	49 51 55 60	13-B-1	2 3 4 5	41.5 41.5 42 41.5	1-6, 1-30
	M/A Set Only	90,000	Steel-Flats	I	0	49 51 55 60	13-B-1	7 8 9 10	44.5 46.5 57 48.5	1-7, 1-30
	M/A Set and Lighting System	90,000	Steel-Flats	I	0	49 51 55 60	13-B-1	11 12 13 14	46 47 58 51	1-8, 1-30
	M/A Set and Traction Motor Blowers	90,000	Steel-Flats	I	0	49 51 55 60	13-B-1	15 16 17 18	51 56 60 64.5	1-9, 1-30
	M/A Set and Brake Air Comp.	90,000	Steel-Flats	I	0	49 51 55 60 60R	13-B-1	19 20 21 22 23	46.5 48.5 59 56.5 57	1-10, 1-30
	M/A Set, Air Comp. Blowers & A/C Comp.	90,000	Steel Flats	I	0	49 51 55 60	13-B-1	24 25 26 27	63 63 63 64.5	1-26, 1-31

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	FIGURE NUMBER OR NOTES
1	All Systems On	90,000	Steel-Flats	I	0	49 51 55 60	13-B-1	31 32 33 34	63 63.5 64.5 67	1-31
	Door Cycle	90,000	Steel-Flats	I	0	51 55 60	13-B-1	28 29 30	66/65 66/62 67/63	Open/Close
2	All Systems Off	90,000	Steel-Flats	I	0	49 51 55 60	13-B-3	94 95 96 97	47 46 46 46.5	
	M/A Set Only	90,000	Steel Flats	I	0	49 51 55 60 60R	13-B-3	98 99 100 101 102	48 54.5 56.5 52.5 53	
	M/A Set and Lighting System	90,000	Steel-Flats	I	0	49 51 55 60	13-B3	103 104 105 106	49.5 54 57 53	
	M/A Set and Brake Air Comp.	90,000	Steel-Flats	I	0	49 51 55 60	13-B-3	107 108 109 110	52 54.5 57.5 55.5	

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	FIGURE NUMBER OR NOTES
2	M/A Set and Traction Motor Blowers	90,000	Steel-Flats	I	0	49 51 55 60	13-B-3	111 112 113 114	52.5 59 63.5 65.5	
	M/A Set and Air Conditioner Blowers (A/C Comp. Not Operative)	90,000	Steel-Flats	I	0	49 51 55 60	13-B-3	115 116 117 118	64 64.5 64 64	
	All Systems On	90,000	Steel-Flats	I	0	49 51 55 60	13-B-3	119 120 121 122	63.5 65 66 66.5	
	Air Comfort Diffuser Survey 6" Below Ceiling	6" to Left of L/H Diffuser Directly Below L/H Diffuser 6" to Right of L/H Diffuser Below Car Centerline Directly Below R/H Diffuser				52	13-B-3	124 125 123 126 127	73 73 73 69 68	
	Door Cycle	90,000	Steel-Flats	I	0	51 53	13-B-3	188 189	74/69 73/70	Open/Close
1	Effect of Car Velocity	90,000	Steel-Flats	I	0	49 51 55 60	13-B-1	31 32 33 34	63 63.5 64.5 67	All Sys. On

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	FIGURE NUMBER
1	Effect of Car Velocity	90,000	Steel-Flats	I	25	49	13-B-2	43	66.5	1-27, 1-33
						51		44	68	
						55		45	66.5	
						60		47	70	
					35	49	13-B-2	48	71.5	1-28, 1-33
						51		49	72.5	
						55		50	68	
						60		51	72	
					50	49	13-B-2	52	74	1-11, 1-33
						51		53	76	
						55		54	71	
						60		55	75	
					70	49	13-B-6	237	82	
					80	51	13-B-2	89	83.5	1-12, 1-33
						55		90	78.5	
						60		91	80	
2	Effect of Car Velocity	90,000	Steel-Flats	I	0	49	13-B-3	119	63.5	1-29
						51		120	65	
						55		121	66	
						60		122	66.5	

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	FIGURE NUMBER
2	Effect of Car Velocity	90,000	Steel-Flats	I	25	49	13-B-4	129	67	1-13, 1-34
						51		130	67.5	
						55		131	65.5	
						60		132	68	
					35	49	13-B-4	137	68	1-14, 1-34
						51		136	68.5	
						55		135	67	
						60		133	70	
					50	49	13-B-4	138	69.5	1-15, 1-34
						51		141	71	
						55		151	68	
						60		170	73.5	
					70	49	13-B-4	[illegible]2?	70	1-34
						51		173	71.5	
						55		174	69	
						60		175?	74	
					80	49	13-B-5	190	73.5	
						51		191	74.5	
						55		192	73	
						60		193	78	
	Acceleration/Deceleration	90,000	Steel-Flats	I	0-50-0	55	13-B-5	187	64-69-64	
					0-80-0	55	13-B-5	186	64-72-64	

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	FIGURE NUMBER OR NOTES
1	Effect of Car Velocity	90,000	Steel-Trued	II	25	49	13-B-9	324	67	Blowers On
						51		325	69.5	
						55		326	66.5	
						60		327	74.5	
				I	25	49	13-B-10	333	56	Blowers Off
						51		334	57	
						55		335	58.5	
						60		336	59	
					35	49	13-B-10	337	59	
						57		338	59.5	
						55		339	59	
						60		340	61	
					50	49	13-B-10	341	63	
						51		342	62.5	
						55		345	61.5	
	Effect of Car Velocity	105,000	Steel-Trued	I	25	49	13-B-10	449	64.5	1-35
						51		450	64	
						55		451	63.5	
						60		452	65	
					35	49	13-B-10	453	65	A/C Comp. On
						51		454	65.5	A/C Off
						55		455	65	
						55		457	64.5	
						60		456	66.5	

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	CAB DOOR POSITION	FIGURE NUMBER OR DEF. BLWR.
1	Effect of Car Velocity	105,000	Steel-Trued	I	50	49	13-B-10	458	68.5		1-35
						51		459	69		
						55		460	66		
						60		462	67.5		
					70	49	13-B-10	480	69.5		1-35
						51		481	67		
						55		482	66.5		
						60		483	67.5		
2	Effect of Car Velocity	105,000	Steel-Trued	I	25	49	13-B-15	486	54.5	Closed	Off
						49		487	65.5	Open	
						51		488	65	Closed	
						55		489	65	Closed	
						60		490	66.5	Closed	
					35	49	13-B-15	491	55	Closed	Off
						49		492	66.5	Open	On
						51		493	64.5	Closed	On
						55		494	67	Closed	On
						60		495	68.5	Closed	On
					50	49	13-B-15	501	67.5	Closed	Off
						49		499	68	Open	On
						51		498	66	Closed	On
						55		497	66	Closed	On
						60		496	66	Closed	On
					50	55	13-B-15	524	64	Closed	On

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	CAB DOOR POSI-TION	FIGURE NUMBER / DEF. BLWR.
2	Effect of Car Velocity	105,000	Steel-Trued	I	70	49	13-B-15	528	64	Closed	Off
						49		529	67	Closed	On
						49		530	70	Open	
						51		531	69.5	Closed	On
						55		532	69.5	Closed	On
		(Possible Wheel Flat)				60		533	70	Closed	On
1	Effect of Car Velocity	90,000	Resil-ient	I	0	49	13-B-18	558	65		1-36
						51		559	64		
						55		560	63		
						60		561	65		
					25	49	13-B-18	562	65		1-36
						51		563	65		
						55		564	65		
						60		565	68		
					35	49	13-B-18	575	67		1-36
						51		574	67		
						55		573	66		
						60		572	68		
					50	49	13-B-18	576	69		1-36
						51		577	67		
						55		578	66		
						60		579	68		
					70	49	13-B-18	584	70		1-36
						51		583	70		
						55		582	68		
						60		581	65		

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)
1	Effect of Car Velocity	105,000	Resil-ient	I	0	49 51 55 60	13-B-20	612 611 610 609	64 62 62.5 63
					50	49 51 55 60	1?-B-20	621 620 618 619	64.5 63.5 61.5 62.5
2	Effect of Car Velocity	90,000	Resil-ient	I	0	49 51 55 60	13-B-21	637 636 635 634	62 62 61 69
					25	49 51 55 60	13-B-21	648 649 650 651	63 62.5 61.5 69
					35	49 51 55 60	13-B-21	655 654 653 652	64 63 61.5 69
					50	49 51 55 60	13-B-21	644 645 646 647	66.5 66.5 64 69
					70	49 51 55 60	13-B-21	657 658 657 656	69 72 67.5 71

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	NOTES
1	Detail Car Survey	90,000	Steel-Flats	I	50	49	13-B-2	52	74	
						51		53	76	
						55		54	71	
						60		55	75	
						2-L		56	69.5	
						50		57	73.5	
						52		58	70	
						52		59	69.5	
						10-L		60	69	
						53		61	72.5	
						54		62	72	
						12-L		63	69	
						16-L		64	70	
						17-L		65	70	
						17-R		66	69	
						16-R		67	69	
						20-R		68	70.5	
						56-L		69	73	Roof
						56-L		70	72.5	Mid
						56-L		71	74	Floor
						57		72	74	Roof
						57		73	72.5	Mid
						57		75	74	Floor
						56-R		76	73	Roof
						56-R		77	72	Mid
						56-R		78	72	Floor
						22-L		80	69	
						25/26-L		81	70	
						58		82	70	
						28-L		83	70	
						31-L		84	74	
						59-L		84	74	
						61		86	76	
						61		87	76	1 Ft. from Return Air Inlet

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	NOTES
2	Detail Car Survey	90,000	Steel-Flats	I	50	49	13-B-4	138	69.5	
						2-L		139	71	
						50		140	71	
						51		141	71	
						5-L		142	68	
						52		143	68.5	
						10-L		144	68	
						53		145	68.5	
						54		146	68.5	
						12-L		147	68	
						15-L		148	66.5	
						17-L		149	67.5	
						18-L		150	66.5	
						55		151	68	
						18-R		152	67	
						17-R		153	68	
						56-L		154	69.5	Roof
						56-L		155	69.5	Mid
						56-L		156	70.5	Floor
						57		157	72	Roof
						57		158	71.5	Mid
						57		159	71	Floor
						56-R		160	71.5	Roof
						56-R		161	71	Mid
						56-R		162	71	Floor
						22-L		163	69	
						25-L		164	70	
						58		165	70.5	
						28-L		166	69.5	
						51-L		167	70.5	
						59		168	72	
						59-R		169	73	
						60		170	73.5	
						61		171	72	

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOCATION	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	NOTES
1	Detail Car Survey	90,000	Steel-Trued	I	50	49	13-B-10	341	63	
						51		342	62.5	
						52-R		343	62.5	
						54-R		344	62.5	
						55		345	61.5	
						56-R		346	63	
						25/26-R		347	64.5	
						59-R		348	65	
						61		349	67	
						16-R		350	62.5	Floor
						16-R		351	60	Mid
						16-R		352	62	Window
						16-R		353	62.5	Roof
						16/17-R		354	62	Roof
						17-R		355	63	Roof
						55		356	62.5	Roof
						17-L		357	63.5	Roof
						16/17-L		358	61	Roof
						16-L		359	62.5	Roof
						16-L		360	61	Window
						16-L		361	60.5	Mid
						16-L		362	62	Floor
						55		363	62.5	Floor
						50-R		364	63	
						5/4-R		365	62	Mid
						9-R		367	63.5	
						11/10-R		368	64	
						17-R		374	65	
						56-R		375	66	
						22/23-R		376	66.5	
						25/26-R		377	66	
						59-R		378	67	

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	NOTES
1	Detail Car Survey	90,000	Steel-Trued	I	50	31-R	13-B-10	379	69.5	
						16-L		380	67.5	
						17-L		381	67-5	
						17-R		382	67.5	
						16-R		383	67	
1	Detail Car Survey	105,000	Steel-Trued	I	50	49	13-B-14	458	68.5	
						51		459	69	
						55		460	66	
						55		461	65.5	Reverse Dir.
						60		462	67.5	
						31-R		463	68	
						59-R		464	69.5	
						28/29-R		465	67.5	
						25/26-R		466	67	
						22/23-R		467	67	
						56-R		468	66.5	
						20-R		469	66	
						18/19-R		470	66	
						16/17-R		471	66.5	
						14/15-R		472	65.5	
						12/13-R		473	66	
						53-R		474	67	
						10/11-R		475	67.5	
						8/9-R		476	67	
						6/7-R		477	66.5	
						4/5-R		478	66.5	
						50-R		479	67	

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	NOTES
2	Detail Car Survey	105,000	Steel-Trued	I	50	50-R	13-B-14	503	63	
						5-R		504	64.5	
						7/8-R		505	63.5	
						12-R		506	66	
						53-R		507	64	
						15-R		508	67.5	
						17/18-R		509	63	
						22-R		510	62.5	
						23-R		511	65	
						56-R		512	71.5	
						25-R		513	70.5	Motor Blower Cover Banging
						27/28-R		514	67.5	
						32-R		515	67	
						59-R		516	63	
						35-R		517	65-5	
						19-L		518	67	
						20-L		519	67	
						55		520	63	
						20-R		521	68.5	
						19-R		522	69	
						55		523	67.5	Roof
						55		524	64	Standing Ear Level

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	STRUCTURE BORNE NOISE (dBA) re 1g rms	ACCEL. DIR.
1	All Syst Off	90,000	Steel-Flats	I	0	49 Floor	13-B-5	215	-44	Vertical
	M/A Set Start					49 Floor	13-B-5	216	-34.5	
	M/A Set					49 Floor	13-B-5	217	-44	
	All Syst Off					53-L Sill	13-B-5	218	-44	
	M/A set Start Up					53-L Sill	13-B-5	219	-44	
	A/R Comp. Start Up					53-L Sill	13-B-5	220	-44.5	
	M/A Set & Air Comp.					56-L Sill	13-B-5	221	-44	
	M/S Set Mtr Blwrs, Air Comp.					56-L Uppr Sill	13-B-6	222	-31	
	Above plus Lighting System					56-L Upper Sill	13-B-6	223	-38	
	Coasting, All Pwr Off	90,000	Steel-Flats	I	50	49 Floor	13-B-6	224	-29	
	Powered Car				35 25	49 Floor	13-B-6	238 239	-32.5 -36.5	Vertical

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	STRUCTURE BORNE NOISE (dBA) re 1g rms	ACCEL. DIR.
1	Powered Car, Ceiling	90,000	Steel-Flats	I	50	49-51	13-B-6	240	-41	Vertical
	Ceiling					51		241	-34	Vertical
	Ceiling					50/51-R		242	-37.5	Vertical
	Door, Top					51-R Door, Top		243	-37	Lateral
	Mid					Mid		244	-32	Lateral
	Low					Low		245	-28	Lateral
	Lower Door Sill					51-L Sill		247	-35	Vertical
	Ceiling					50/51-L		248	-36	Vertical
	Upper Door Sill					50-L		249	-33	Vertical
	Door, Top					50-L		250	-39	Lateral
	Mid					50-L		251	-29	Lateral
	Low					50-L		252	-38	Lateral
	Sidewall, Mid Car									
	Low					50-L		253	-38	Lateral
	Mid					50-L		254	-39	Lateral
	Top					50-L		255	-38	Lateral
	Ceiling					16-L		256	-43.5	Vertical
	Diffuser					17-L		257	-41	Vertical
	Ceiling					16-R		258	-44	Vertical
	Sidewall, Upper					16-R		259	-37	Lateral
	Mid					16-R		260	-38	Lateral
	Low					16-R		261	-40	Lateral
	Ceiling					57		262	-42.5	Vertical
	Lower Door Sill					56		263	-34	Vertical
	Ceiling					60		264	-38.5	Vertical
	Ceiling					61		265	-42	Vertical

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	STRUCTURE BORNE NOISE (dBA) re 1g rms	ACCEL. DIR.
1	Powered Car Door Sill	90,000	Steel-Flats	I	50	59-L	13-B-6	266	-32	Vertical
	Ceiling, Diffuser					60		267	-38	Vertical
	Ceiling, Return Air Inlet					61		268	-42	Vertical
	Door Sill					59-L		269	-32	Vertical

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	NOTES	FIGURE NUMBER
1	Coasting Car - All Systems Off	90,000	Steel-Flats	IV	[illegible]	51	13-B-6	226	63.5		
					22	51		227	64.5		
					11	51		228	58		
					5	51		229	49.5		
					25	51		230	89		
					25	60		232	86		
					15	60		233	84		1-37
					9-10	51		234	73		1-37
					10-20	51		235	78		1-37
1	Absorption Test	90,000	Steel-Flats		0						
2	Absorption Test	90,000	Steel-Flats		0						
1	Wall	90,000	Steel-Flats	I	25	4R	13-B-8	285	80	Exterior	1-16, 1-39
			(Lights On)		25			286	62	Interior	1-39
			(Lights Off)		25			287	60.5	Interior	1-17, 1-39
					35			289	87	Exterior	
1	Truck	90,000	Steel-Flats	I	25	59-R/60	13-B-8	290	88	Exterior	
					35			291	92	Exterior	1-18, 1-41
					35			292	71.5	Interior	1-19, 1-41
					50			293	101	Exterior	
					50			294	72	Interior	
					0 - 70			295	81/106	Exterior	
					70			296	106	Exterior	
					70			298	78.5	Interior	

ABSORPTION COEFFICIENT (α*)

CAR	Loc.	Tape No.	Test Pt.	500 Hz	1000 Hz	2000 Hz	4000 Hz
1	60	13-B-6	203	0.30	0.27	0.26	0.28
	52		204	0.27	0.24	0.25	0.28
	55		205	0.23	0.23	0.26	0.29
	58		206	0.26	0.24	0.25	0.27
2	55	13-B-6	207	0.22	0.22	0.22	0.24
	52		208	0.25	0.20	0.23	0.24
	51		209	0.23	0.21	0.22	0.25
	49		210	0.32	0.24	0.31	0.36

*Norris-Eyring equation

TABLE 1-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRACK SEC.	VELOCITY (MPH)	LOC.	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	ACCEL. DIR.	FIGURE NUMBER
1	End	90,000	Steel-Flats	I	0		13-B-8	299	60	Exterior	
					0			300	63	Interior	
					25			301	82	Exterior	1-40
					25			302	62	Interior	1-40
					70			303	98	Exterior	
	Body, Safety Strap, Near Power Pick-Up Shoe	90,000	Steel-Flats	I	0		13-B-8	435	81		
					25			436	100		
					35			437	101		
					50			438	104		1-20, 1-38
					70			439	107		1-21
					0 - 50			440	81-105		
	MIC on Truck 1 (#2 Axle)	90,000	Steel-Flats	I	0		13-B-8	441	87		1-22
					25			442	98		1-25
					35			443	100		1-23
					50			444	104		1-24, 1-38
					70			445	107		
					0 - 50			446	78/95		

DATA PT 4

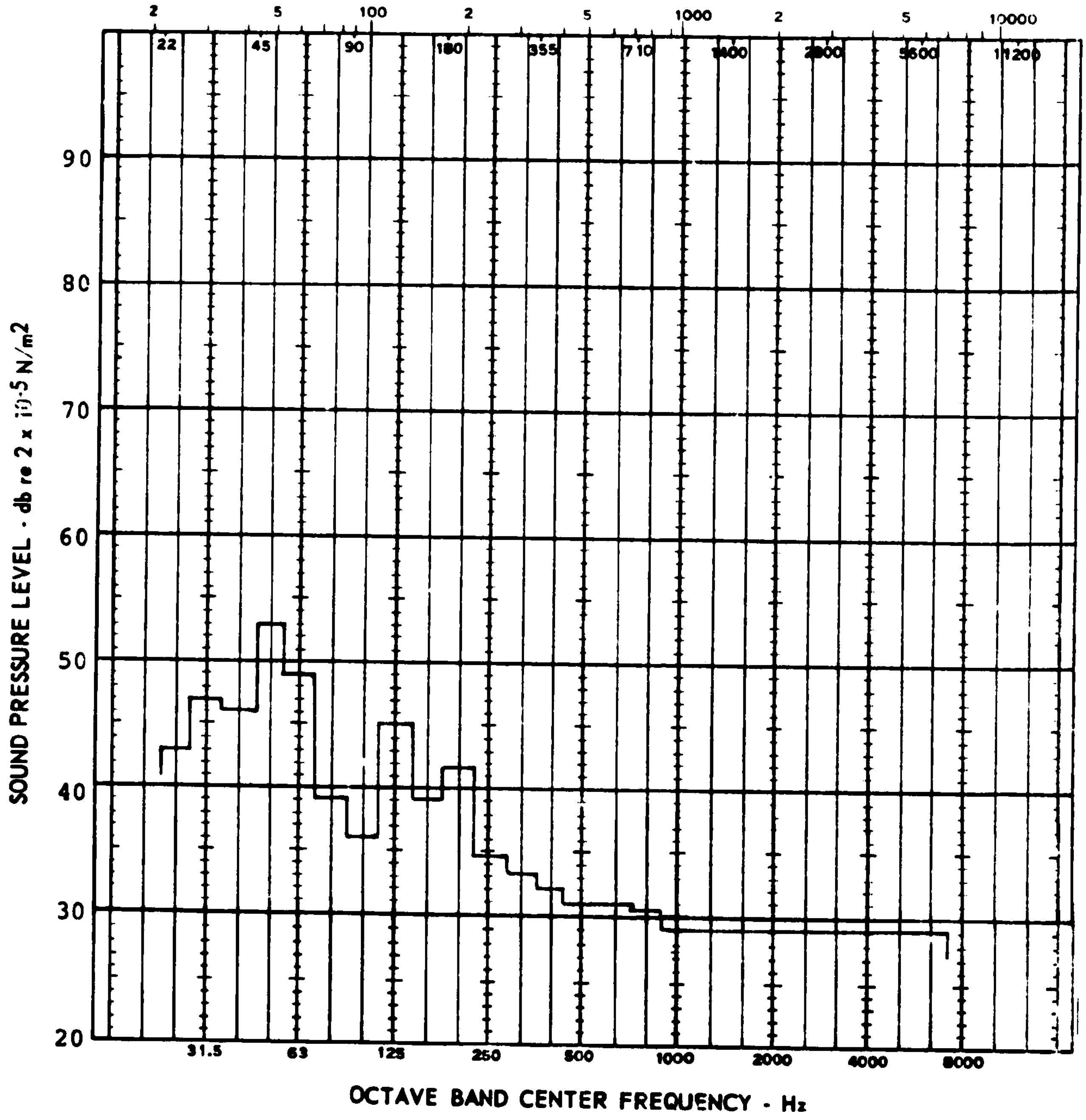


Figure 1–6. Interior Noise at 0 MPH with All Systems Off (Car No. 1; Position 55)

DATA PT 9

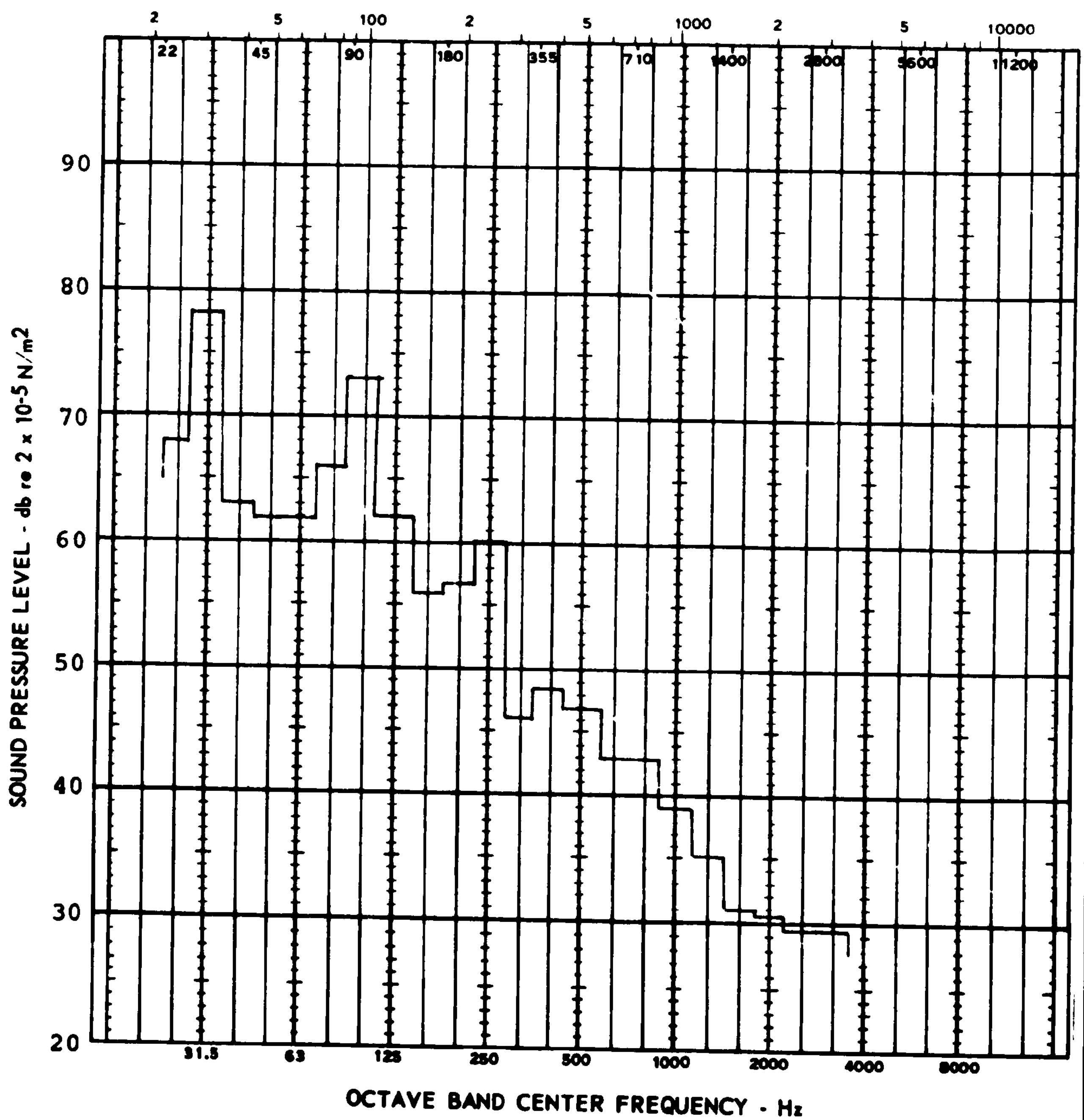


Figure 1–7. Interior Noise at 0 MPH with Only the Motor Alternator On (Car No. 1; Position 55)

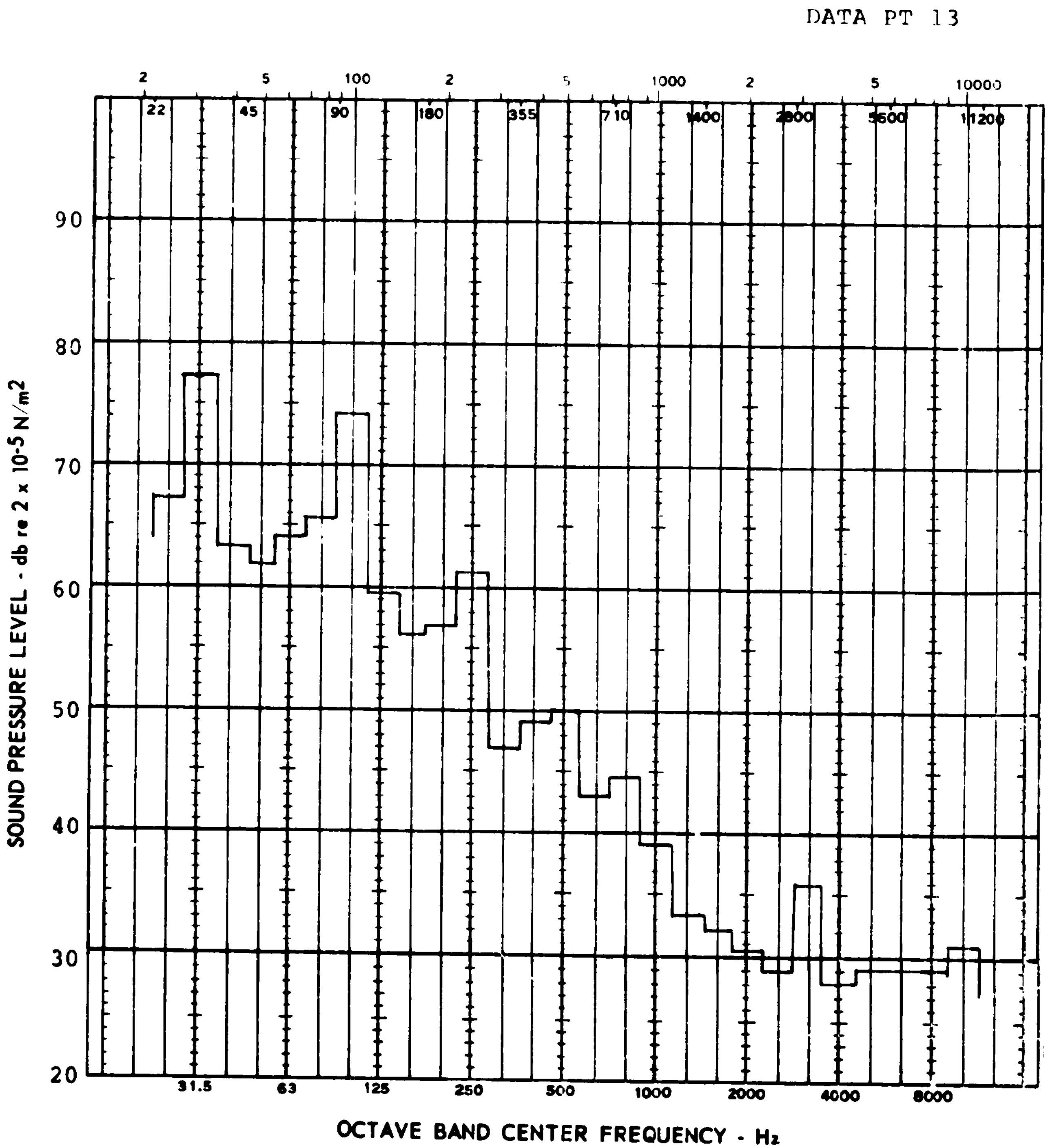


Figure 1–8. Interior Noise at 0 MPH with Motor Alternator and Lighting System On (Car No. 1; Position 55)

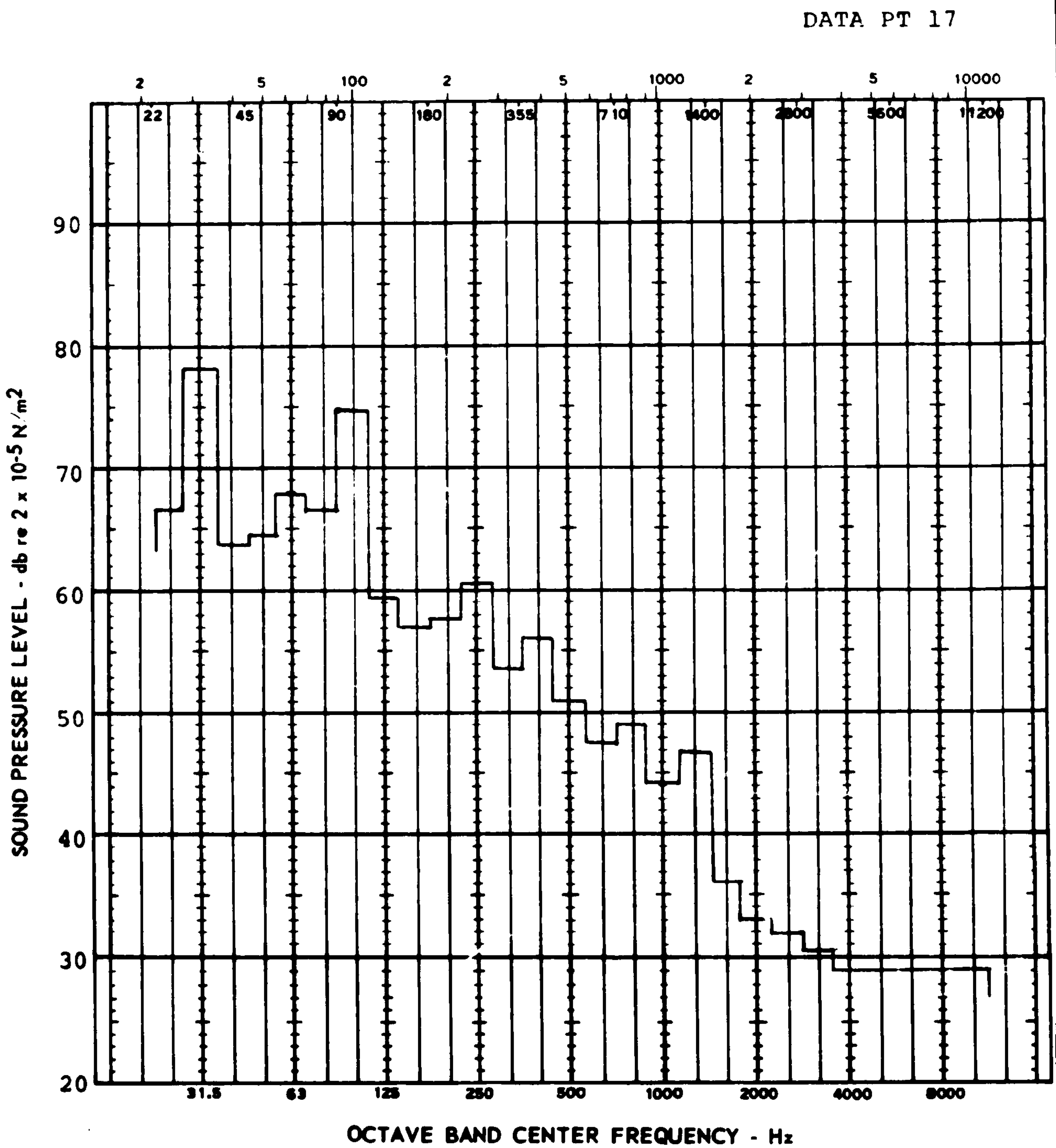


Figure 1–9. Interior Noise at 0 MPH with Motor Alternator and Motor Blowers On (Car No. 1; Position 55)

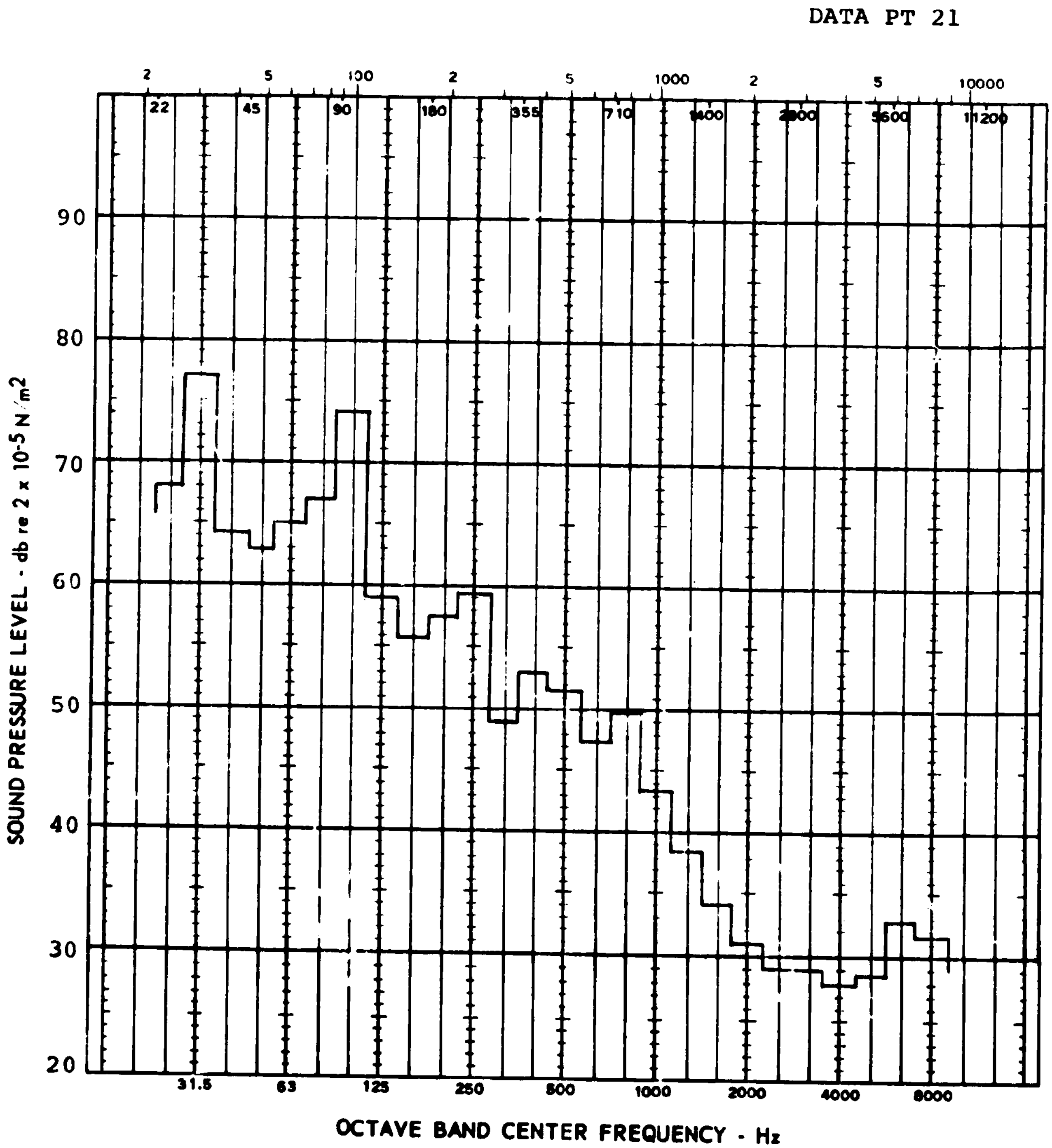


Figure 1–10. Interior Noise at 0 MPH with Motor Alternator and Brake Air Compressor On (Car No. 1; Position 55)

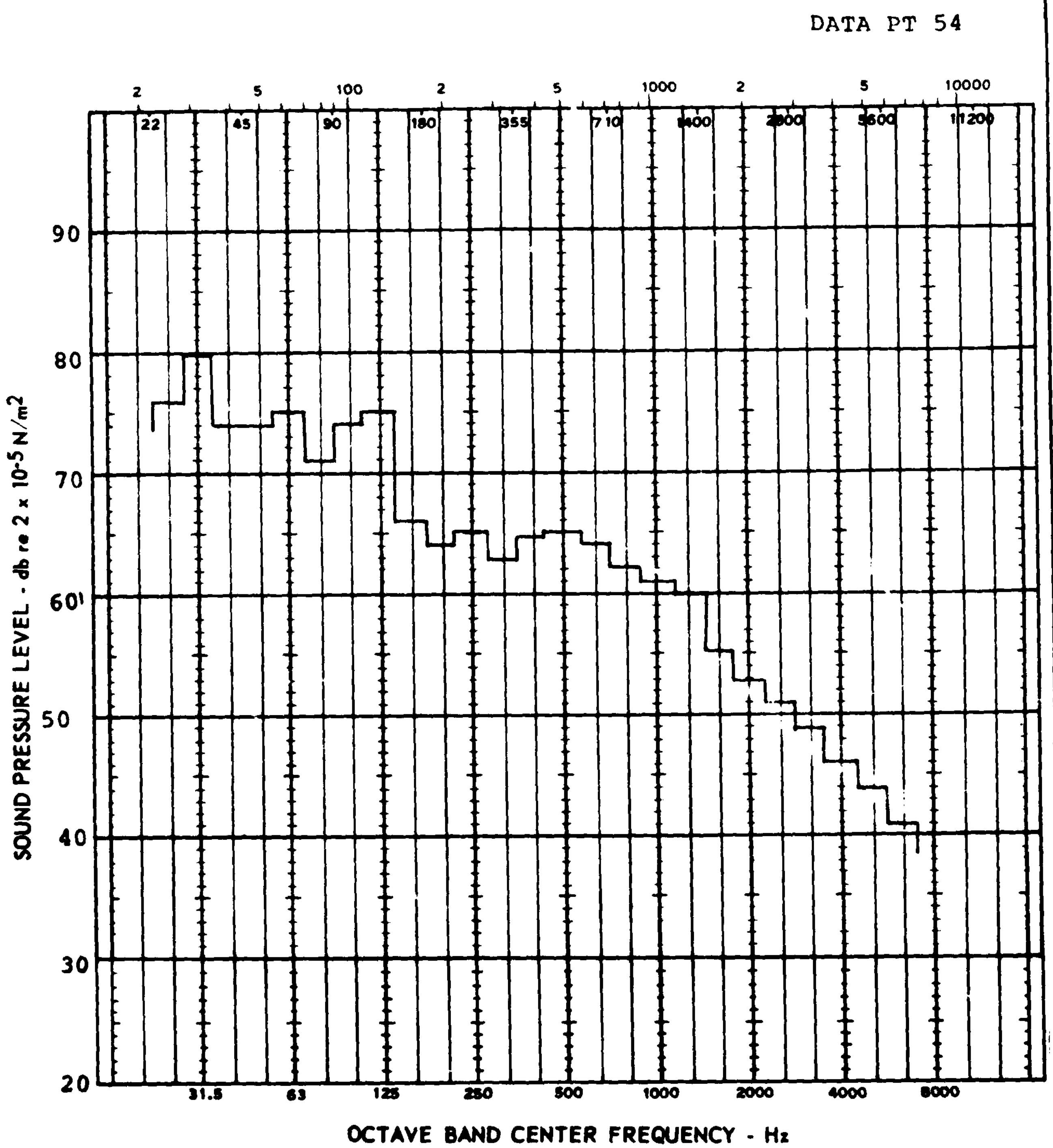


Figure 1–11. Interior Noise at 50 MPH with All Systems On (Car No. 1; Steel Wheel Flats; Position 55)

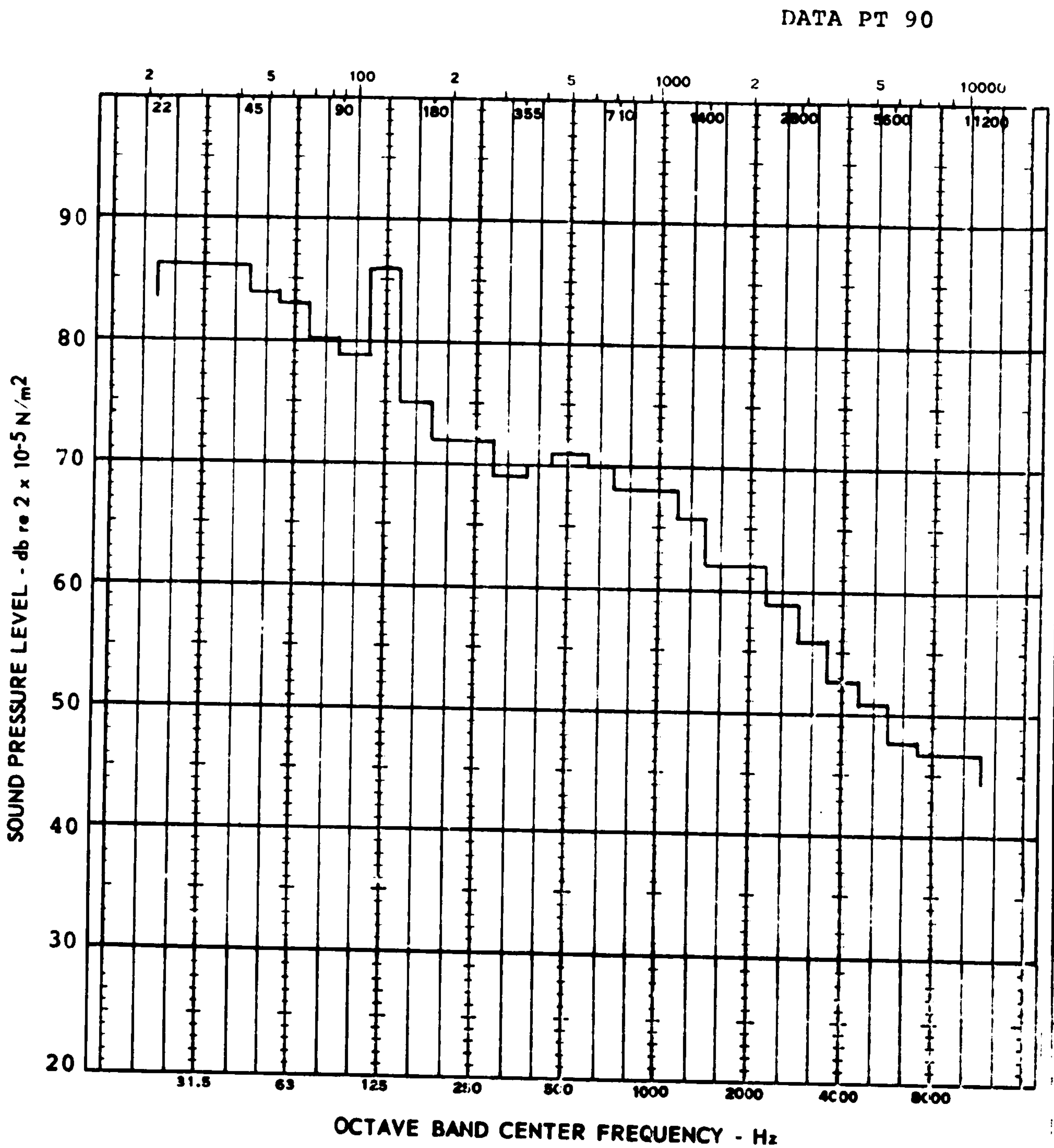


Figure 1–12. Interior Noise at 80 MPH with All Systems On (Car No. 1; Steel Wheel Flats; Position 55)

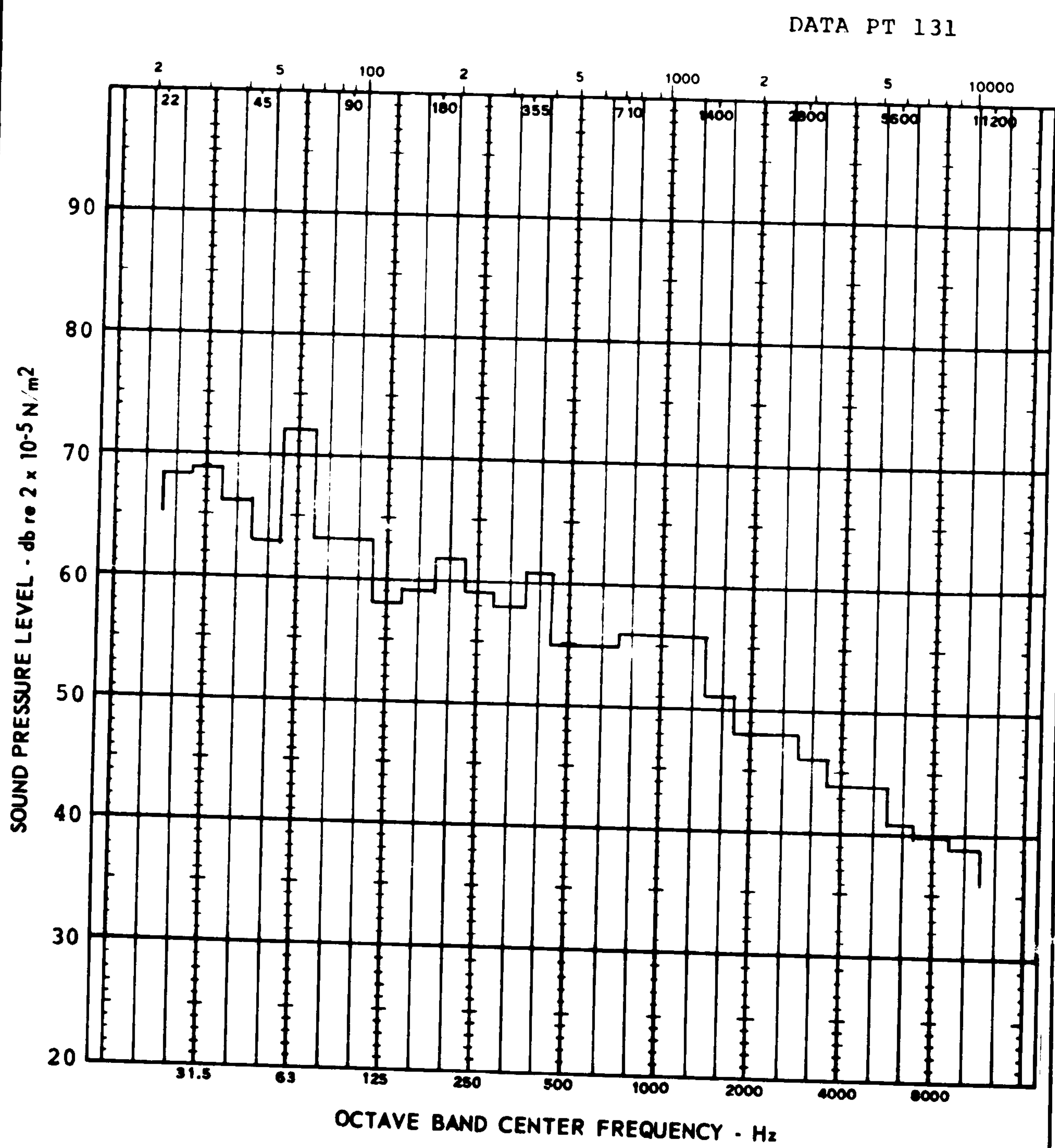


Figure 1–13. Interior Noise at 25 MPH with All Systems On (Car No. 2; Steel Wheel Flats; Position 55)

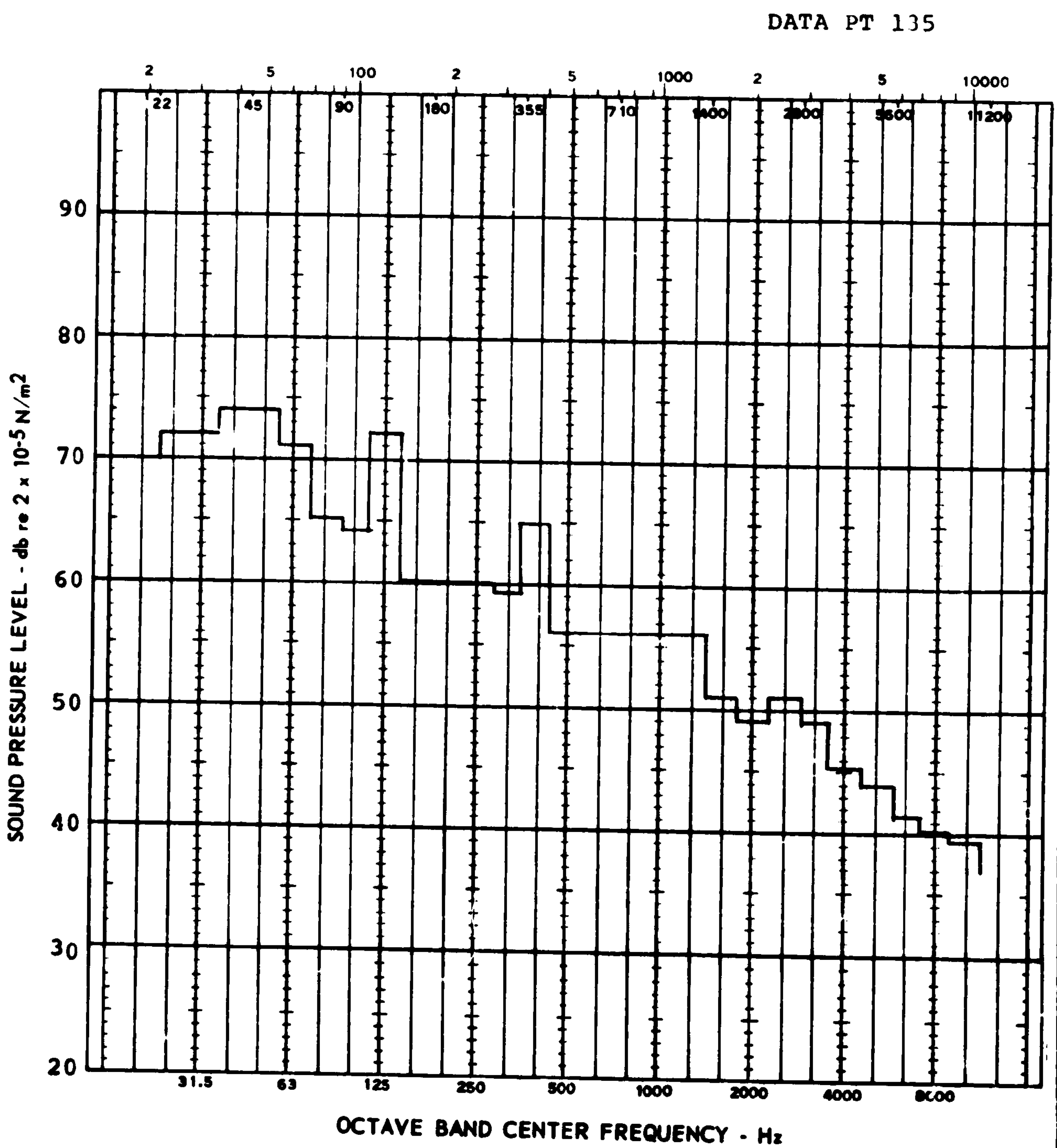


Figure 1–14. Interior Noise at 35 MPH with All Systems On (Car No. 2; Steel Wheel Flats; Position 55)

DATA PT 151

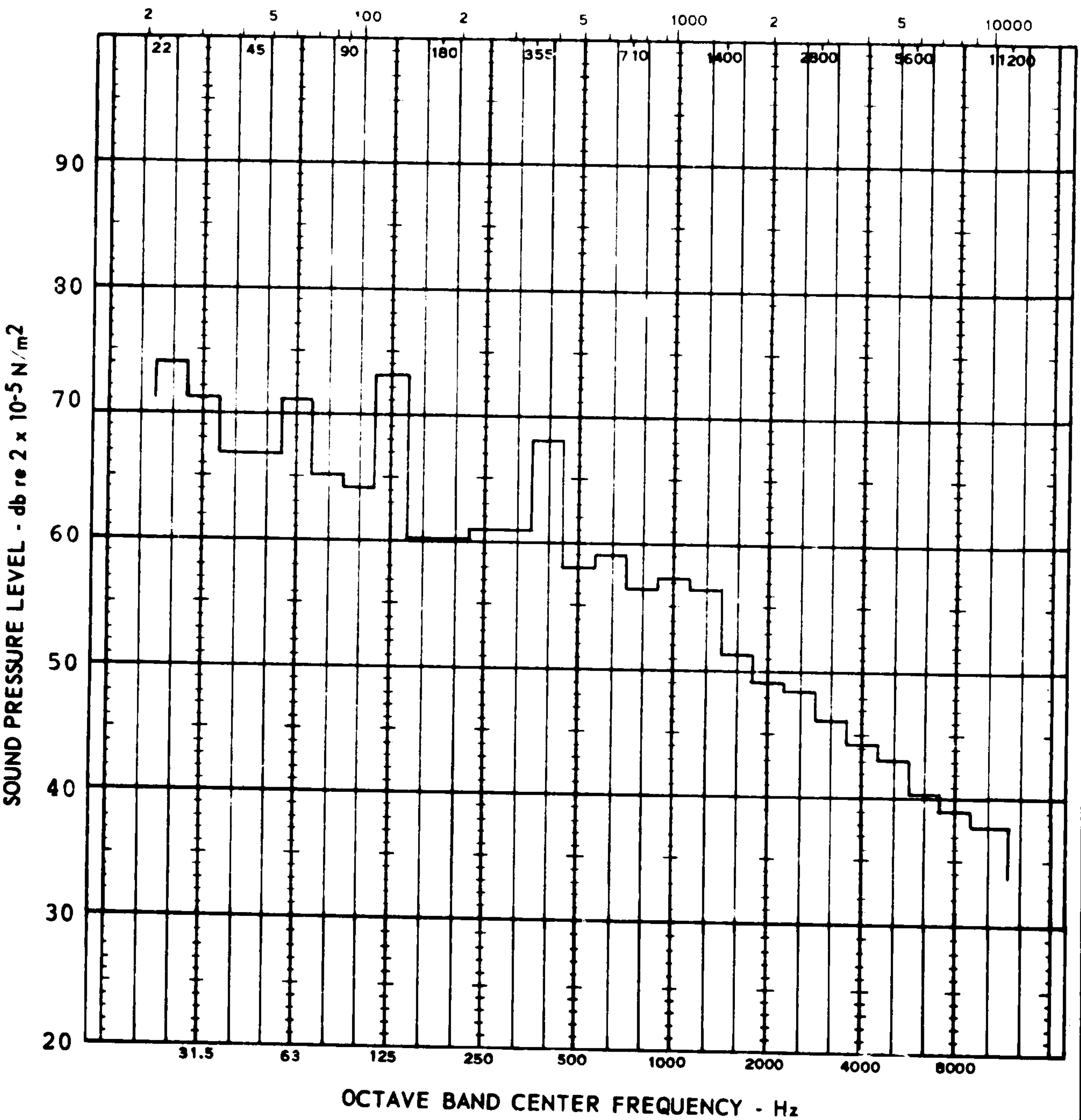


Figure 1–15. Interior Noise at 50 MPH with All Systems On (Car No. 2; Steel Wheel Flats; Position 55)

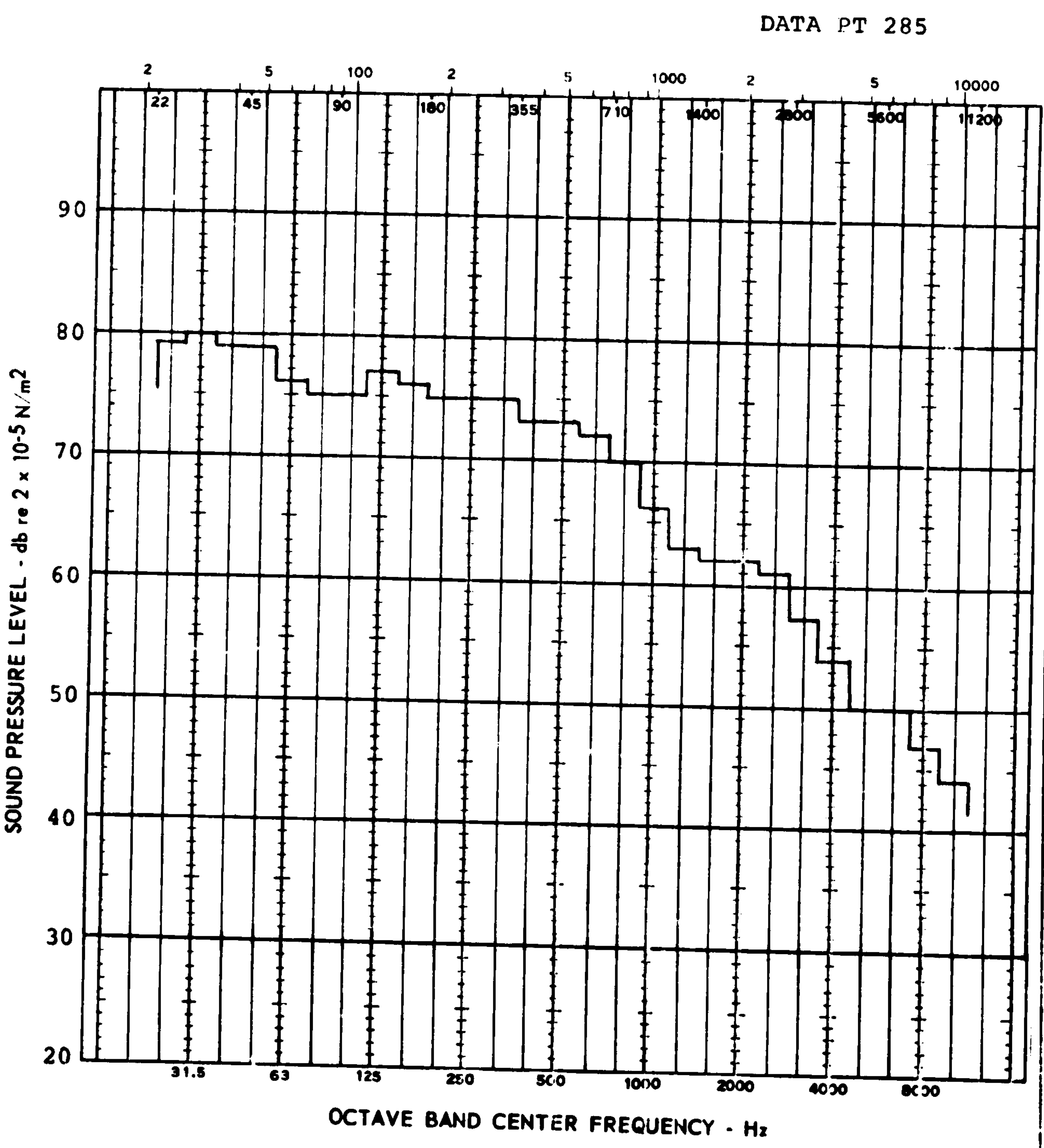


Figure 1-16. Exterior Noise at 25 MPH with Steel Wheel Flats (Sidewall Location 102)

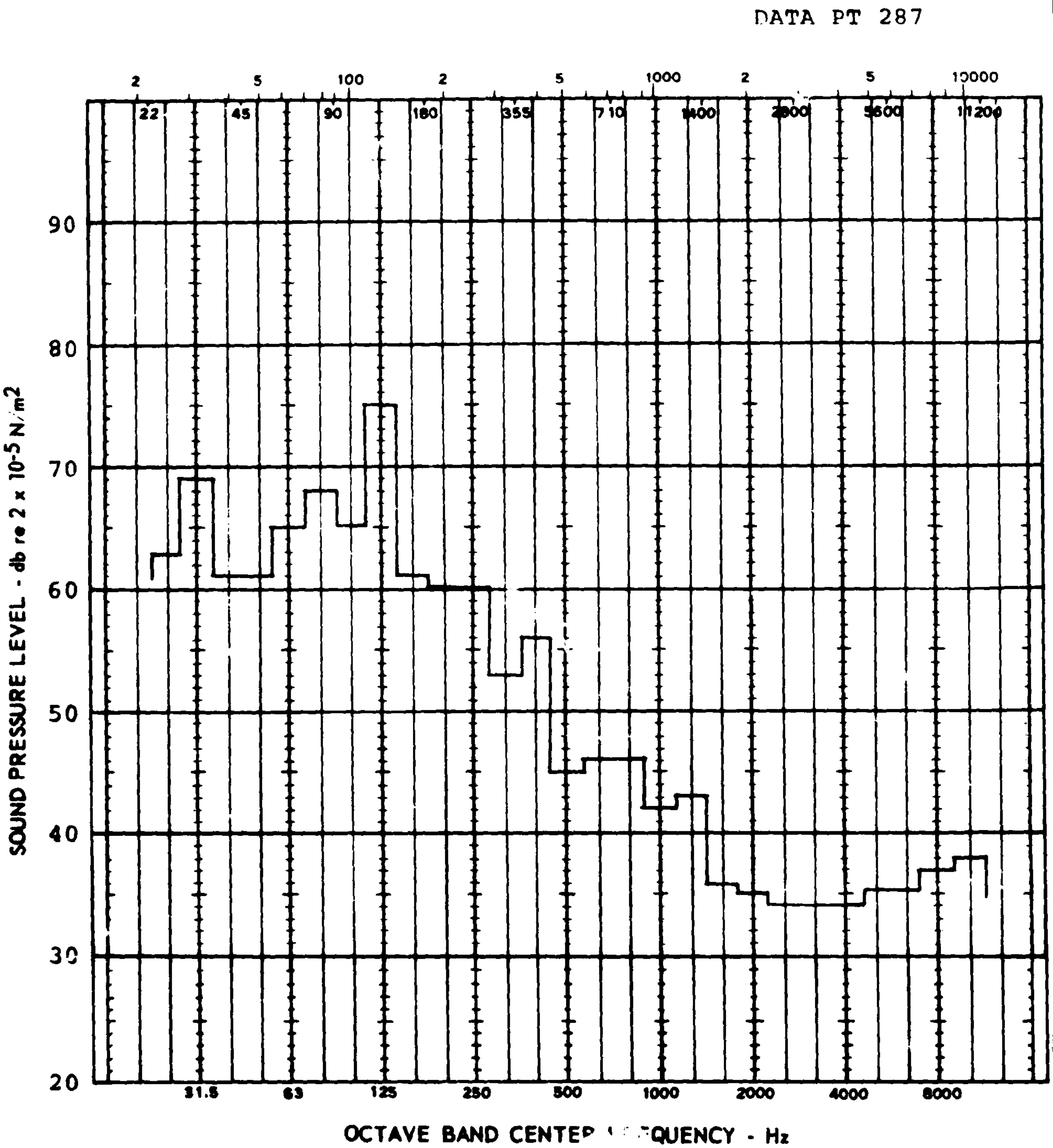


Figure 1—17. Interior Noise at 25 MPH with Steel Wheel Flats (Sidewall Location 102)

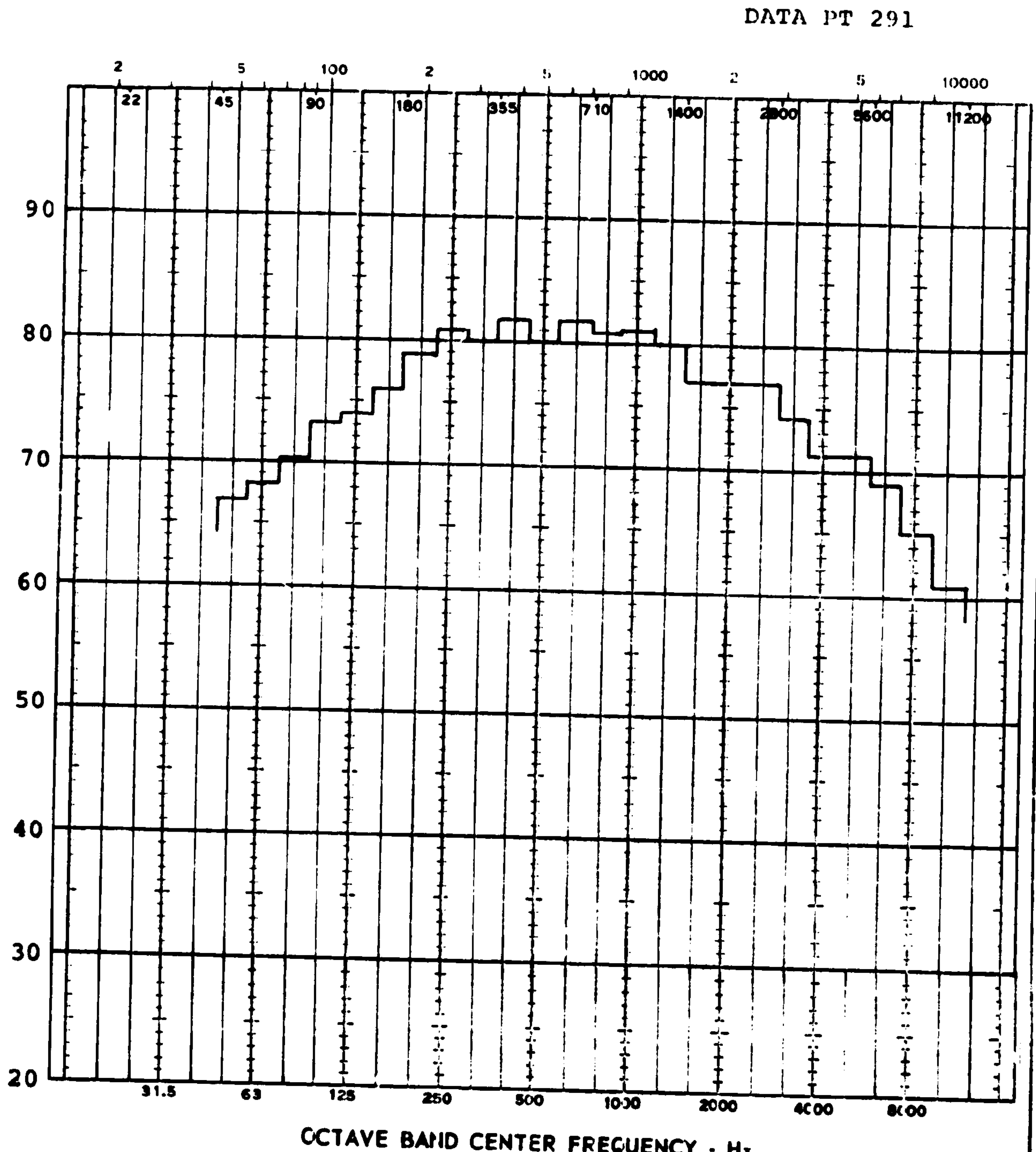


Figure 1–18. Exterior Noise at 35 MPH with Steel Wheel Flats (Sidewall Location 102)

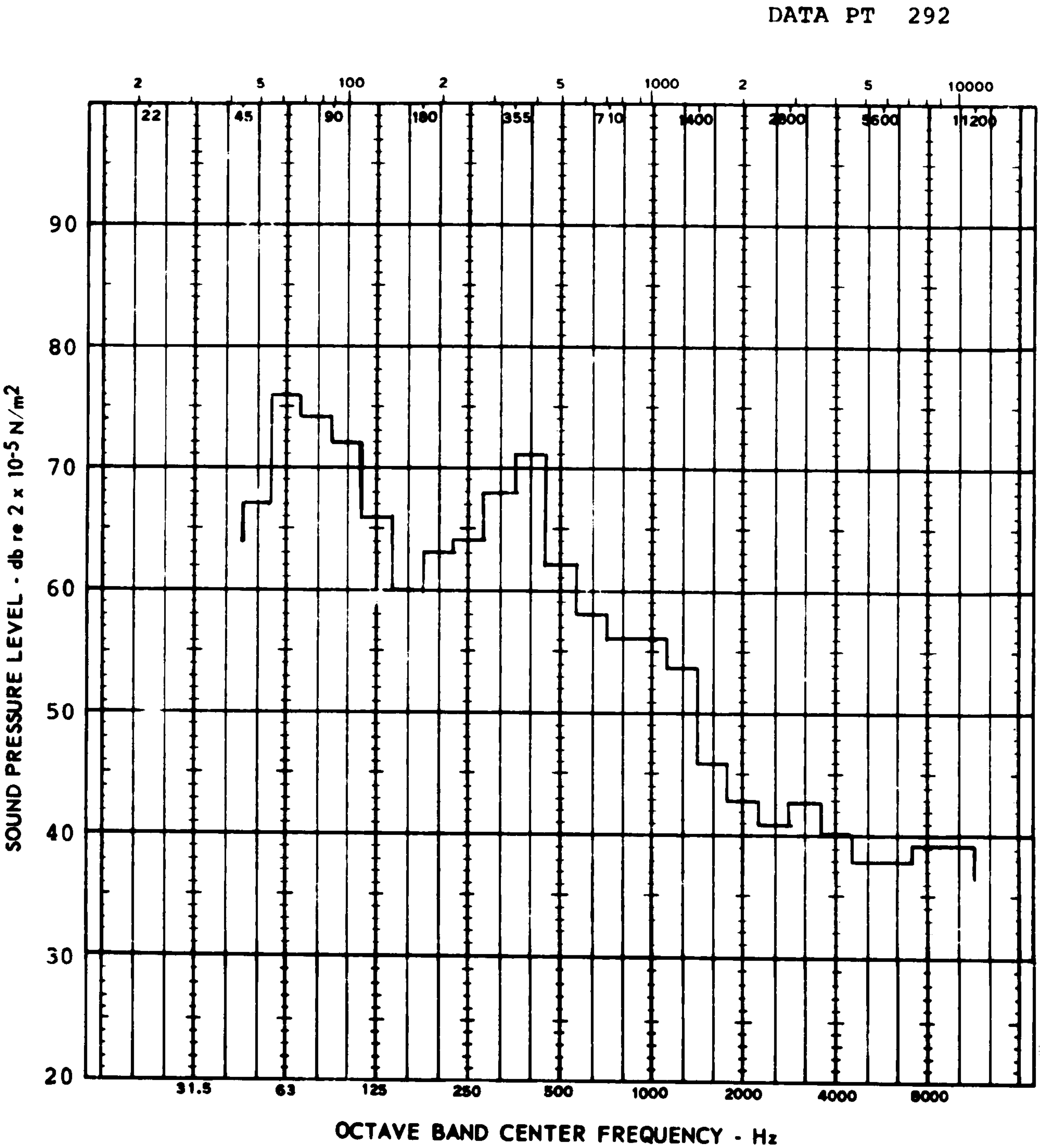


Figure 1–19. Interior Noise at 35 MPH with Steel Wheel Flats (Sidewall Location 102)

DATA PT 438

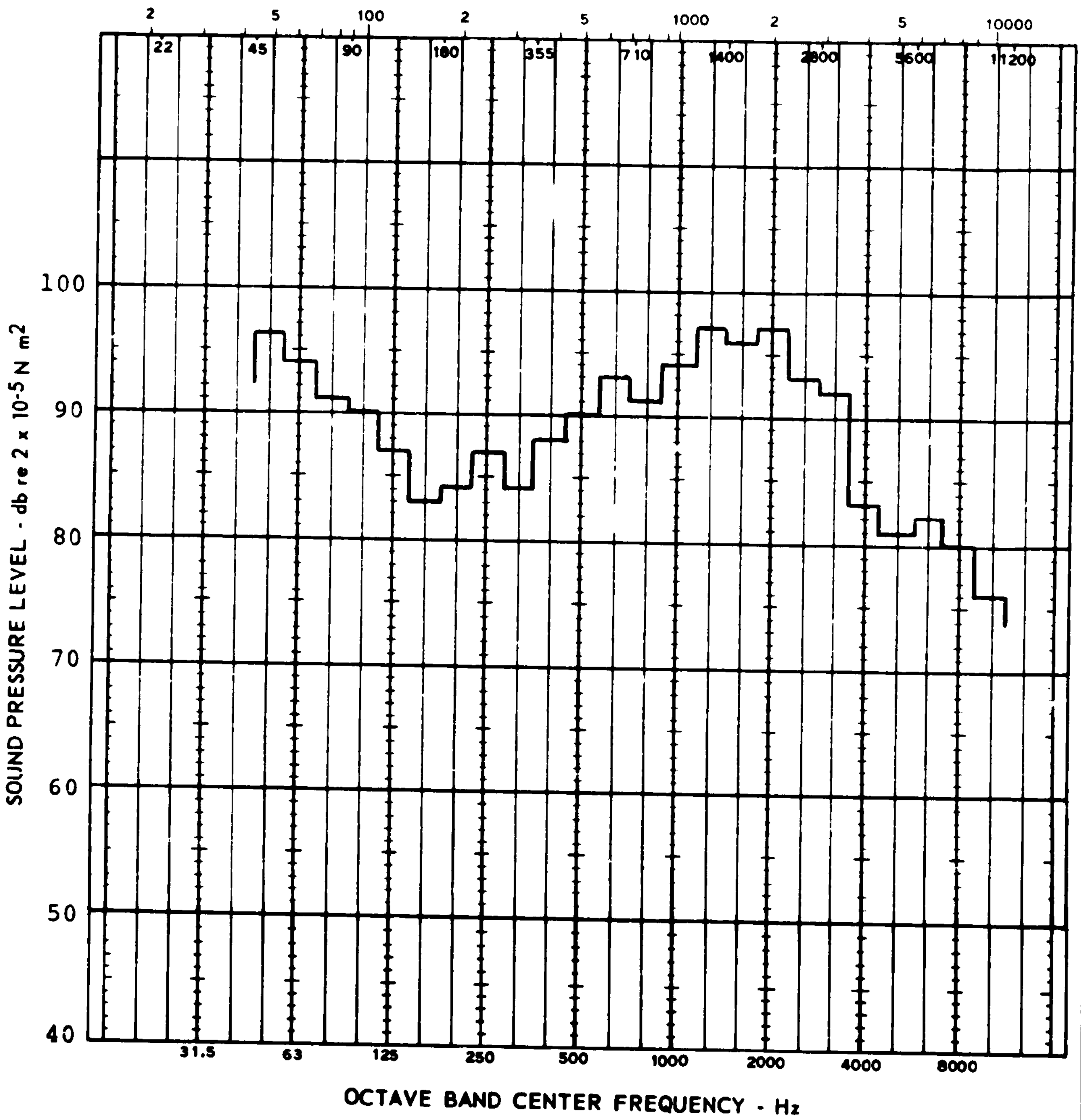


Figure 1–20. Exterior Noise at 50 MPH at Microphone on Safety Strap Near Power Pickup Shoe (Car No. 1; 90,000 Pounds; Steel Wheels; No Flats)

DATA PT 439

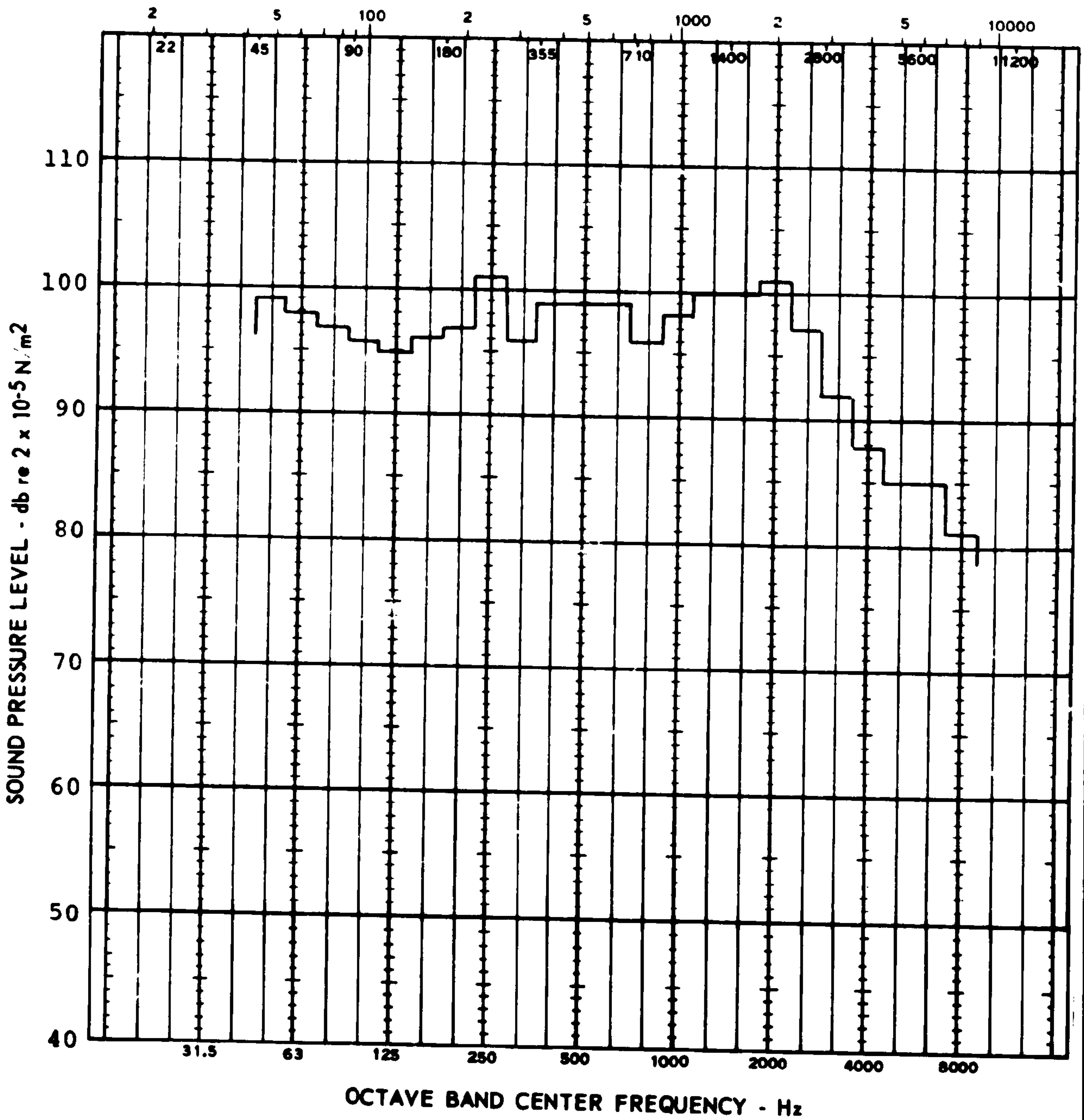


Figure 1–21. Exterior Noise at 70 MPH at Microphone on Safety Strap Near Power Pickup Shoe (Car No. 1; 90,000 Pounds; Steel Wheels; No Flats)

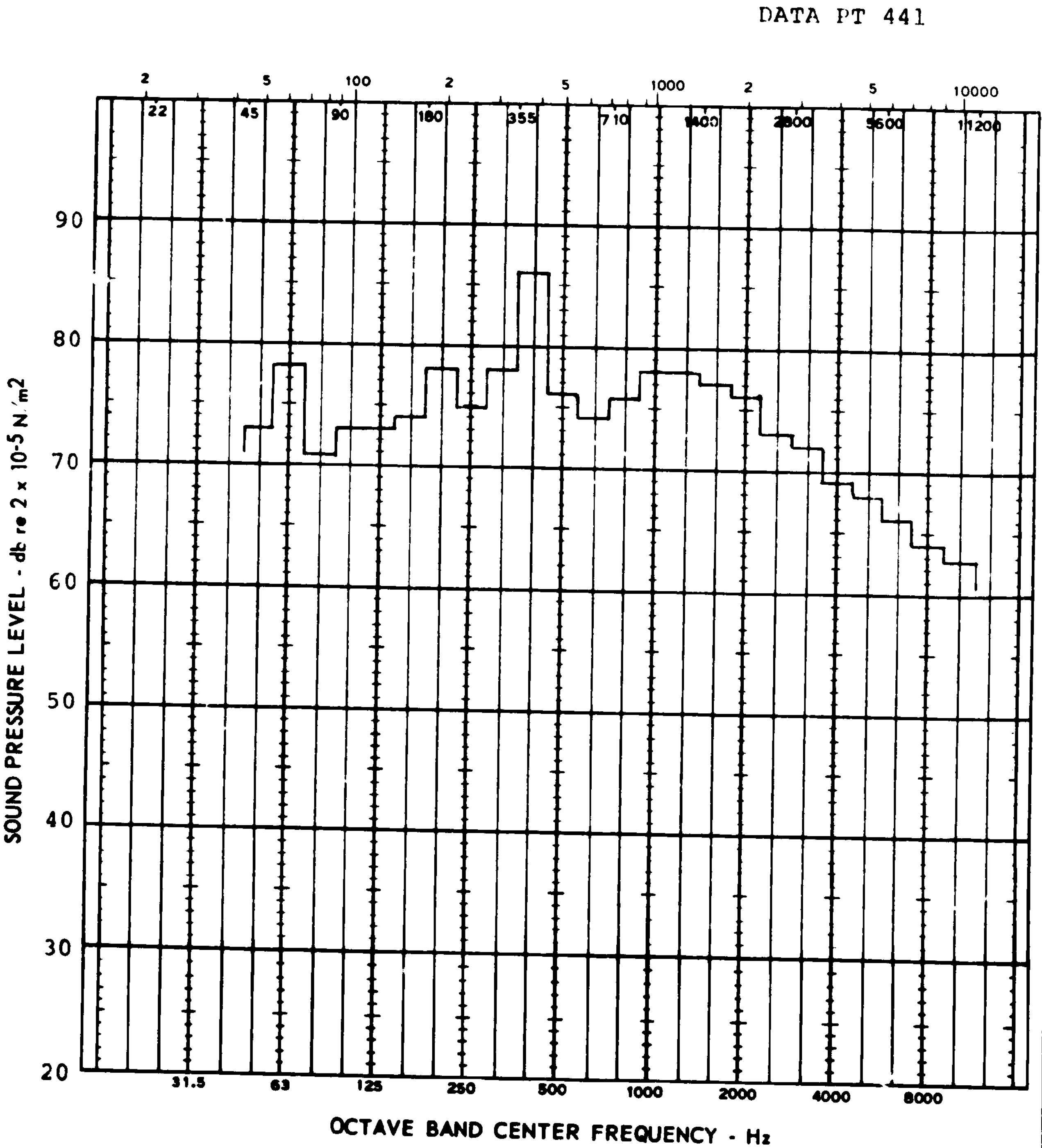


Figure 1–22. Exterior Noise at 0 MPH at Microphone on No. 1 Truck (Car No. 1; 90,000 Pounds; Steel Wheels; No Flats)

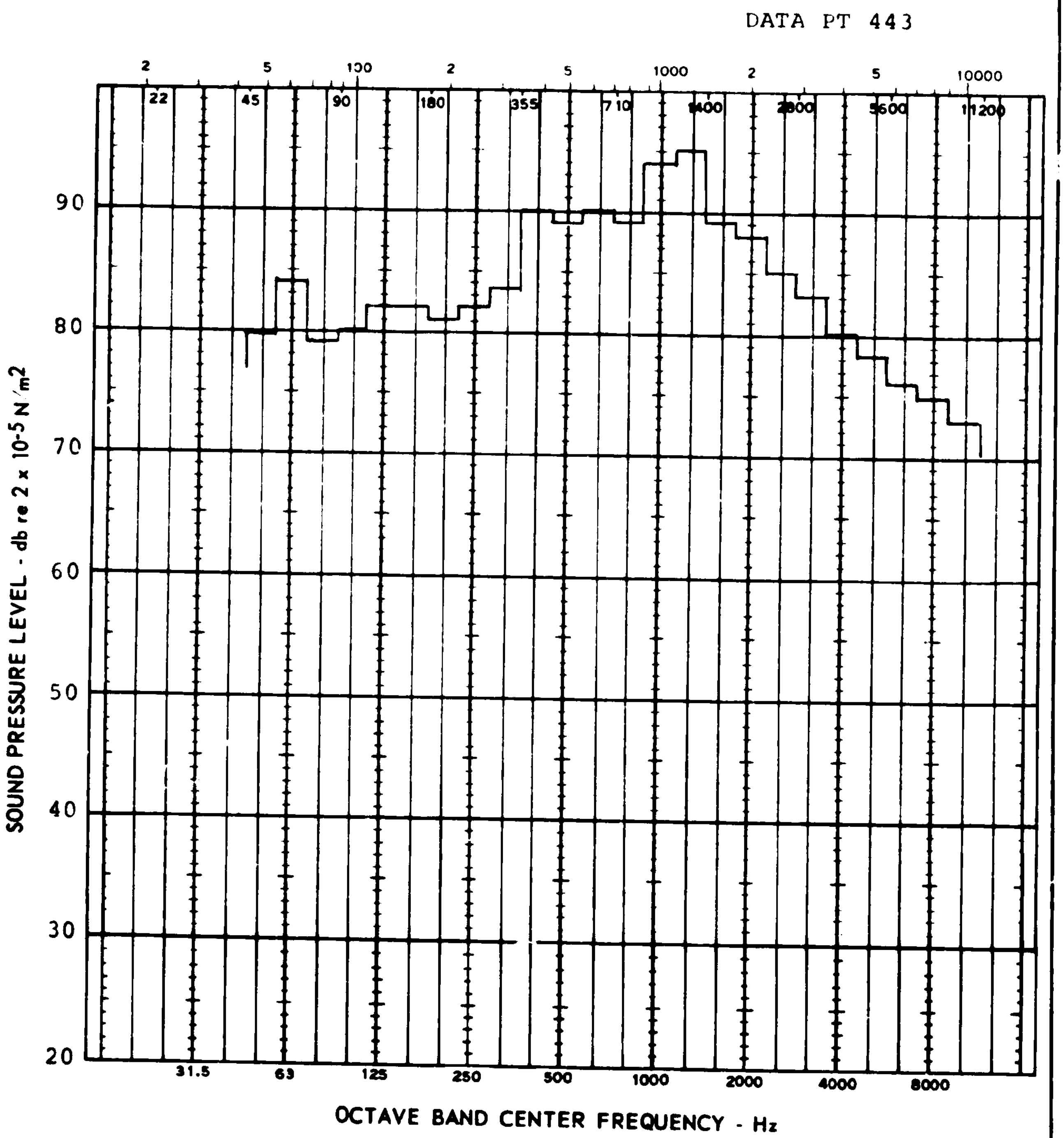


Figure 1–23. Exterior Noise at 35 MPH at Microphone on No. 1 Truck (Car No. 1; 90,000 Pounds; Steel Wheels; No Flats)

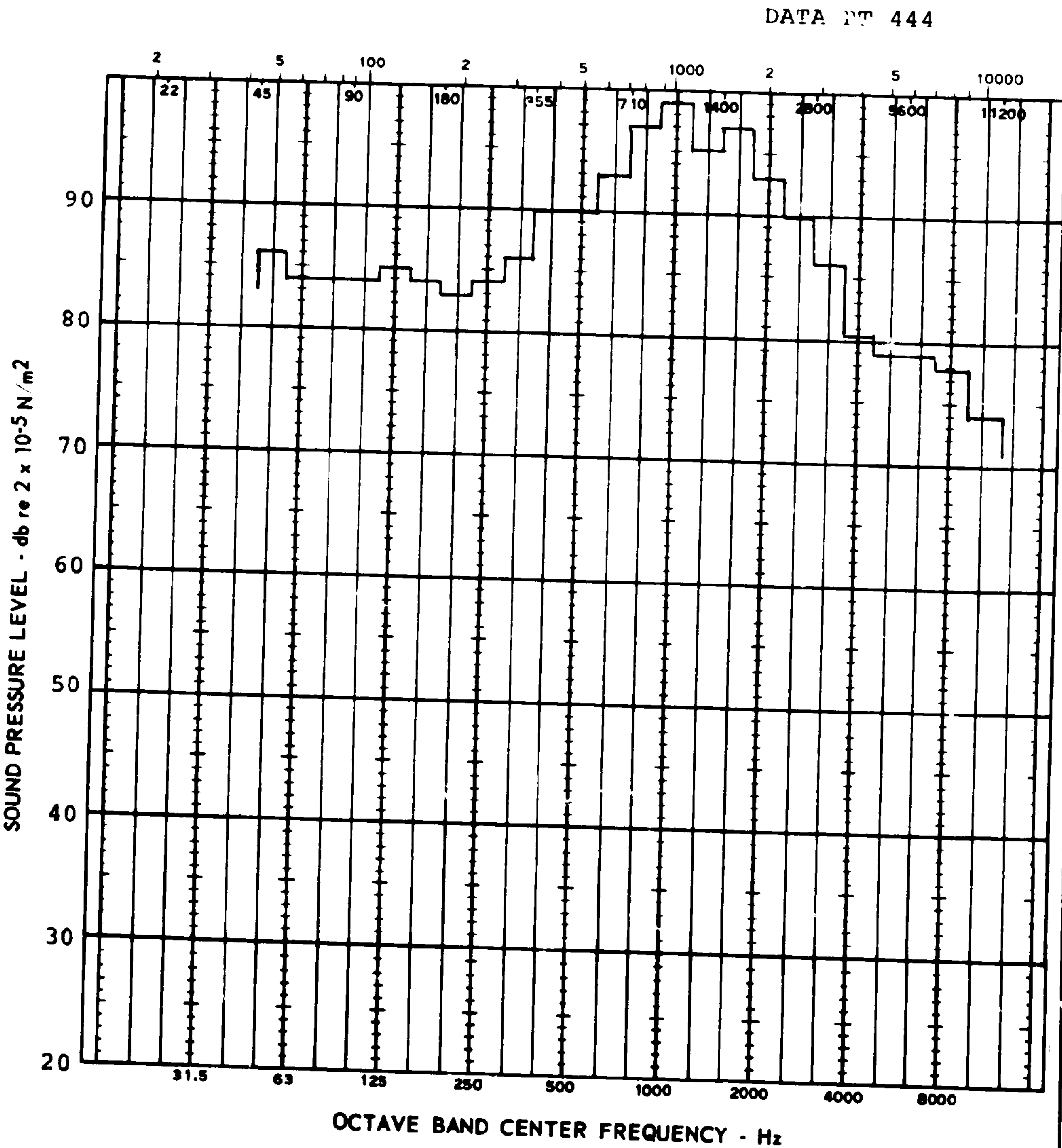


Figure 1–24. Exterior Noise at 50 MPH at Microphone on No. 1 Truck (Car No. 1; 90,000 Pounds; Steel Wheels; No Flats)

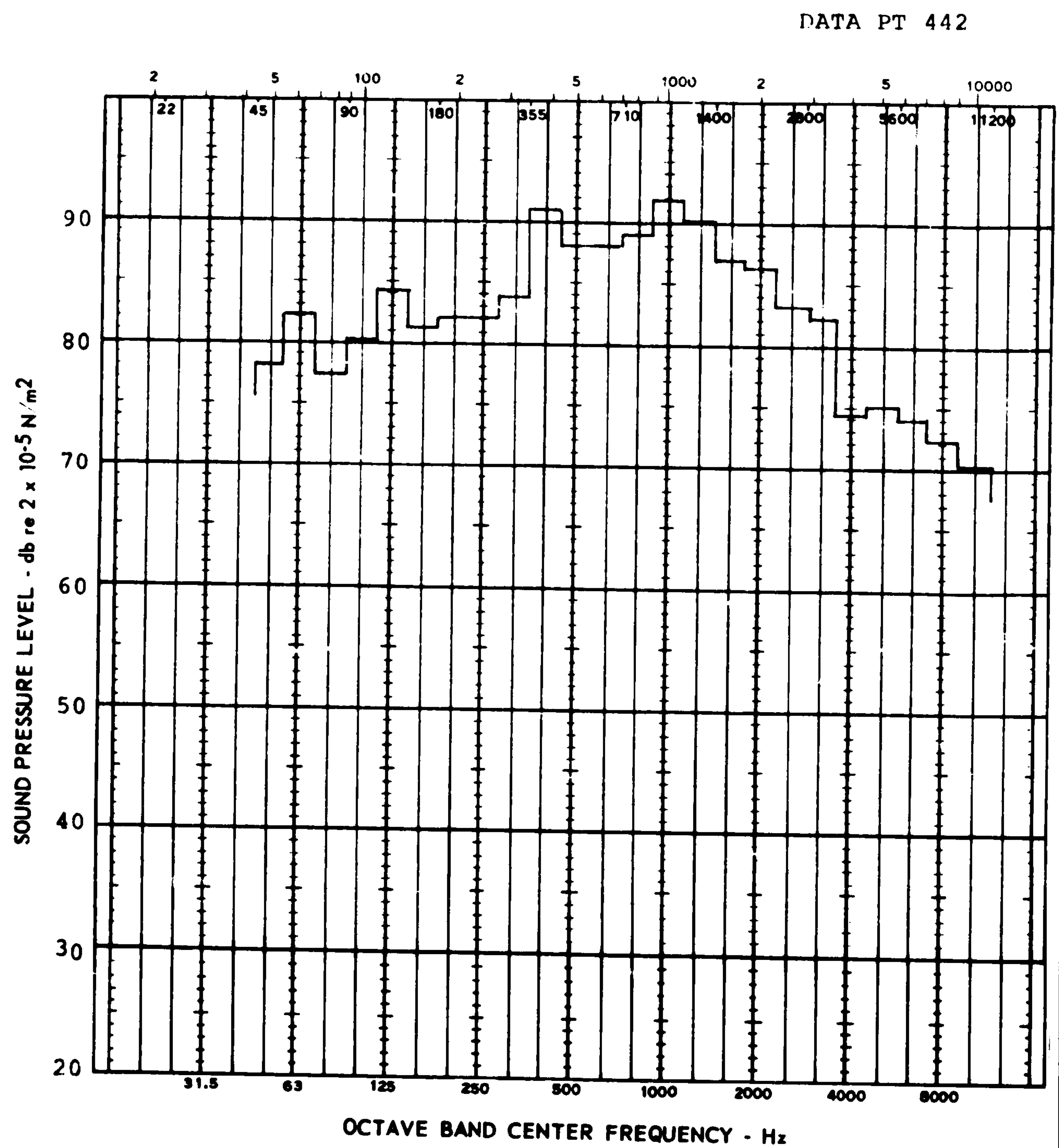


Figure 1–25. Exterior Noise at 25 MPH at Microphone on No. 2 Axle of No. 1 Truck (Car No. 1; 90,000 Pounds; Steel Wheels; No Flats)

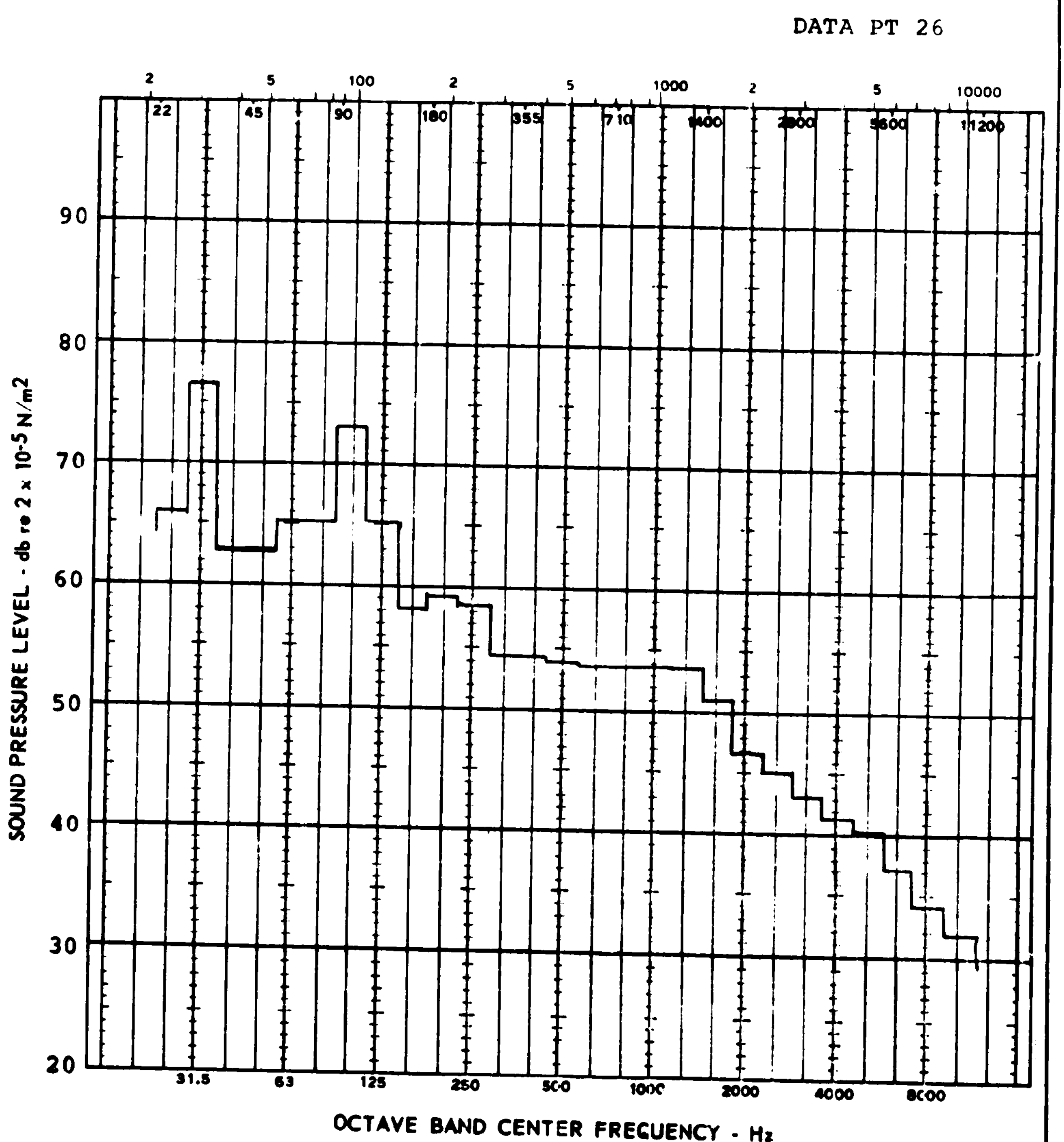


Figure 1–26. Interior Noise at 0 MPH with All Systems On (Car No. 2; Position 55)

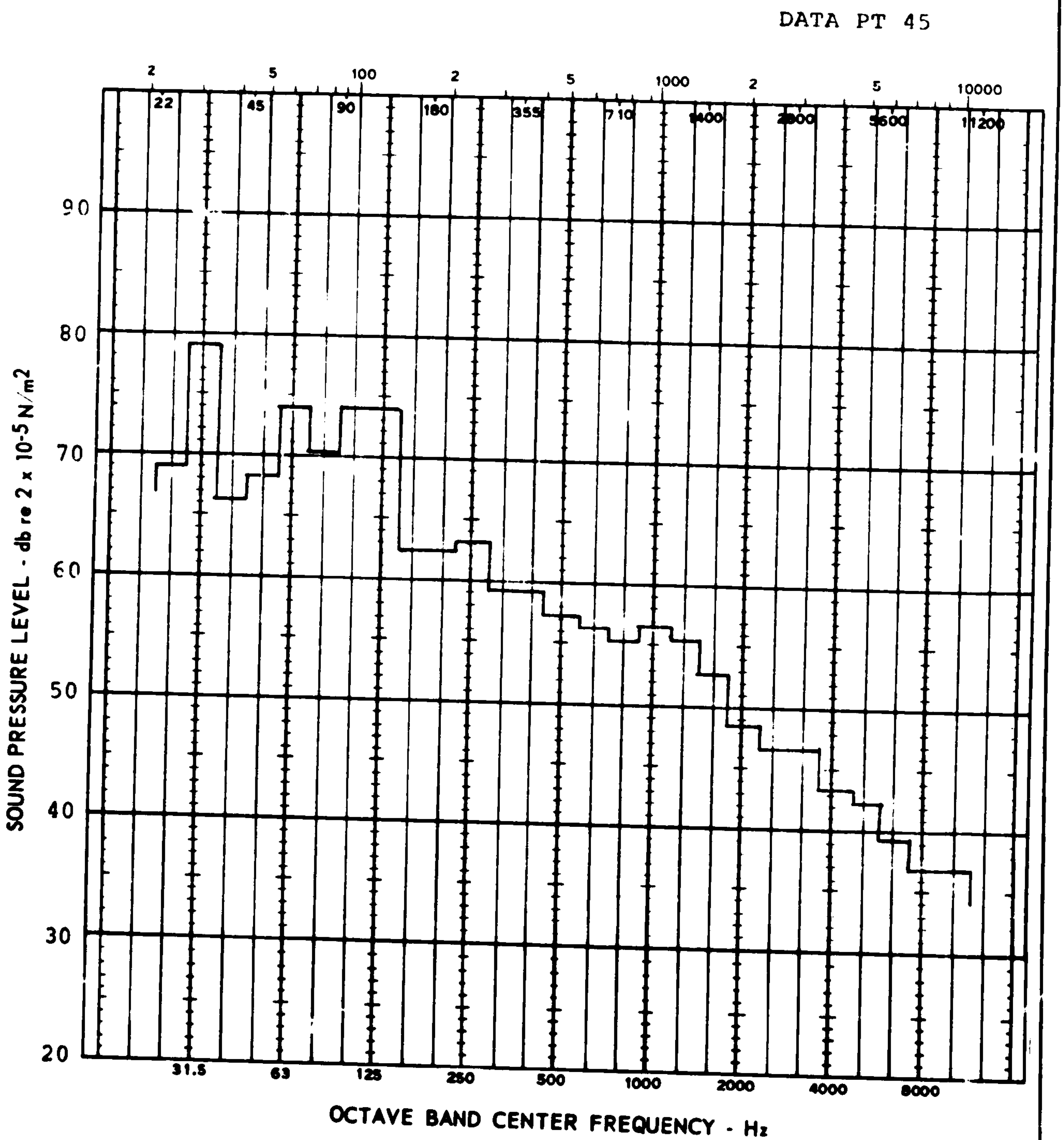


Figure 1–27. Interior Noise at 25 MPH with All Systems On (Car No. 1; Position 55; Steel Wheel Flats)

DATA PT 50

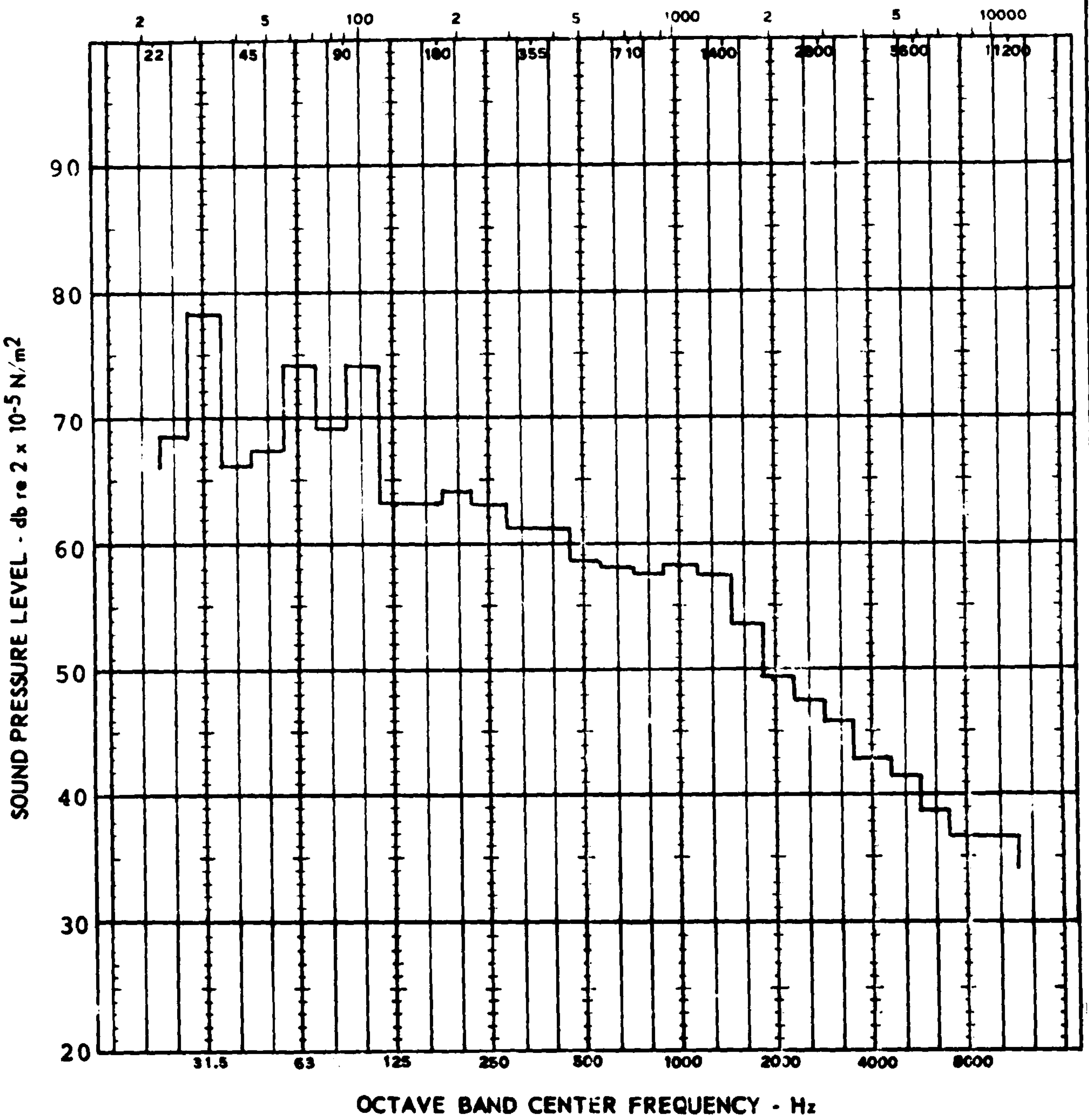


Figure 1–28. Interior Noise at 35 MPH with All Systems On (Car No. 1; Steel Wheel Flats; Position 55)

DATA PT 121

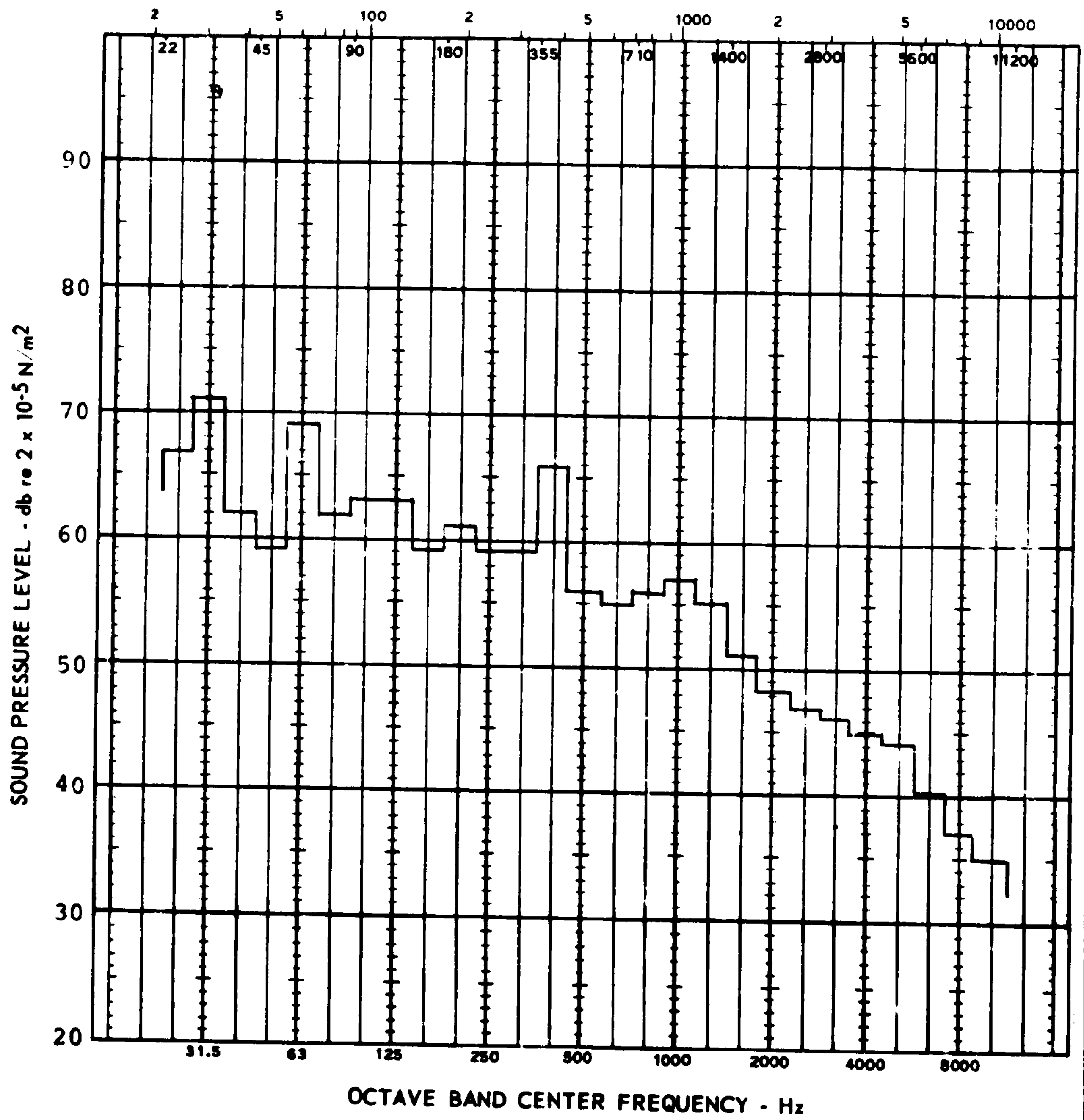


Figure 1–29. Interior Noise at 0 MPH with All Systems On (Car No. 2; Steel Wheel Flats; Position 55)

UNAVERAGED SPECTRA

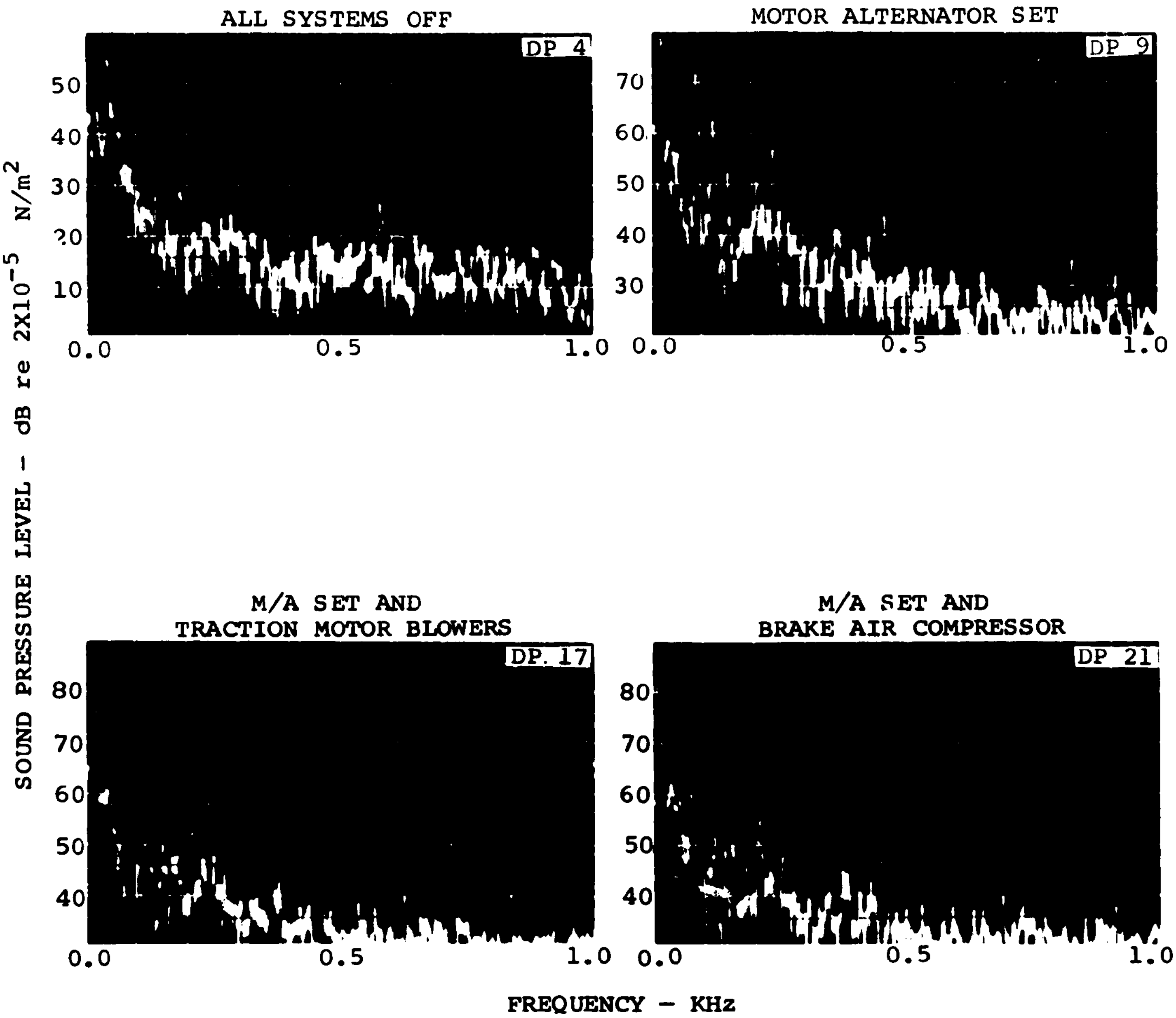


Figure 1–30. Interior Noise from Equipment, Car at Rest (Position 55)

UNAVERAGED SPECTRA

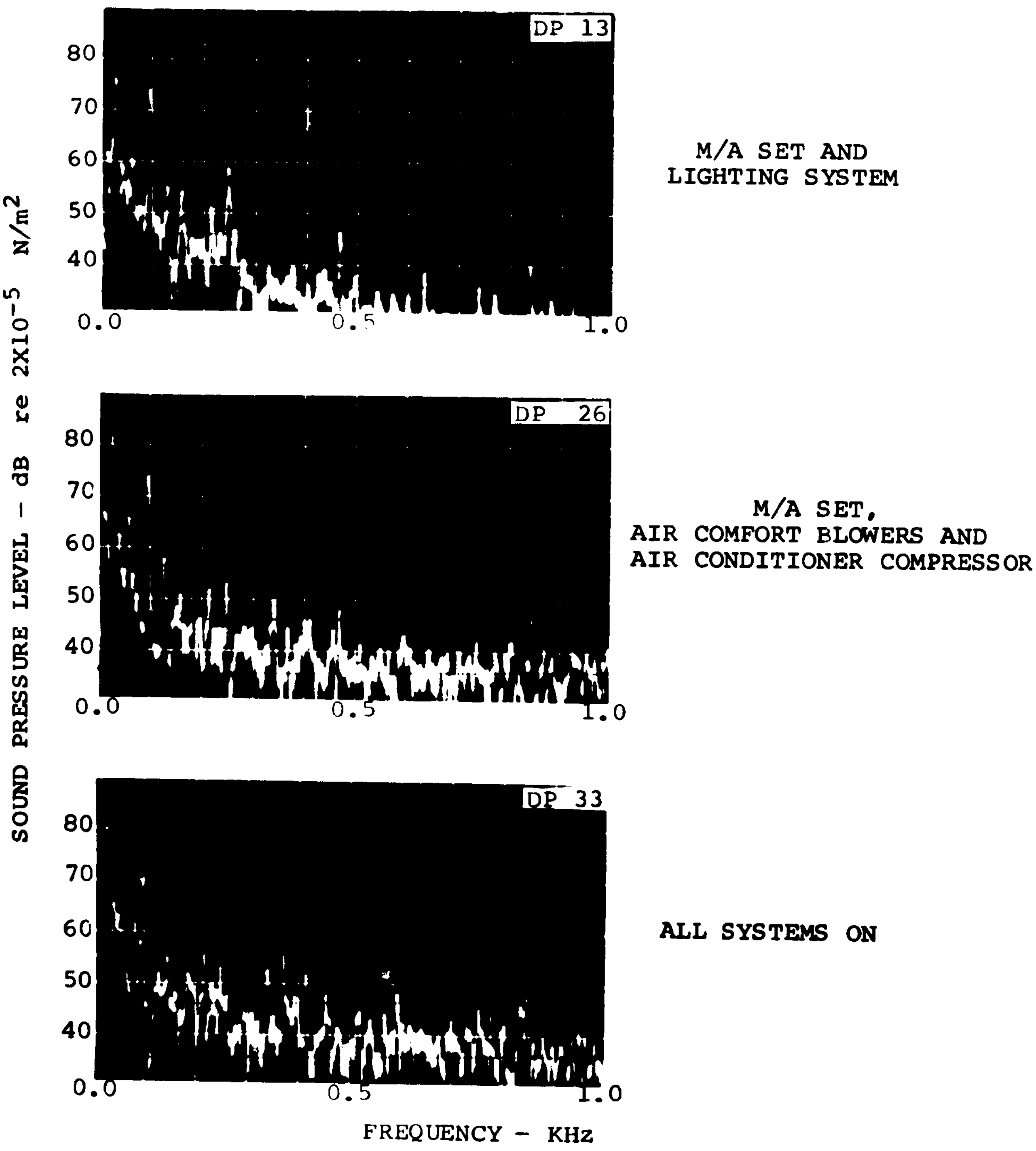


Figure 1–31. Interior Noise from Equipment, Car at Rest (Position 55)

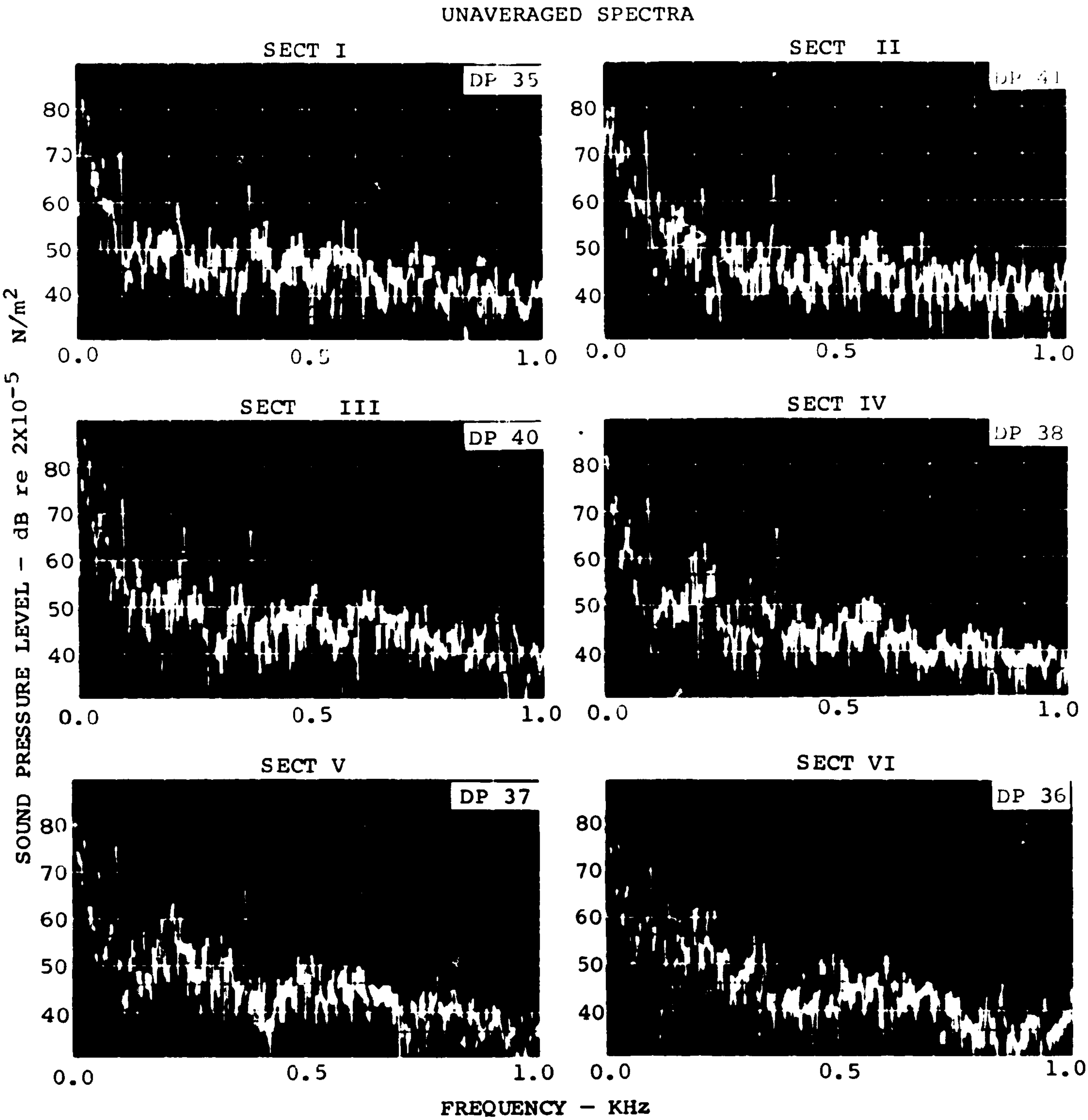


Figure 1–32. Effect of Track Construction on Interior Noise at 50 MPH (Position 55; Track Sections I to VI)

UNAVERAGED SPECTRA

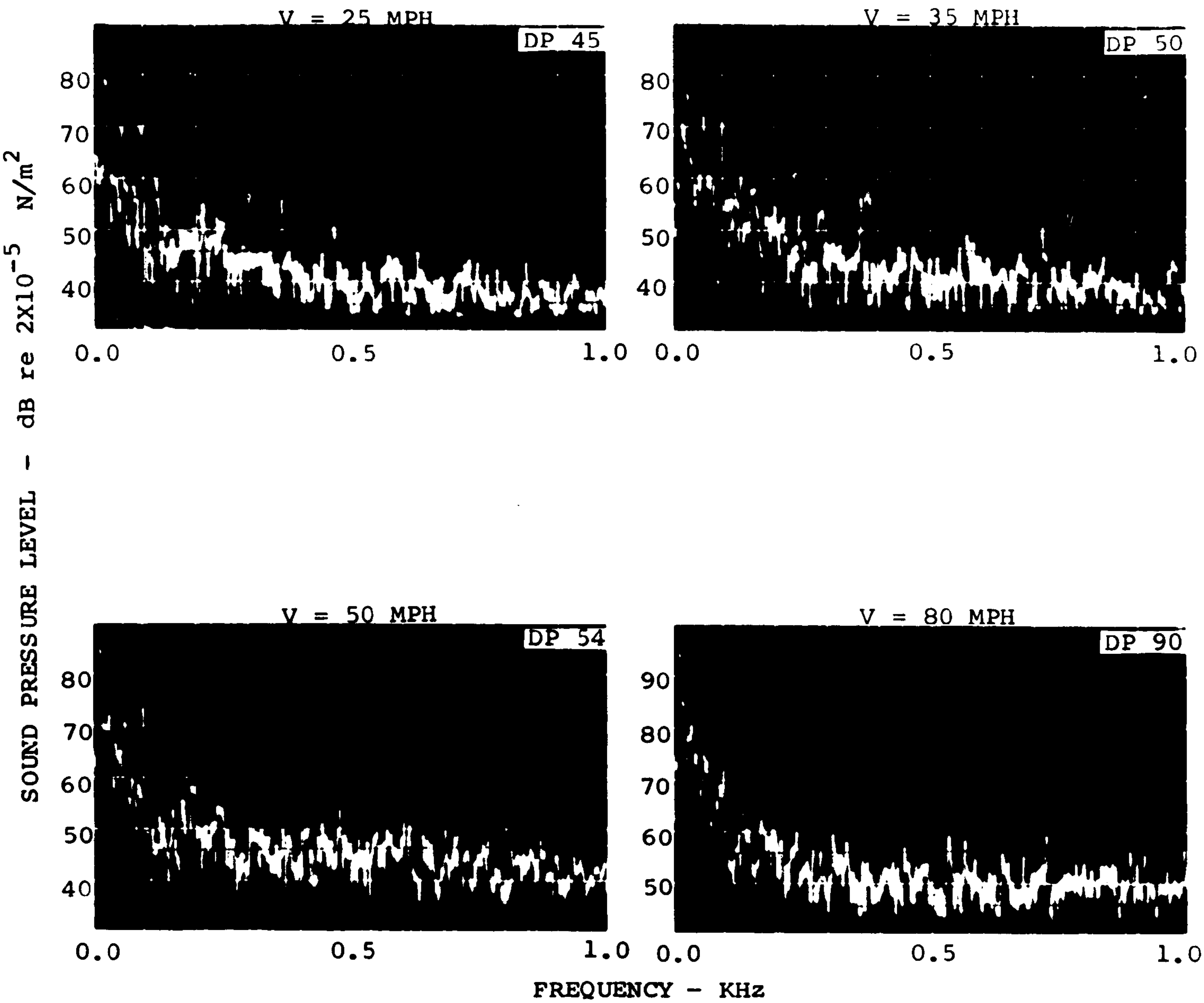


Figure 1–33. Effect of Car Speed on Interior Noise (Car No. 1; 90,000 Pounds; Steel Wheel Flats; Position 55)

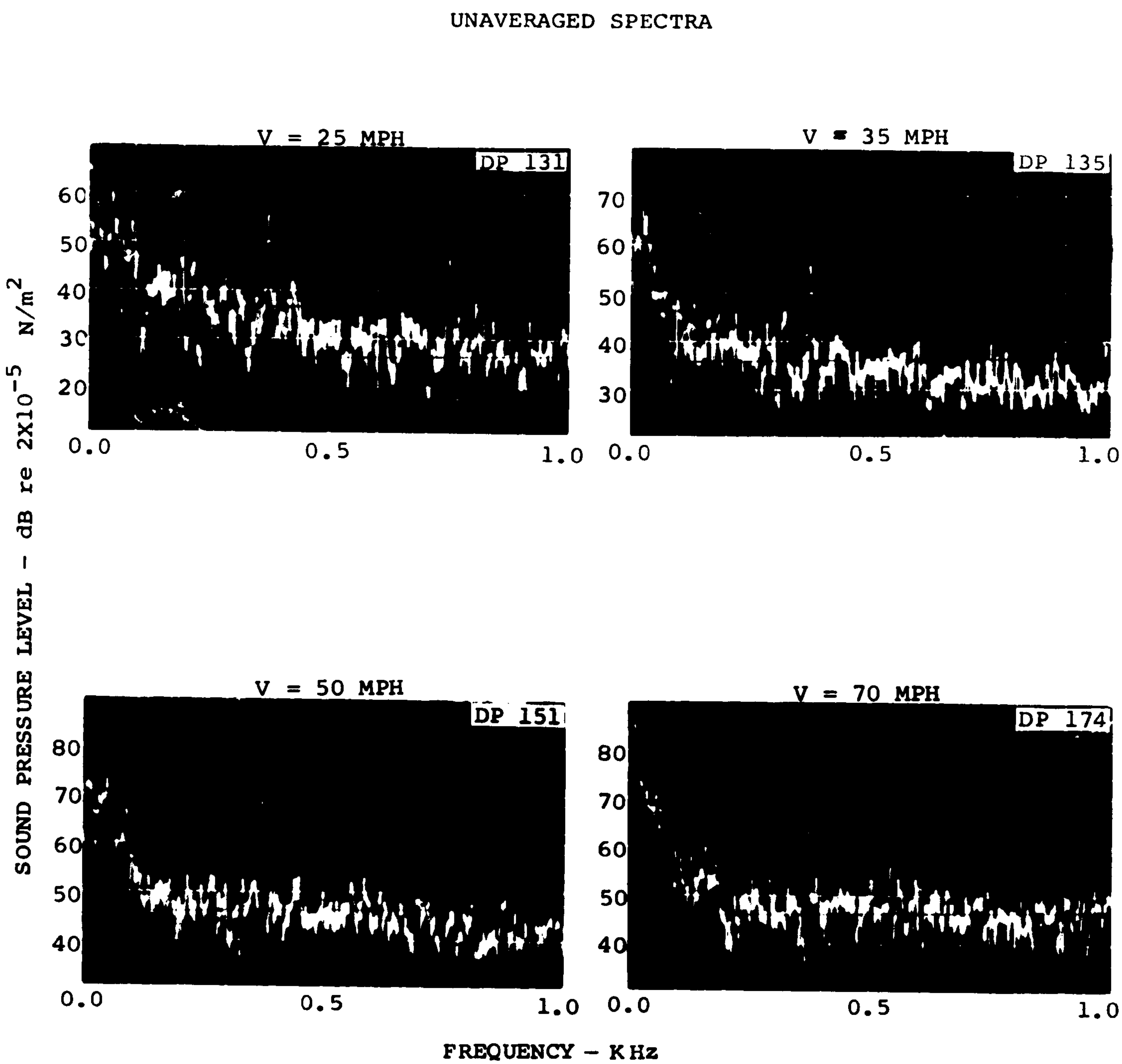


Figure 1–34. Effect of Car Speed on Interior Noise (Car No. 2; 90,000 Pounds; Steel Wheel Flats; Position 55)

UNAVERAGED SPECTRA

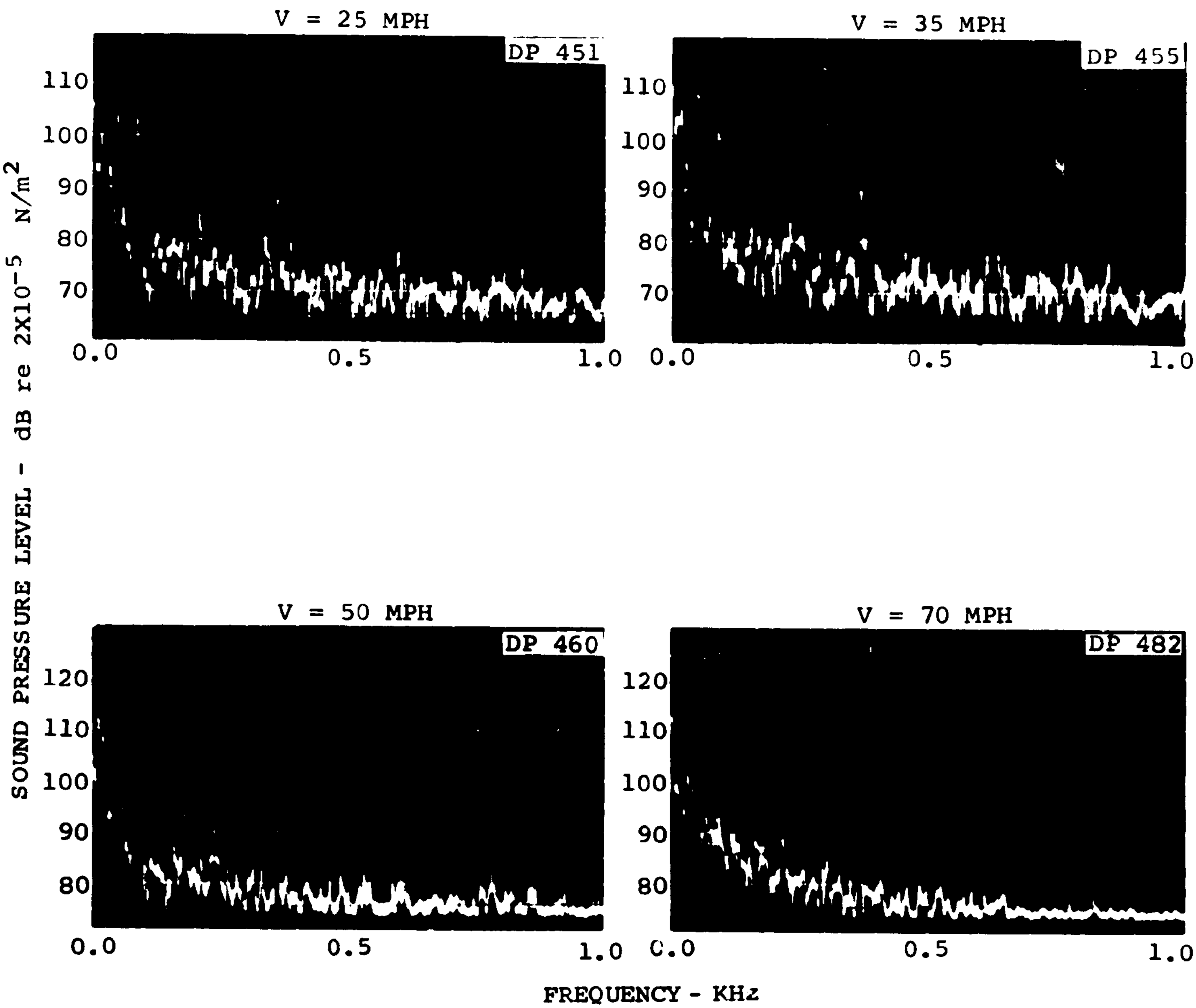


Figure 1–35. Effect of Car Speed on Interior Noise (Car No. 1; 105,000 Pounds; Trued Steel Wheels; Position 55)

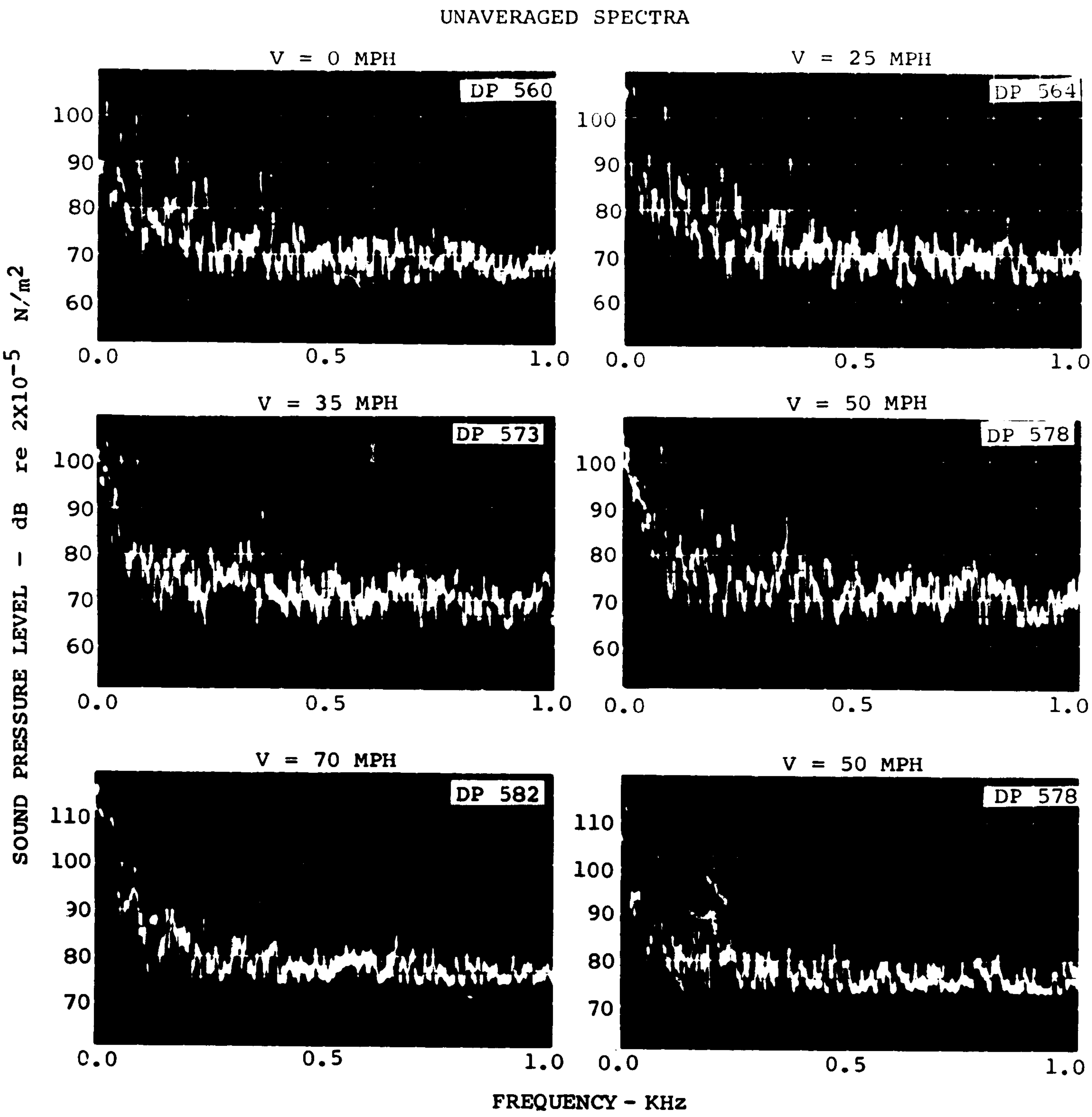


Figure 1–36. Effect of Car Speed on Interior Noise (Car No. 1; 90,000 Pounds; Resilient Wheels; Position 55)

UNAVERAGED SPECTRA

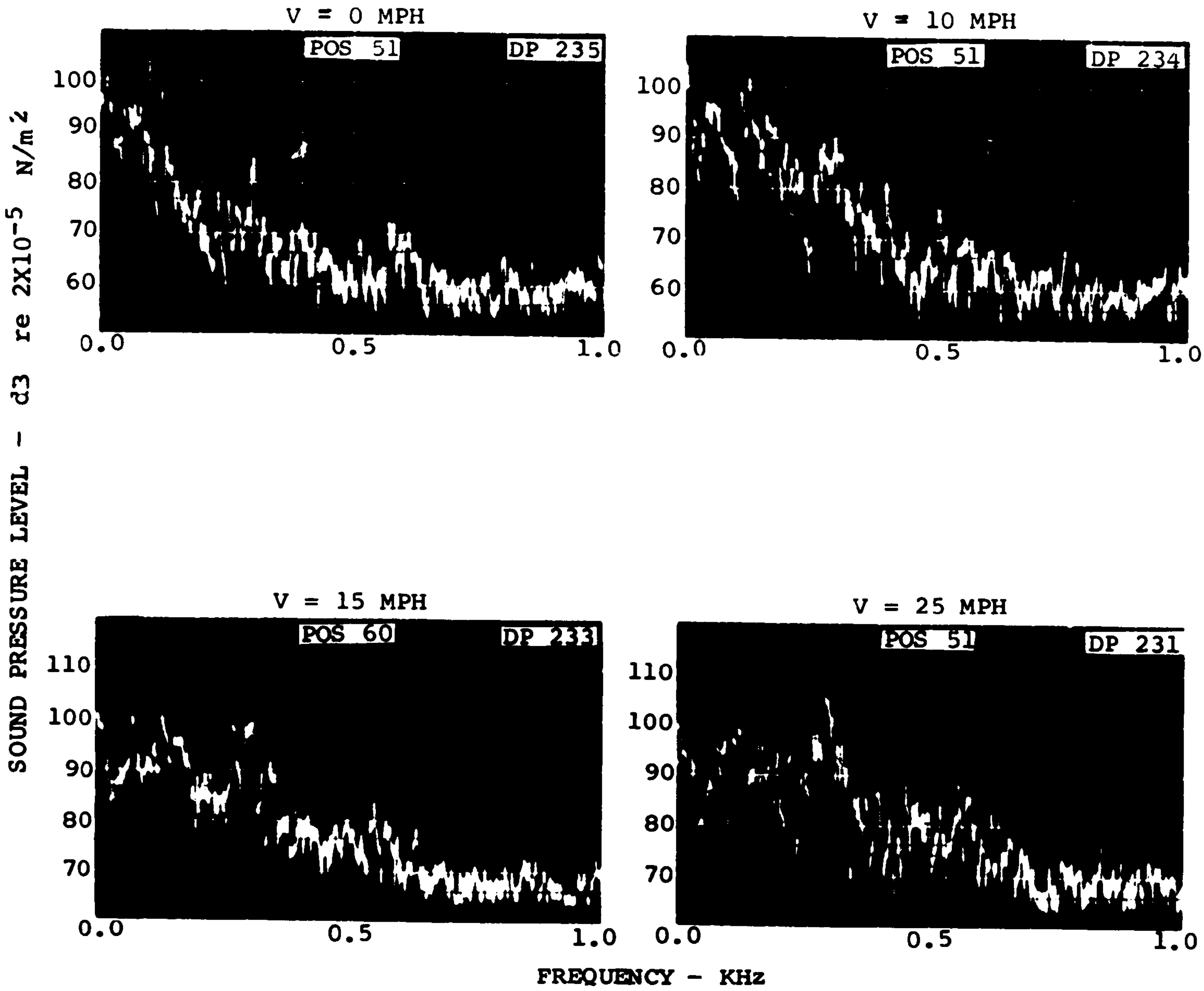


Figure 1–37. Interior Noise During Coasting with All Systems Off (Car No. 1; 90,000 Pounds; Steel Wheel Flats; Track Section IV)

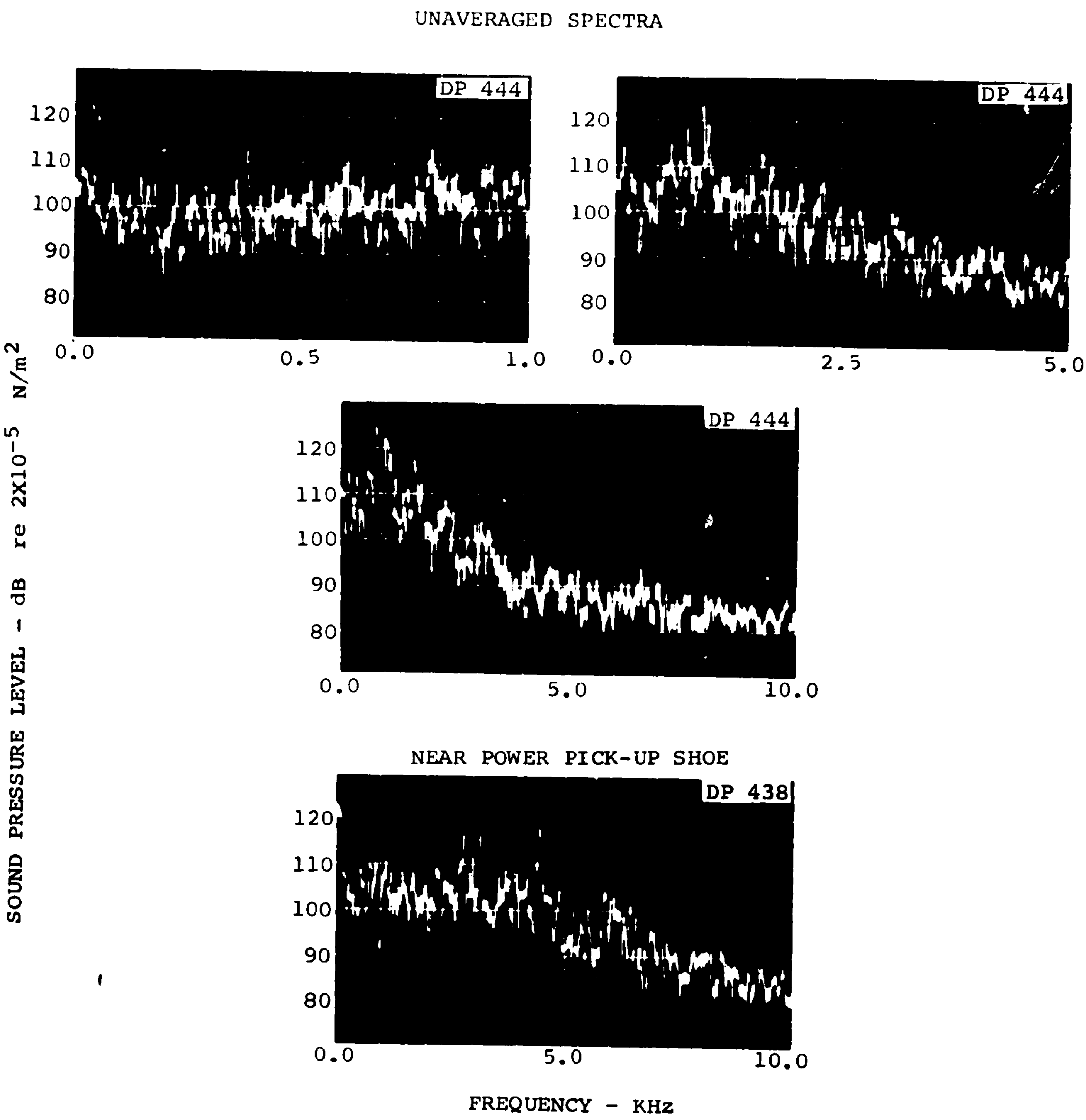


Figure 1–38. Undercar Noise at No. 1 Truck at 50 MPH (Car No. 1; 90,000 Pounds; Trued Steel Wheels)

UNAVERAGED SPECTRA

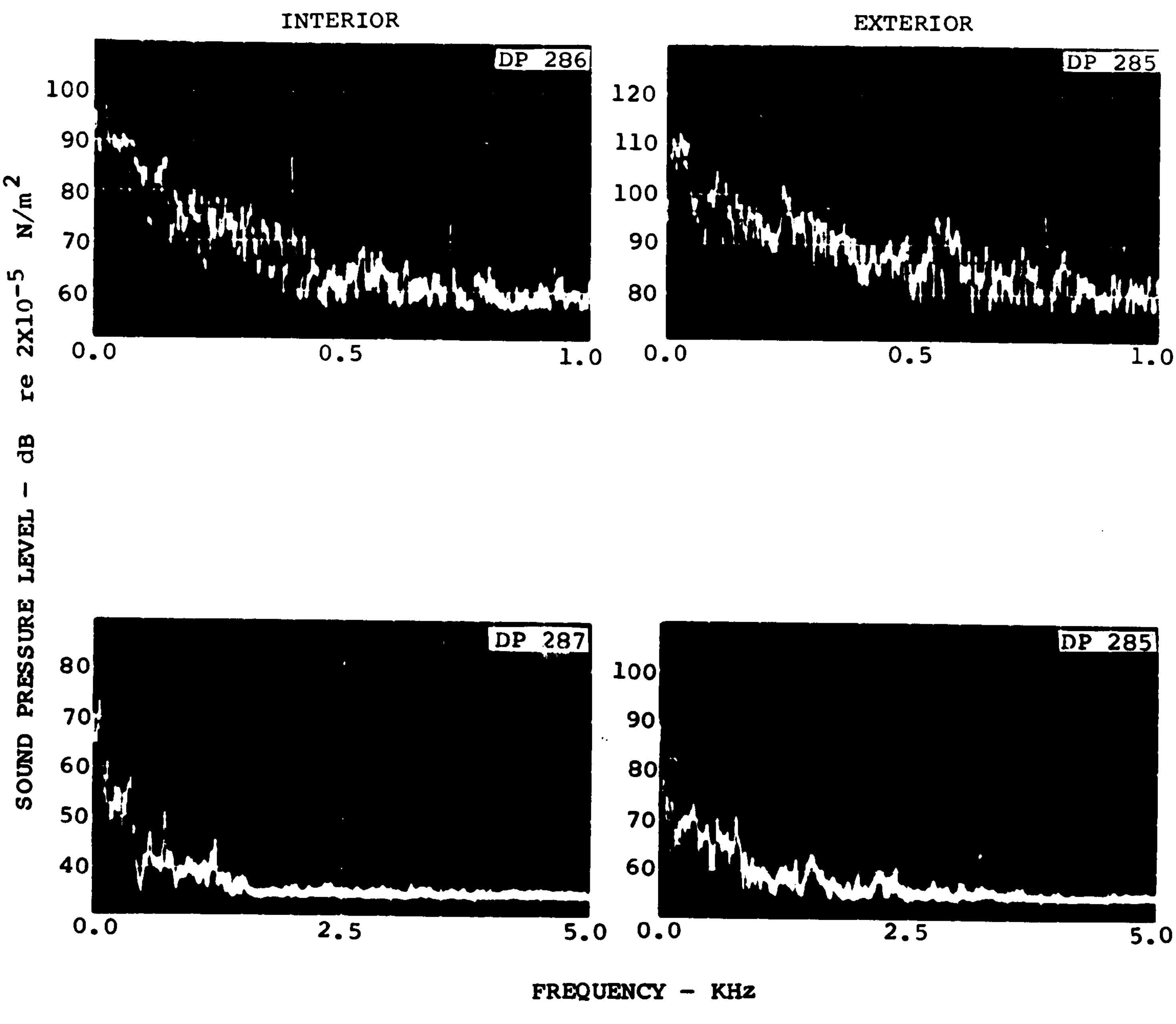


Figure 1–39. Car Body Noise Reduction at 25 MPH (Car No. 1; 90,000 Pounds; Steel Wheel Flats; Wall Microphone)

UNAVERAGED SPECTRA

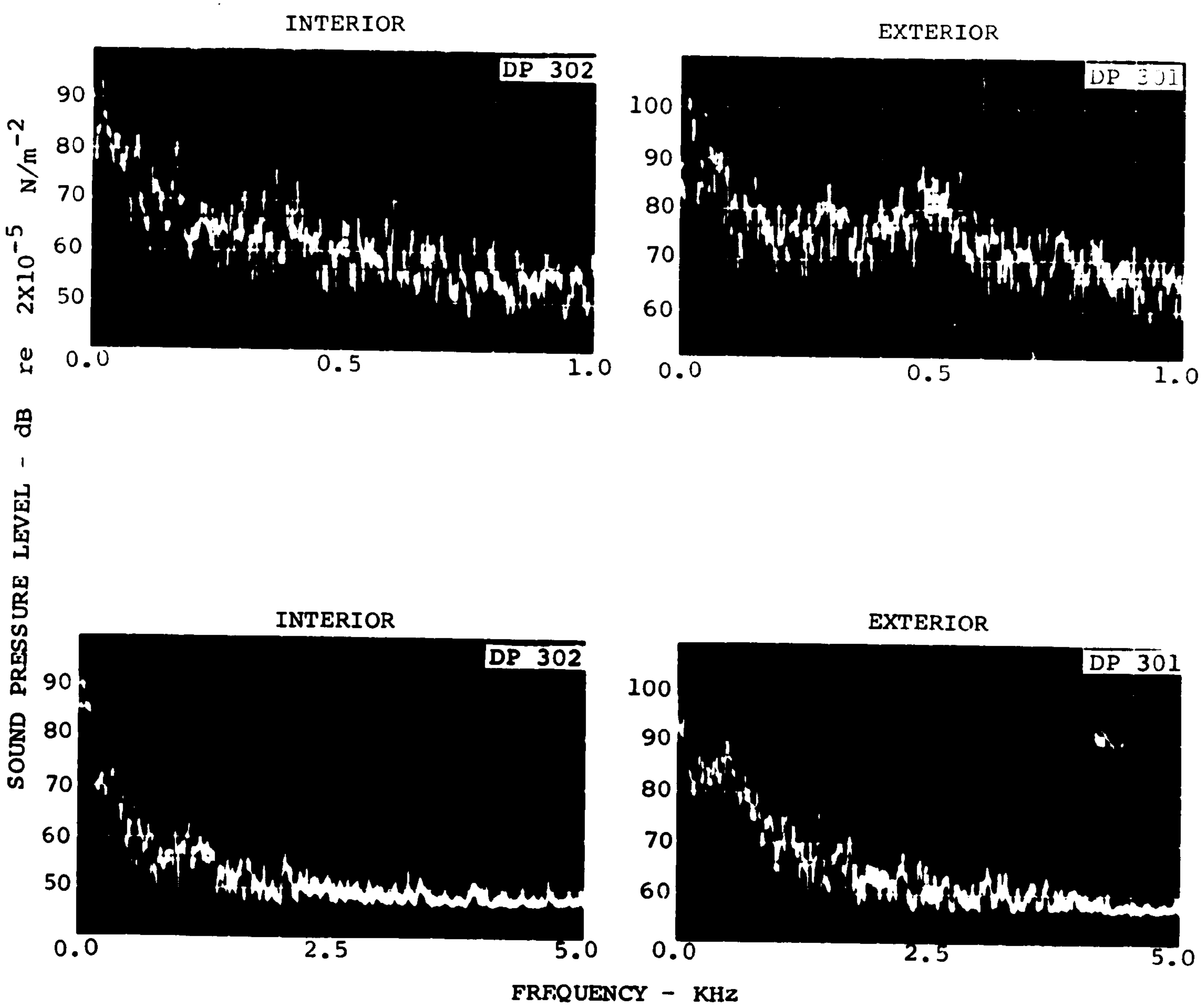


Figure 1—40. Car Body Noise Reduction at 25 MPH (Car No. 1; 90,000 Pounds; Steel Wheel Flats; End Microphone)

UNAVERAGED SPECTRA

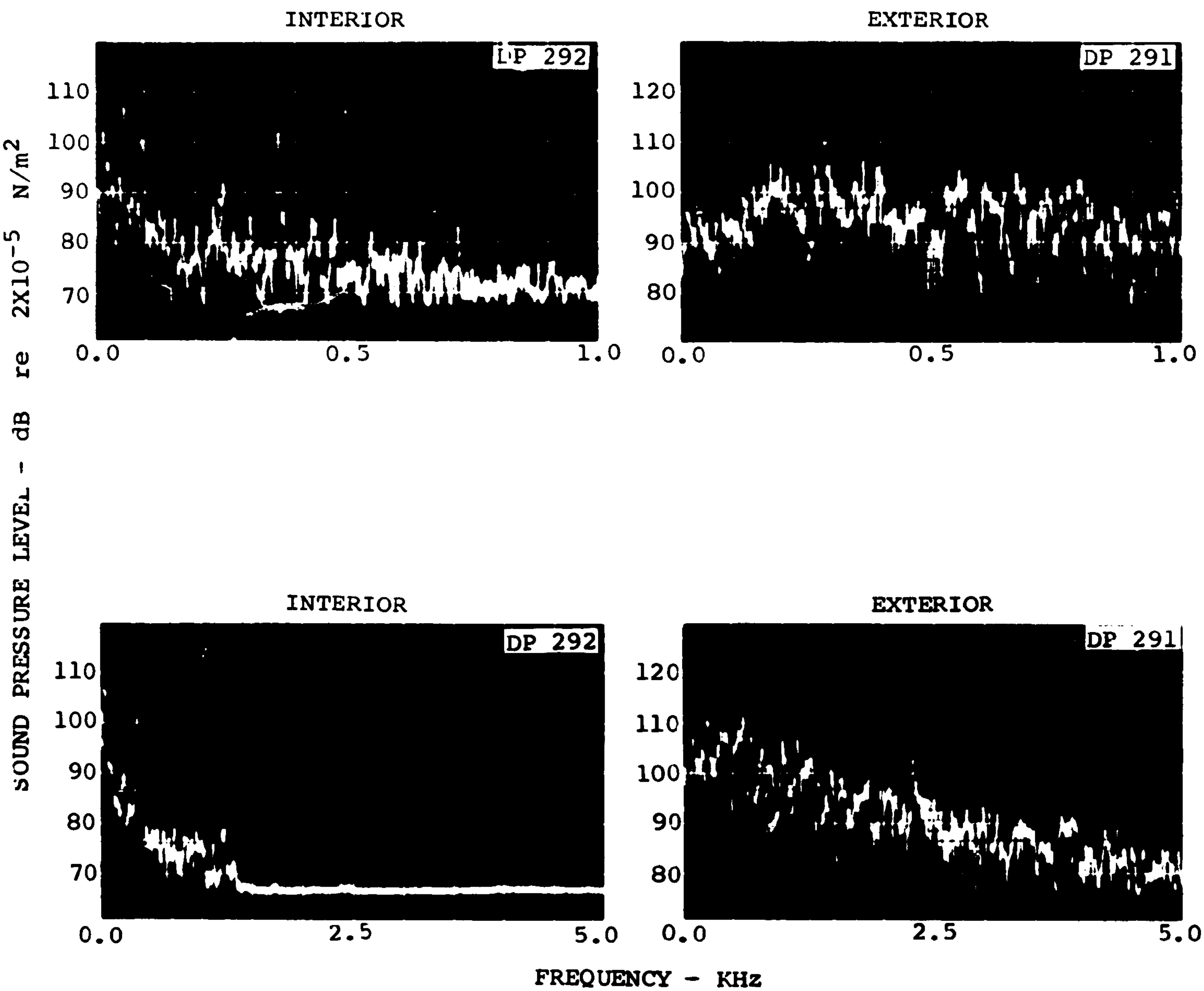


Figure 1—41. Car Body Noise Reduction at 35 MPH (Car No. 1; 90,000 Pounds; Steel Wheel Flats; Truck Microphone)

1.6 PRELIMINARY ANALYSIS

1.6.1 Interior Noise Control Features

Car body construction pertaining to noise control is shown in Figures 1-42 through 1-44. The upholstered seats of Car No. 1 provide absorption that is not achieved with the hard shell glass fiber seats of Car No. 2. Both cars have carpeted windscreens at each door which provide added absorption to that of the carpeted floor. In addition to the car body itself, the air spring suspension between truck and body provides substantial isolation of truck structure-borne noise. The Acousta Flex wheels achieve a reduction in noise on tangent and large radius curve track, as measured at the HSGTC, as a result of damping not present in the steel wheel (Figure 1-45).

1.6.2 Comparison of Measured Interior Noise with SOAC Goals

A comparison of the SOAC exterior noise levels with the goals is made in Figure 1-46. Data for the low-density car is presented as being representative. The high-density car (No. 2) displays a wider envelope of levels because of the return air splitter configurations at the ends of the car. This configuration permits reduced evaporator blower noise at the "A" end (1 to 2 dBA), and higher blower noise at the "B" end (1 to 2 dBA), than the lower density (No. 1) car. Return air silencers have been recommended for both cars to achieve more uniform levels within each car.

1.6.3 Effect of Velocity

Noise levels inside the car are established primarily by the undercar equipment, the air comfort system blowers in the overhead region at both ends of the car, and the noise from wheel/rail interaction. The lighting system ballasts are also audible at low speeds but are not an important contributor to the spectrum. When the car is at rest and operating at low speeds (below 25 mph) the equipment noise predominates in the "A" weighted levels and masks the wheel/rail noise. At speeds greater than 25 mph, the wheel/rail noise also contributes to the audible spectra, and its amplitude is a function of the wheel construction and tire surface quality.

Figure 1-47 shows interior noise trends as a function of speed, with wheel surface quality and the masking effects of equipment noise as parameters. Flat spots on the wheel tire significantly contribute to the acoustic signature of the car, which degrades as the number of flats increases. Note the difference in the high-speed noise of Cars 1 and 2 resulting from dissimilar "flat" patterns on the wheels of each car. The total number of flats on the wheels of Car No. 1 at the time of documentation was 20, with 8 flats 1 inch or more in length. The No. 2 car, on the other hand, had 13 flats, of which only three were 1 inch or more in length.

Due to differences in the air conditioner evaporator blower levels, which arise from slight differences in the installation of the fresh and return air splitters in Cars No. 1 and 2, the noise levels below 25 mph display up to 5 dBA difference; consequently, a completely valid comparison of speed is not possible between cars. Above 25 mph where the wheel/rail noise contributes, the trend for the data with flats approaches 2.5 dBA for each 10 mph increment while the data with "trued" steel wheels displays less than 1 dBA per each 10 mph increase. The total change in level for the car with flats over its entire speed range (interpolated at 20 mph) was 13 dBA, while the car with no flats increased by only 3 dBA over the same speed increment. Trends documented with the resilient Acousta Flex wheels (no wheel flats) are similar to the steel wheels with no flats. Ideally, speed trends should be identified during conditions in which all car systems (other than those required for operation) are off.

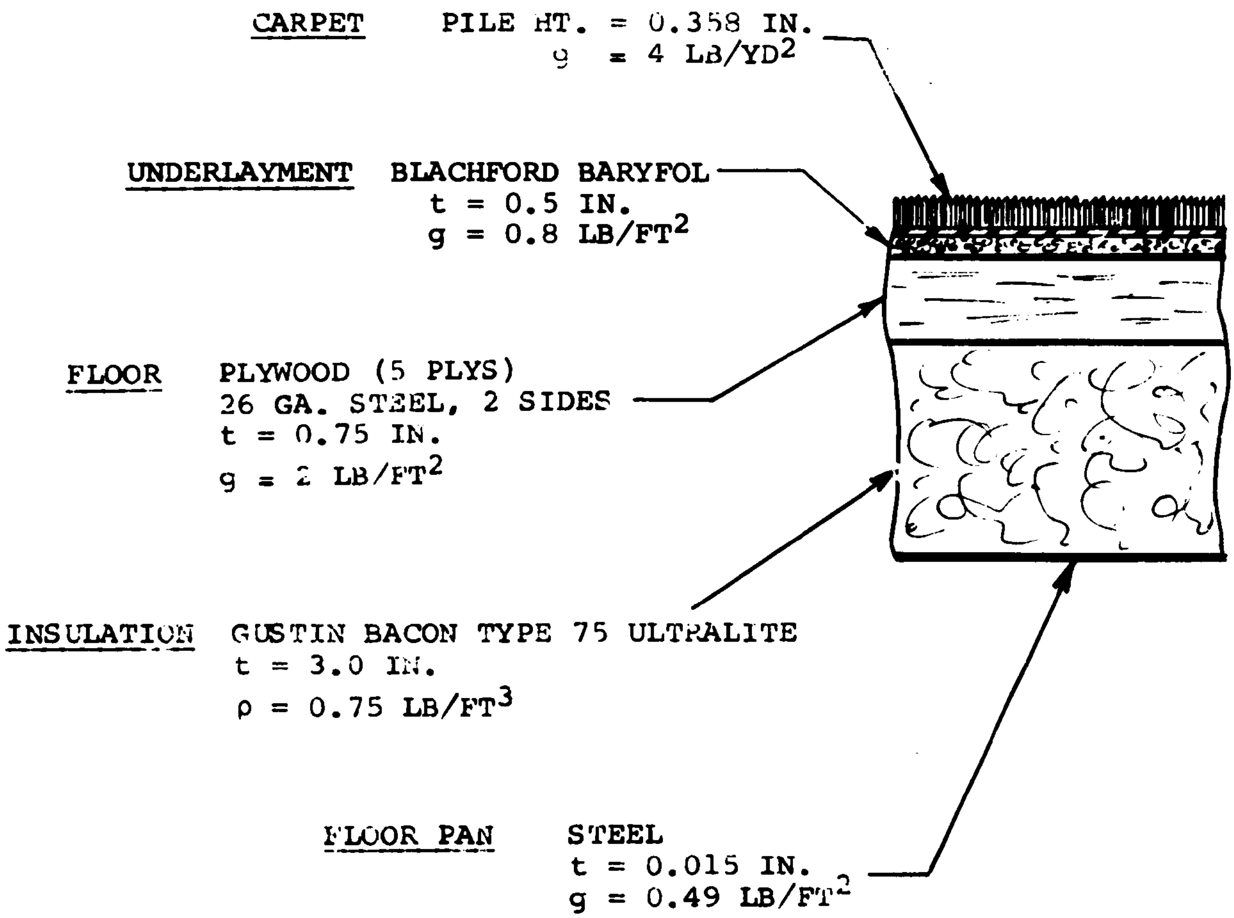


Figure 1–42. Car Body Noise Reduction Features, Floor Construction

WINDOW GLASS

t = 0.25 IN.
g = 3.25 lb/ft^2

SKIN STEEL-SHEET, t = [illegible].078 IN.
CORRUGATED, t = 0.042 IN.

DAMPING 1/32 IN. SPRAYED INSULMAT

LINER

FIBERGLASS REINFORCED PLASTIC
t = 0.125 IN.
g = 0.91[illegible] FT^2
OR
MELAMINE ON ALUMINUM
t = 0.154 IN.
g = 1.75 16/FT^2

INSULATION - GUSTIN BACON TYPE 75 ULTRALITE
0.002 IN. ALUM. FACING (INNER FACE)
THICKNESS - 1.0 IN.
DENSITY - 0.75 LB/FT^3

Figure 1–43. Car Body Noise Reduction Features, Sidewall Construction

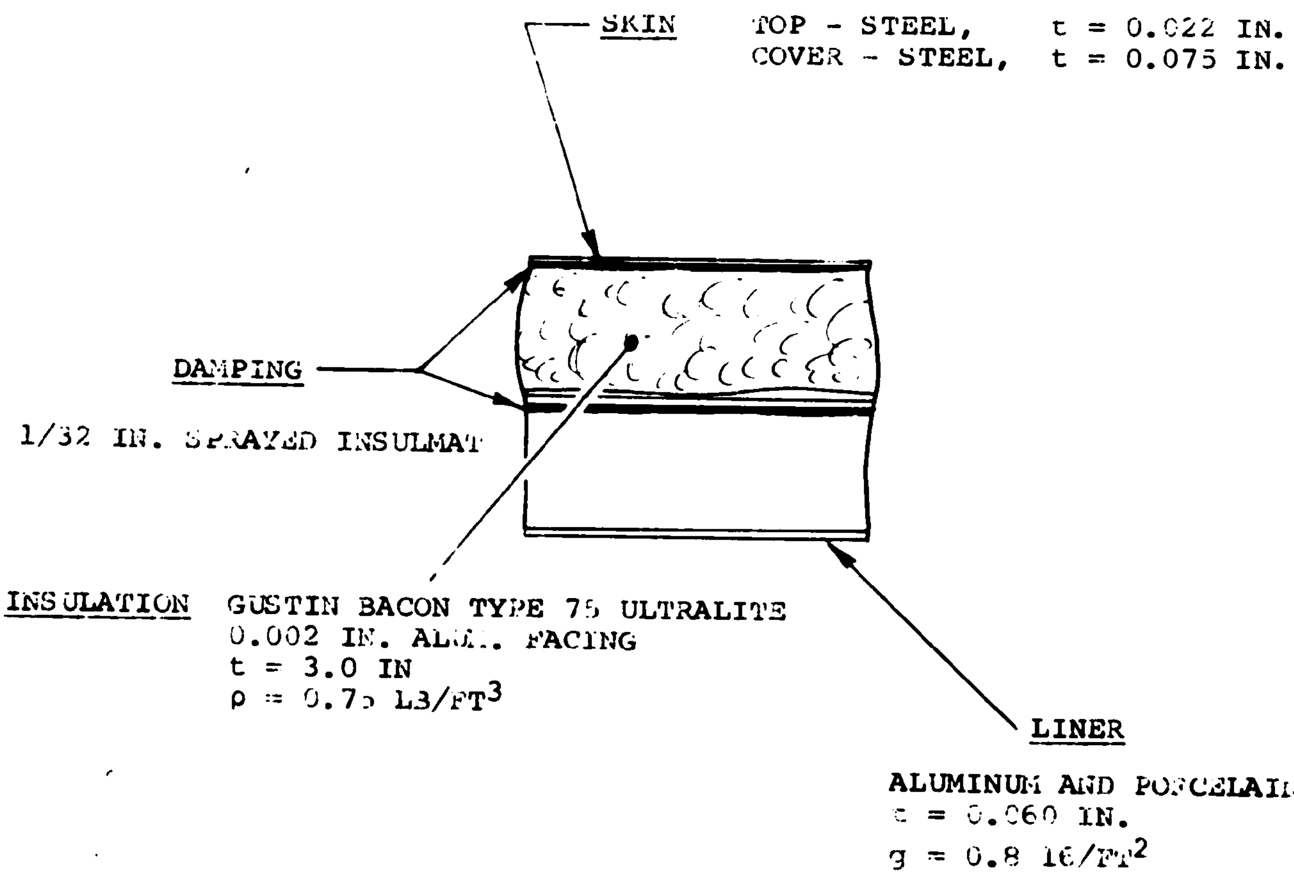


Figure 1-44. Car Body Noise Reduction Features, Ceiling Construction

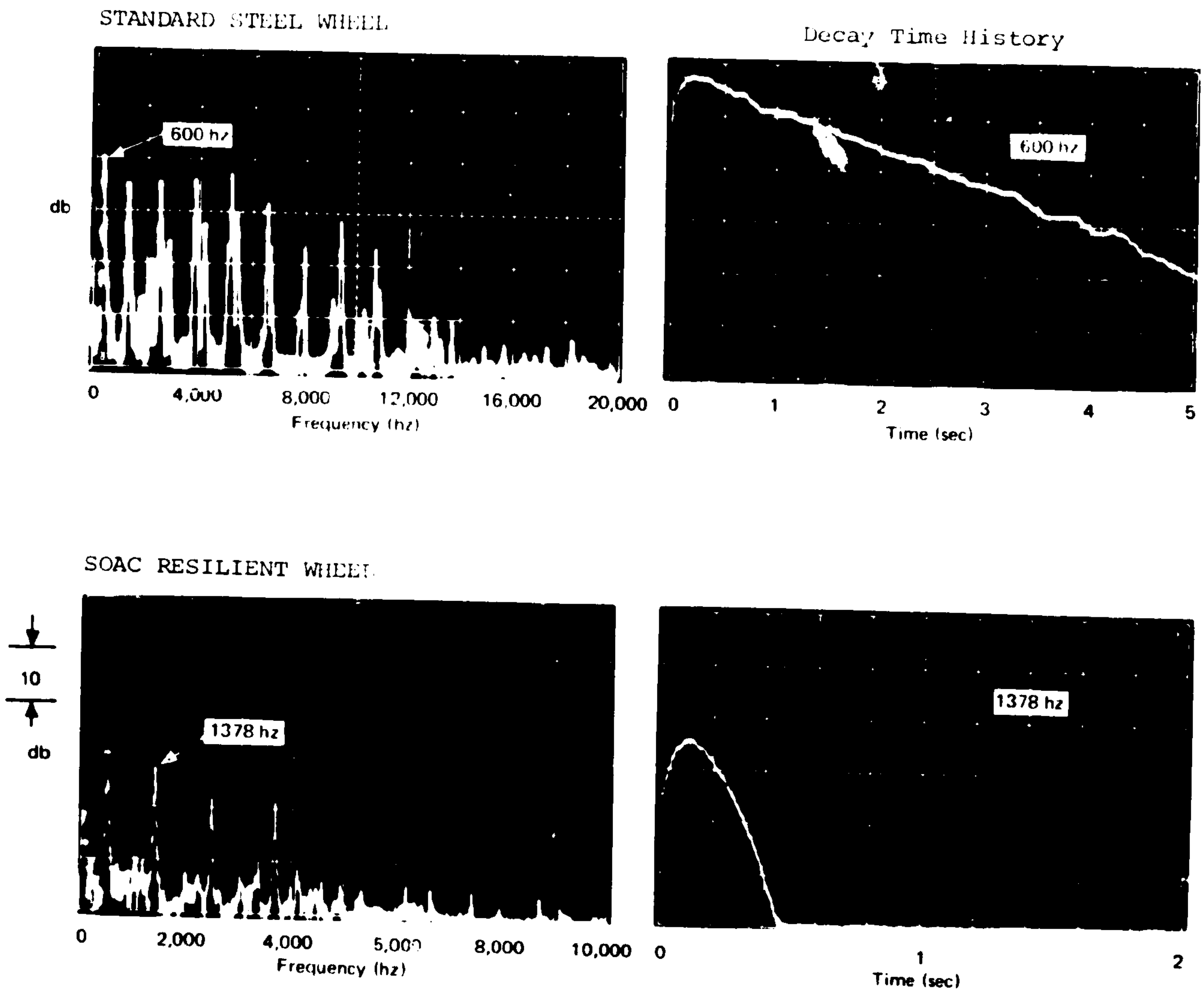


Figure 1-45. Comparison of Wheel Frequencies and Decay Rates

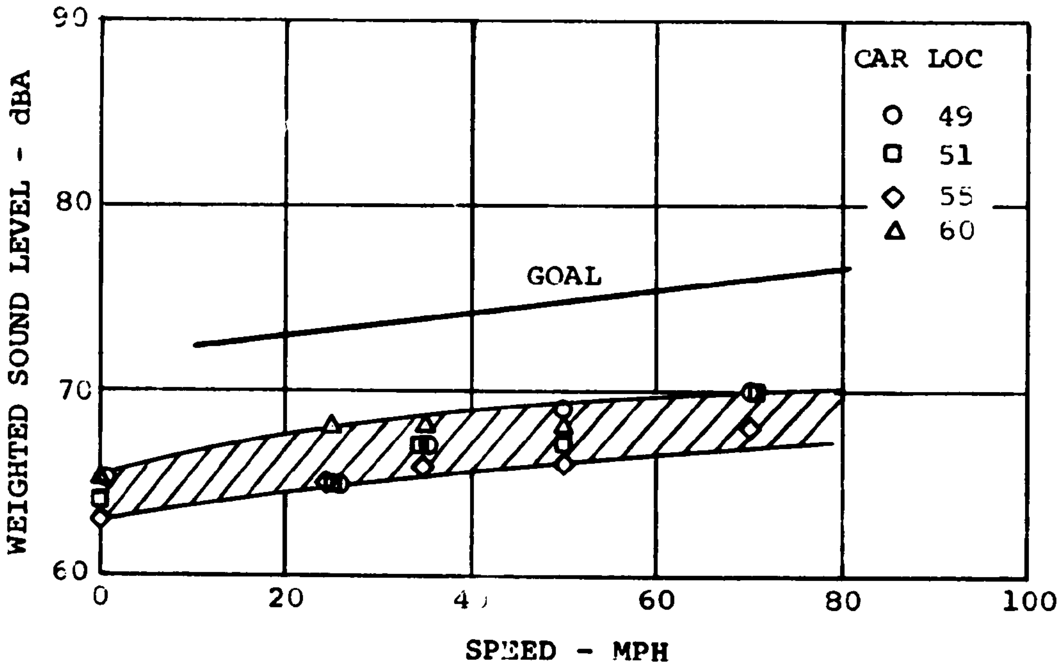


Figure 1–46. Comparison of Interior Noise Levels with Goals (Car No. 1; 90,000 Pounds)

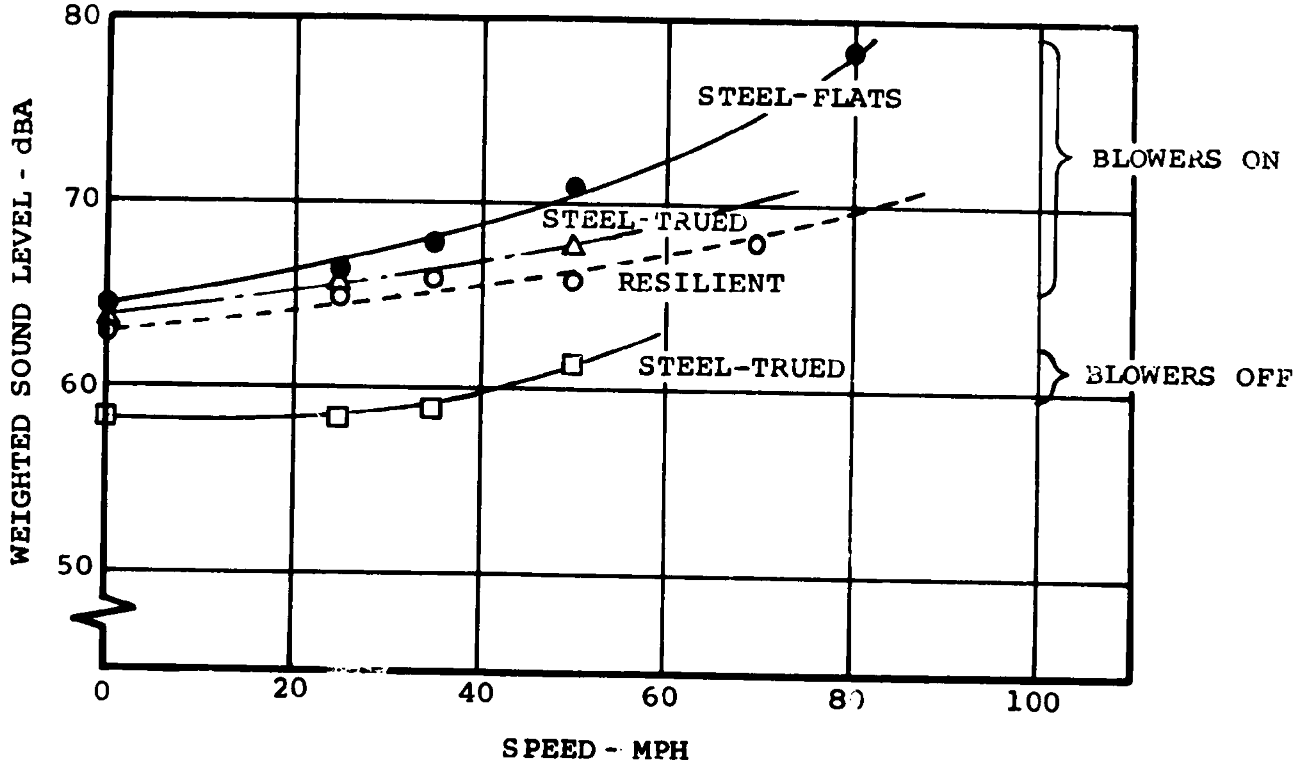


Figure 1–47. Effect of Wheel Configuration on Interior Noise (Car No. 1; 90,000 Pounds; Track Section I)

Section 2

WAYSIDE NOISE

2.1 SUMMARY

Sequence

Table 2-1 gives the test run numbers for the wayside noise testing.

TABLE 2-1. WAYSIDE NOISE SURVEY TEST RUN LOG

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

Test Procedures

Detailed test procedures are presented in SOAC ENGINEERING TEST PROGRAM TEST PROCEDURES (Reference 1).

Objective

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

Status

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

2.2 TEST DESCRIPTION

The microphone was located at a distance of 50 feet from the track centerline for all of the data points surveyed, and a distance of 15 feet for selected runs. The types of wayside noise surveyed were as follows:

a. Equipment noise
b. Speed effect (include repeat runs)
c. Track construction effect
d. Distance effect
e. Two-car effect
f. Power condition effect
g. Resilient wheels

Sound measurements were made in a manner which allowed a complete time history of each measured sound signal to be retained on a magnetic tape. Subsequent data reduction included standard "A" weighted acoustical levels, 1/3-octave band analysis and narrow band spectrum analysis for selected data points.

2.3 INSTRUMENTATION

2.3.1 Field Measurement Equipment

The instrumentation used for measurement of noise levels consisted of a 1-inch condenser microphone with battery operated cathode-follower and a 1/4-inch, single-channel tape recorder. Table 2-2 lists the specific items of equipment by manufacturer, model, and serial number. For wayside measurements, the microphone was mounted on a tripod for each of the passby measurements and a windscreen installed to reduce the interference of wind on the data. The recorder was operated at a tape speed of 7-1/2 ips to achieve a good frequency response characteristic. A gain/attenuation system consisting of 10 dB incremental steps was incorporated in the recorder to maintain accuracy of the system.

2.3.2 Calibration

The recorder was calibrated prior to testing using a swept-frequency sinusoidal insert voltage over the range 20 Hz to

TABLE 2-2. WAYSIDE NOISE MEASUREMENT INSTRUMENTATION

Item	Manufacturer	Model	Serial No.
1. Tape Recorder	Kudelski	NAGRA III	PHO 67-10290
2. Tape Recorder	Kudelski	NAGRA III	PHO 67-10441
3. Microphone, 1-inch	B&K	4131	73624
4. Power Supply	B&K	2630	168943
5. Microphone	B&K	4131	205686
6. Power Supply	B&K	2630	87507
7. Calibrator	B&K	4230	395443

20 kHz at a level of 100 mv. The input signal was applied at the cathode follower, recorded on magnetic tape, and played back on the same recorder to produce the frequency response curve shown in Figure 1-4. Microphone response does not change system accuracy over the frequency range from 2 to 15 kHz.

During the test period, a known signal (94 dB at 1000 Hz) was recorded on each tape to establish system sensitivity as well as a reference level for analysis of the data.

2.3.3 System Accuracy

a. The frequency response of each microphone to a sinusoidal wave of consistent amplitude lies within the limits of 10 Hz to 15 kHz linear ±1 dB for sound pressure levels in the range of 50 to 120 dBSPL.

b. Each complete assembly of noise measurement and recording equipment (including cables) had an electrical frequency response linearity of within ±2 dB from 50 Hz to 10 kHz for a range of signal voltage levels corresponding to input sound levels of 50 dB to 120 dBSPL at the microphone sensor.

c. The total harmonic distortion of the sound sensing microphone equipment did not exceed 1 percent over the measurement dynamic range.

d. The total harmonic distortion of the assembled noise measurement and recording equipment did not exceed 4 percent over the measurement dynamic range.

2.4 TEST PROCEDURES

Locations selected for wayside noise surveys had relatively flat terrain on both sides of the right-of-way. Trackside locations are shown in Figure 2-1; specific sites are indicated

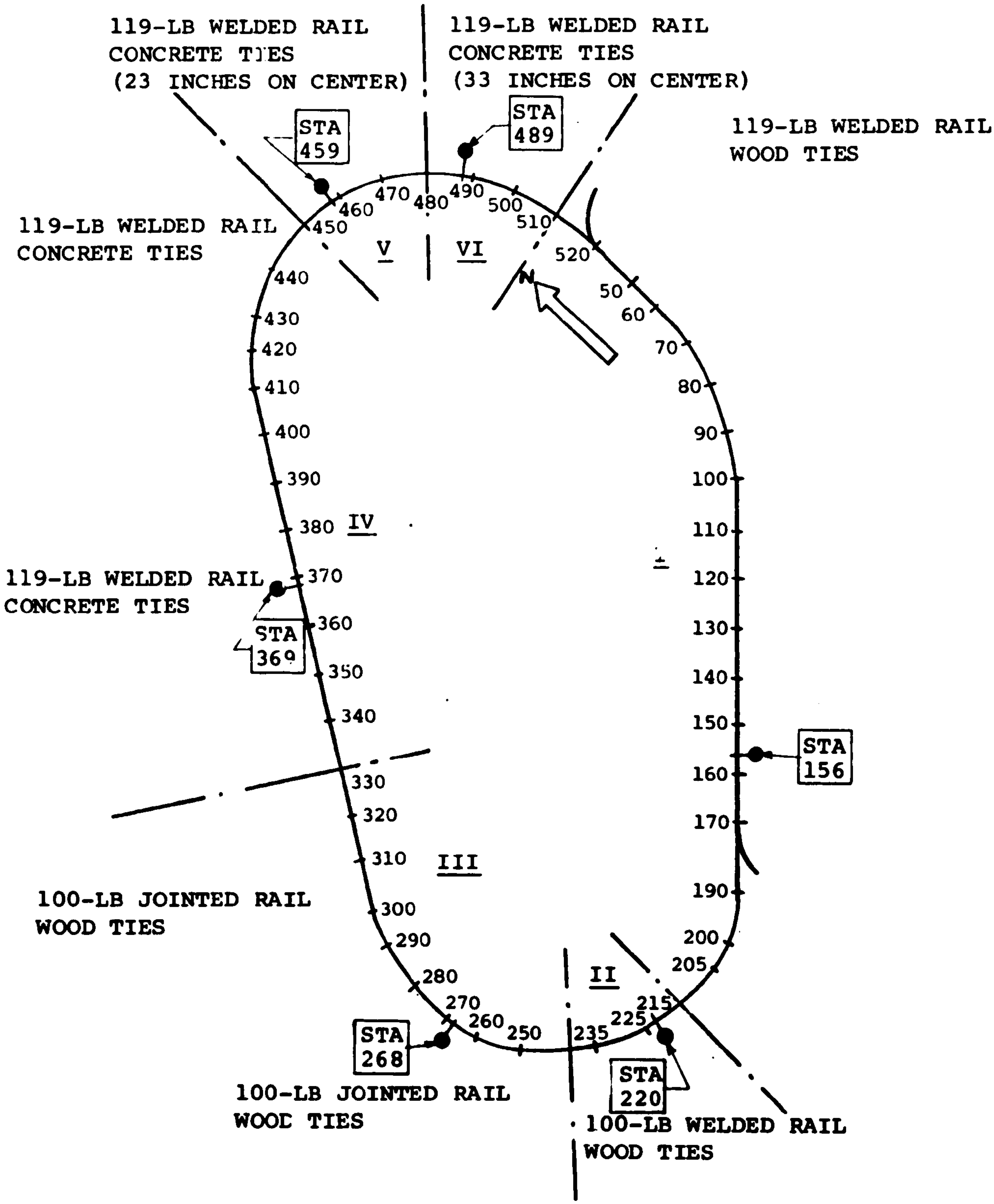


Figure 2–1. Microphone Locations for Wayside Noise Survey on UMTA Rail Transit Test Track

in Figure 2-2. Measurements of wayside noise were made at a distance of 50 feet from the track centerline on the outside of the test oval (the third rail is on the inside). Selected data points were recorded 15 feet from the track centerline, as well. Height of the microphone as mounted on the tripod was 5 feet above the local ground level and approximately 3 feet above rail height.

A brief investigation at the Track Section I location showed that there was no observable difference in passby noise with car direction for dBA weighting if car speed was held constant. Thus, to facilitate noise measurements, data were taken with the car operating in both directions.

Measurements of ambient noise showed that levels were, in all cases, substantially greater than 10 dBA below maximum passby levels and thus did not contribute to reported sound levels of the car.

Detailed testing procedures are as follows:

Pre-Test Procedures

a. Ballast car to required weight (AW ____)

b. Set-up and calibrate instruments at the test site.

c. Move the car to the test zone.

2.4.1 Equipment Noise Survey, Wayside Noise

The purpose of this sequence of tests is to determine the effect on exterior noise levels of cycling various undercar equipment items.

a. Position the SOAC car at a boarding platform away from other noise sources with all equipment turned off.

b. Set-up and calibrate the recording system per previously described procedures.

c. Position the microphone at the ear level of a standing passenger on the platform.

d. Start the recorder prior to equipment cycle, identify the test point, and record gain level by voice.

e. Start up each item of equipment noted below and record approximately 15 seconds of noise data for each record.

    1. All equipment off

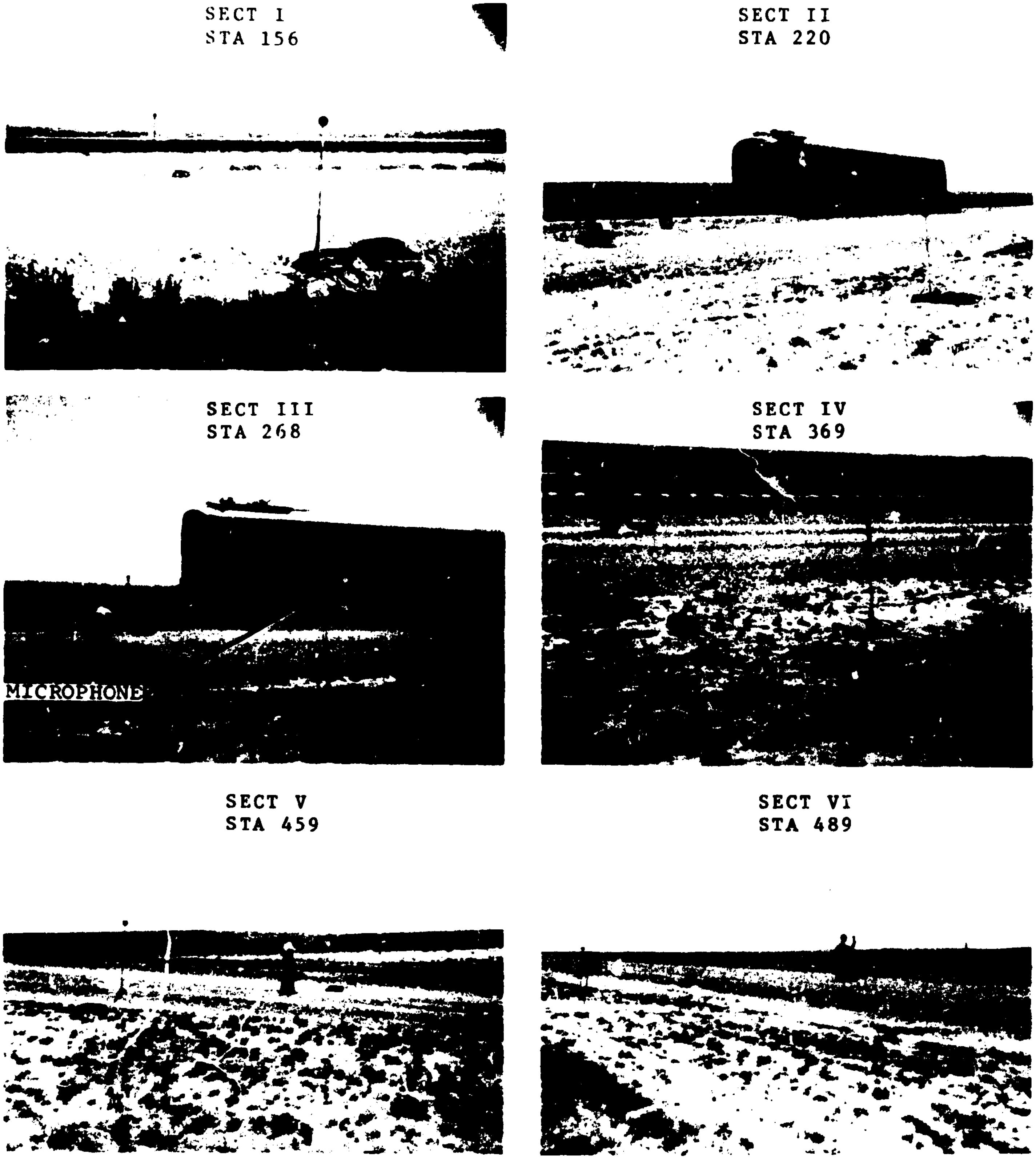


Figure 2–2. Trackside Microphone Locations

2. Lighting system inverter

3. Motor alternator start-up

4. Air conditioning compressor

5. Traction motor blowers

6. Brake air compressor

7. Passenger door cycle

8. Venting of brakeline

9. Service stop: decelerate from 50 mph; stop at platform with a passenger door at the platform; cycle doors and accelerate to 50 mph.

f. Stop recorder and enter record number on Log Sheet.

2.4.2 Effect of Car Speed on Wayside Noise

The purpose of this sequence of tests is to determine the effect of car speed on wayside noise of both SOAC cars at two car weights (90,000 and 105,000 pounds).

a. Set-up and calibrate the recording system per previously described procedures at a level, tangent portion of Track Section I on the outside of the loop at a distance of 50 feet from track centerline.

b. Position the microphone at a height 5 feet above the rail.

c. Start the recorder prior to the passby of the car. Identify the test point, location, amplifier gain level, and ambient weather conditions by voice.

d. For each passby, maintain car test speed for a minimum of 10 seconds prior to passing the microphone. Maintain test speed for the same length of time after passing the microphone.

e. The passby direction of motion of the car will be the same for all runs unless the wind is calm, in which case either end of the car may lead. In this case, document the car end approaching the microphone.

f. Determine the effect of data repeatability by obtaining three data points at the 50 mph test condition.

2.4.3 Distance Effect on Wayside Noise

The purpose of this sequence of tests is to determine the effect of distance on SOAC wayside noise. Using at least two data channels, position a reference microphone 15 feet from the track centerline, and progressively position a second microphone at 50, 100, and 200 foot distances on the level, tangent portion of Track Section I. This test will be performed on one car at a single car weight (90,000 pounds).

a. Set-up and calibrate the recording system per previously described procedures.

b. Position the microphones at a height of 5 feet above the rail.

c. Start the recorder prior to the passby of the car; identify the test point; record amplifier gain level, location, and ambient weather conditions by voice.

d. For each passby, maintain car test speed for a minimum of 10 seconds prior to passing the microphone. Maintain test speed for the same length of time after passing the microphone.

e. The passby direction of the motion of the car will be the same for all runs unless the wind is calm, in which case either end of the car may lead. In this case, document the car end approaching the microphone.

2.4.4 Effect of Track Construction on Wayside Noise

The purpose of this sequence of tests is to determine the effect of the different types of track section construction on SOAC wayside noise. The test will be evaluated on one SOAC car at the 90,000-pound weight.

a. Set-up and calibrate the recording system per previously described procedures at a distance of 50 feet from the track centerline and at a height of 5 feet above the rail on the outside of the test loop.

b. Start the recorder prior to the passby of the car. Identify the test point, location, amplifier gain level, and ambient weather conditions by voice.

c. For each passby, maintain car test speed for a minimum time of 10 seconds prior to passing the microphone. Maintain test speed for the same length of time after passing the microphone.

d. The passby direction of motion of the car will be the same for all runs unless the wind is calm, in which case either end of the car may lead. In this case, document the car end approaching the microphone.

2.4.5 Coupled-Car Wayside Noise Levels

The purpose of this sequence of tests is to determine the effect on wayside noise of running two SOAC cars at one car weight (90,000 pounds). Track Section I will be used for the evaluation.

a. Set-up and calibrate the recording system per previously described procedures at a distance of 50 feet from the track centerline and at a height of 5 feet above the rail on the outside of the test loop.

b. Start the recorder prior to the passby of the car. Identify the test point, location, amplifier gain, and ambient weather conditions by voice.

c. For each passby, maintain the car at test speed for a minimum of 10 seconds prior to passing the microphone. Maintain test speed for the same length of time after passing the microphone.

d. The passby direction of motion of the car will be the same for all runs unless the wind is calm, in which case either end of the car may lead. In this case, document the car end approaching the microphone.

2.4.6 Car Body Noise Reduction Survey

The purpose of this sequence of tests is to determine the noise reduction of the SOAC car body. Tests will be conducted for the sidewall, car floor, and car end. Car weight will be 90,000 pounds.

a. Mount one microphone on the exterior wall of the car, approximately at midpoint between the sill and roof (not at a window). Install a nose cone on the forward facing microphone and route the lead wire through the nearest passenger door, minimizing all acoustical leaks.

b. Set-up an interior microphone at a location just inside the exterior system. For a single channel tape recorder, connect the exterior and interior microphone leads to a switching box.

c. Calibrate recording system per previously described procedures.

d. Indentify the test point and record gain level. Record at least 15 seconds of data for both the interior and exterior microphone. Stop the recorder and enter record number and amplifier gain on a log sheet.

e. Repeat steps (a) through (d) for a microphone mounted on the outside at the B end of the car, approximately at midpoint of the panel adjacent to the end door.

f. Repeat steps (a) through (d) for a microphone mounted on the No. 2 truck safety strap on the third rail side of the car to measure noise of the third rail collector shoe.

2.4.7 Effect of Resilient Wheels on Wayside Noise

The purpose of this sequence of tests is to determine the effect of resilient wheels on the wayside noise level of each of the SOAC cars. Tests will be conducted at 90,000-pound car weights. Car configuration will be the same as for the noise survey with steel wheels, except that resilient wheels will be installed.

a. Set-up and calibrate the recording system per previously described procedures at each required location. The microphone shall be located at distance of 50 feet from the track centerline on the outside of the loop at a height of 5 feet above the rail.

b. Start recorder prior to the passby of the car. Identify the test point, location, record amplifier gain level, and ambient weather conditions by voice.

c. For each passby, maintain the car at test speed for a minimum of 10 seconds prior to passing by the microphone. Maintain test speed for the same length of time after passing the microphone.

d. The passby direction of the motion of the car will be the same for all runs unless the wind is calm, in which case either end of the car may lead. In this case, document the car end approaching the microphone.

e. The effect of data repeatability will be determined by obtaining three data points at the 50 mph test condition.

2.5 WAYSIDE DATA

Much of the data obtained at the wayside during car passby was recorded during variable conditions of temperature and wind velocity. As a result, some data recorded on the same car with the vehicle at rest and all systems operating display differences of 3 to 6 dBA. Corrections have not been made to these data to "standard day" conditions accounting for wind, temperature and pressure, and any comparisons which are made between configurations (e.g., wheels) should account for these anomalies.

The Boeing Vertol Company operates a Calibration/Certification Laboratory to insure the maintenance of instrumentation standards traceable to the National Bureau of Standards. Analyzer characteristics such as filter bandwidths are checked twice yearly, as are microphone calibrators. Frequency response characteristics of record systems are typically run prior to each test program.

The basic analysis of all data recorded during the program consists of a frequency analysis using an "A" weighting network (see Table 2-3). Selected data points have also been analyzed using 1/3-octave band filters (preferred frequencies) as in Figures 2-3 through 2-10. All data reported has been converted to sound pressure levels referenced to 2.0 x 10^{-5} n/m^2.

Where narrow band components required identification, data were analyzed with a digital analyzer (Federal Scientific UA-6 Spectrum Analyzer). Data from this analysis are presented in the form of oscilloscope photographs. For passby noise, the frequency spectra was captured at the maximum level for that run. These spectral data are presented in Figures 2-11 through 2-18.

2.6 PRELIMINARY ANALYSIS

2.6.1 Comparison with SOAC Goals

A comparison of measured wayside noise levels with SOAC goals (Figure 2-19) shows that goals have been achieved above 35 mph. Below 35 mph, the noise of the traction motor blowers establishes the "A" weighted sound levels of the car.

A comparison of noise levels for each wheel configuration (Figure 2-20) indicates that the increase in wayside noise of measured steel wheel levels over the levels for resilient wheels is 2 to 3 dBA over the car operating speed range, as is expected.

2.6.2 Effect of Two Cars on Wayside Noise

Comparison of wayside noise levels for single and two-car trains (Figure 2-21) shows an increase of 3 dBA for the second car at speeds below 50 mph. At 70 mph, there is an increase of 8 dBA over the single car level which may stem from small magnitude flats on the second car not present on the first car and not significant at the lower apeeds. No documentation of wheel flats exists for these test runs for either car, however. A 2 to 3 dBA increase for the second car would be predicted on the basis of doubling the number of cars (randomly phased sources) and this is confirmed at the lower speed values.

2.6.3 Effect of Wheel and Rail Surface Roughness

Data obtained on the SOAC with wheel flats is substantially higher than displayed by the wheels after they had been trued. The initial survey was obtained on the cars after the wheels had developed numerous flats. Later in the program, the surfaces of the wheels were smoothed by removing the flats, using grinding stones fixed to the wheel brake pads, applying a relatively light load to the brake system, and then towing the car until the flats had been removed. Noise from these two configurations are compared in Figure 2-22. Wayside noise is shown to be dependent on the number and magnitude of flats on the wheels.

Rail surface also plays a role in establishing wayside noise levels. As expected, the smoothest rail surfaces produce the lowest noise levels. An illustration of this can be seen by comparing car noise on each of the six track sections at the HSGTC. Each section of track was ground smooth, to the same standards, in February 1973, but Track Section I had more usage throughout the year. This section of track is used by heavy locomotives and equipment cars traveling between the Army Depot at Pueblo and the test site at the HSGTC. This generates a rail surface with higher roughness than the other track sections in the test oval which are used only for test purposes. In the period since grinding, these latter sections had been used for SOAC testing only.

A plot of the data obtained in May and June 1973 from each of these sections (Figure 2-23) reveals a grouping of data for the relatively unused track sections, and higher levels for Track Section I. Measurement of both rail and wheel roughness should be made in conjunction with noise levels to more accurately assess the effect of the wheel/rail interface on wayside and interior noise.

TABLE 2-3. WAYSIDE NOISE DATA

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRK/ SECT MARKER	VELOCITY (MPH)	DIST. FROM TRACK ℄ (FT)	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	WIND (MPH)
1	5 Ft from M/A Set				0		13-B-5	197	91.5	0
	5 Ft from Air Cond. Comp.				0			198	87.5	
	5 Ft from Brakeline Analog Vent				0			201	95	
	Platform Level at No. 1 Door						13-B-17			
	M/A Startup				0	10		550	78	
	Brake Air Compressor				0	10		551	83	
	Air Cond.				0	10		552	80	
	#1 Blower Fan				0	10		553	80	
	#2 Blower Fan				0	10		554	81.5	
	Fwd Door Cycle				0	10		555	79	
	Approach to Stop				50-0-50	10		556	60-81-60	
2		90,000	Steel-Flats	IV/373	0	50	13-B-4	184	69	10
					25			178	76	
					35			179	82	
					50			180	84	
					70			182	87.5	
					80			183	89	

TABLE 2-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRK/ SECT MARKER	VELOCITY (MPH)	DIST. FROM TRACK ℄ (FT)	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	WIND (MPH)
1		90,000	Steel-Flats	IV/370	0	50	13-B-7	272	71	
					25			273	80	
					35			274	83	
					50			275	88.5	
					70			276	89	
					80			277	90	
1&2 Car	2 Powered	90,000	Steel-Flats	I/157	25	50	13-B-8	305	79	
					35			306	82	
					50			307	87	
					65			308	87	
					70			309	87	
					80			310	89	
1		90,000	Steel-Trued	III/268	25	50	13-B-11	384	72	10
					25			385	71	
					35			386	72	
					50			387	75	
					70			389	77	
				IV/369	0			395	-	
					25			390	70.5	
					35			391	74	
					50			392	Not Avail.	
					70			393	78	
				V/459	0			400	69	
					25			396	72	
					35			397	73	
					50			398	76	
					70			399	78	

TABLE 2-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRK/ SECT MARKER	VELOCITY (MPH)	DIST. FROM TRACK ℄ (FT)	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	WIND (MPH)
1		90,000	Steel-Trued	VI/489	25 35 50 50 50 70	50	13-B-11	402 403 404 405 407 406	72 72.5 74.5 74 77	10
1		90,000	Steel-Trued	III/268	0 25 25 35 50 70	15	13-B-12	419 409 410 411 413 414	75.5 80.5 83 88 89 93	10-15
				IV/369	25 35 50 70	15	13-B-12	415 416 417 418	86 89 89 94	
				V/459	25 25 35 50 70	15		420 421 422 423 424	78 85 89 92 92.5	
				VI/48	50 70	15		426 427	88.5 92.5	

TABLE 2-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRK/ SECT MARKER	VELOCITY (MPH)	DIST. FROM TRACK ℄ (FT)	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	WIND (MPH)
1		90,000	Steel-Trued	I/156	25	50	13-B-13	430	76	10-15
					35			431	77	
					50			432	78	
					70			433	81	
1&2		90,000	Steel-Trued	I/157	0	50	13-B-16	536	72	
					25			539	81	
					25 CCW			540	81	
					35 CW			541	83	
					35 CCW			542	82	
					50			538	82	
					50 CCW			544	85	
					70			537	84	
					70 CW			543	87	
					80 CW			545	89	
					80 CCW			546	89	
1		90,000	Resil-ient	I/156	0	60	13-B-19	586	70	10-15
					25			587	76	
					35			588	77	
					50			589	79	
					50			590	78	
					70			591	81	
				II/220	0			592	70	
					25			593	73	
					50			594	78	
				III/268	0			595	67	
					25			596	74	
					50			597	77	
				IV/368	0			598	64	
					25			599	71	
					50			600	75	

TABLE 2-3. Continued

CAR	CONDITION	WEIGHT (LB)	WHEEL CONFIG.	TRK/ SECT MARKER	VELOCITY (MPH)	DIST. FROM TRACK ℄ (FT)	TAPE NO.	TEST PT.	WEIGHTED SOUND LEVEL (dBA)	WIND (MPH)
1		90,000	Resil-ient	V/459	0	50	13-B-19	601	64	
					25			602	68	
					50			603	74	
				VI/489	0			604	64	
					25			605	71	
					50			606	74	
1		105,000	Resil-ient	I/156	0	50	13-B-20	622	69	
					25			623	70	
					35			624	72	
					50			626	74	
					70			627	75	
2		90,000	Resil-ient	I/156	0	50	13-B-21	660	68.5	5-15
					25			661	70	
					35			662	71	
					50			663	74	
					70			664	75	
					80			665	76	
1&2		105,000	Resil-ient	I/156	0	50	13-B-22	674	72	15
					25			673	74	
					35			672	75	
					50			671	78	
					70			670	82	
					80			669	85	

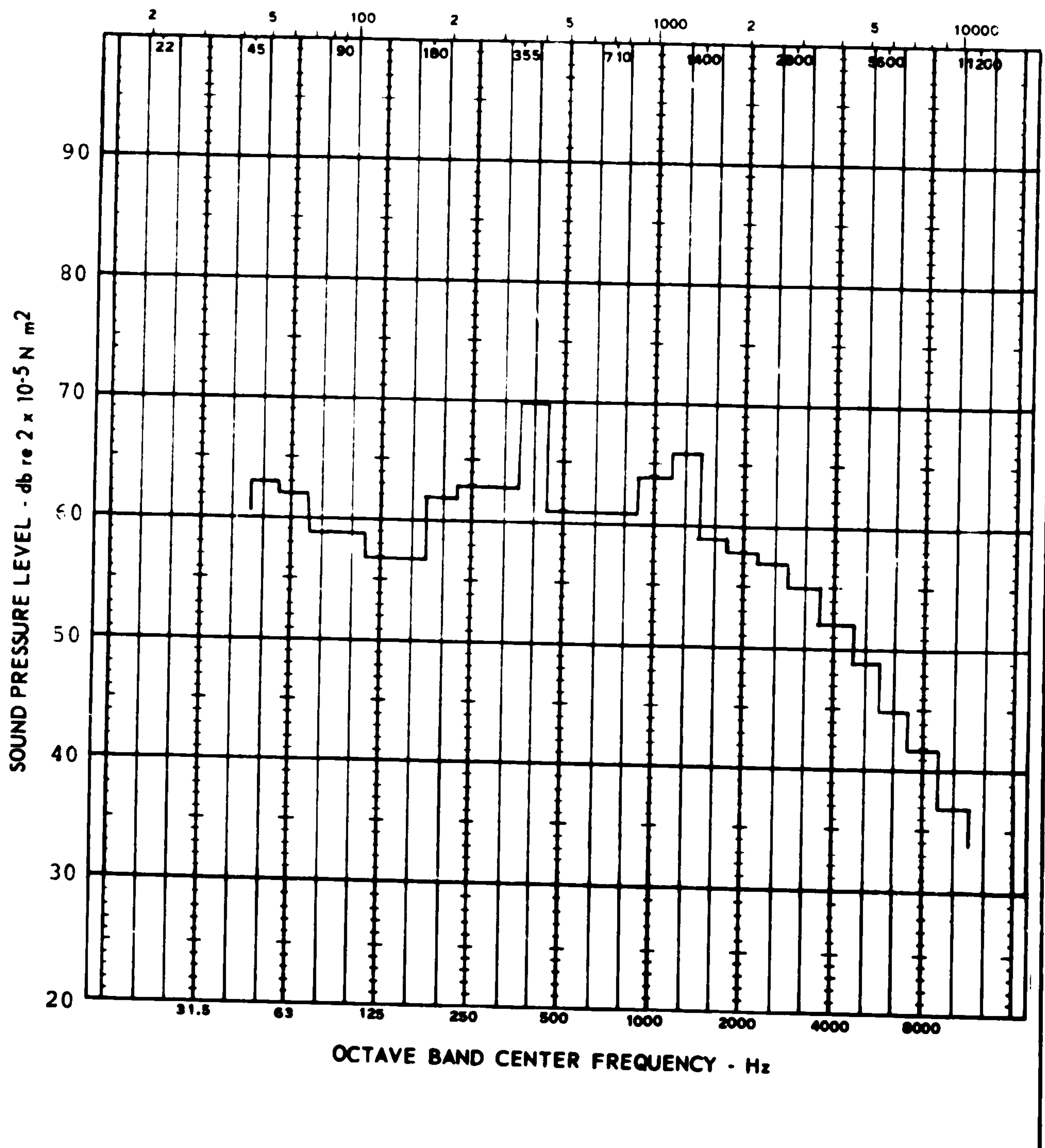


Figure 2–3. Wayside Noise at 25 MPH 50 Feet from Track Centerline Data Point 430 (Car No. 1; 90,000 Pounds; Steel Wheels; No Flats; Track Section I)

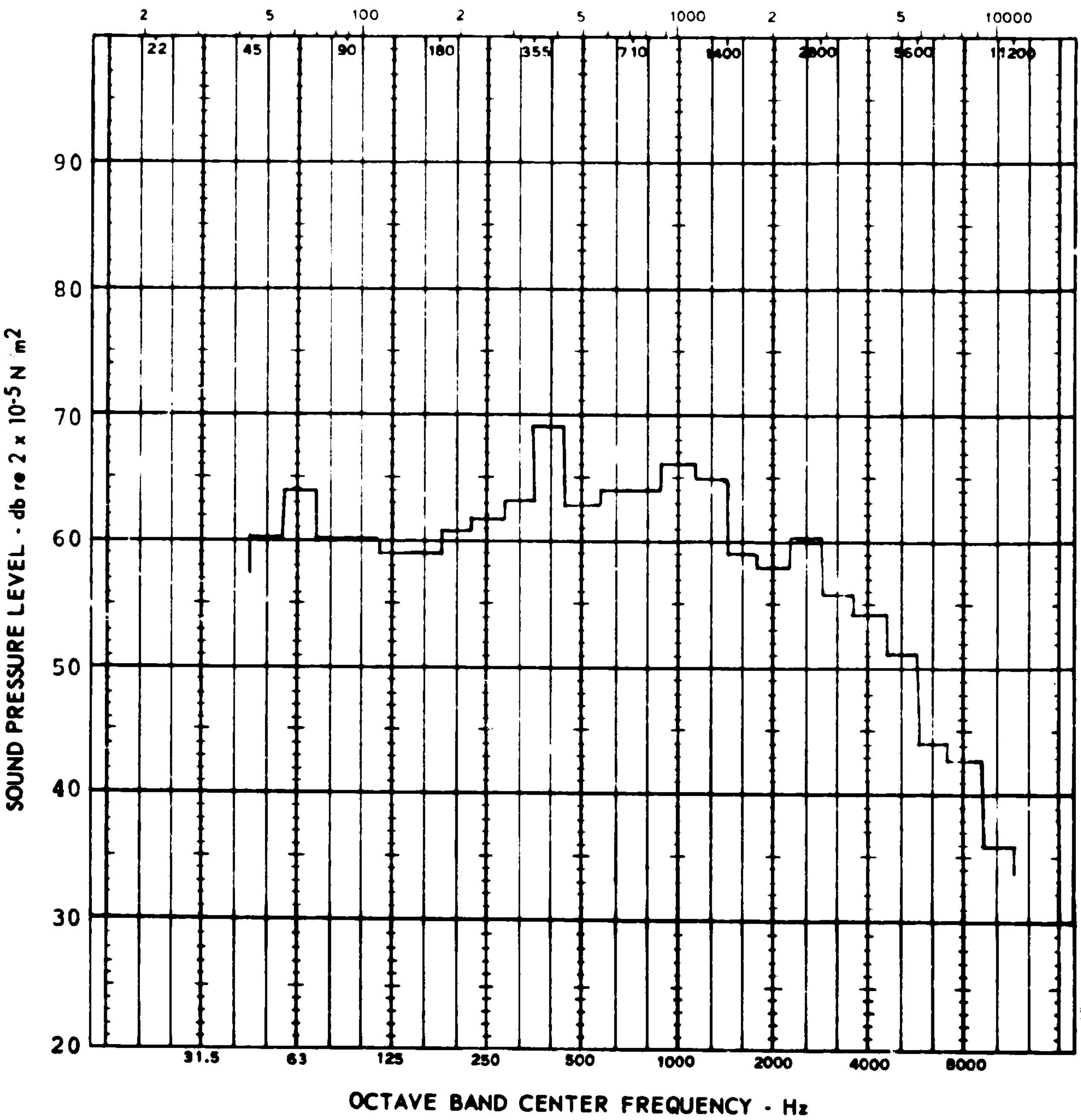


Figure 2–4. Wayside Noise at 35 MPH 50 Feet from Track Centerline Data Point 431 (Car No. 1; 90,000 Pounds; Steel Wheels; No Flats; Track Section I)

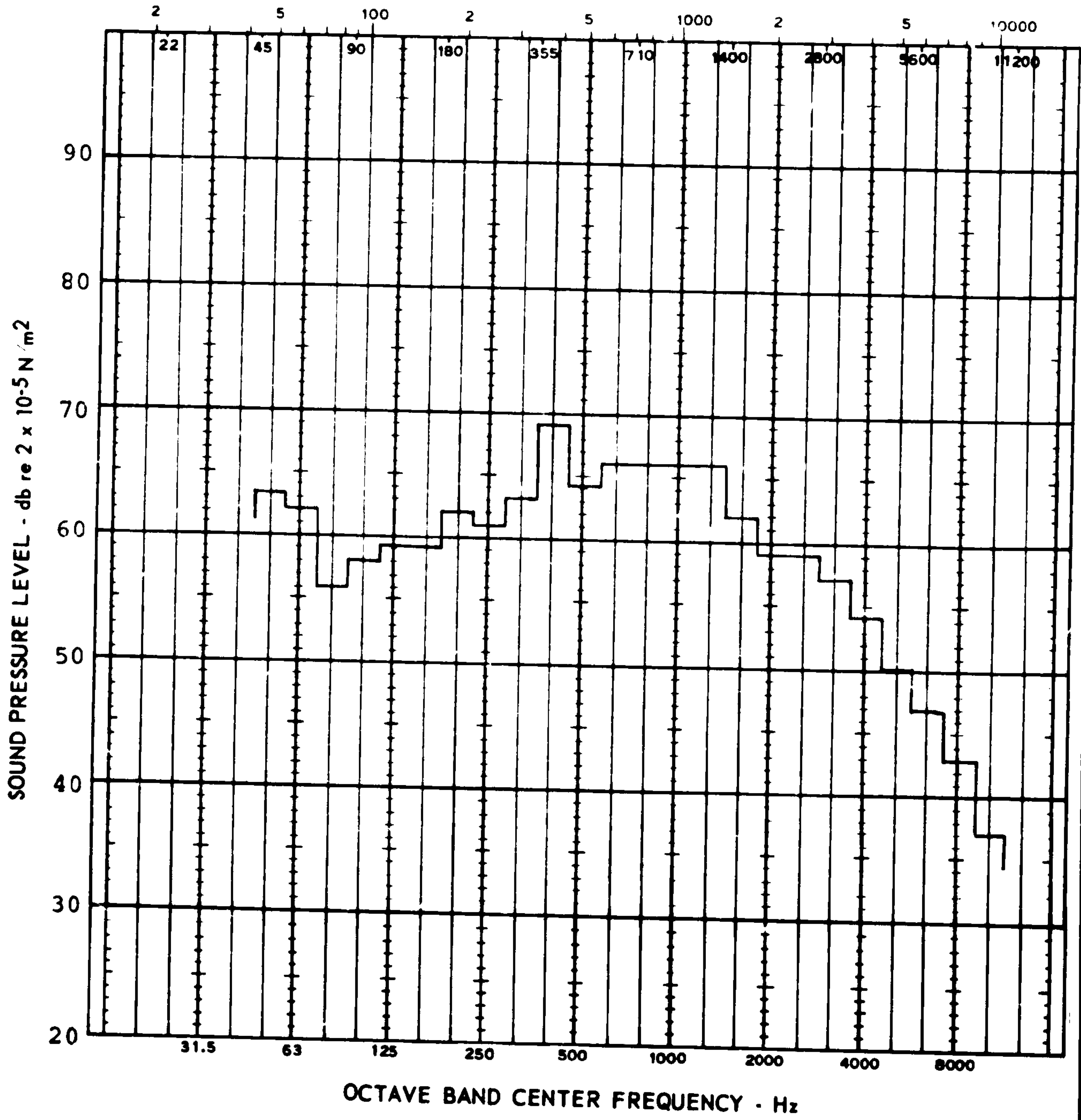


Figure 2–5. Wayside Noise at 50 MPH 50 Feet from Track Centerline Data Point 432 (Car No. 1; 90,000 Pounds; Steel Wheels; No Flats; Track Section I)

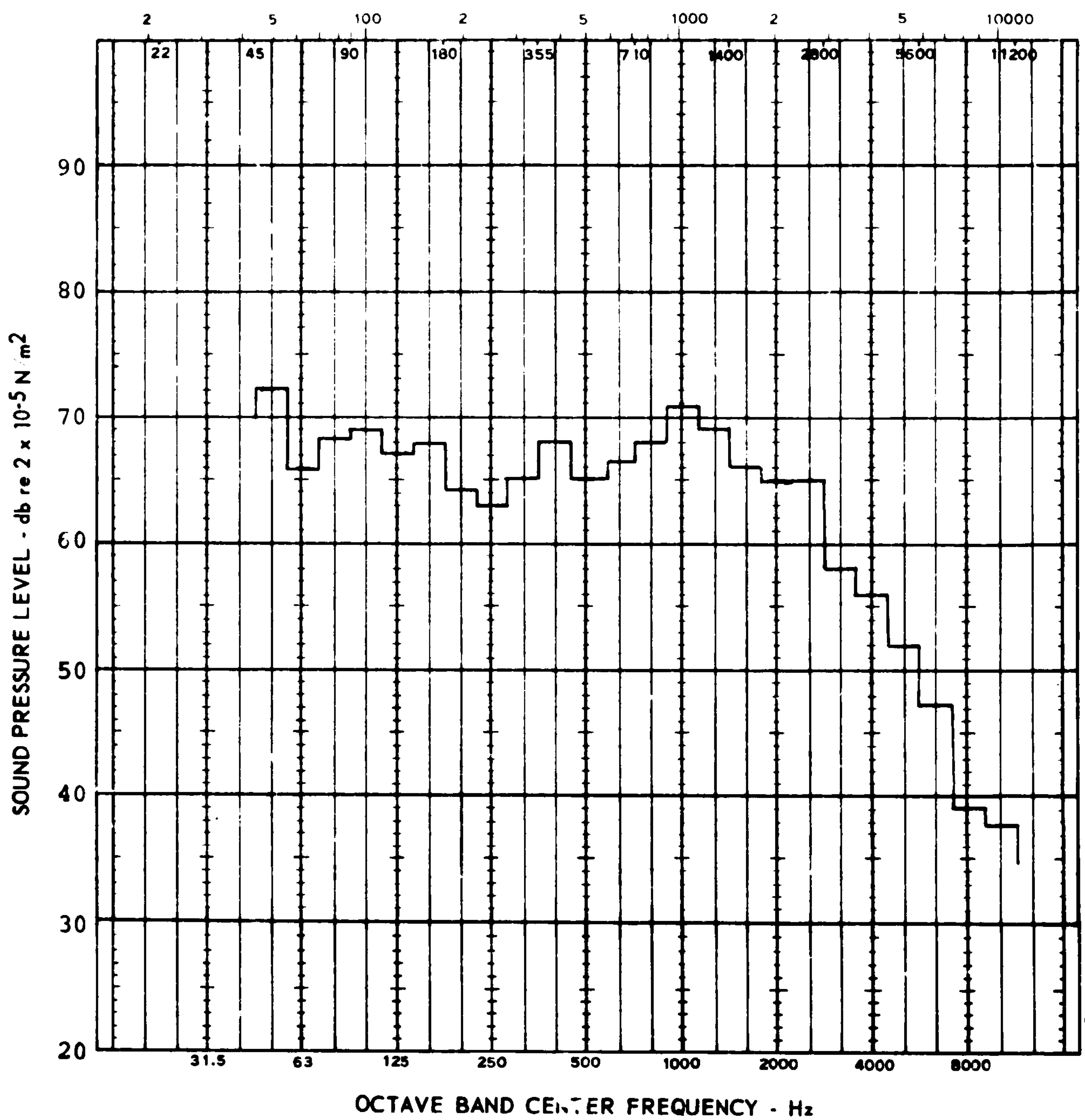


Figure 2–6. Wayside Noise at 70 MPH 50 Feet from Track Centerline Data Point 433 (Car No. 1; 90,000 Pounds; Steel Wheels; No Flats; Track Section I)

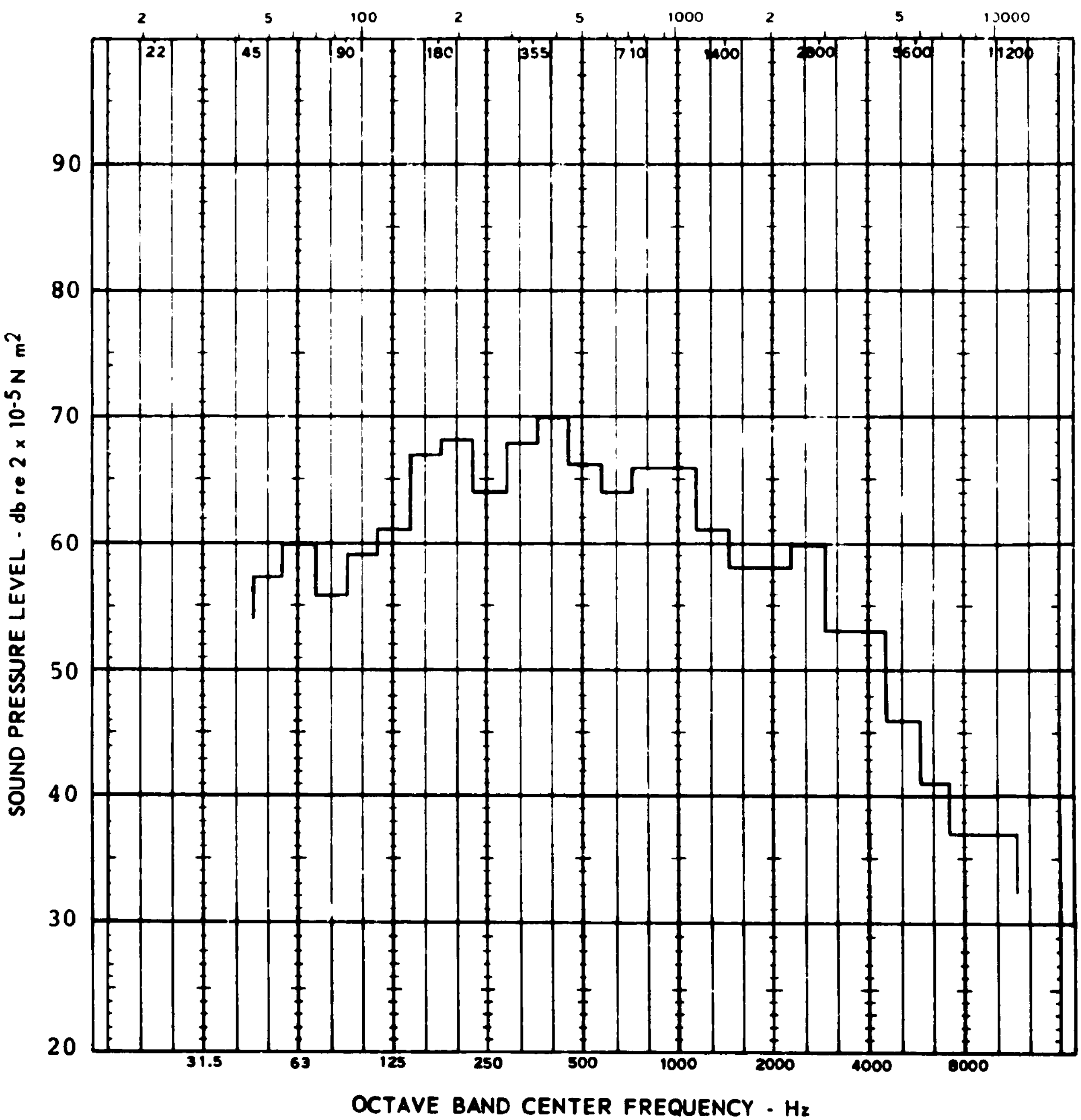


Figure 2–7. Wayside Noise at 25 MPH 50 Feet from Track Centerline Data Point 587 (Car No. 1; 90,000 Pounds; Resilient Wheels; Track Section I)

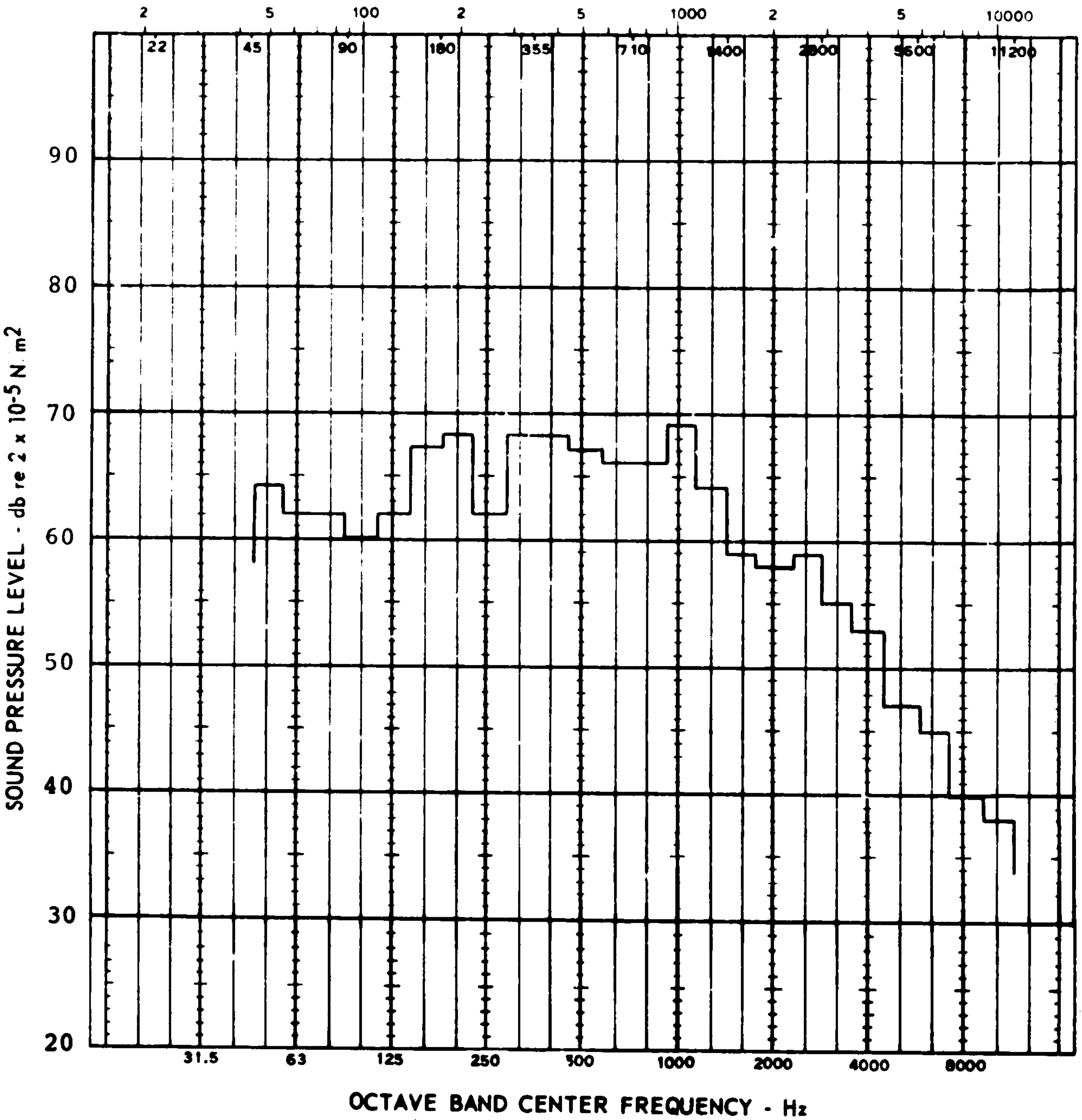


Figure 2–8. Wayside Noise at 35 MPH 50 Feet from Track Centerline Data Point 588 (Car No. 1; 90,000 Pounds; Resilient Wheels; Track Section I)

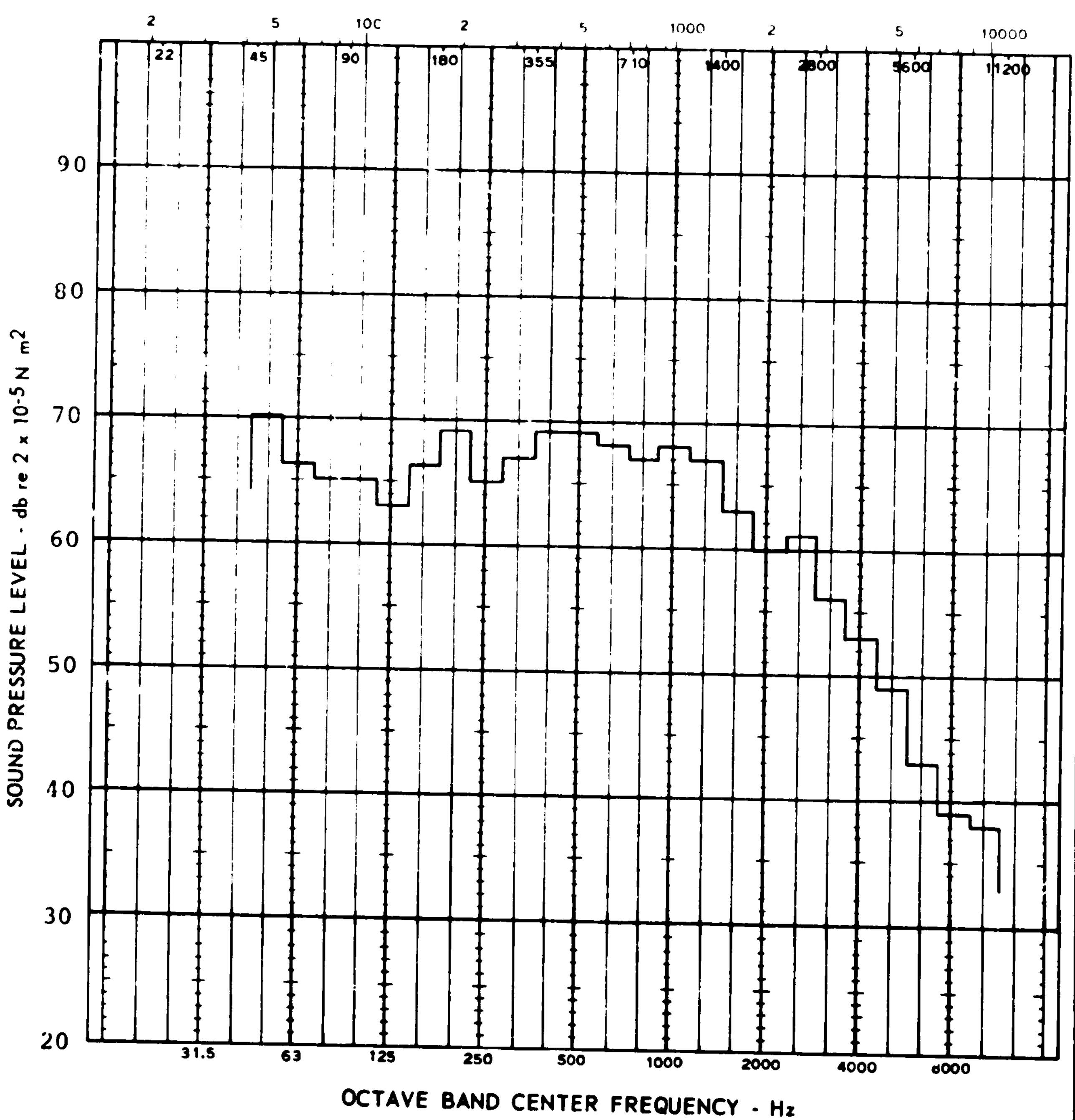


Figure 2–9. Wayside Noise at 50 MPH 50 Feet from Track Centerline Data Point 590 (Car No. 1; 90,000 Pounds; Resilient Wheels. Track Section I)

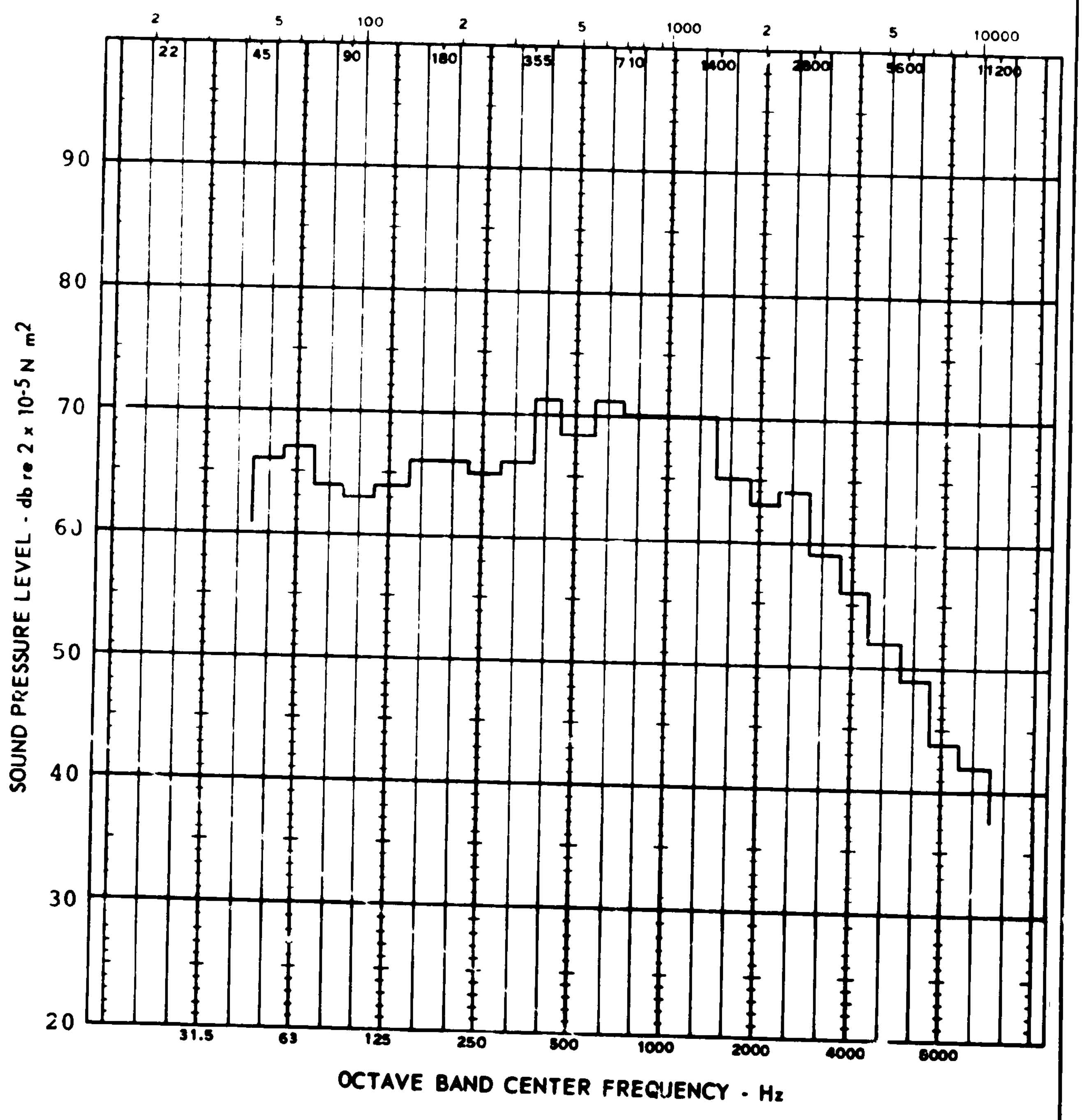


Figure 2–10. Wayside Noise at 70 MPH 50 Feet from Track Centerline Data Point 591 (Car No. 1; 90,000 Pounds; Resilient Wheels; Track Section I)

UNAVERAGED SPECTRA

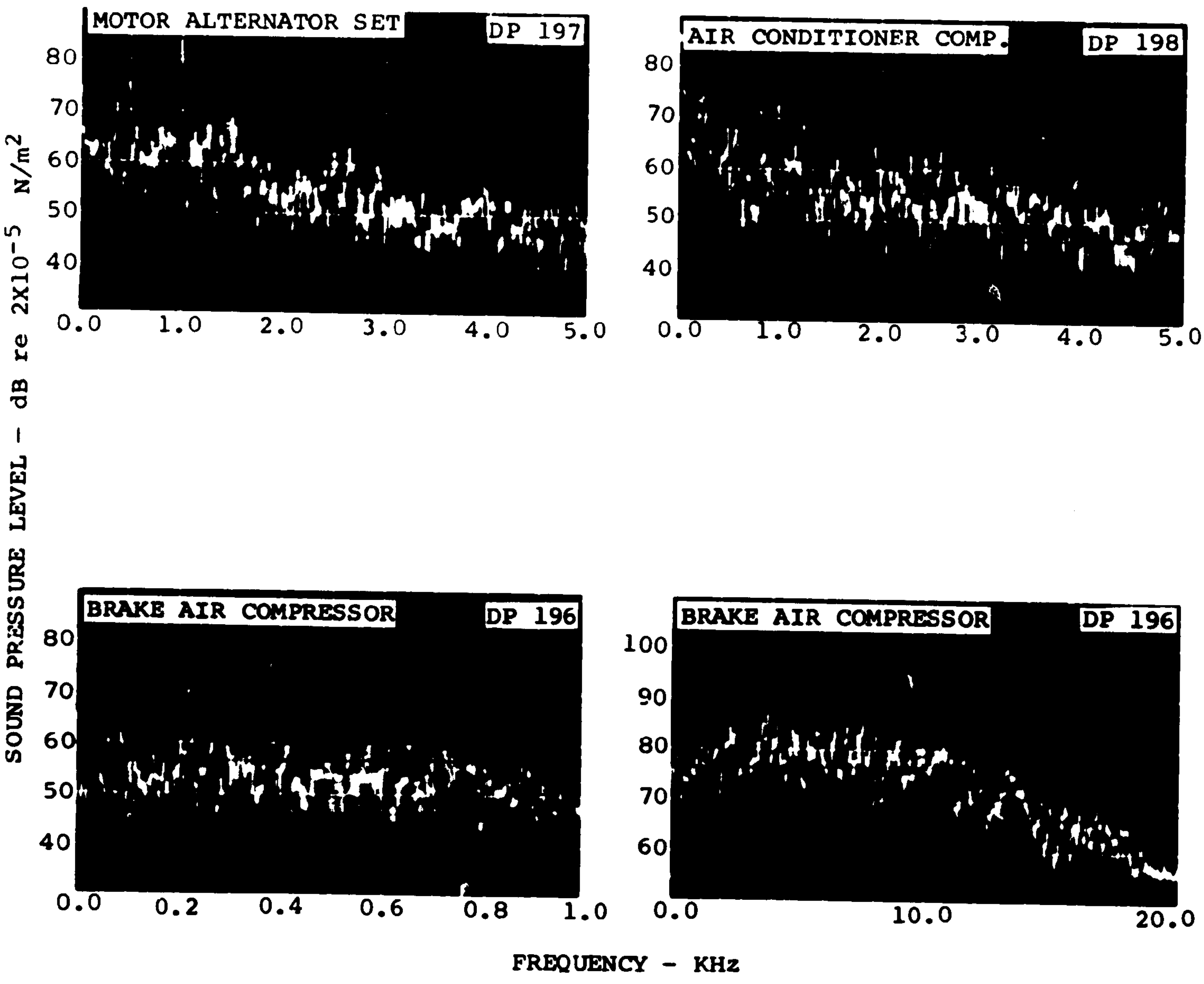


Figure 2–11. Noise from Undercar Equipment Measured at Ground Level 5 Feet from Car

UNAVERAGED SPECTRA

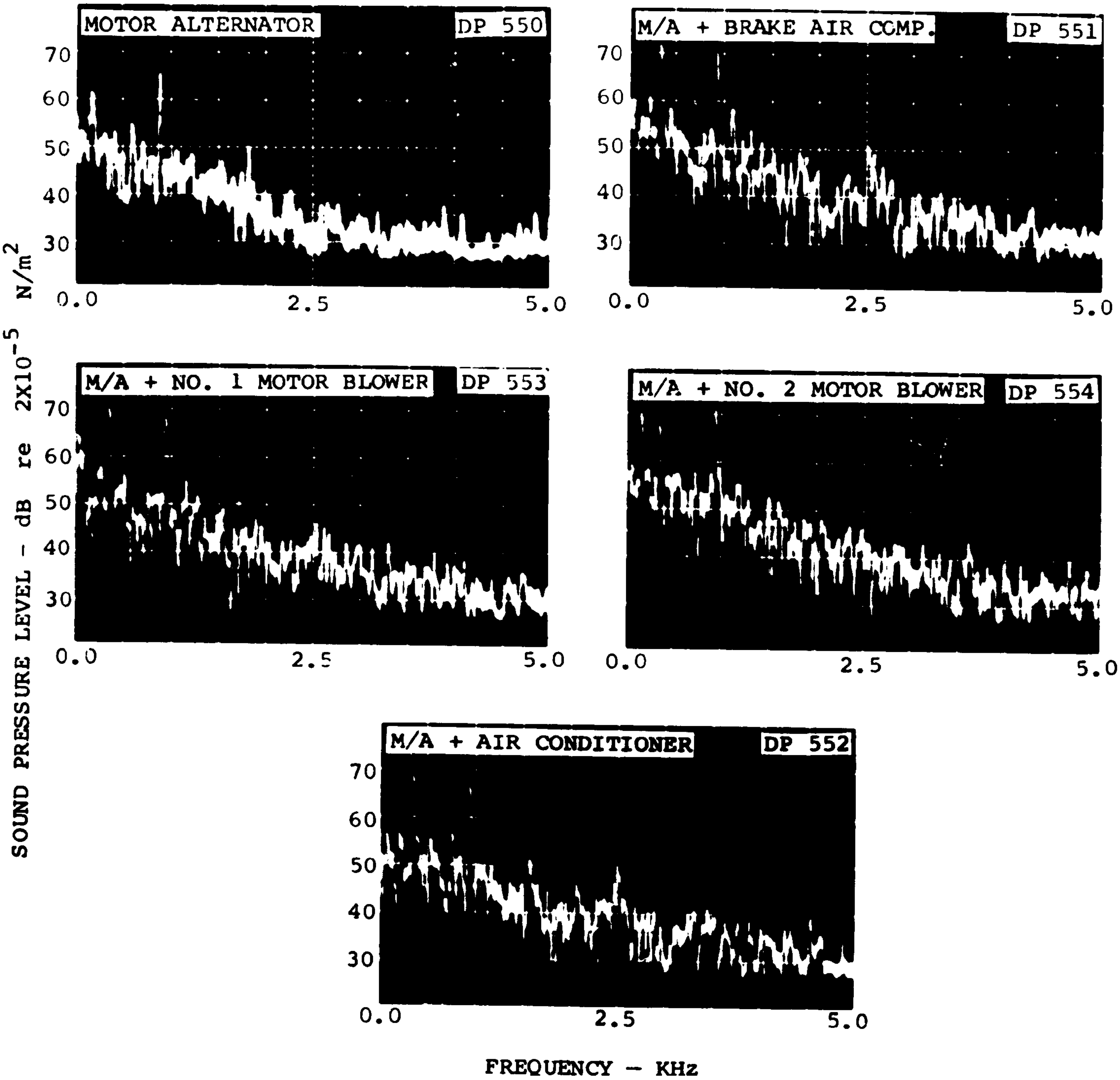


Figure 2–12. Noise from Car Equipment Measured on Boarding Platform at Passenger Ear Level 5 Feet from Car

UNAVERAGED SPECTRA

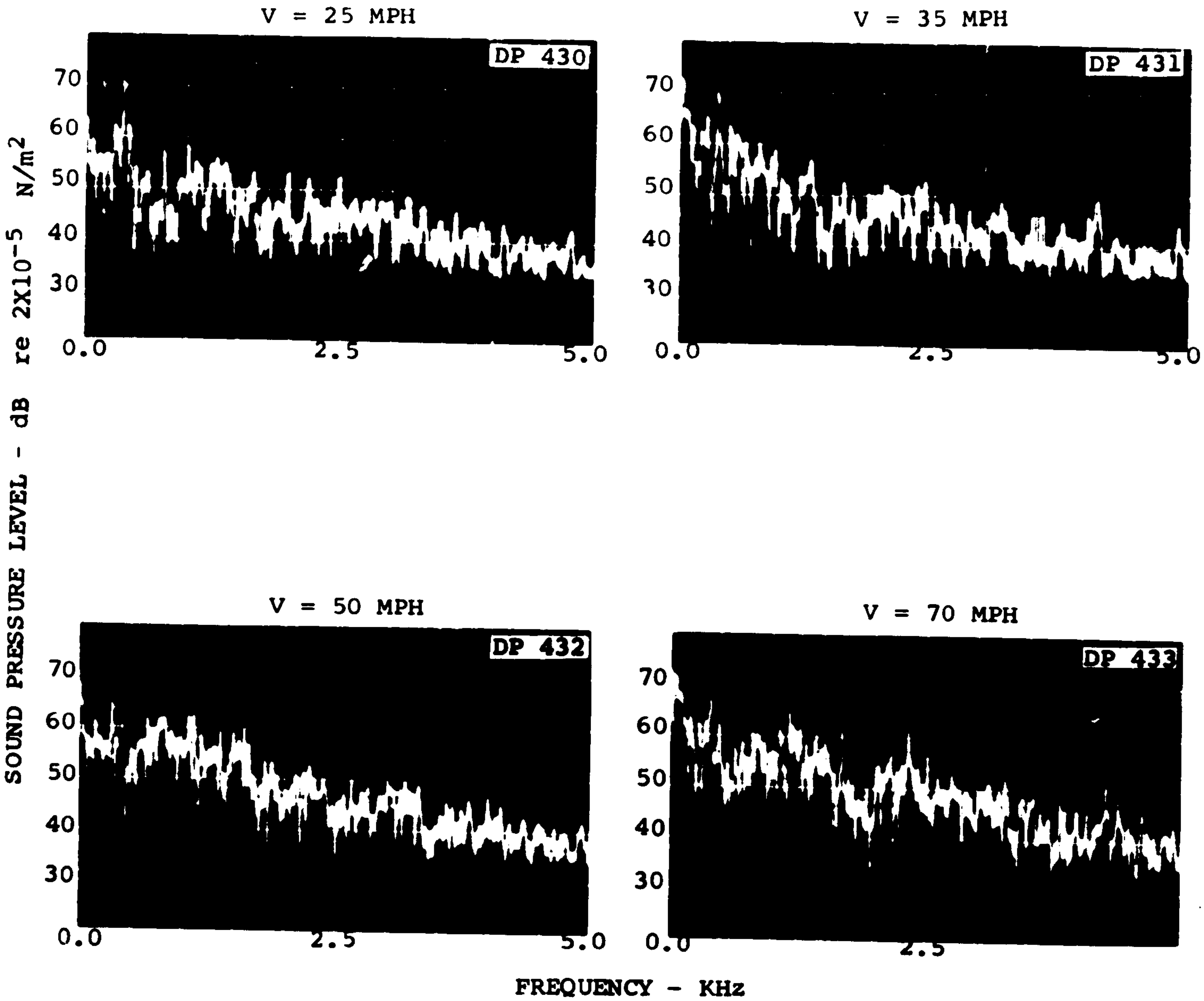


Figure 2–13. Passby Noise at Various Speeds 50 Feet from Track Centerline (Trued Steel Wheels; Track Section I)

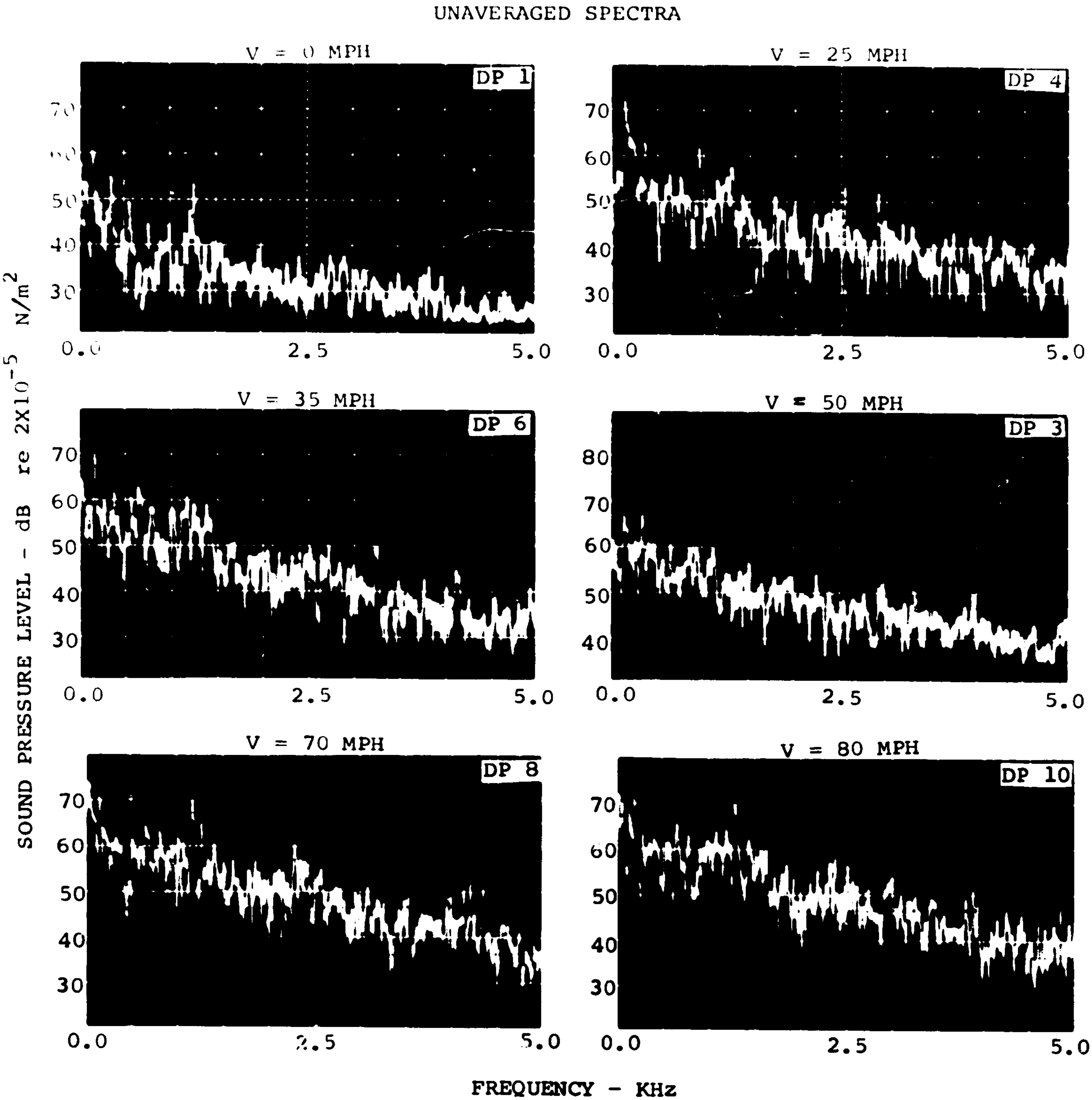


Figure 2–14. Passby Noise at Various Speeds 50 Feet from Track Centerline (Two-Car Train; Steel Wheel Flats; Track Section I; Clockwise Direction)

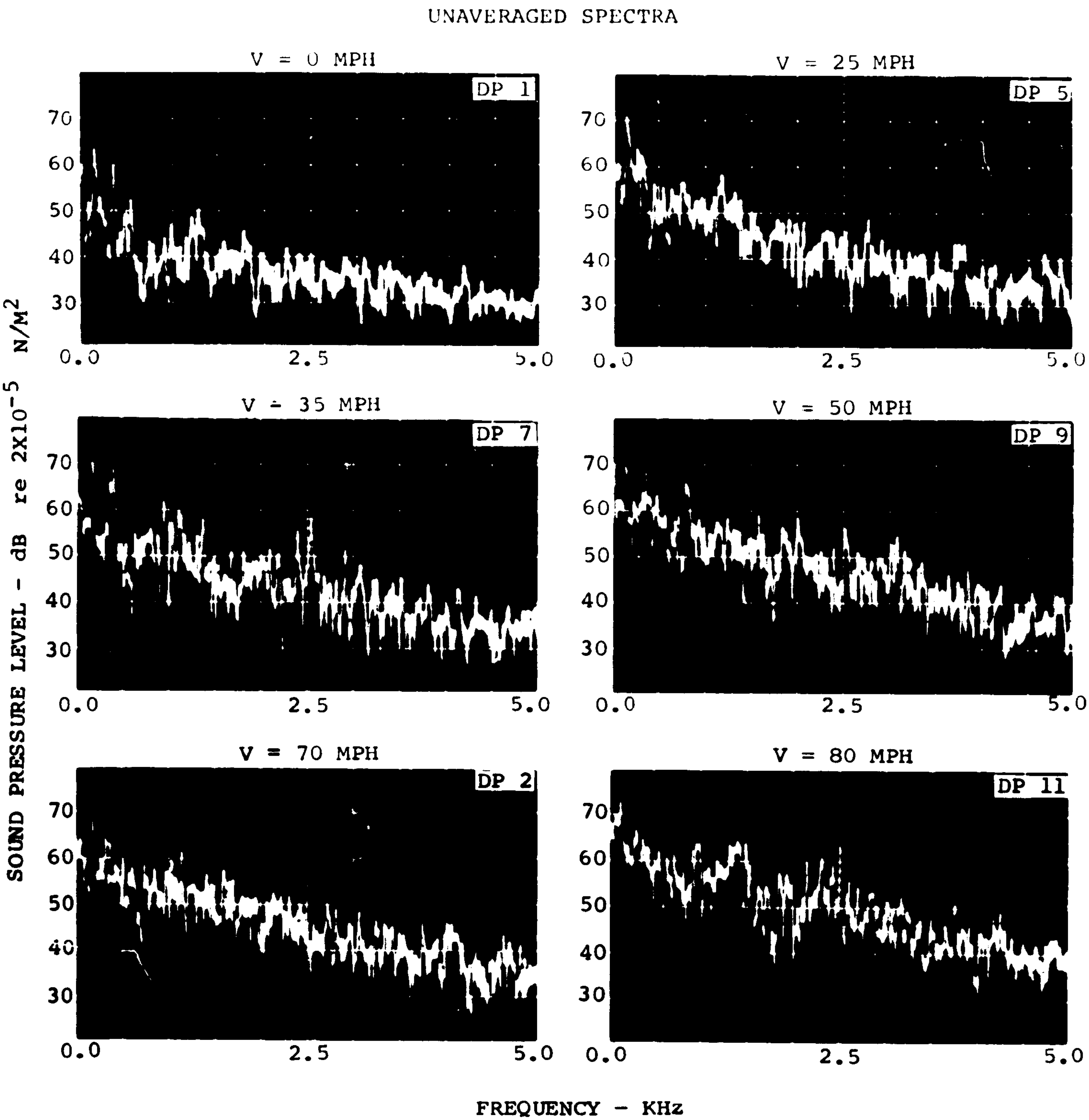


Figure 2–15. Passby Noise at Various Speeds 50 Feet from Track Centerline (Two-Car Train; Steel Wheel Flats; Track Section I; Counterclockwise Direction)

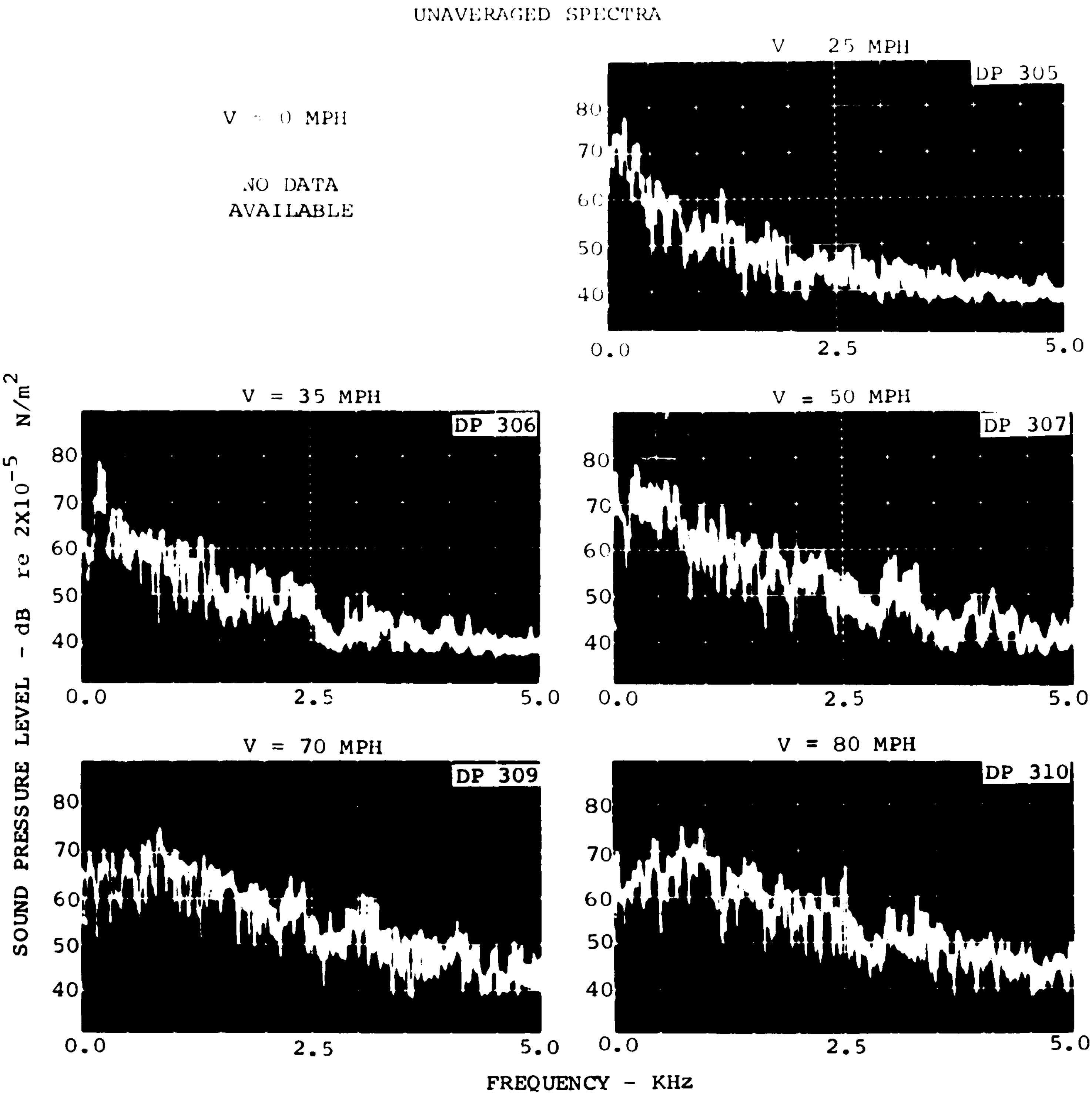


Figure 2–16. Passby Noise at Various Speeds 50 Feet from Track Centerline (Two-Car Train; One Car Powered; 90,000 Pounds; Steel Wheel Flats; Track Section I)

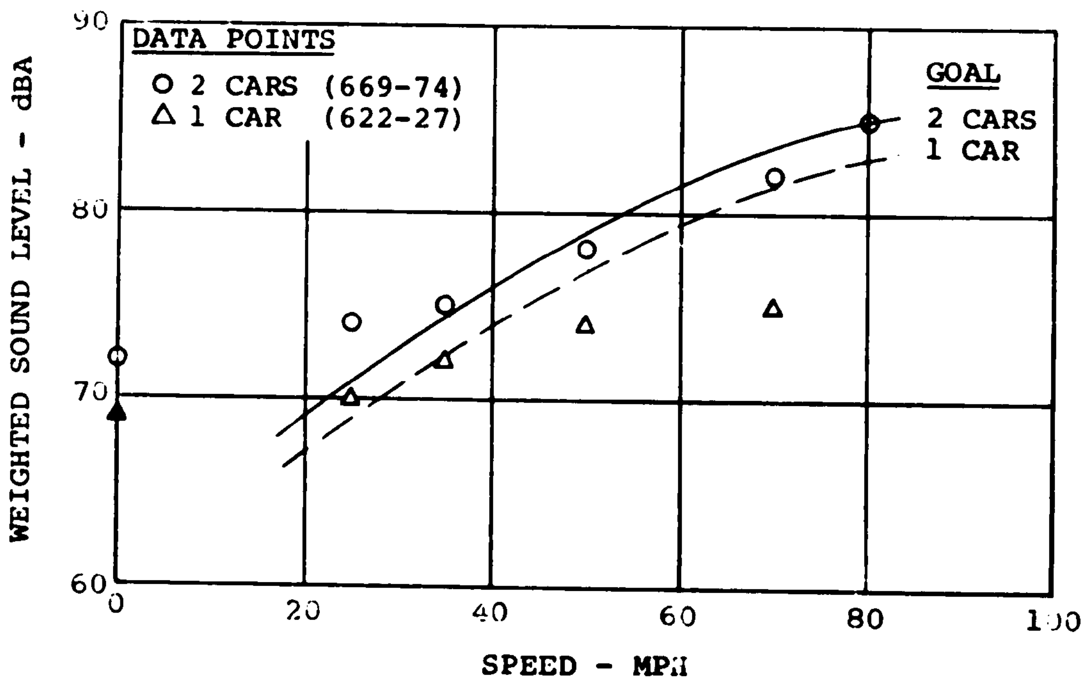


Figure 2–17. Comparison of Goals with Noise Levels 50 Feet from Track Centerline (105,000 Pounds; Resilient Wheels; Track Section I)

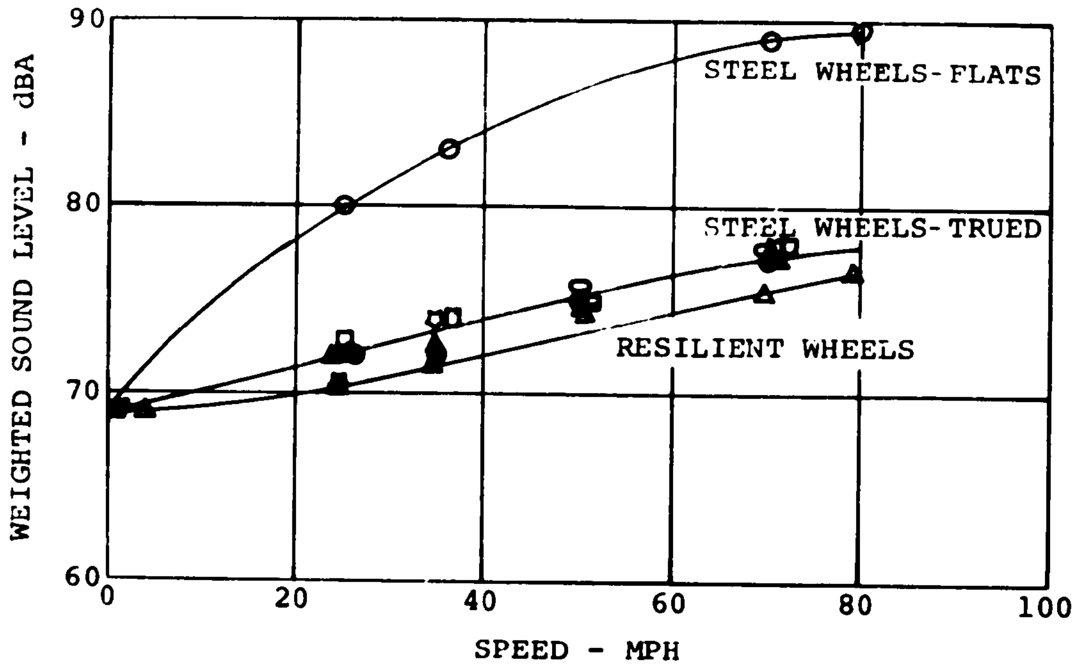


Figure 2–18. Effect of Wheel Configuration on Wayside Noise 50 Feet from Track Centerline (90,000 Pounds; Track Section I)

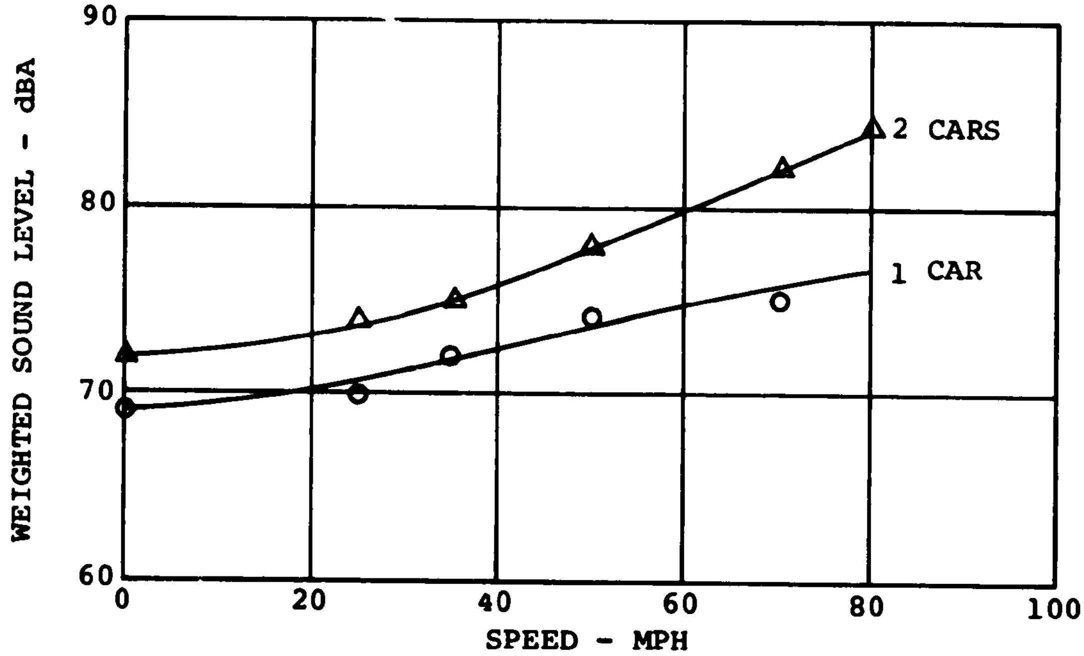
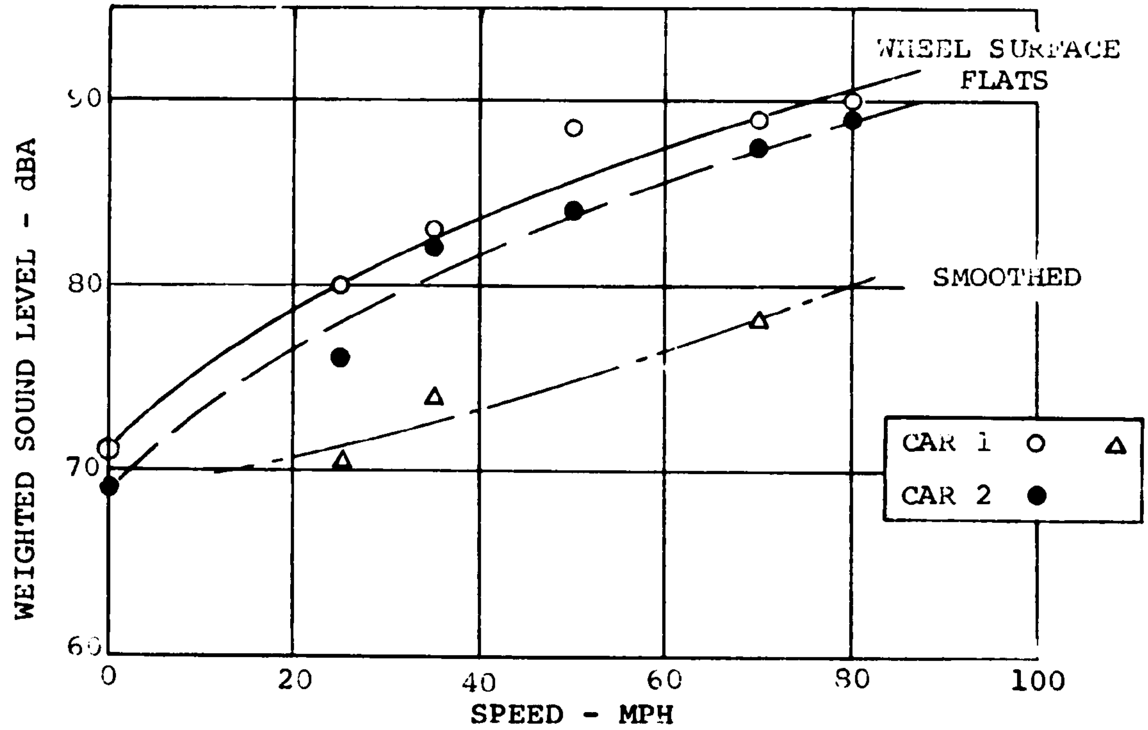


Figure 2–19. Effect of Speed on Wayside Noise 50 Feet from Track Centerline (105,000 Pounds; Resilient Wheels; Track Section I)



WHEEL FLATS	< 1"	≥ 1"
Car 1	12	8
Car 2	10	3

Figure 2–20. Effect of Wheel Surface Roughness on Noise 50 Feet from Track Centerline (90,000 Pounds; Track Section IV)

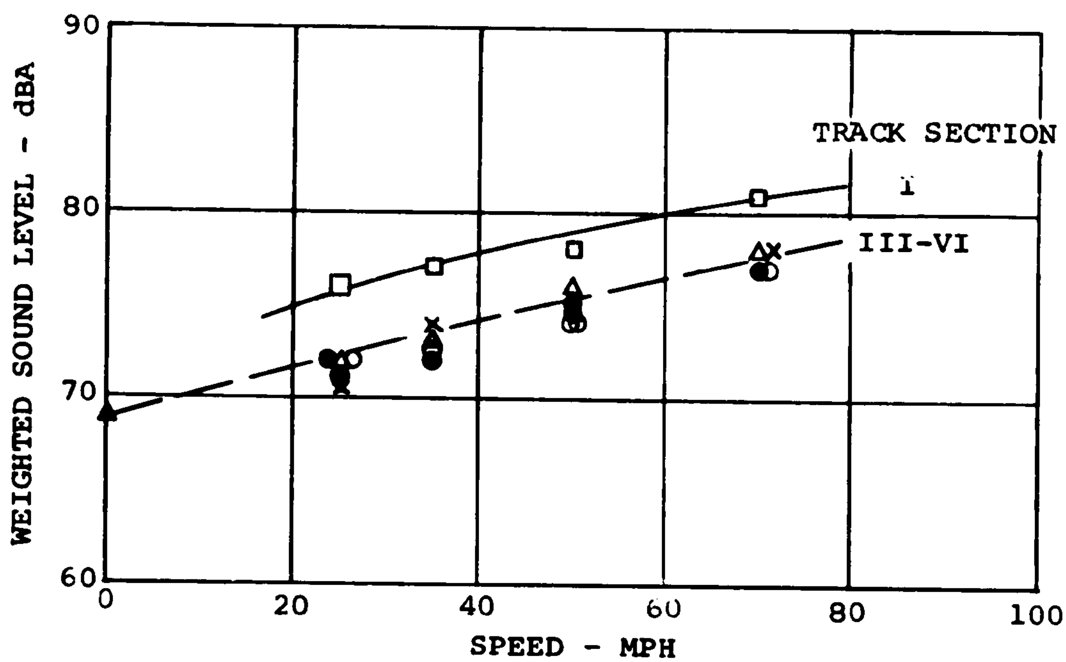


Figure 2–21. Effect of Wheel Surface Roughness on Noise 50 Feet from Track Centerline (Car No. 1; 90,000 Pounds; Trued Steel Wheels)