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TRUCK NOISE VIII

THE DETERMINATION OF THE PRACTICAL NOISE CONTROL RETROFITTING OF PRE-1970 TRUCK AND COACH MODELS

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Pontiac MI 48053

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16. Abstract

A retrofit noise package was selected for four representative GMC vehicles; i.e. two Heavy Duty Conventionals, one cab-over engine Heavy Duty Astro, and one 53 passenger transit coach, to achieve optimum noise reduction. The selection of this material came from commercially available items submitted by various component suppliers.

A new system of noise-source isolation was developed in order to evaluate the vendor-supplied material. The best one of these components was then selected for the final Retrofit Noise Package.

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PREFACE

THE PROGRAM

This investigation of potential noise reduction of pre-1970 GM heavy vehicles is intended to provide the U.S. Department of Transportation, the trucking industry, and the bus industry, with information, techniques, and methods that may be applied in future efforts toward vehicle noise reduction and an improved environment. The work on this program was performed by the GMC Truck & Coach Division of the General Motors Corporation under a fixed fee contract sponsored by the U.S. Department of Transportation, Office of Noise Abatement, Mr. W. Harry Close, Director; and managed for the U.S. Department of Transportation, Transportation Systems Center, by Mr. Robert L. Mason, Task Manager.

We also acknowledge the contributions to this report of Mr. Fred W. Krey and Mr. Lewis Z. Levy of the GMC Truck & Coach Division, Pontiac, Michigan and Mr. Donald W. Glasenapp and Mr. Dale L. Zielinski of the GM Desert Proving Ground, Mesa, Arizona.

OBJECTIVES

The general objectives of the General Motors study relating to the Department of Transportation diesel truck and bus noise reduction program were:

1. To assess, demonstrate, and document the noise reduction potential of optimized commercially available exhaust, intake, and fan subsystems on a past model fleet cross section of diesel powered highway trucks and buses.

2. To study the feasibility of retrofitting such older model vehicles to bring them up to such present day regulated standards as the recently promulgated Interstate Motor Carrier Noise Emission Standards.

3. To accomplish these objectives using the best commercially available components which would be interchangeable with standard hardware, without necessitating major structural modification to the vehicles and without causing degradation of performance characteristics.

4. To provide documentation for application by the truck and bus user. This includes descriptions of procedures used, results obtained, and final component selection.

CONCLUSIONS

The major conclusions resulting from this study are as follows:

1. Exhaust system noise reduction was the most effective means of reducing pass-by noise levels generated by the test vehicles. Considerable improvements have been made in exhaust system design and construction; thus, upgrading exhaust systems on the existing fleet of trucks appears to be a fruitful approach toward attaining a high degree of noise reduction.

2. Exhaust systems were so chosen that no degradation of engine performance characteristics, due to exhaust retrofit, would result. This was verified by checking that the retrofit exhaust system did not cause the system back pressure to be increased above the engine manufacturer's specified limits.

3. In the General Motors investigation, the fan noise levels changed, by insignificant amounts, with changes in fan blade configuration. This indicated that changes in fan blade environment (i.e., engine-mounted shrouds, close tip clearance, etc.) were necessary to achieve significant cooling system noise reductions. This would have involved extensive structural modifications. Therefore, this was not attempted, as our original objective was to retrofit the vehicles with hardware that reduced noise levels, but did not require major structural modification to the vehicles.

4. The fan clutch was chosen to reduce noise generated by the cooling fan. This method was also in keeping with our original project guidelines. The "on-off" or viscous clutch driven fan effectively eliminated the contribution of noise generated by the cooling system during the 'fan-off' mode, which can account for 90-97 percent of the fan operating time for trucks and somewhat lower percentages for bus operation. In addition, 10-15 fan horsepower can be saved, resulting in a significant improvement of fuel economy.

5. There appeared to be little to be gained in the reduction of overall vehicle noise by the use of engine compartment shields. This is due to the fact that the engine noise did not predominate in the pass-by test noise spectrum. The exception occurred with the close fitting shields applied directly to the Cummins power plant. These engine shields produced a significant noise reduction when applied to the Cummins 250 engine in the JN9500 test vehicle.

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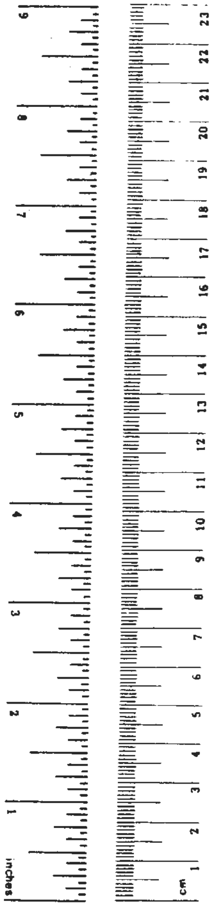
METRIC CONVERSION FACTORS

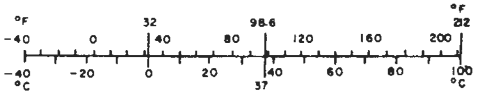
Approximate Conversions to Metric Measures

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



Approximate Conversions from Metric Measures

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



1. INTRODUCTION

In response to public demands and concern that environmental noise be brought under control, Congress passed the Noise Control Act of 1972 (hereafter referred to as the "Act"). The Act gives the Environmental Protection Agency (EPA) the authority to set standards for noise emission of various products. The Act also specifies that the Administrator of EPA must take into account the best available technology and the cost of compliance before he sets noise emission standards.

Section 6 of the Act directs the EPA to promulgate noise emission standards for products distributed in commerce which the administrator of the EPA determines to be major noise sources. One of the first products so considered was new trucks over 10,000 pounds GVWR. The combination of operational noise emission standards issued under Section 18 of the Act and new vehicle standards issued under Section 6 represent the regulatory program for reduction of motor carrier noise emission standards which EPA is following.

Section 18 of the Act directed the Administrator of EPA to publish regulations for motor carriers engaged in interstate commerce. The regulations issued under this section include standards setting limits on noise emissions resulting from the operation of motor carriers engaged in interstate commerce regardless of the date of manufacture of the vehicle.

The final regulations were published October 21, 1974 and became effective October 15, 1975. The regulation applies to motor vehicles operated in interstate commerce and which weigh over 10,000 pounds. The following standards apply to total vehicle noise:

1. 90 dBA at 50 feet at speeds greater than 35 mph.
2. 86 dBA at 50 feet at speeds of less than 35 mph.
3. 88 dBA at 50 feet under a prescribed stationary run-up test.
4. Visual exhaust system inspection.
5. Visual tire inspection.

As these standards apply to both new vehicles and to vehicles which are currently part of the in-use fleet, the Department of Transportation (DOT) charged with enforcing this regulation, initiated a truck noise control retrofit program, the results of which are to be applicable to the retrofit of the in-service motor carrier fleet.

The project objective was to assess, demonstrate and document the noise reduction potential of commercially available hardware. This report documents the work accomplished by General Motors towards achieving that objective.

2. TEST VEHICLE SELECTION

In the selection of particular truck and bus models for test and development work, it was necessary to consider vehicles whose specific noise problem and solutions would have the most general application to the wide variety of truck and bus models on the road today. Based on these considerations, the four vehicles chosen for this study were selected as being representative of the high volume vehicles which General Motors previously built.

The vehicles chosen were:

1. 1967 model year JI9500, having a 92" conventional cab with a tandem axle. It had a naturally aspirated 6-71 in-line Detroit Diesel engine; its SAE J366a passby noise level as originally manufactured was approximately 88 dBA.

2. 1969 model year DH9502, having a 74" aluminum tilt cab with a tandem axle. It had a naturally aspirated 8V-71 Detroit Diesel engine; its SAE J366a sound level as originally manufactured was approximately 92-93 dBA.

3. 1969 model year JN9500, a 92" conventional cab, tandem axle truck with a naturally aspirated NHC 250 Cummins Diesel engine. This class of vehicle was manufactured at the nominal sound level of 88 dBA.

4. 1969 model year transit coach, T8H5305, a 53 passenger coach with an 8V-71 Detroit Diesel engine and automatic transmission. It was originally manufactured at a nominal SAE J366a level of 88 dBA.

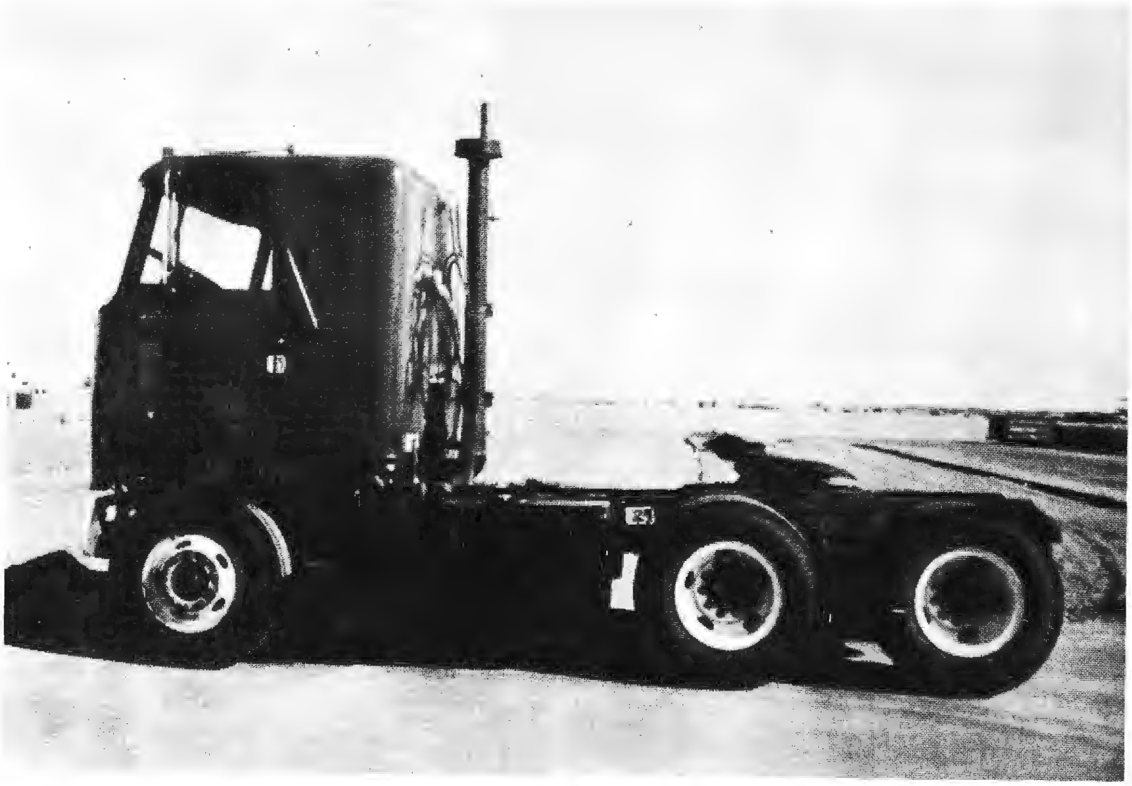
Table 1 lists test vehicle specifications and Figures 1 through 4 portray the vehicles evaluated in this program. The vehicles are shown equipped with the final, recommended retrofit hardware.

TABLE 1 TEST VEHICLE SPECIFICATIONS

	Intake System			Exhaust System *		
Vehicle Model	Type	Part No.	Air Cond.	Muffler Location	Muffler GMC No.	Tailpipe Location
DH-9502	Donaldson dry	657906	Yes	SV	716117	SV
JN-9500	Donaldson dry	8878962	-	SH	685217	SH
JI-9500	Donaldson oil bath	8867238	-	SH	695423	SH
T8H5305	Donaldson oil bath	2494846	-	SH	667515	SH

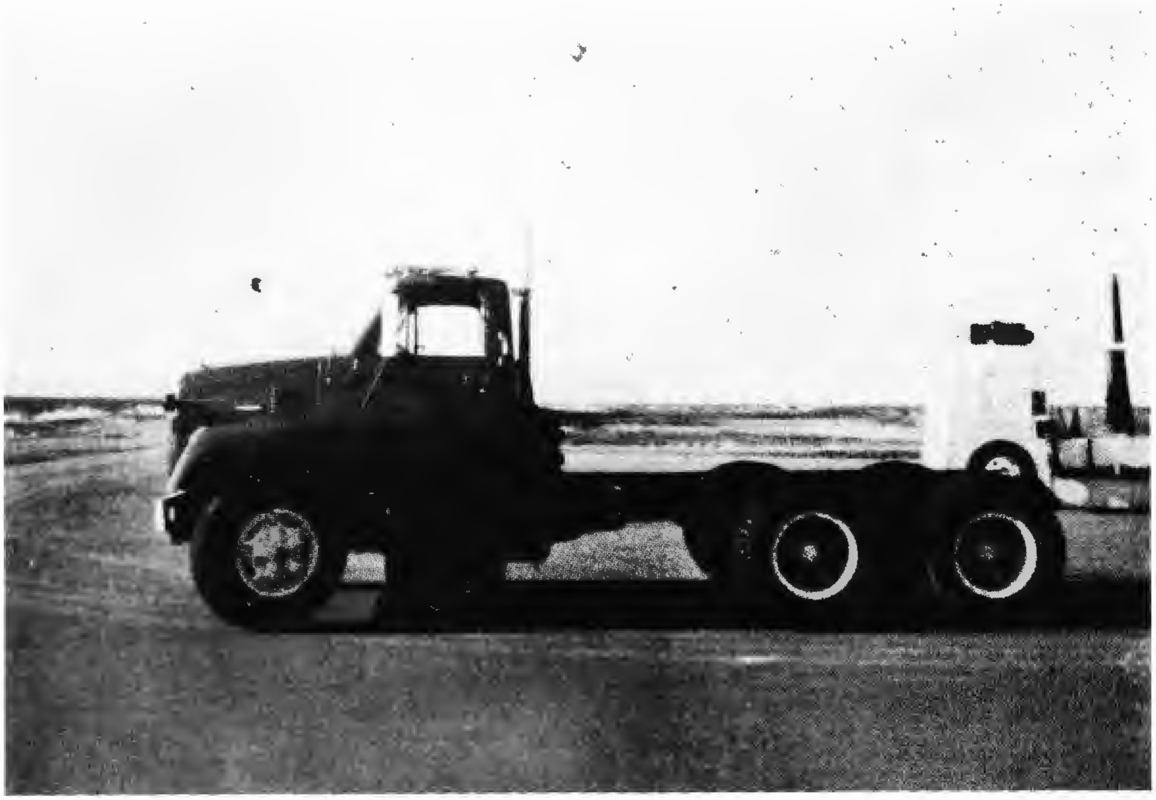
	Cooling System					Engine		
Vehicle Model	Radiator Part No.	Fan Site	Fan Part No.	Fan Speed Ratio	Air Cond.	Type	Injector Size	Full Load Gov. RPM
DH-9502	674445	28 x 6 x 2.62	660945	1.05:1	Yes	8V-71N	55 mm	1950
JN-9500	684235	28 x 4 x 2.62	675350	1.0:1	-	NHC 250	(250 H.P.)	2100
JI-9500	664372	28 x 4 x 2.62	675350	1.05:1	-	6-71N	60 mm	2100
T8H5305	685269	26 x 6 x 2.62	660946	1.0:1	-	8V-71N	55 mm	1800

* SV - Single Vertical
SH - Single Horizontal



TEST VEHICLE DH9502 Figure 1

TEST VEHICLE JI9500 Figure 2



TEST VEHICLE JN9500 Figure 3

TEST VEHICLE T8H5305 Figure 4

3. NOISE SOURCE IDENTIFICATION AND EVALUATION TEST PROCEDURES

In considering a typical overall vehicle noise emission problem, there are a number of sources which contribute to the total vehicle noise level. The four major engine related sources are the air intake system, exhaust system, cooling fan and engine block ringing. There was a need to develop a procedure to identify the individual noise sources and to determine their levels for the following reasons:

1. The level of each source had to be identified so that engineers could address the major noise problems.
2. The level produced by each source had to be measured independently so that modifications to that source could be evaluated.
3. Data obtained for component source on one vehicle could be more easily applied to a different vehicle which contains some of the same or like components.

In this retrofit investigation, source identification was followed by the development of noise reduction techniques which were then applied to the various sources, and evaluated by test.

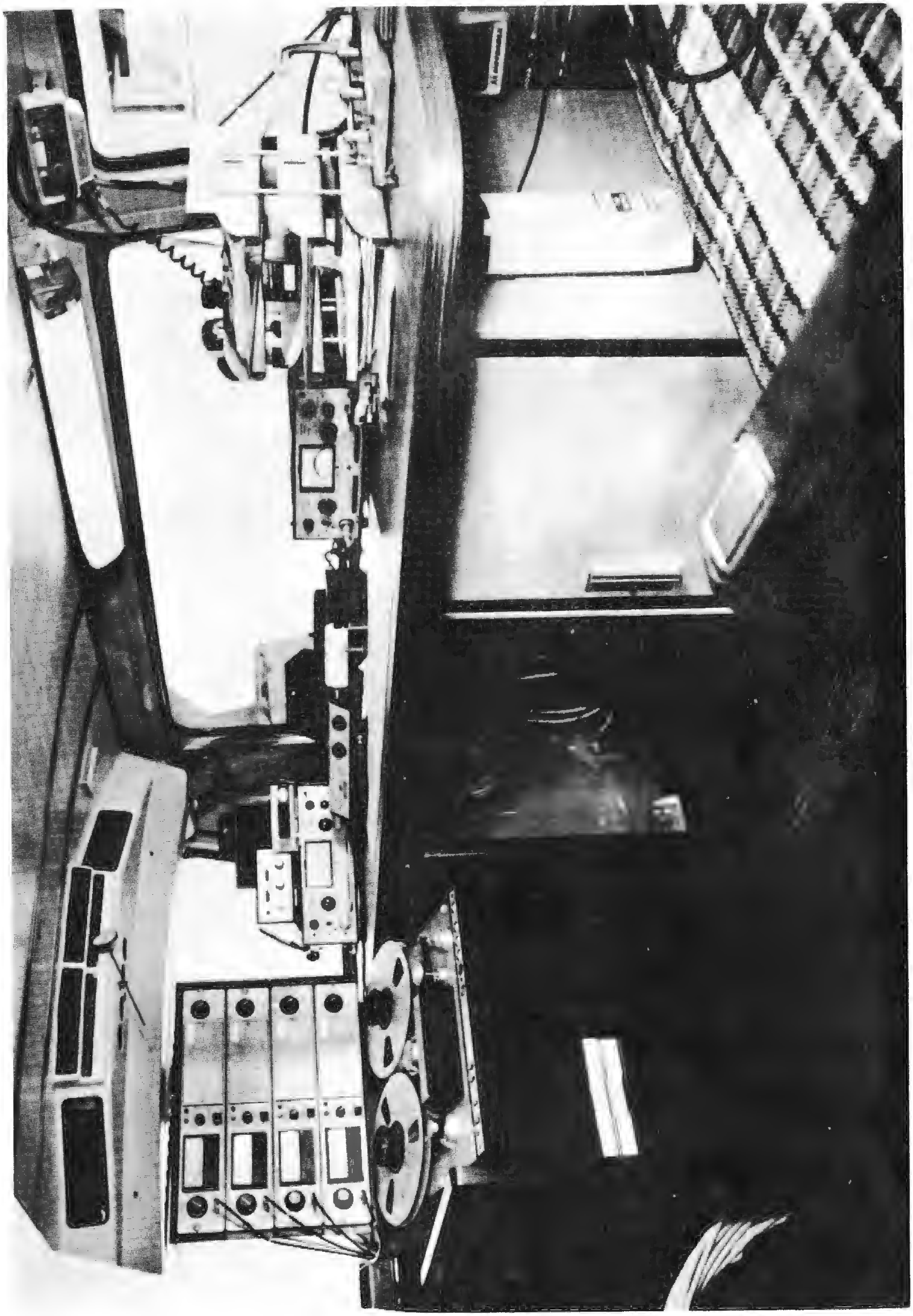
3.1 Test Site and Instrumentation

All test vehicles were sent to the General Motors Desert Proving Ground in Mesa, Arizona for development and testing. At this site the climatic conditions are favorable for the uninterrupted outdoor testing required. The Desert Proving Ground is also well equipped with instrumentation to handle the recording and analysis of test data.

The following is a list of instrumentation used to record and evaluate sound pressure levels during the test phase of the program:

1. Bruel and Kjaer Type 2203 Precision Sound Level Meter.
2. Bruel and Kjaer Type 3347 1/3 Octave Real Time Analyzer.
3. Bruel and Kjaer Type 2305 Graphic Level Recorder.
4. Bruel and Kjaer Type 4145 Condenser Microphone 1".
5. Bruel and Kjaer Type 4230 Acoustical Calibrator.
6. Ampex Type 440B 4 Channel Audio Tape Recorder.
7. Sony Type 772 Portable Tape Recorder.
8. Bruel and Kjaer Type 2607 Measuring Amplifier.

This instrumentation was used to record data on both paper and magnetic tape. It provided both a visual display of the time-history of the noise source and storage capability for retrieval or analysis of test data. Most of this equipment is part of the mobile noise test van shown in Figure 5.



MOBILE INSTRUMENTATION LABORATORY

Figure 5

3.2 Quieting Vehicles to a Minimum Level for Source Identification

The first step in reducing total vehicle noise was to measure the sound levels of the four major noise sources - engine, exhaust, fan, and intake. A major portion of the effort involved in the program consisted of quieting the vehicles to a minimum noise level and exposing individual noise sources for measurement. Measurement of engine noise included that which is radiated from the surfaces of the engine structure and also that noise generated by the transmission. Total exhaust noise was measured as the noise emitted at the tail pipe outlet as well as that generated due to the vibration of the mechanical components of the exhaust system. The fan noise measurement included that resulting from vibratory modes as well as blade aerodynamic noise. The combustion air intake system noise measurement was made at the inlet of the system.

A unique method of removing other miscellaneous vehicle noise was used and will be discussed in this report. The laboratory approach to quieting the vehicle in order to study individual sources is not commercially feasible because it uses oversize plenums attached to the vehicle, and vehicle modifications which do not allow adequate cooling.

The reduction of noise due to engine block ringing is by far the most complex. Noise from this source is radiated from many surfaces. Sound energy can be radiated from the space under the wheelwell; it can be reflected from the road surface and from the exposed area behind the cab. By encapsulating the entire vehicle in acoustic material from the fenders to the road surface a major portion of the engine radiated noise was eliminated.

Reducing the noise emanating from the exhaust system required treatment in the following two areas:

1. Noise from the outlet of the exhaust system.
2. Noise caused by the vibration of the exhaust pipes and muffler shell.

The approach to attenuating exhaust outlet noise involved the use of an oversized silencer which was fabricated and placed in series with the production exhaust system.

Shell radiation from the exhaust pipes and mufflers was reduced by attaching an isolated barrier between the source and the observer. This was achieved by wrapping the exhaust system with high temperature fiberglass and covering it with a high mass barrier. The fiberglass mat acted as a spring mechanism while a lead sheet, with a surface density of 2 pounds per square foot, was used as the barrier material.

The cooling system fan noise was reduced to zero for the source isolation procedure by removing the fan from the subassembly. It was advantageous to completely remove the fan blade assembly so that engine noise would not be radiated through the assembly causing the fan to act as a speaker element even though it was not rotating.

An additional oversized air intake silencer was devised to attenuate intake noise to a very low level for purposes of source isolation. It consisted of an insulated plenum placed in series with the production intake.

With the use of these devices the overall vehicle noise levels ranged from 70-75 dBA. This appeared to be the range where component noise level measurements could be made with sufficient accuracy since all component levels were anticipated to be at least 6 dBA above this 70-75 dBA background noise level.

3.3 Design and Fabrication of Hardware for Source Isolation

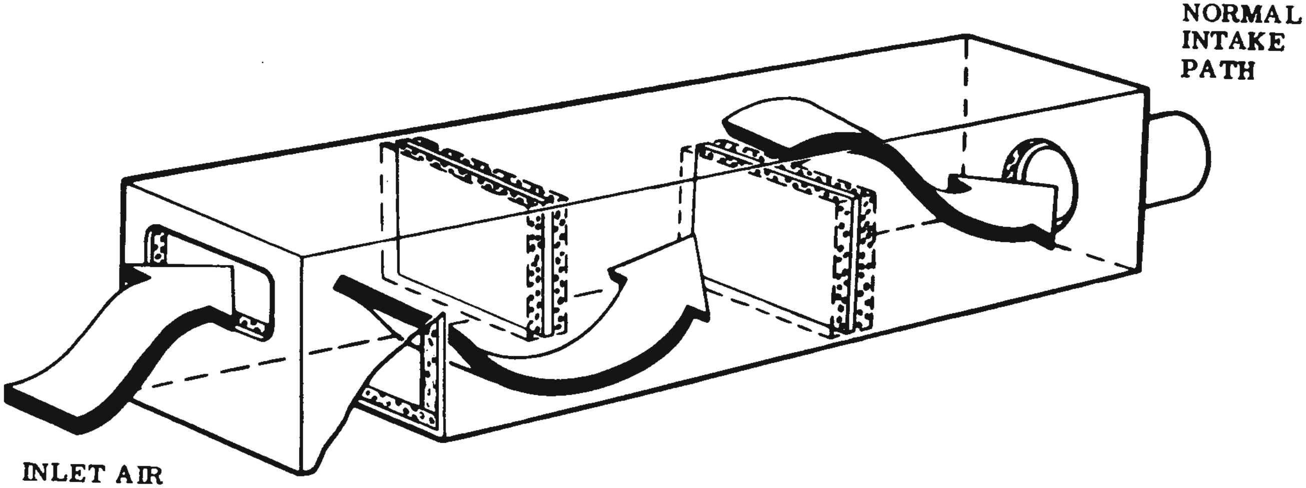
Much of the hardware used in the Retrofit Program was designed and fabricated by the GM Engineering Staff at the Desert Proving Ground in Mesa, Arizona. This included intake silencers, muffler outlet silencers, and masking procedures.

3.3.1 Inlet Air Intake Silencer

The air intake silencer shown in Figure 6 is a lined duct with staggered inlet and outlet. No line of sight exists between inlet and outlet. The intake silencer was constructed from 20 gauge sheet metal formed into a box. Air is induced at one end and must pass through a labyrinthine interior structure before it exits from the unit. The interior of the additional silencer was treated with a 1 inch fiberglass liner. This additional silencer was connected to the standard intake system using a flexible hose.

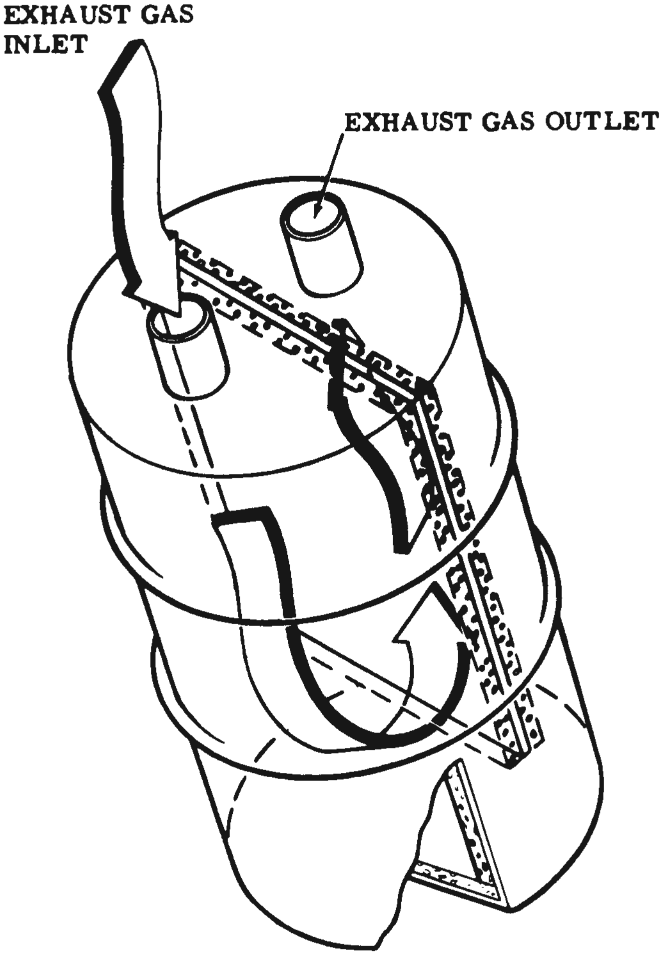
3.3.2 Exhaust System Outlet Silencer

The additional exhaust silencer was designed following the same principles as the intake silencer. It is a two chamber plenum with staggered inlet and outlet ducts. This unit, shown in Figure 7, was constructed from a 55 gallon drum lined with an expanded open cell absorptive foam. Four-inch diameter inlets and outlets were used. One of the advantages of the intake and exhaust silencers was their universality of application. These two pieces of hardware could be adapted to most of the vehicles involved in this program.



INLET AIR INTAKE SILENCER

Figure 6



EXHAUST SYSTEM OUTLET NOISE SILENCER

Figure 7

3.3.3 Engine Encapsulation

Total engine encapsulation for purposes of source isolation is a complex operation. The method used here was quite different from that used in previous work. The old method involved surrounding the engine with hand formed metal shields and acoustic material in a box like configuration. This entailed routing insulation around tubes, wires and other paraphernalia. The new system not only isolates the engine but also the drive train and transmission.

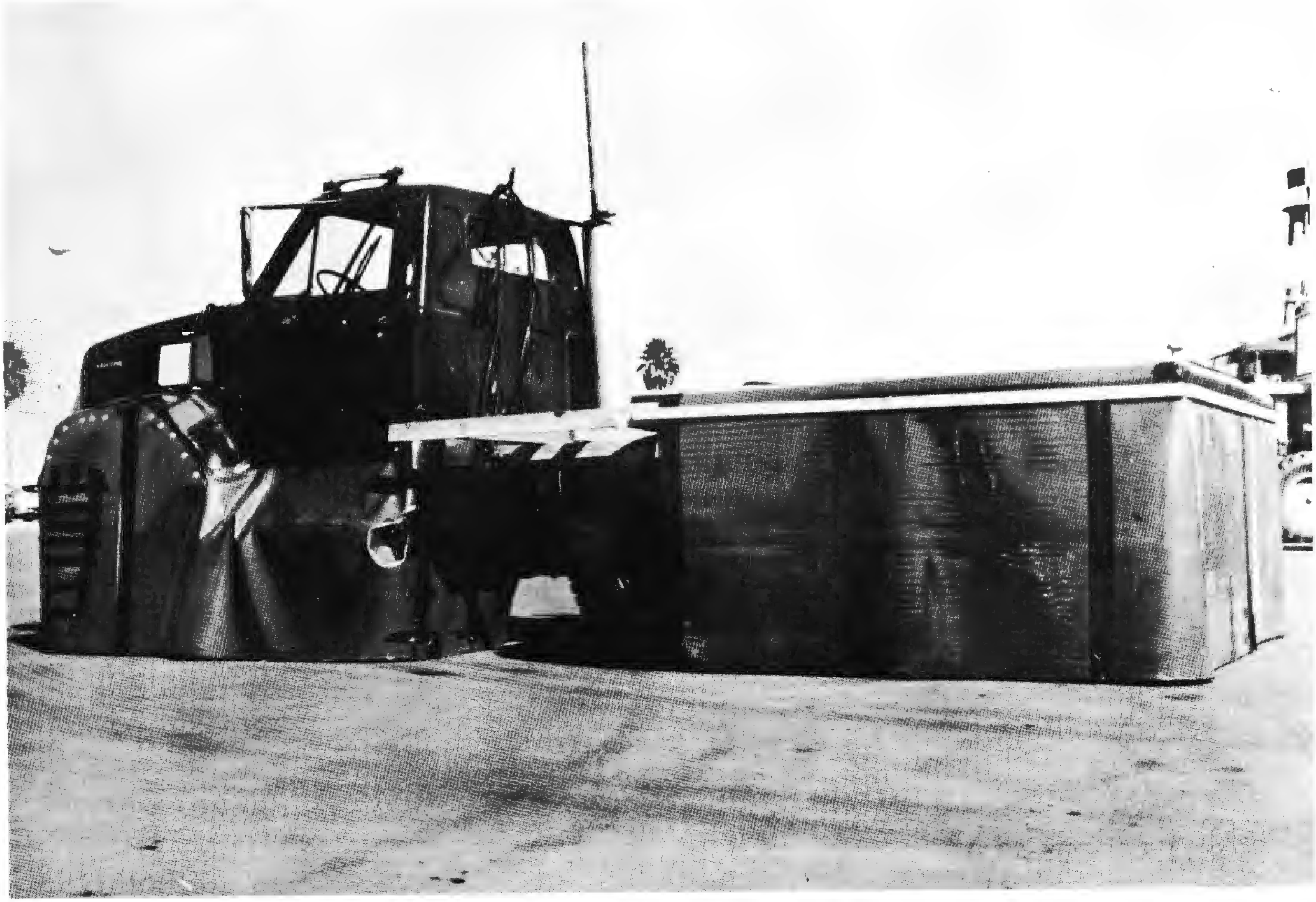
A wooden frame was attached to the frame rails and front bumper of the trucks to allow installation of the acoustic material used to isolate all other truck noise. A two layer acoustic material was attached to the wooden frame with metal fastners and draped down to the level of the road bed. From this point almost any component could be exposed and its noise level determined by removing a portion of the encapsulating material. A picture of the completed installation is shown in Figure 8 and a diagram of the material used is seen in Figure 9.

3.3.4 Fan Drive Apparatus

The determination of the fan noise contribution during a passby test is a complex problem. The engine cannot be used to drive the fan due to its noise output. Also, as previously explained, it is difficult to place a close fitting enclosure only around the engine and anything but a very close fitting enclosure will change the fan noise path. Consequently, a remote fan drive system was designed and fabricated for use with each of the test vehicles.

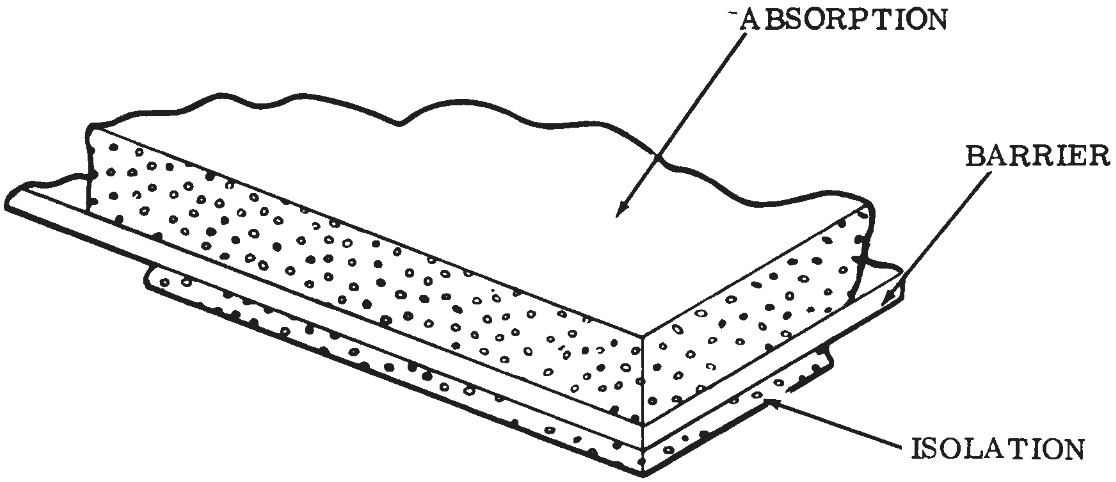
Fan noise was accomplished with a remotely driven hydraulic fan drive system called the "Kool Pack." Figure 10 is a picture of this device installed on a vehicle. Basically the "Kool Pack" is an acoustically treated box with a hydraulic pump which actuates a motor attached to the fan drive by "V" belts. In turn, the pump is driven by a 150 horsepower 307-V8 engine. Hydraulic hoses extend from the pump within the acoustic box to the motor mounted on a bracket attached to the engine block.

The box which contains the engine and hydraulic pump suppresses noise generated by these components. The total noise generated by this system was less than 65 dBA and therefore it does not affect fan noise measurements. A cutaway diagram of this device is shown in Figure 11.



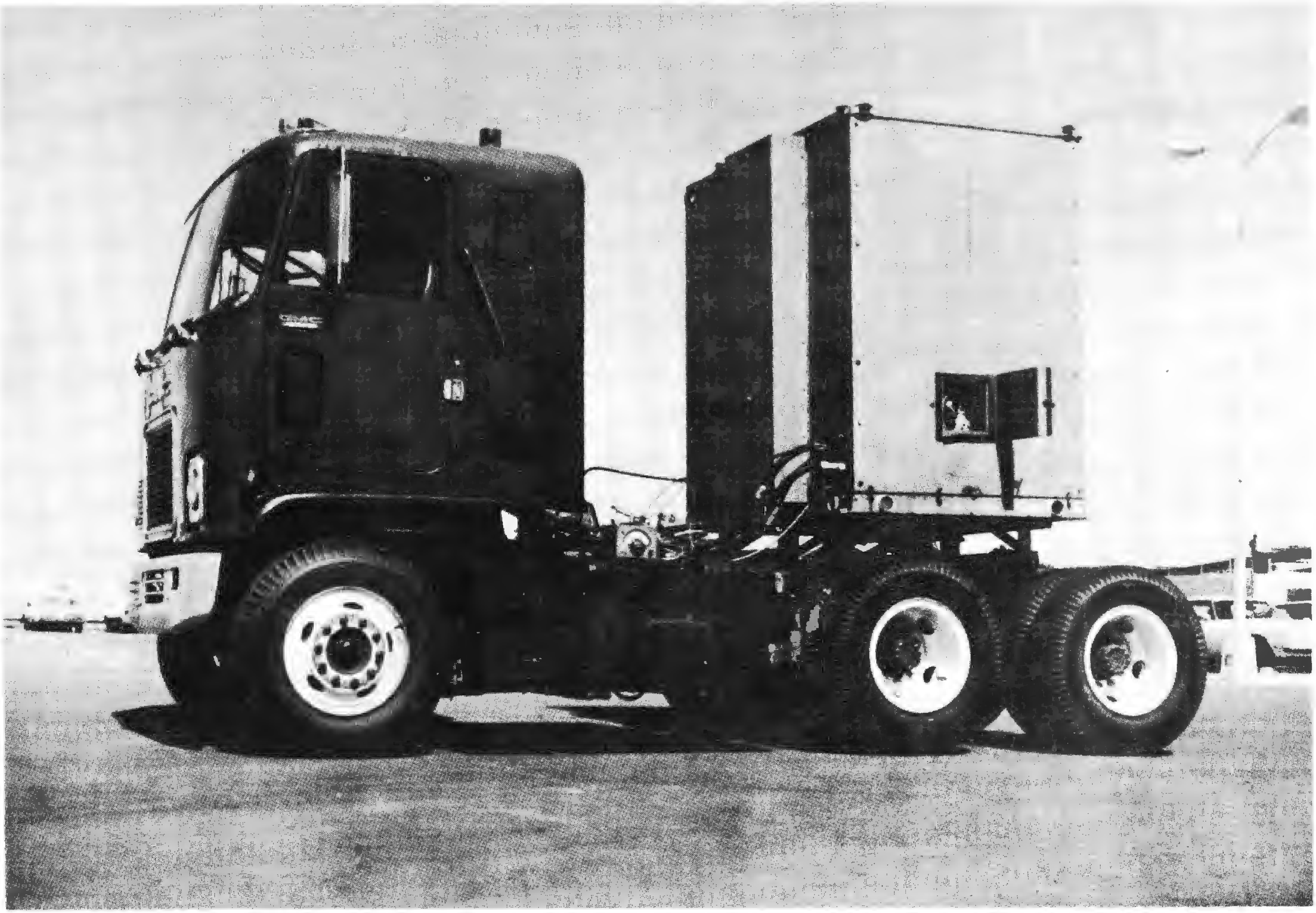
ENCAPSULATION OF THE VEHICLE

Figure 8



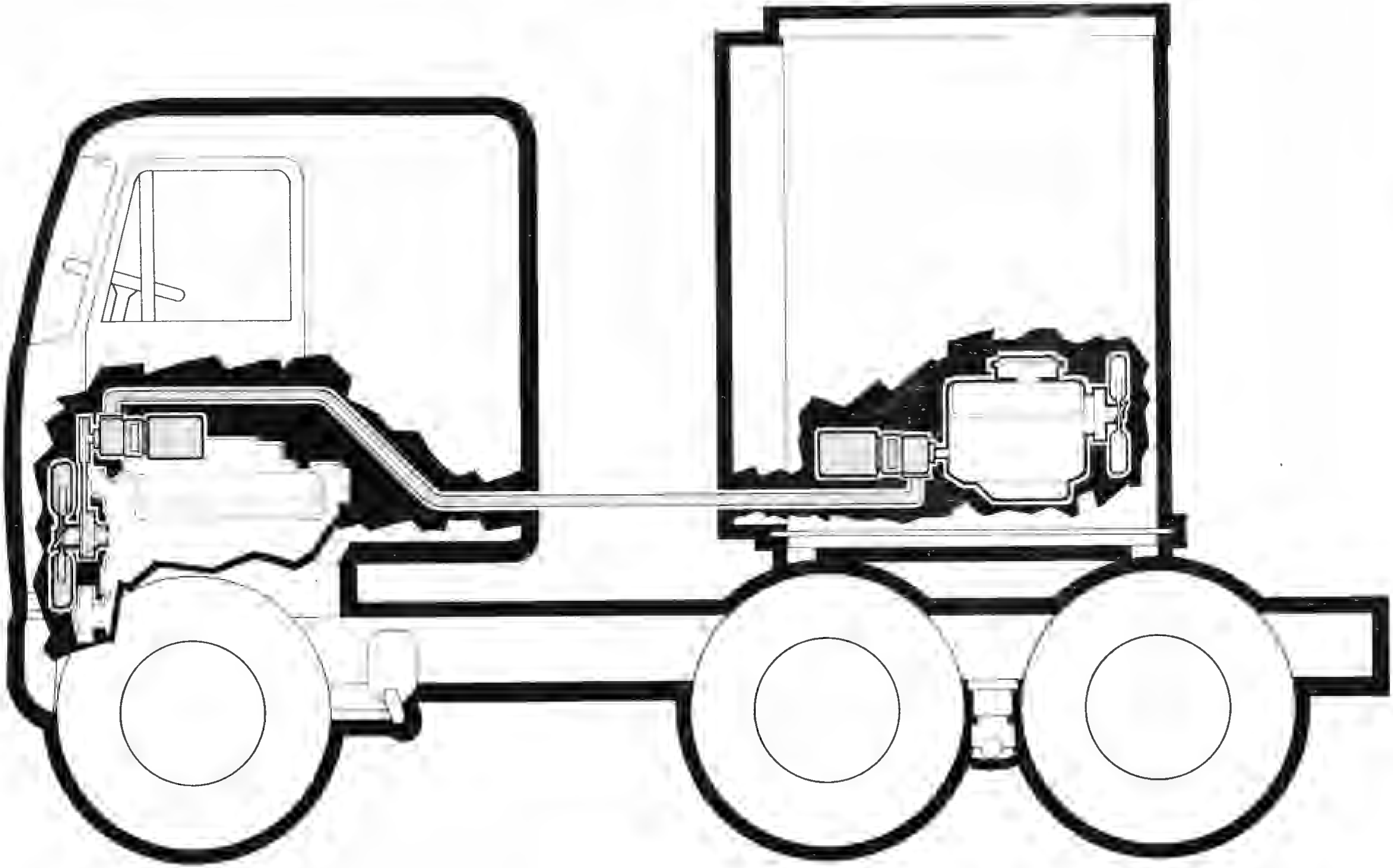
THREE LAYER ACOUSTICAL MATERIAL

Figure 9



INSTALLATION OF THE "KOOL PACK"

Figure 10



CUT-AWAY VIEW OF THE "KOOL PACK"

Figure 11

3.4 Procedure for Noise Testing

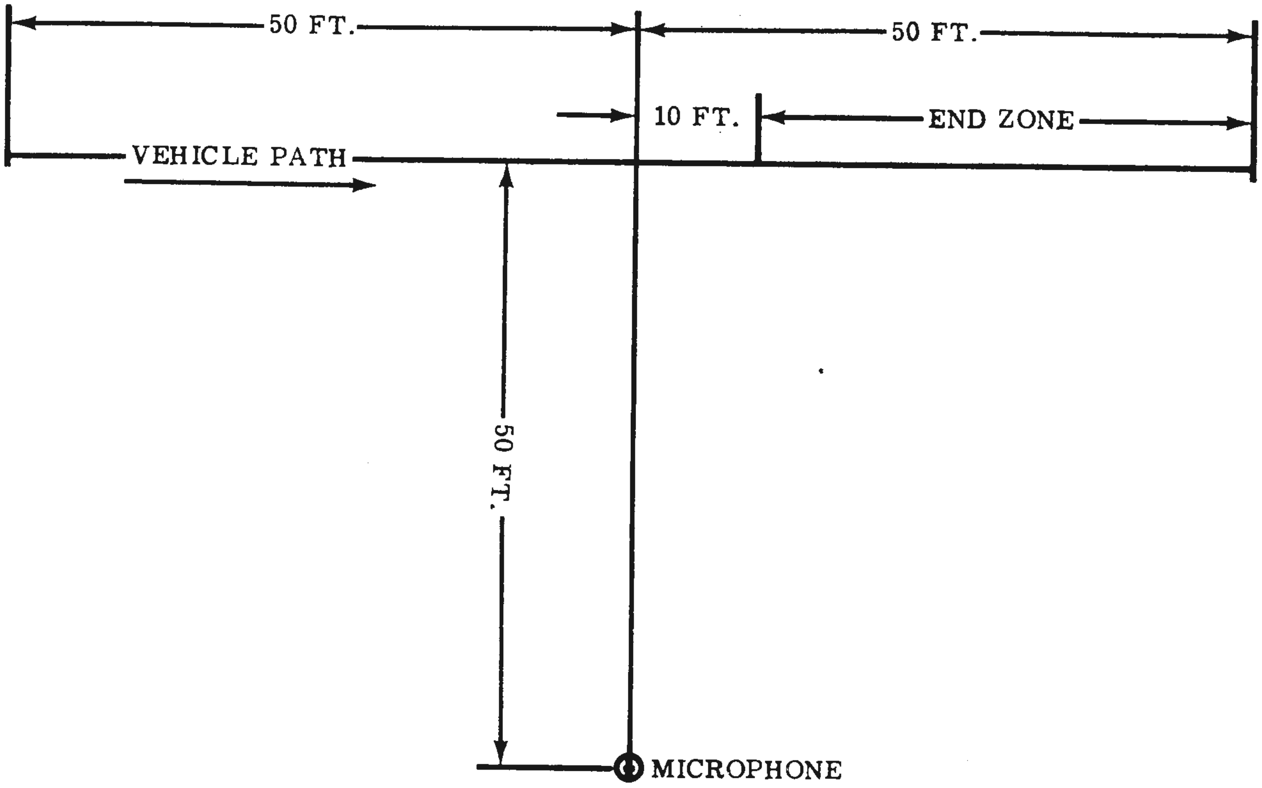
Passby Noise Testing - The SAE J366a test procedure was used to determine noise level ratings for this project. This procedure specifies a lane which is 100 feet long. The microphone is located 50 feet from the centerline of the vehicle path and 4 feet above the ground plane. The normal to the vehicle path from the microphone shall establish the microphone point on the vehicle path. An acceleration point is established on the vehicle path 50 feet before the microphone point and the end point is 100 feet from the acceleration point and 50 feet from the microphone point. The end zone is the last 40 feet of vehicle path prior to the end point. A diagram of the test area is given in Figure 12. The vehicle approaches the acceleration point of the test zone at an engine speed which is 2/3 of the maximum rated governed speed. When the acceleration point is reached the operator applies full throttle until the end of the test zone is cleared. The transmission gear must be pre-selected such that the vehicle reaches rated governed speed within the end zone without exceeding 35 mph. The measurement of the noise levels for the SAE J366a test procedure requires use of fast meter response and A-weighting. The sound level for each side of the vehicle is the average of the two highest readings which are within 2 dBA of each other.

3.4.1 Fan Noise Testing

The procedure for determining the sound level of the fan involved the use of the "Kool Pack." The "Kool Pack" has the capability of driving the fan through a wide range of operating speeds, and therefore could be used to simulate fan operation during the passby test procedure.

To simulate the fan operation during the J366a test, stationary recordings of fan noise were taken at five positions along the center line of the test lane. The data points were located at 50 feet and 25 feet before the microphone centerline, on the microphone centerline, and at 25 feet and 50 feet after the microphone centerline.

The vehicle was positioned at each point and the fan speed was adjusted to compare with the J366a passby fan speeds at that location. The fan speed was controlled by increasing or decreasing the remote engine speed or displacement of the hydraulic pump of the "Kool Pack." Recordings were made when the correct fan speed had been reached and the vehicle was stationary at the corresponding data point before, after, or at the microphone centerline.



SAE J366a TEST COURSE

Figure 12

3.4.2 Cooling Tests

Tests were conducted to determine the effect of the retrofit components on the cooling ability of the vehicle. The measure of cooling performance is expressed as the air-to-boil (ATB) number. This is a mathematical means of comparing the cooling ability of different vehicle configurations. It also enables a comparison of cooling tests conducted at different ambient temperatures. The ATB number is generally specified by the engine manufacturer as a vehicle installation requirement to be fulfilled by the truck designer.

Mathematically, ATB is expressed as:

$$ATB = 212^{\circ}F. - T_T + T_A$$

Where

T_T = Radiator Top Tank Temperature in $^{\circ}F$.

T_A = Ambient Air Temperature in $^{\circ}F$.

Cooling tests are run at two data points - maximum horsepower and maximum torque to ensure that the worst possible conditions are being considered. To determine the effect of the retrofit components on engine cooling performance, an air-to-boil number must be obtained for the baseline or production condition of the vehicle. This baseline cooling number should compare favorably with that obtained for the noise retrofit package. If this does not occur, the point at which cooling and noise reduction are optimized must be determined and the appropriate sound level suppression components chosen.

4. MUFFLER COMPONENT SELECTION

4.1 Objective

It was necessary to find the "off the shelf" muffler which would reduce the exhaust noise to the desired level without lowering the efficiency of the engine. Mufflers available at the time of testing were obtained from three major sources: Donaldson, Nelson, and Stemco Manufacturing Companies.

The first step in evaluation of these components was to quiet the vehicles to the lowest noise level possible, using the previously described new method of encapsulating the vehicle in absorption material. The mufflers were also wrapped so that shell radiation and outlet noise were attenuated to a level at which they were not a contributing source.

4.2 Test Procedure

Once the quiet condition had been reached the next step in muffler component testing was to unwrap the muffler and remove the overkill barrel. Since the major concern during this study was with component levels only, it was decided that total exhaust noise should be measured as opposed to the separation of shell and outlet noise. This enabled a simple comparison to be made between different mufflers.

The SAE J366a passby test was then run to evaluate total exhaust noise. To obtain a value for the exhaust noise contribution to the total vehicle noise, it is necessary to mathematically separate the exhaust noise from the total vehicle noise. As an example of this calculation, consider the DH 9502 data. In the quiet condition, the SAE J366a level was 75.1 dBA and when the muffler was unwrapped, a level of 83.2 dBA was measured. To obtain a true contribution of the exhaust noise, the baseline or quieted noise level must be subtracted from the noise level with the muffler exposed. Appendix A, Figure A2, page 39, is then used to find the numerical difference between the muffled sound level and the unmuffled sound level. The numerical difference between the exposed exhaust noise level and the quieted level is 8.1 dBA and this gives a subtraction factor of .7 dBA which, when applied to the exposed exhaust noise level of 83.2 dBA, gives an exhaust noise contribution of 82.5 dBA. This testing and calculation procedure was performed for each muffler and the most effective muffler was chosen from the resulting figures.

4.3 Test Results

Tables 2 through 5 give results of the passby tests for each vehicle and muffler choice. Figures 13 through 16 graphically show the same results. The mufflers selected for each vehicle are underlined. The selection of these mufflers was based upon two factors - back pressure and sound level attenuation. According to engine manufacturer's specifications, the muffler back pressure could not exceed four inches of mercury on the truck nor could it exceed six inches of mercury on the coach.

The conclusion drawn from this muffler retrofit study is that a component in the retrofit package which can significantly affect the vehicle performance is the muffler. Any increase in back pressure above the engine manufacturer's limits due to the muffler would decrease the efficiency of the engine. Therefore, back pressure along with sound level attenuation had to be considered in muffler selection.

5. COOLING SYSTEM MODIFICATIONS

Cooling systems are typically designed to meet the worst case operational air temperature condition which is generally defined as 200°F. top tank with 100°F. ambient. Air-(temperature)-To-Boil is the ambient temperature at which the engine coolant would boil if the truck is operated at full load, rated engine speed and moving at 15 miles per hour. It is rare that a truck operates in this severe environment, but nevertheless radiator and fan parameters have been established to meet this condition because of the expectation that unusual conditions will be encountered on some occasions. Therefore, in the case of the direct drive fan, it always pumps air at a rate to meet the most severe condition, and thereby will always generate some noise when the engine is operated.

A clutching device, which allows decoupling of the fan when additional cooling air is not required, is an attractive method of eliminating fan noise a major percentage of the time. At highway speeds ram air is sufficient for cooling and therefore the fan operation is rarely required. Tests to determine the fraction of operational time during which the fan is engaged have been conducted by various agencies.

A field test which recorded the operating time of a fan clutch was conducted during the DOT Quiet Truck Program by International Harvester Company. * Twenty-four vehicles were instrumented and records kept for a one year period. A summary of the results indicates that the total time the fan was engaged (fan on time) was under three percent of total truck operating time and the significant fan on time was below one percent.

* Text of Department of Transportation Proposed Compliance Procedures for Interstate Motor Carrier Noise Emission Standards, February 28, 1975, 49 CFR Part 325.

TABLE 2

Mufflers Tested On DH9502 *

Muffler Part Number	Muffler Noise Contribution (dBA)		Back Pressure
	Right Side	Left Side	
Nelson 704334 (original equipment)	87.1	81.0	3.0" Hg
Stemco 9869	82.5	79.1	3.2" Hg
Donaldson MBM 10-0025	91.8	88.9	3.2" Hg
Donaldson WKM 10-0064	83.5	80.2	3.3" Hg
Stemco 9417	80.0	78.8	4.1" Hg
Donaldson 5080B322	79.4	79.2	4.1" Hg
Nelson T-14061	82.7	78.5	4.6" Hg
Stemco 9870	82.5	79.1	3.2" Hg

TABLE 3

Mufflers Tested On T8H5305 *

Current Production	74.1 **	73.9	4.3" Hg
Nelson T13680	71.4	73.9	4.6" Hg
Original Muffler	72.5 **	75.7	4.7" Hg

* All tests were conducted according to the SAE J366a test procedure.

** Current production muffler has a larger diameter than the original muffler so as to reduce the back pressure. This results in a somewhat higher sound level for the larger diameter muffler but exhaust noise is still not a problem.

TABLE 4

Mufflers Tested On JN9500 *

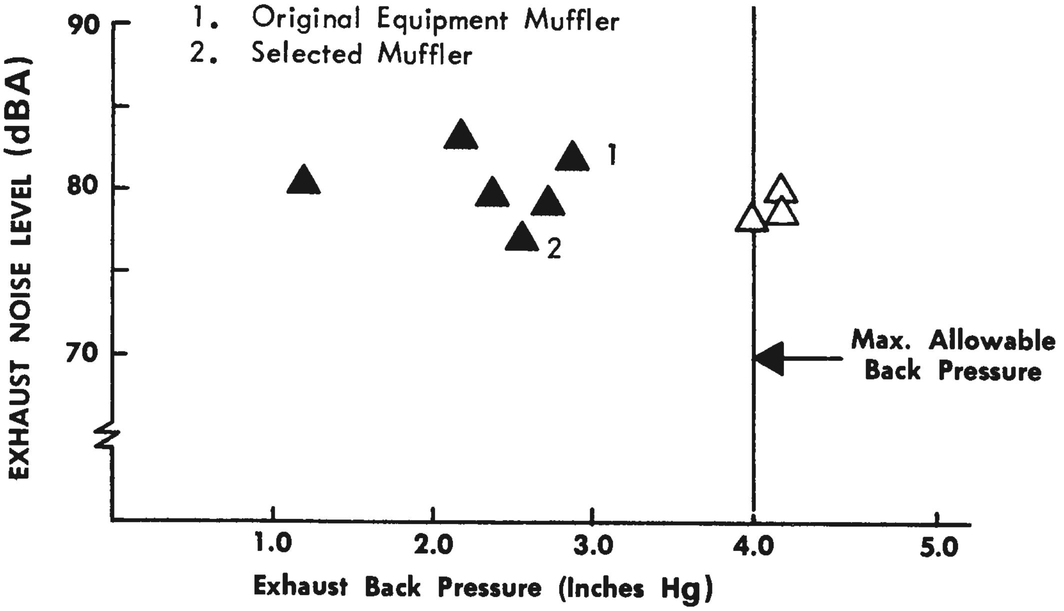
	Muffler Noise Contribution (dBA)		
Muffler Part Number	Right Side	Left Side	Back Pressure
Donaldson MPM09-0141	77.7	75.4	.5" Hg
Current Production	81.5	76.3	1.0" Hg
Donaldson WTM 10-0066	75.7	73.5	1.2" Hg
Stemco 9353	76.5	73.3	1.2" Hg
Original Production	78.6	72.3	1.5" Hg
Stemco 9400	80.7	72.6	1.7" Hg
Nelson T14062	77.5	75.0	2.3" Hg
Nelson T14063	76.3	76.1	2.4" Hg

TABLE 5

Mufflers Tested On J19500 *

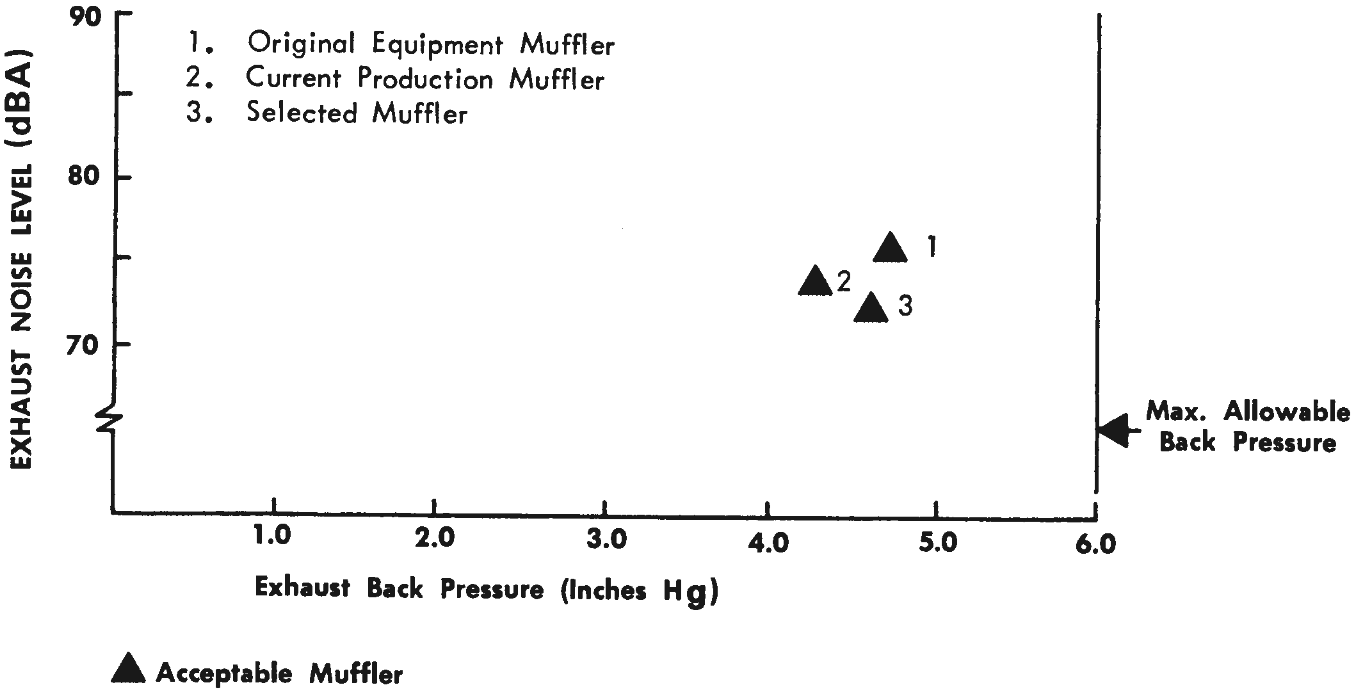
Donaldson MPM09-0141	80.7	79.0	1.2" Hg
Donaldson 695424	83.3	77.1	2.2" Hg
GMC P/N 2488077	79.7	75.7	2.4" Hg
Donaldson WTM 10-0066	77.6	70.9	2.5" Hg
Stemco 9353	79.7	73.0	2.6" Hg
Original Production	81.9	79.0	2.9" Hg
Nelson T14062	78.8	75.1	4.0" Hg
Nelson T14063	78.7	74.8	4.1" Hg
Donaldson 5080B339	80.2	70.4	4.2" Hg

* All tests were conducted according to the SAE J366a test procedure.



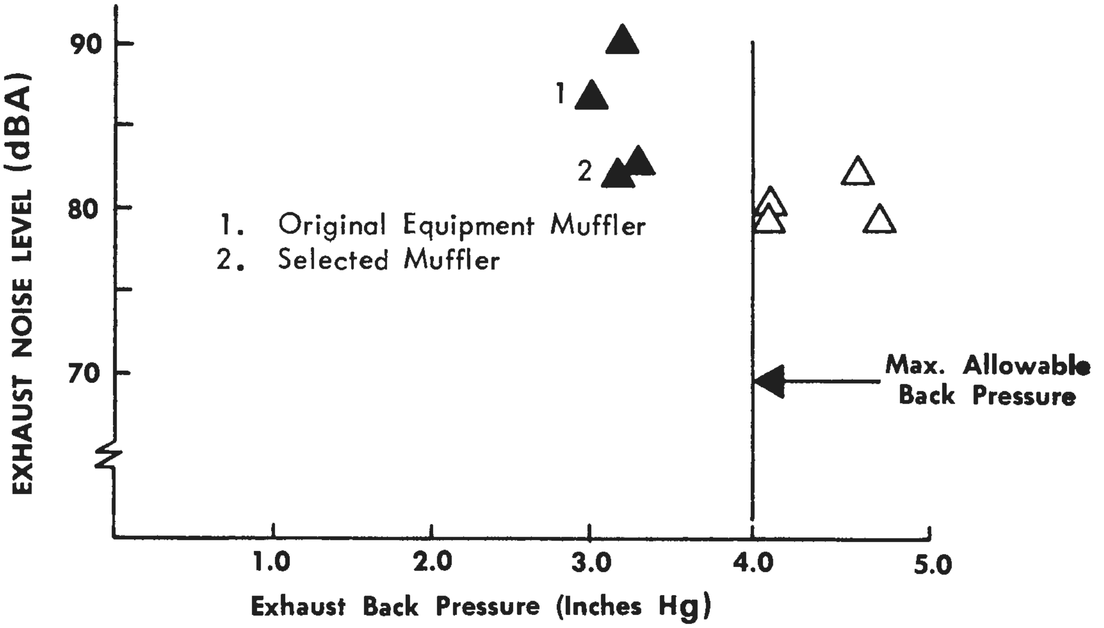
J19500 NOISE REDUCTION FROM MUFFLERS

Figure 13



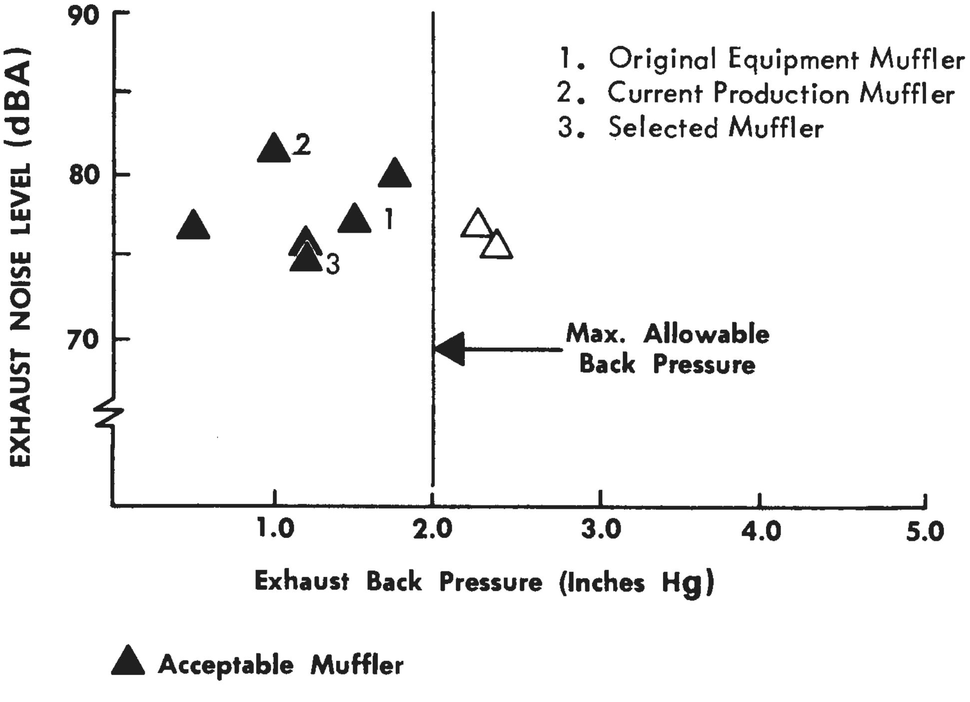
T8H5305 NOISE REDUCTION FROM MUFFLERS

Figure 14



DH9502 NOISE REDUCTION FROM MUFFLERS

Figure 15



JN9500 NOISE REDUCTION FROM MUFFLERS

Figure 16

Significant fan on time is that time when the engine is operating above 1600 revolutions per minute (RPM). Below 1600 RPM, fan noise is well below the maximum level and is not significant. Fan engagement time varies with driving conditions and ambient air temperature. In addition to reducing noise emission, clutched fans save significant amounts of energy, since on trucks fans consume on the order of 15 horsepower (HP). Obviously, declutching the fan will save this amount of power during a major part of operational time. Also, by holding the engine temperature within the best operating range, maintenance and down time are lowered.

The efficiency of a cooling system is a significant factor when considering the level of noise generated. If the air flow efficiency can be increased with a different type of fan, it would allow a reduction in fan speed. Slowing down the fan results in reduced turbulance created by the fan and thus lowers the noise level. A variety of fans were tested in an effort to find a replacement which would result in reduced noise levels. Thirteen fans were tested resulting in no significant decrease in fan noise levels. The results are shown in Table 6. An improved shroud with reduced tip clearance has been proved to increase air flow efficiency but has not been put into production at this time. It has also been proven that the optimal fan immersion for cooling and flow efficiency is around 66%. This is the reason for the one inch fan spacer installed as part of the retrofit package on the DH9502. (Ref. Truck Noise IV-C by Shrader and Page, DOT-TST-74-22, pg. 32, May 1974).

Since fan clutches, when disengaged, eliminate fan noise and reduce the overall noise level of a vehicle while saving fuel, the final retrofit package for the cooling system includes a fan clutch on three of the four vehicles. It is estimated that the potential fuel savings generated by the use of the fan clutch could save more than the initial cost of the product.

TABLE 6

Fan Noise Levels (dBA)

		Vehicle Position From Microphone Centerline (Feet)				
		Before		On Centerline	After	
A. DH 9502		-50	-25	0	+25	+50
Production	Right	71.3	75.0	78.6	82.0	80.0
	Left	70.2	74.0	78.3	79.8	80.6
Schwitzer 916328	Right	72.2	74.9	78.0	82.0	79.8
	Left	71.2	73.3	79.9	80.6	80.7
Flex-O-Lite 3328	Right	72.0	75.8	79.2	82.0	79.8
	Left	70.7	74.2	79.8	81.0	79.5
Flex-O-Lite 3228	Right	72.9	77.0	82.0	83.2	83.5
	Left	72.0	77.4	82.9	85.9	84.1
B. JN 9500						
Production	Right	74.6	81.4	82.0	79.8	76.7
	Left	74.7	78.3	78.9	78.1	79.9
Schwitzer 916330	Right	76.4	80.5	82.2	79.9	78.1
	Left	72.8	78.4	79.9	80.3	76.9
Flex-O-Lite 3326	Right	77.7	81.2	81.4	80.1	79.0
	Left	74.3	77.1	80.4	82.0	81.0
C. JI 9500						
Production	Right	67.4	71.6	76.7	78.6	76.0
	Left	67.5	72.0	76.8	78.1	77.4
Schwitzer 916330	Right	67.0	71.3	75.9	78.7	74.2
	Left	67.9	72.2	76.8	77.5	75.6
Flex-O-Lite 3326	Right	68.7	72.3	76.8	77.5	75.6
	Left	68.9	72.5	74.8	76.2	74.9
Flex-O-Lite 3226	Right	70.2	74.0	78.8	78.4	76.6
	Left	68.8	73.1	77.4	80.0	76.7
D. T8H5305	J366a					
Production	Right	76.5				
	Left	83.7				
Viscous Fan	Right	70.0				
	Left	73.0				

6. ENGINE NOISE REDUCTION

Reduction of mechanical noise emanating from the diesel engine itself is one of the most difficult truck noise problems. We have studied internal engine modifications, use of covers and panels, and complete enclosure of the engine in order to reduce noise emissions.

Internal engine modifications which reduce the noise source are more desirable than acoustic engine compartment treatments. Accordingly, investigations have been made of combustion noise and mechanical noise emitted from diesel engines. It was concluded first that it would be necessary to reduce mechanical noise before reductions in combustion noise would be significant. Identification of the levels of individual mechanical noise sources such as the crank and flywheel, gear train, fuel pump, governor, oil pump, water pump, blower, valve train, injectors and pistons, were made on a production engine in wide use.

Our data indicated that piston slap is the major single noise source on the test engines and that these engines are not likely to be made significantly quieter by internal modifications unless piston slap is reduced. A number of approaches to reduce piston slap are being pursued. These concepts include reducing piston clearance, controlling piston motion and reducing piston stiffness. However, these methods of sound level reduction were beyond the scope of the original project guidelines of using only commercially available components. Therefore, we relied on acoustic treatment to the engine compartment to reduce engine radiated noise. Commercially available body-mounted side shields and close fitted engine covers and panels were used in an attempt to reduce this noise source.

A complete engine compartment enclosure provides the best noise isolation but it causes engine water and oil cooling requirements to rise significantly. Complete enclosures restrict the normal air flow around the engine and prevent the usual disipation of heat. The build up of heat caused by the use of these enclosures causes engine compartment temperature to increase 100°F. to 200°F. on current production vehicles. This elevated temperature will undoubtedly affect the durability of some engine mounted components. Besides being initially expensive, such an enclosure would also require added maintenance time due to the reduced ease of serviceability of the engine.

External body mounted side shields produced by GMC Truck & Coach were tested for the JI, JN, DH and modified dust shields from GM were tested on the coach. In addition to the shields for the JN, Cummins Engine Company makes engine mounted side shields for their products. These Cummins shields were found to be an effective means of reducing engine noise on the Cummins engine.

The external body mounted side shields tested were found to be virtually ineffective in reducing the engine noise emitted under the SAE J366a test. Noise generated by the engine was escaping from the bottom of the engine compartment and reflecting off the road surface. Therefore, a more complete encapsulation of the engine was needed to produce a significant noise reduction. This was accomplished on two of the test vehicles as shown in Table 7.

The first step in determining the noise reduction obtained using side shields was to test the engine in the baseline condition. The baseline condition had all noise sources except the engine attenuated. This included pipes and mufflers being wrapped with lead and asbestos, a muffler outlet silencer, and the fan removed, leaving the engine as the dominant source. The shields were then installed on the vehicle and the SAE J366a test run to evaluate their effectiveness. These results are summarized in Table 7 below.

TABLE 7

Engine Noise Reduction Component Performance

Vehicle		Noise Level (dBA)
JN 9500	Engine Baseline	82.5
	Side Shields	81.8
	Cummins Side Shields	80.3
DH 9502	Engine Baseline	80.9
	Side Shields	80.0
	Engine Tunnel Liner w/Side Shields	80.3
JI 9500	Engine Baseline	80.9
	Side Shields	81.0
T8H5305	Engine Baseline	73.3
	Belly Pans w/o insulation	73.0
	Belly Pans w/insulation	71.2
	Insulated Engine Comp. w/Belly Pans	70.6

7. RETROFIT SUMMARY

Table 8 is a summary of the performance data on the selected vehicles with and without the selected retrofit component packages. Also included is an estimate of the total package cost including labor to an individual vehicle owner (fleet estimate for coach). Data relating to the cooling ability of the vehicle is given to show compliance of the vehicle to engine manufacturers cooling requirements.

TABLE 8

SUMMARY OF THE PERFORMANCE DATA ON THE SELECTED VEHICLES

	Noise Level (dBA)		Cooling (ATB)	
	R.H.	L.H.	@Max. HP	@ Max. Torque
DH 9502 Tilt Cab, Detroit Diesel, 8V-71 318 HP				
Baseline	92.7	93.9	112°F.	106°F.
Stemco 9869 Muffler and 1" Fan Spacer	86.5	84.9	116°F.	111°F.
Est. Price: $106 *				
JN 9500 Conventional, Cummins NHC-250, 250 HP				
Baseline	84.9	86.8	109°F.	102°F.
Donaldson WTM10-006	85.2	84.2	-	-
Horton Fan Clutch (9800) & Cummins Engine Shields	82.6	81.8	-	-
Est. Price: $560 *				
JI 9500 Conventional, Detroit Diesel 6-71N, 201 HP				
Baseline	84.0	82.7	114°F.	101°F.
Donaldson WTM10-006	83.3	81.8	-	-
Horton Fan Clutch (9843)	80.7	81.8	115°F.	103°F.
Est. Price: $489 *				

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* Material and labor as of October 1974.

T8H5305 53-Passenger Transit Bus, Detroit Diesel 8V-71N, 242 HP

	Noise Level (dBA)		
	R.H.	L.H.	Cooling (ATB)
Baseline	82.2	85.5	123°F.
Nelson T13680 Muffler	81.6	85.0	-
Engine Belly Pans with Insulation	78.6	83.7	109°F.
Hydraulic Fan Drive	77.9	81.9	108°F.

Est. Price: $555 *

* Material and labor as of October 1974.

APPENDIX A

ACOUSTICS

ACOUSTICS

This section discusses basic acoustics as applied to vehicle noise reduction. The purpose is to illustrate the need to identify the major truck noise sources for component noise reduction. Knowledge of basic acoustics will also help the reader to analyze the test results presented in this report.

Sound is any pressure fluctuation that can be sensed by the human ear. Noise is sound, however, it is considered to be undesirable or unwanted by the human spectator. Since this is a subjective, rather than objective, reaction to a stimulus, noise to one observer may be harmony to another.

From the standpoint of noise work in general, and truck noise in particular, the amplitude as well as rate of pressure fluctuation must be considered. Since the human ear responds to a range of pressure fluctuations where the ratio of the loudest to the quietest perceived tones is $10^7:1$, the measurement of sound in terms of pressure becomes cumbersom. A convenient mathematical tool has been employed to compress this range. This scale is commonly used and has the units of decibel (dB). Mathematically, the amplitude of the sound (pressure fluctuation) is expressed by a sound pressure level (SPL) given by

$$SPL = 20 \log \frac{P}{P_{ref}} \text{ (units are dB)}$$

Where the pressure, P, is the root-mean-square value of the signal averaged over a period of time T. P_{ref} is a reference pressure and has been selected as 2×10^{-5} N/m^2. This selection was based on data that indicated this is the lower limit of pressure fluctuation to which normal humans can respond. This is known as the threshold of hearing and corresponds to a SPL = 0 dB while the upper limit or threshold of pain is approximately 140 dB.

The rate of pressure variation (frequency) also affects the human observer. Generally, the higher frequencies from 1000 to 4000 hertz (Hz) are more audible than the lower frequencies. The measuring instrumentation takes into account this effect by means of an electronic filtering network. This filter discriminates against the low frequency signals and gives more weight to the 1000 - 4000 Hz band in order to simulate the sensitivity of the human ear.

This filtering is called "A" weighting. The standard response curve of an "A" filter is shown in Figure A 1.

When a sound measurement is made utilizing an instrument with an "A" weighting filter, the result is expressed as the A weighted sound level or dB A. This A weighted sound level has high correlation with subjective judgment of loudness.

Let us now consider the problem of reducing overall vehicle noise emission. In a typical vehicle noise problem there are a number of sources which contribute to the total vehicle noise level. There is a need to develop a procedure to identify the individual noise sources and to determine their levels for three reasons:

1. The level produced by each source has to be identified so that the engineers can address the major problems.
2. It is required that the level produced by each source can be measured independently so that modifications to that source can be evaluated.
3. By considering the total noise from individual vehicles to be a combination of individual sources, data obtained independently on these sources can be applied to predict overall vehicle noise.

Before some examples are cited it may be helpful to explain the simplified chart used for the addition of sound levels. This chart obviates the need for converting from a logarithmic to linear base when adding decibels. This chart is shown in Figure A 2. Take the numerical difference between two levels being added. Follow through to either the abscissa or ordinate and add this value to the correct level to find the logarthmic sum of the two levels.

To demonstrate the use of this chart and the need to determine the independent source levels, let us consider a truck with the following component levels and add pairs of sources to finally determine the calculated vehicle sound level.

Engine	80 dBA	86 dBA	87 dBA
Fan	85 dBA		
Exhaust	78 dBA	80dBA	
Intake	76 dBA		
Logarithmic Sum	87 dBA		

If we had methods to reduce any one of the sources by 6 dBA, it can be shown that the greatest overall reduction would be obtained if this reduction was applied to the dominant source, in this case the fan. The effect of reducing each component is shown as follows:

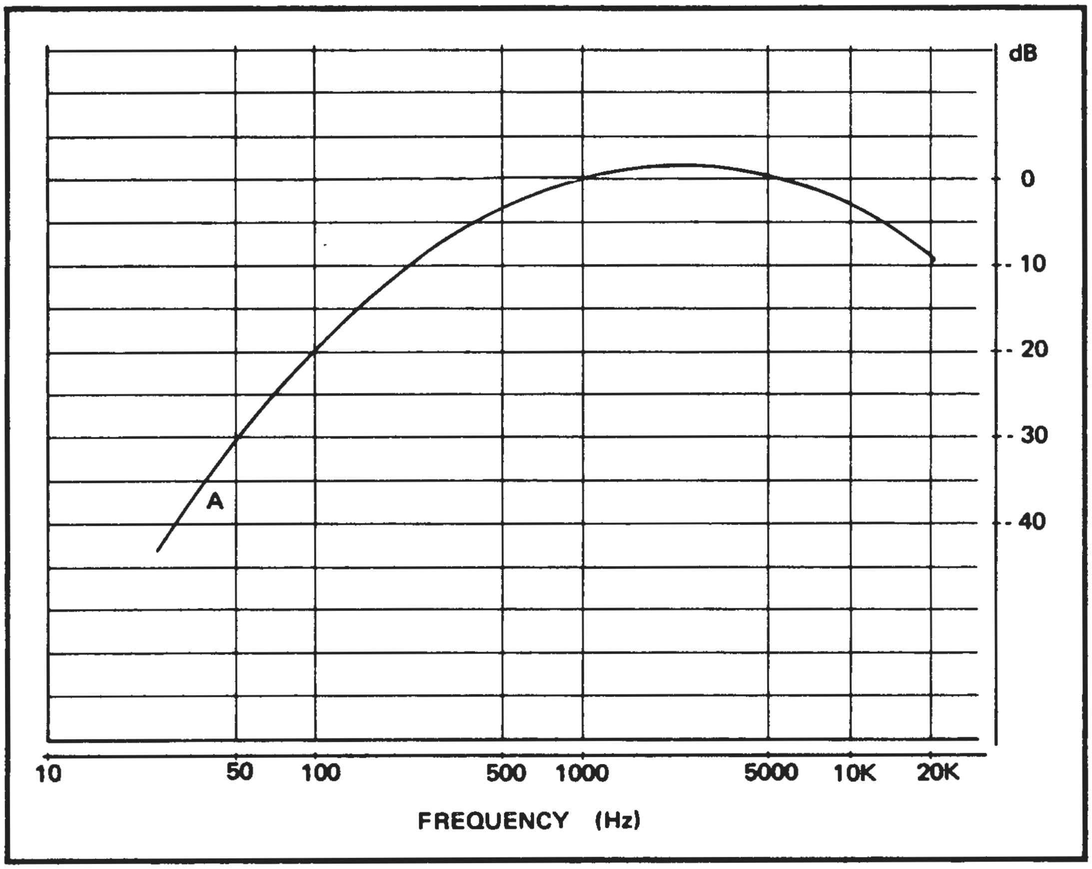


FIGURE A1 — CHARACTERISTIC CURVE OF AN "A" WEIGHTED FILTER

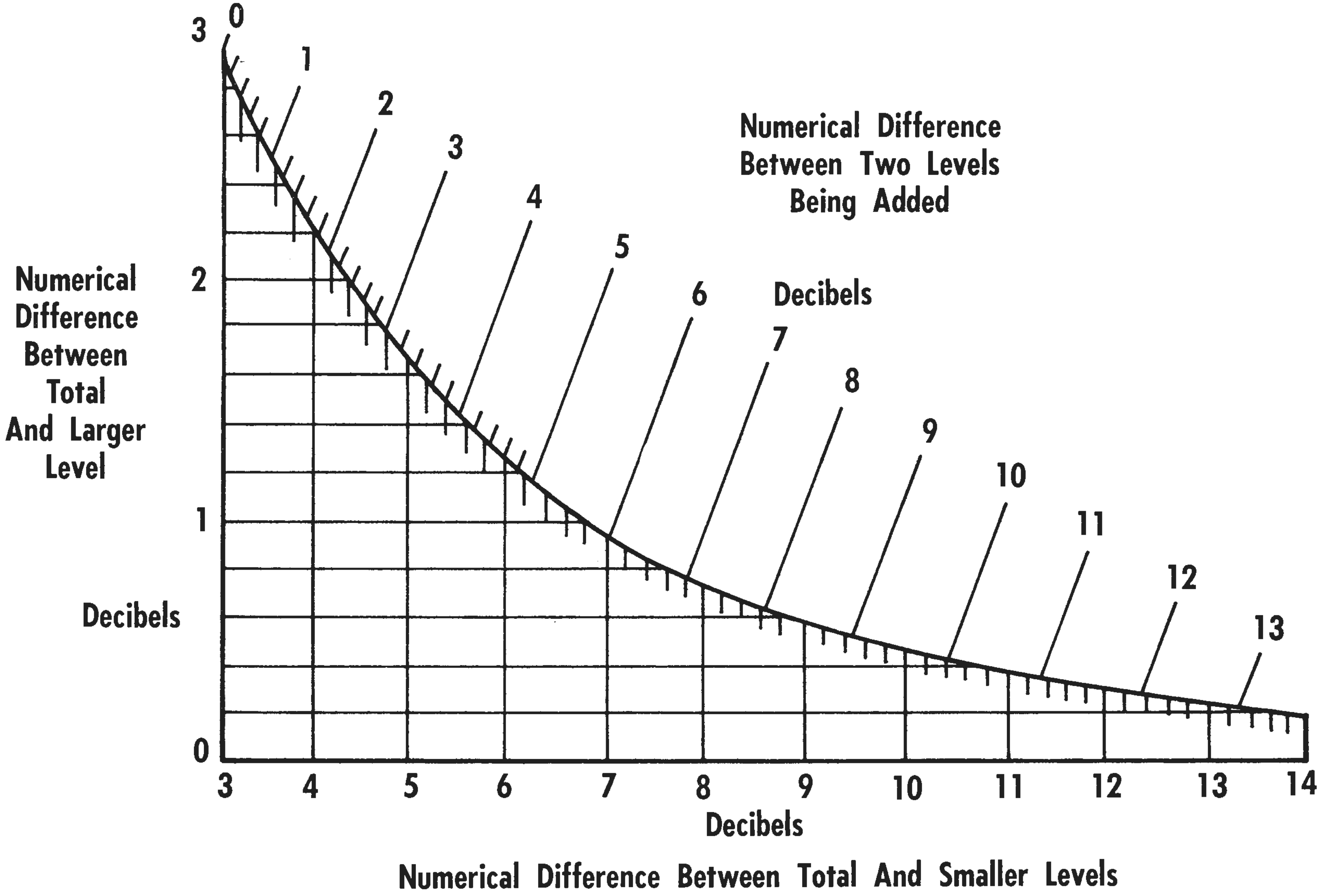


FIGURE A2 – COMBINING LEVELS OF UNCORRELATED NOISE SIGNALS

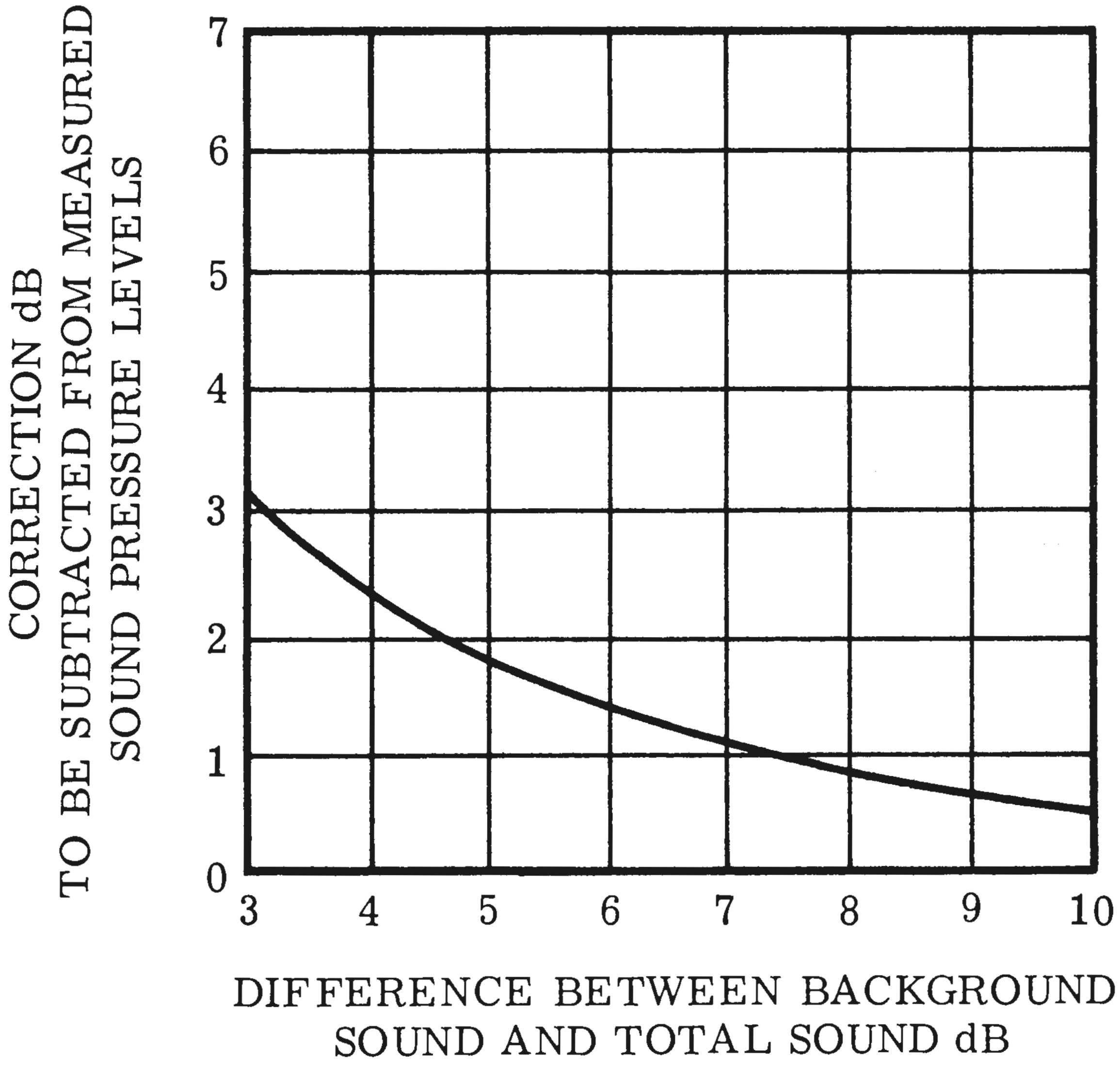


FIGURE A3 – CORRECTION FOR BACKGROUND SOUND

Effect of Reducing Engine Noise Level by 6 dBA

Engine 80 - 6 =	74 dBA
Fan	85 dBA
Exhaust	78 dBA
Intake	76 dBA
Logarithmic Sum	86.5 dBA

Effect of Reducing Fan Noise Level by 6 dBA

Engine	80 dBA
Fan 85 - 6 =	79 dBA
Exhaust	78 dBA
Intake	76 dBA
Logarithmic Sum	84.5 dBA

Effect of Reducing Exhaust Noise Level by 6 dBA

Engine	80 dBA
Fan	85 dBA
Exhaust 78 - 6 =	72 dBA
Intake	76 dBA
Logarithmic Sum	86.8 dBA

Effect of Reducing Intake Noise Level by 6 dBA

Engine	80 dBA
Fan	85 dBA
Exhaust	78 dBA
Intake 76 - 6 =	70 dBA
Logarithmic Sum	86.8 dBA

These calculations demonstrate that to obtain a significant overall noise reduction, work would first have to be done to identify the noise levels on all components before a reduction in the dominant source could be achieved.

Accuracy of Component Noise Measurement

There are numerous sources of variability in making vehicle passby noise measurements. These include test site and equipment differences and environmental effects - particularly temperature. The effect of these variables is not totally understood, nor is it adequately documented. In making component measurements by the techniques described in this report, i.e., by first quieting all the major noise sources and then uncovering the source of interest, another possible error is introduced. The magnitude of this error is dependent upon the difference in noise level between the quiet condition and the level with component uncovered. Consider the following situation:

Quiet Condition	77 dBA
Exhaust Condition	80 dBA

If the noise level in the quiet condition was controlled by sources other than exhaust, then the actual exhaust level would be 77 dBA. If the quiet condition was controlled by exhaust, then the actual exhaust noise contribution would be 80 dBA. The following table, derived using Figure 3A, shows the effect of the quiet condition level on the accuracy of the component level measurement.

Quiet Condition dBA	Test Component Uncovered dBA	Estimated Component Level dBA
70	80	79 1/2 - 80
74	80	79 - 80
77	80	77 - 80
80	80	0 - 80

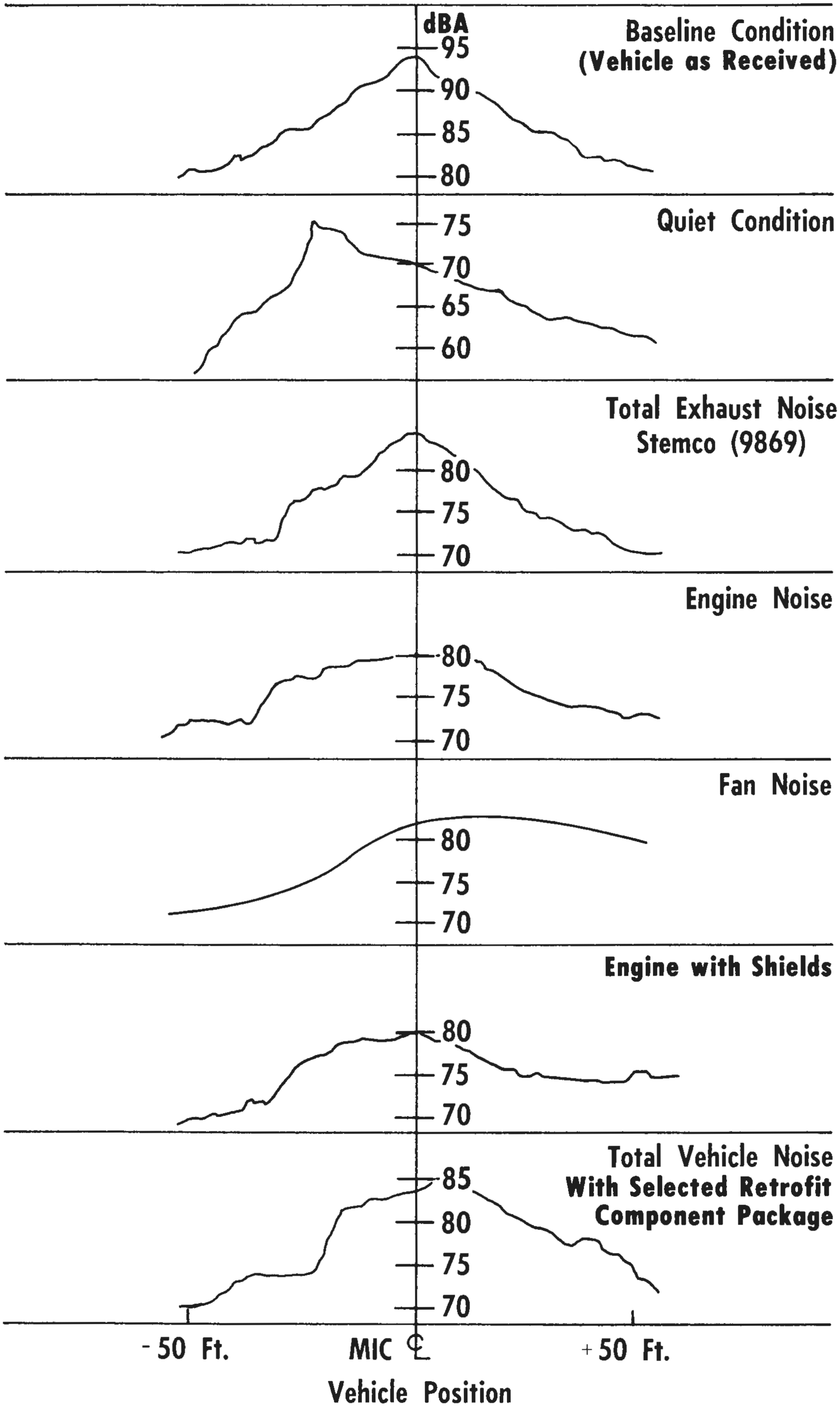
It is apparent from this table that the quiet condition must be approximately 6 dBA below the component level to provide accurate measurements of component level.

APPENDIX B

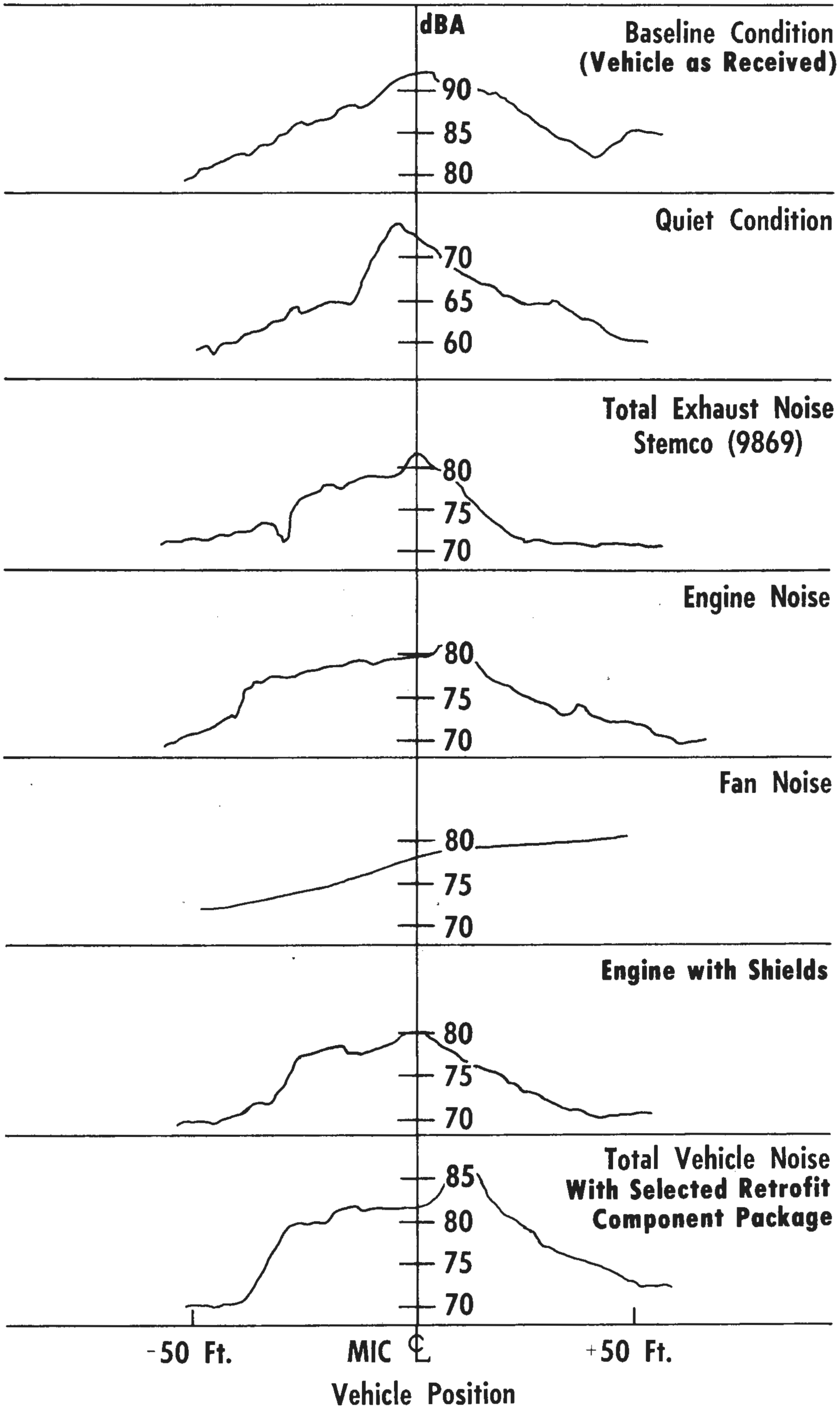
TIME HISTORIES AND OCTAVE BAND SPECTRA FOR EACH COMPONENT AND VEHICLE CONDITION

The following graphs show the time histories and octave band spectra for each component and vehicle condition. The time histories indicates the relationship between position and vehicle noise level obtained from the SAE J366a passby test; the spectra shows the maximum of each 1/3 octave band throughout the test course.

DH9502 RIGHT SIDE

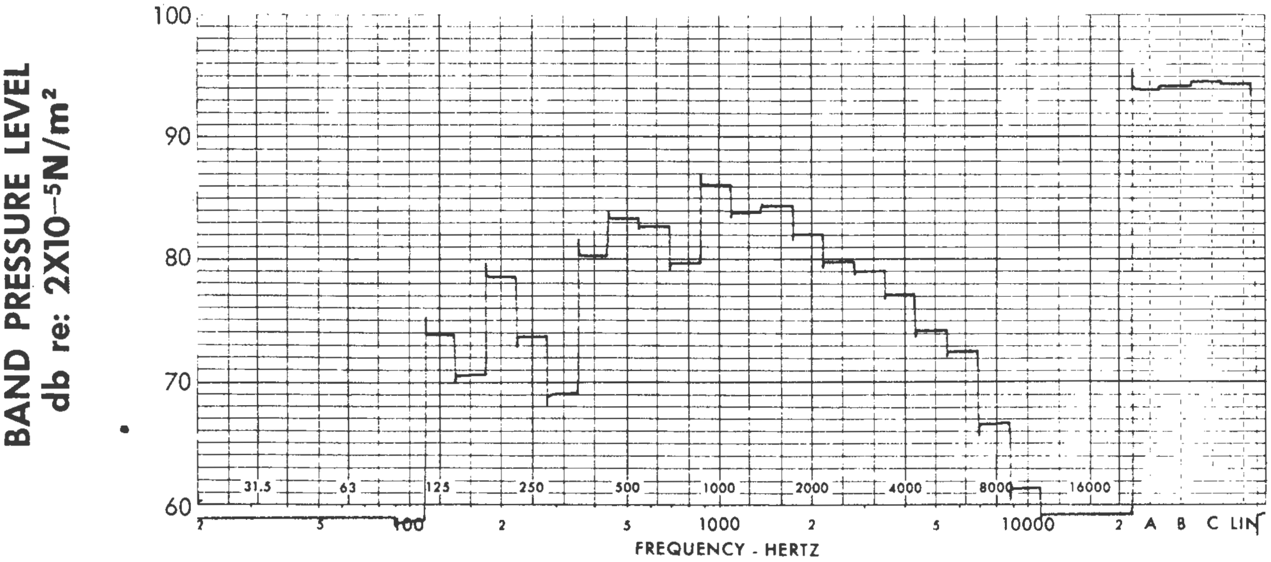


DH9502 LEFT SIDE

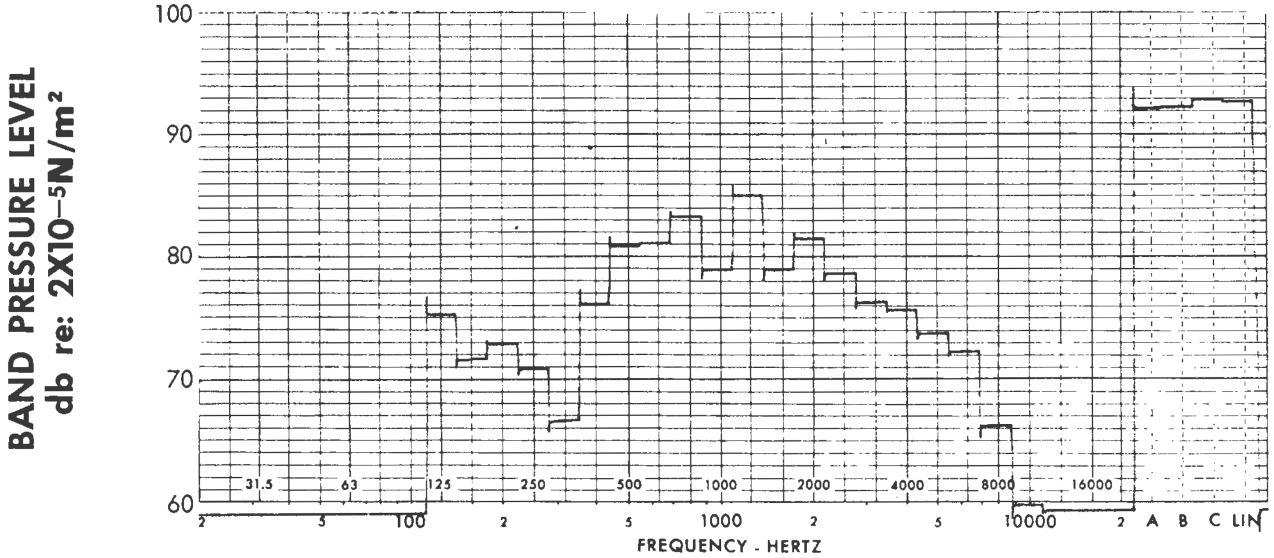


VEHICLE MODEL: DH9502
BASELINE TOTAL VEHICLE NOISE

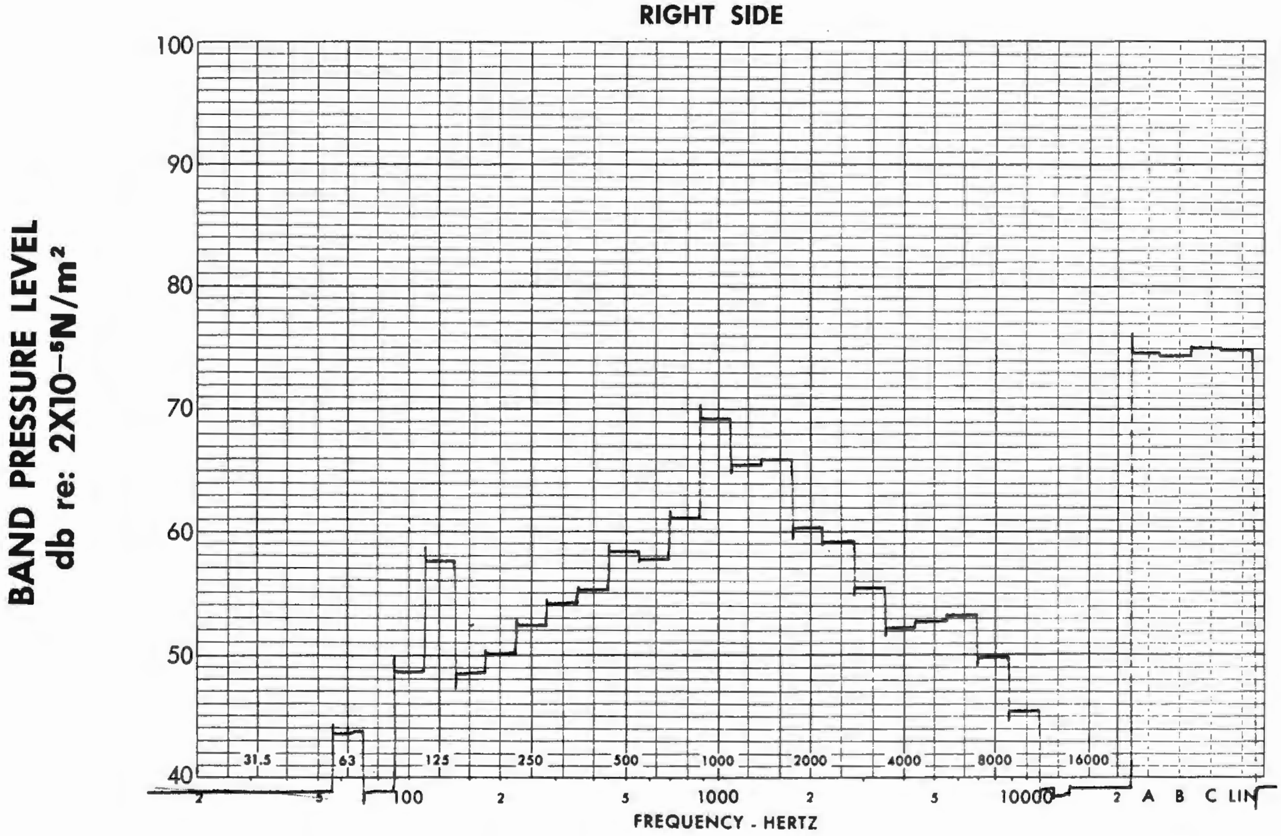
RIGHT SIDE

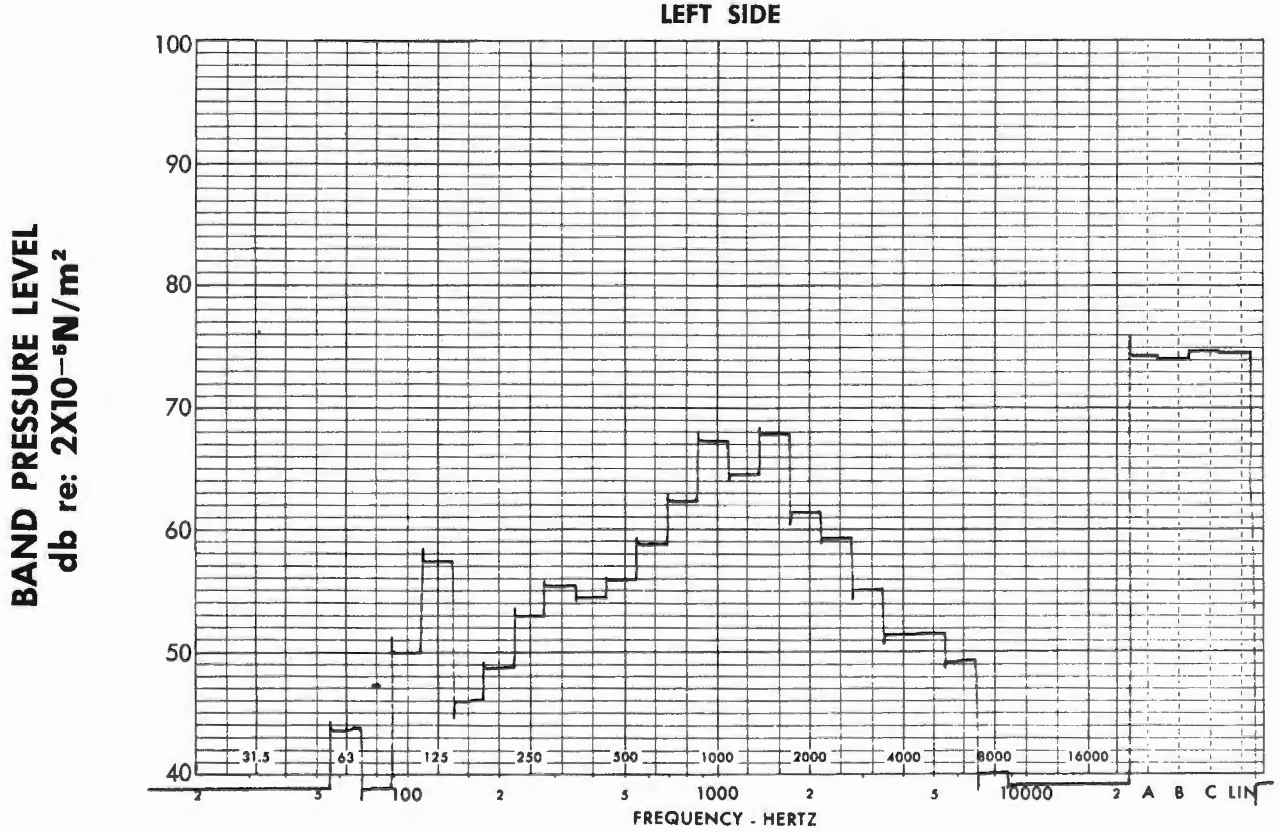


LEFT SIDE



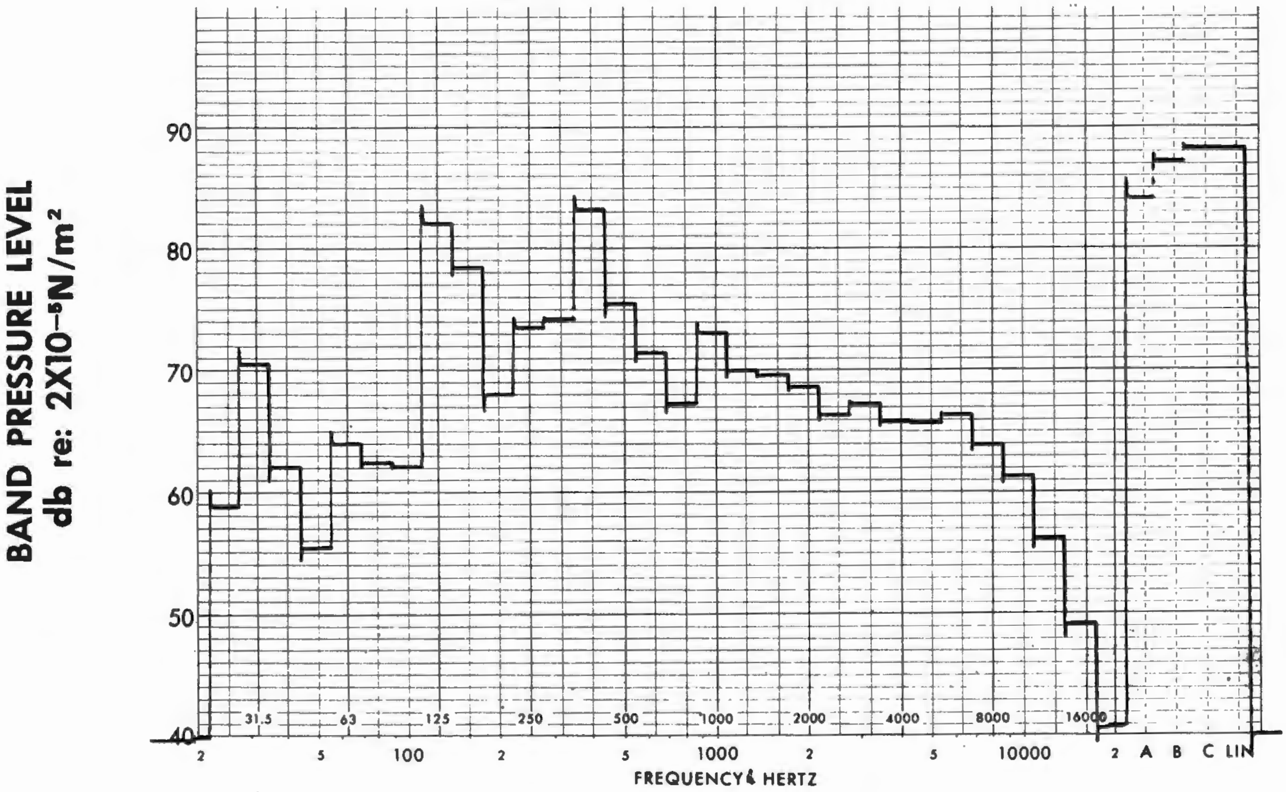
VEHICLE MODEL: DH9502
TOTAL QUIET



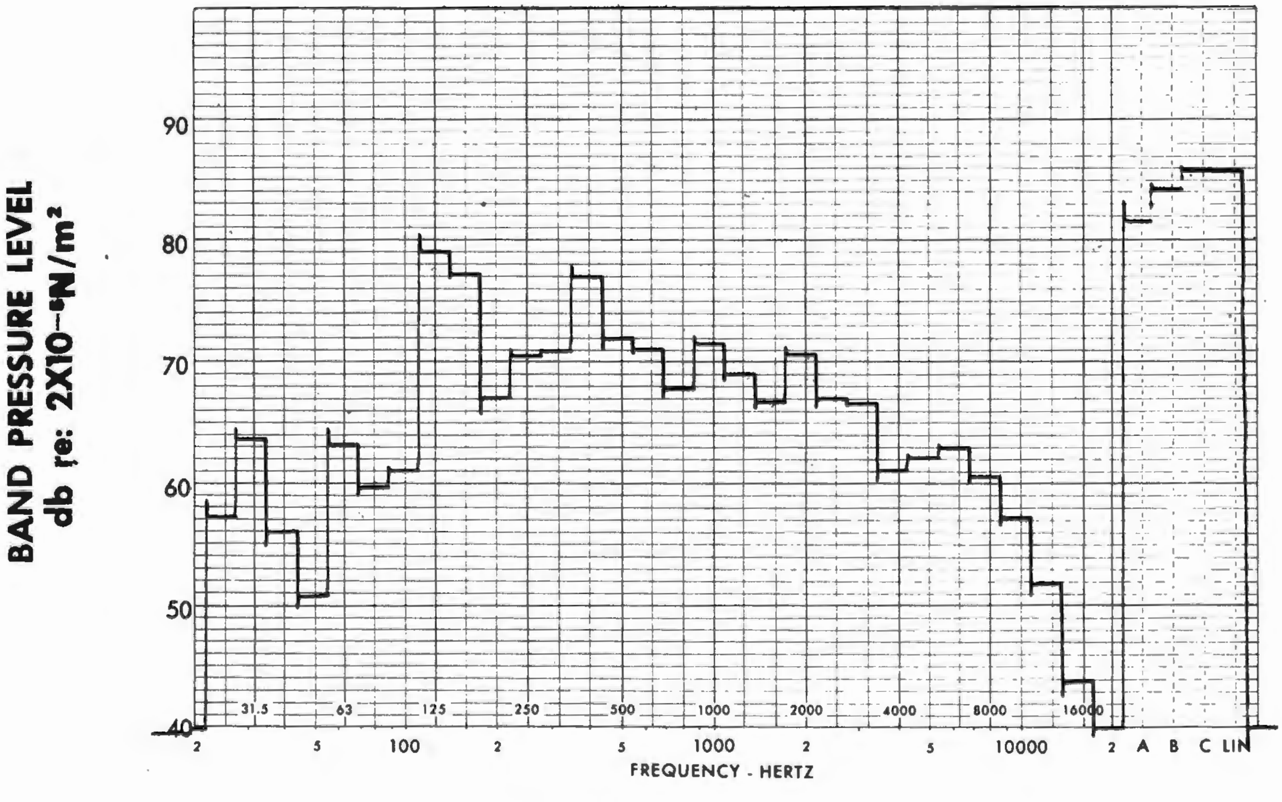


VEHICLE MODEL: DH9502
EXHAUST NOISE - STEMCO 9869

RIGHT SIDE

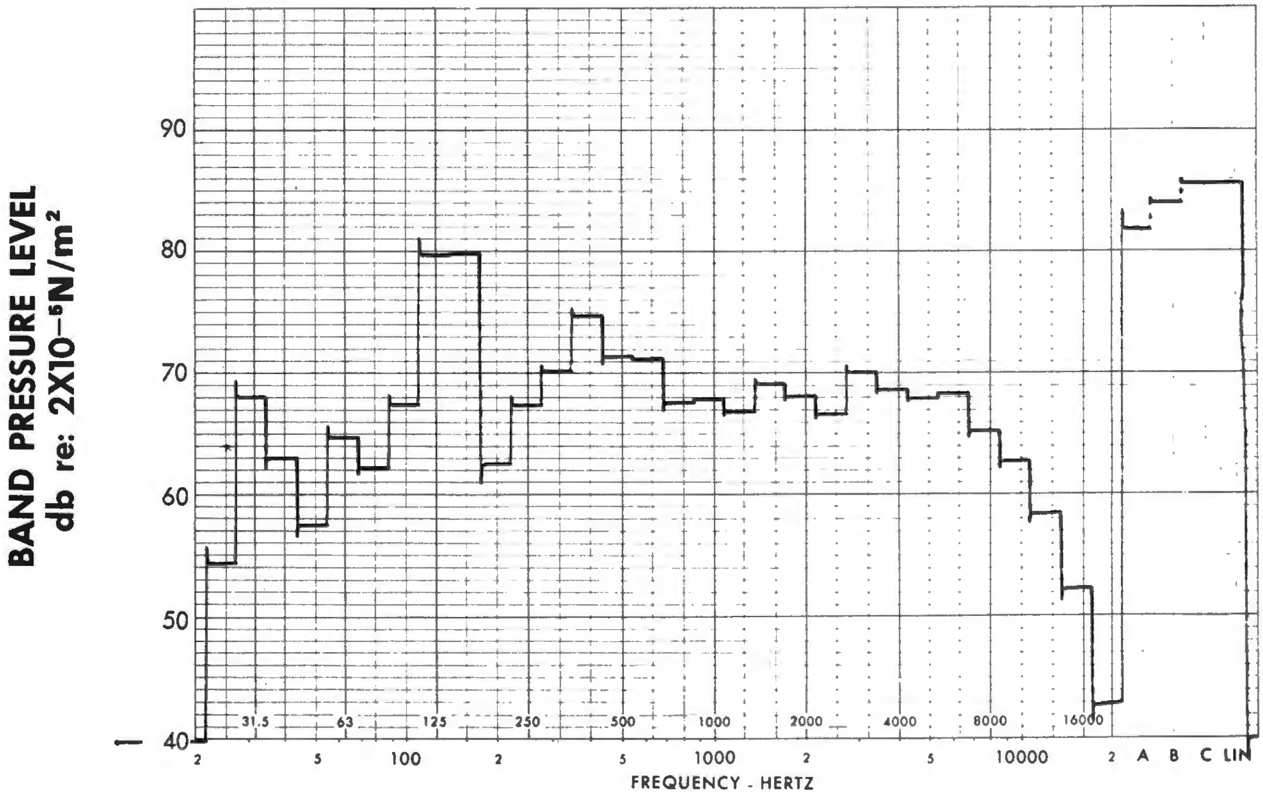


LEFT SIDE

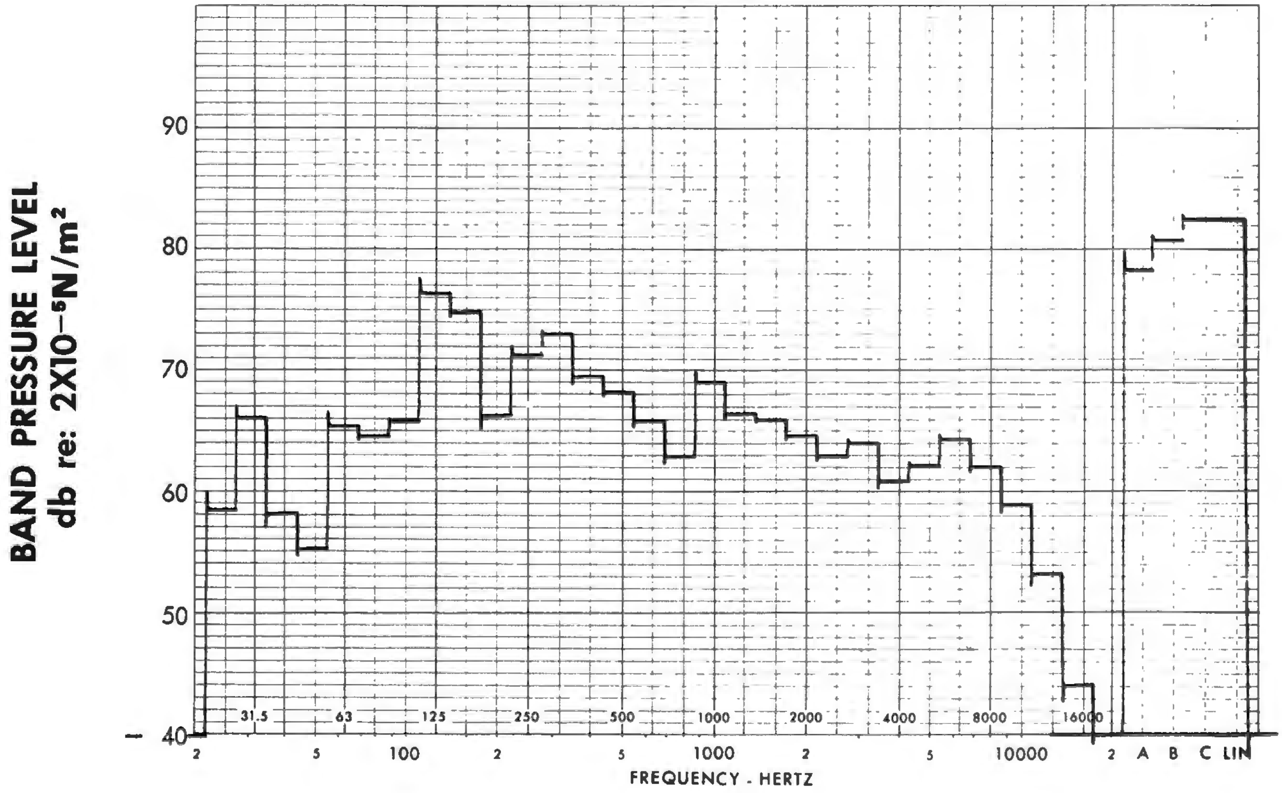


VEHICLE MODEL: DH9502
EXHAUST NOISE - 9870

RIGHT SIDE

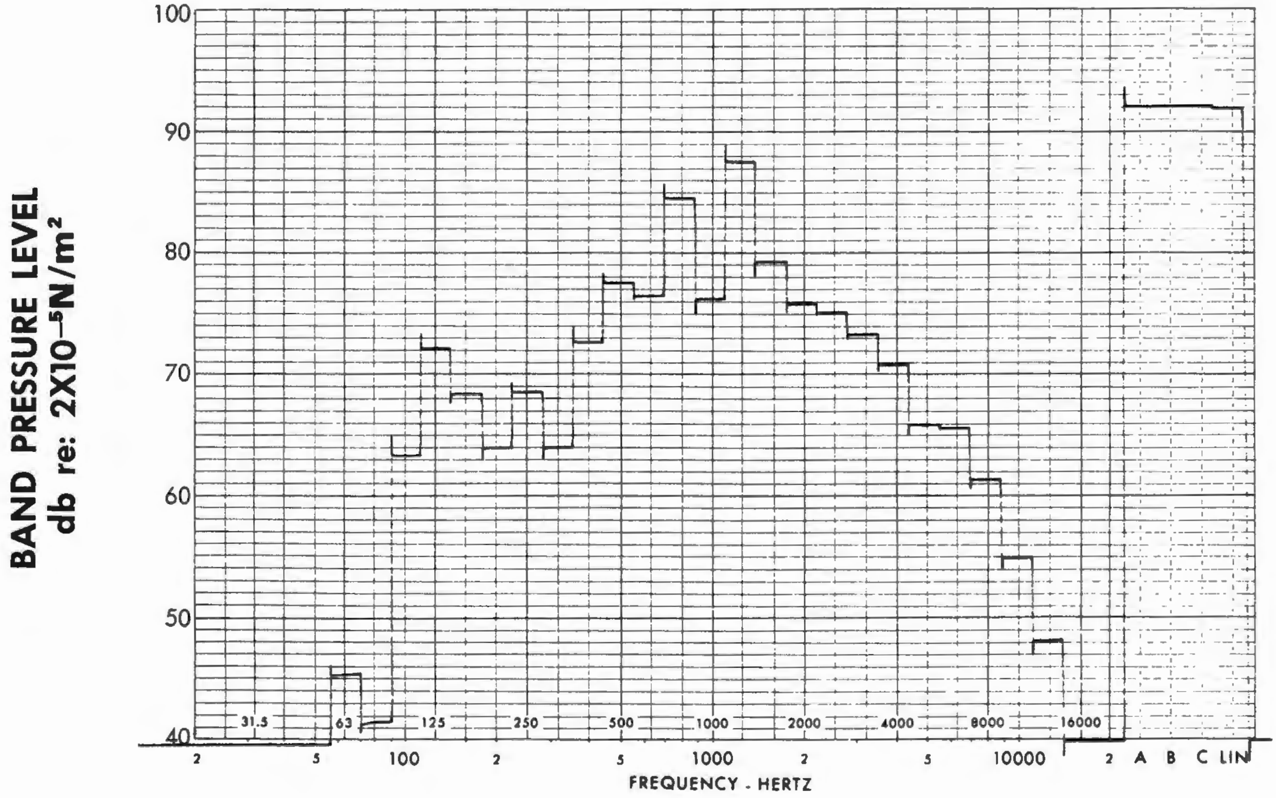


LEFT SIDE

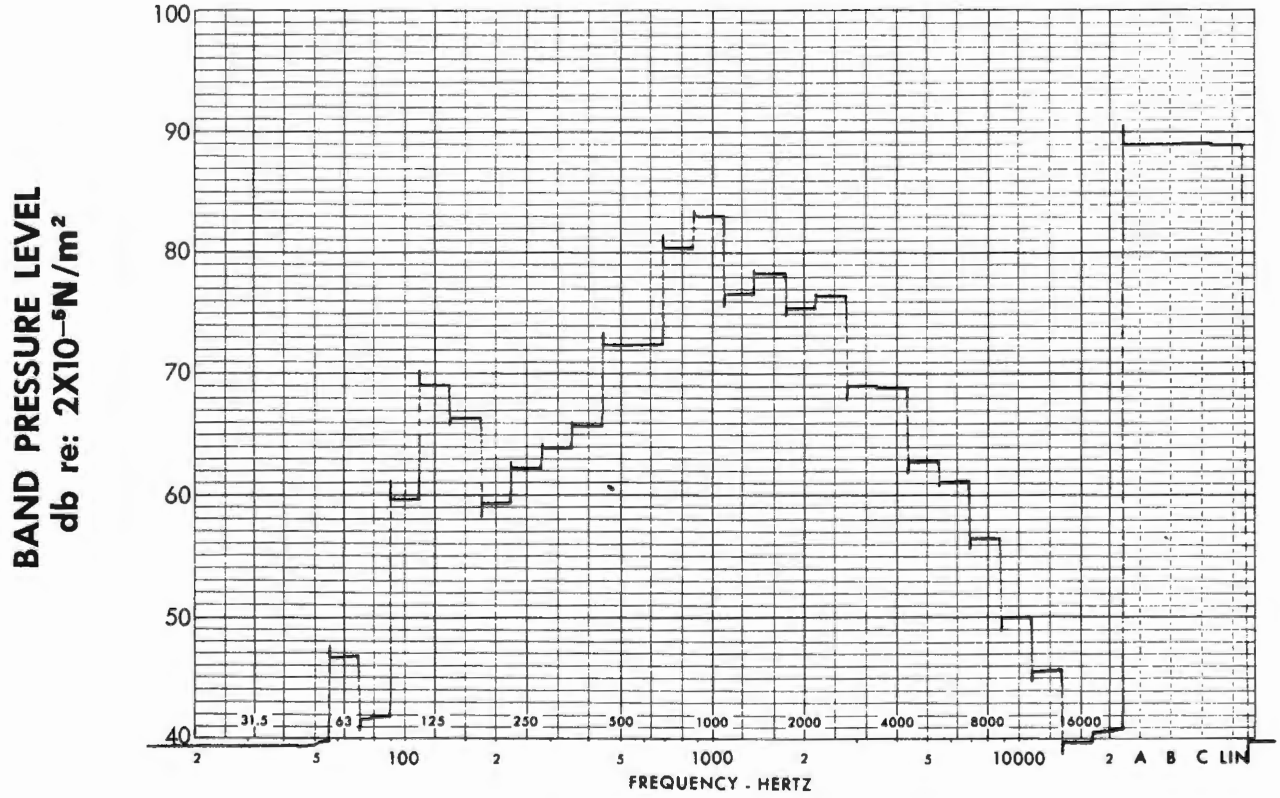


VEHICLE MODEL: DH9502
EXHAUST NOISE - PRODUCTION

RIGHT SIDE

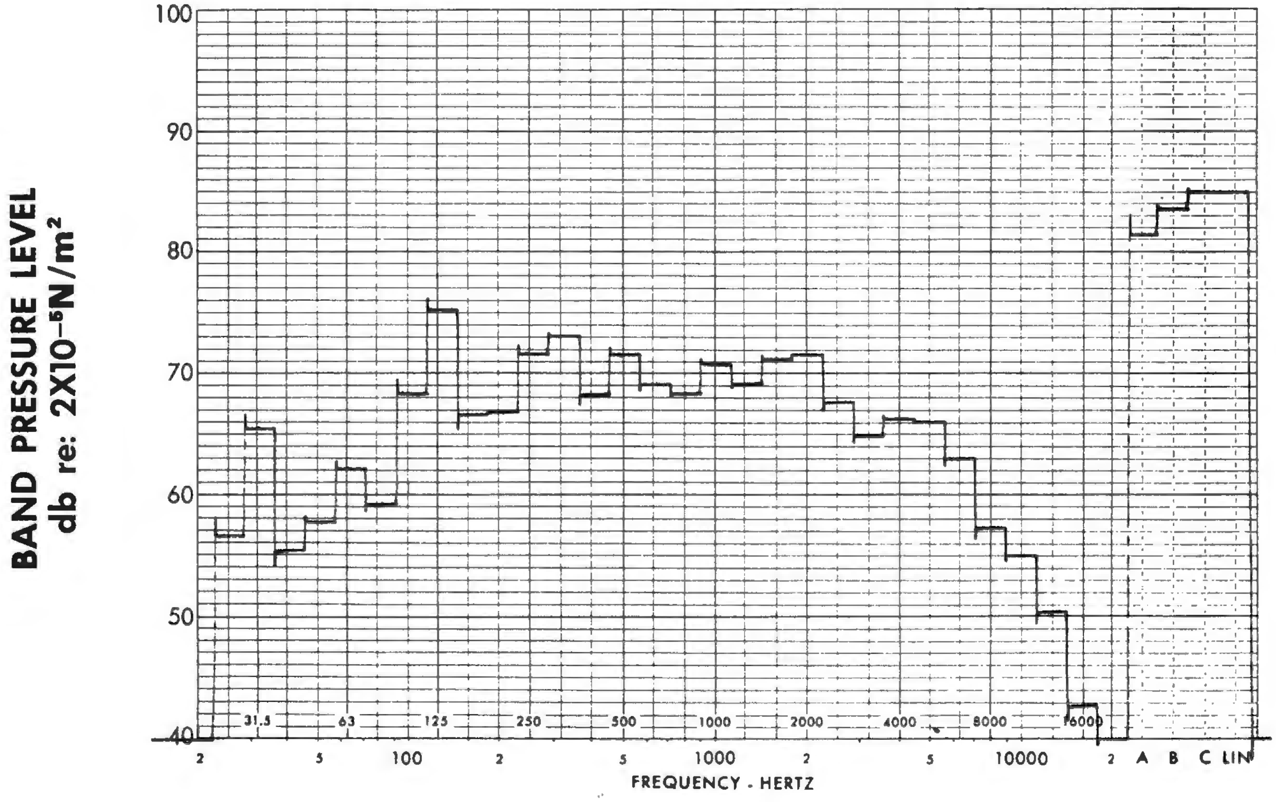


LEFT SIDE



VEHICLE MODEL: DH9502
ENGINE NOISE LEVEL

RIGHT SIDE



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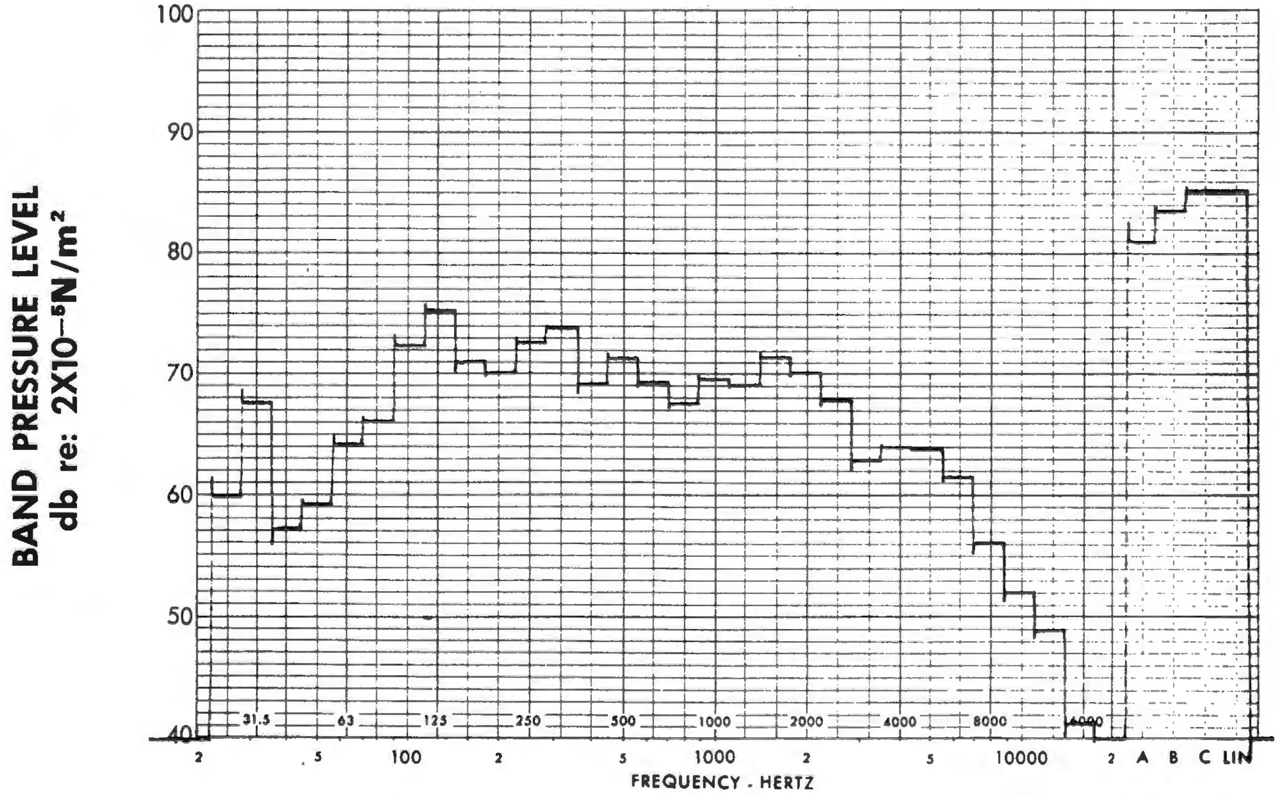
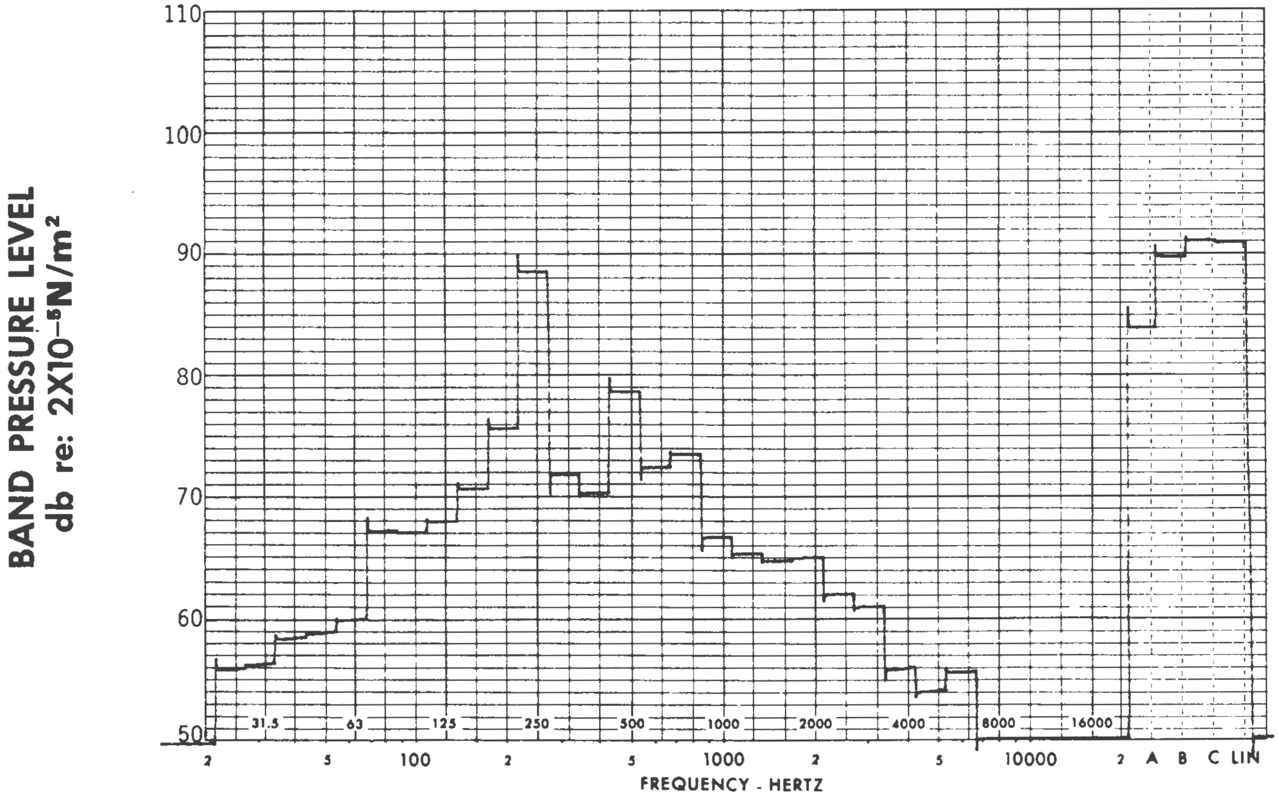


VEHICLE MODEL: DH9502
FAN NOISE

RIGHT SIDE



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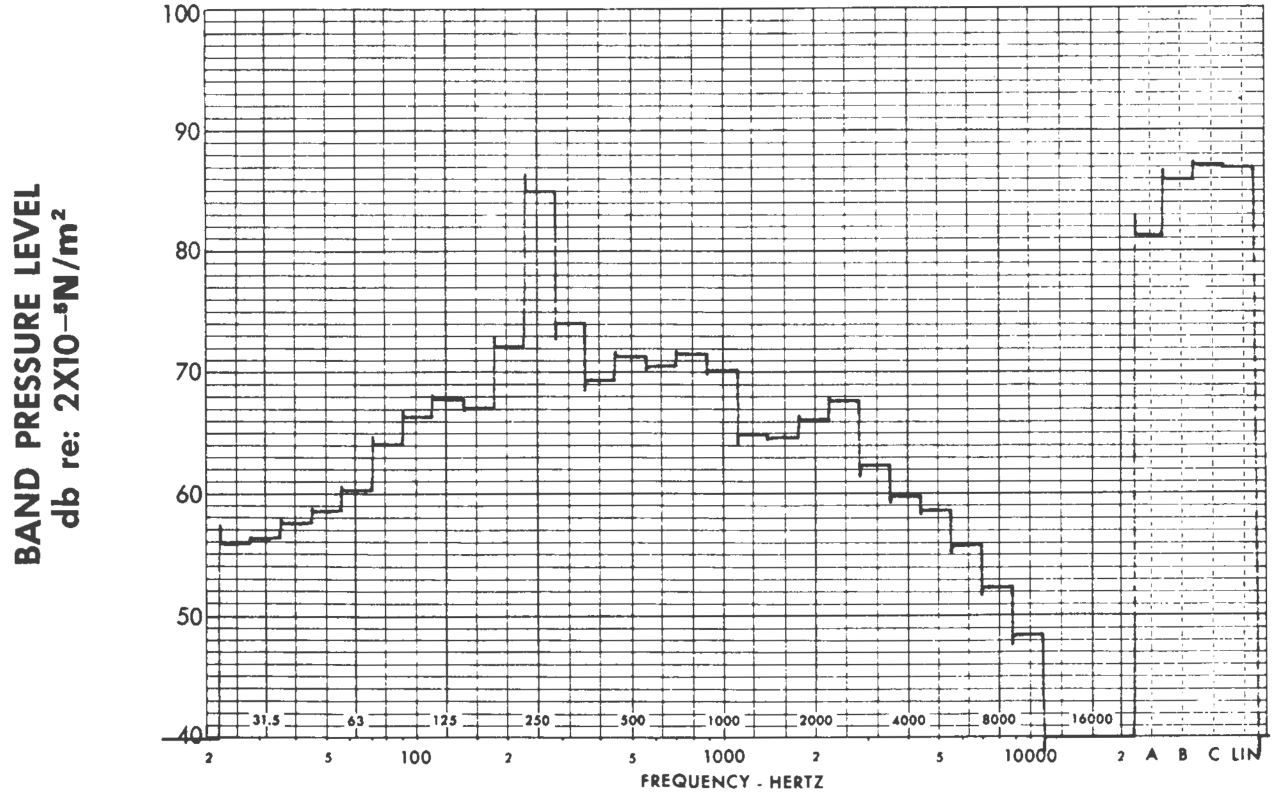
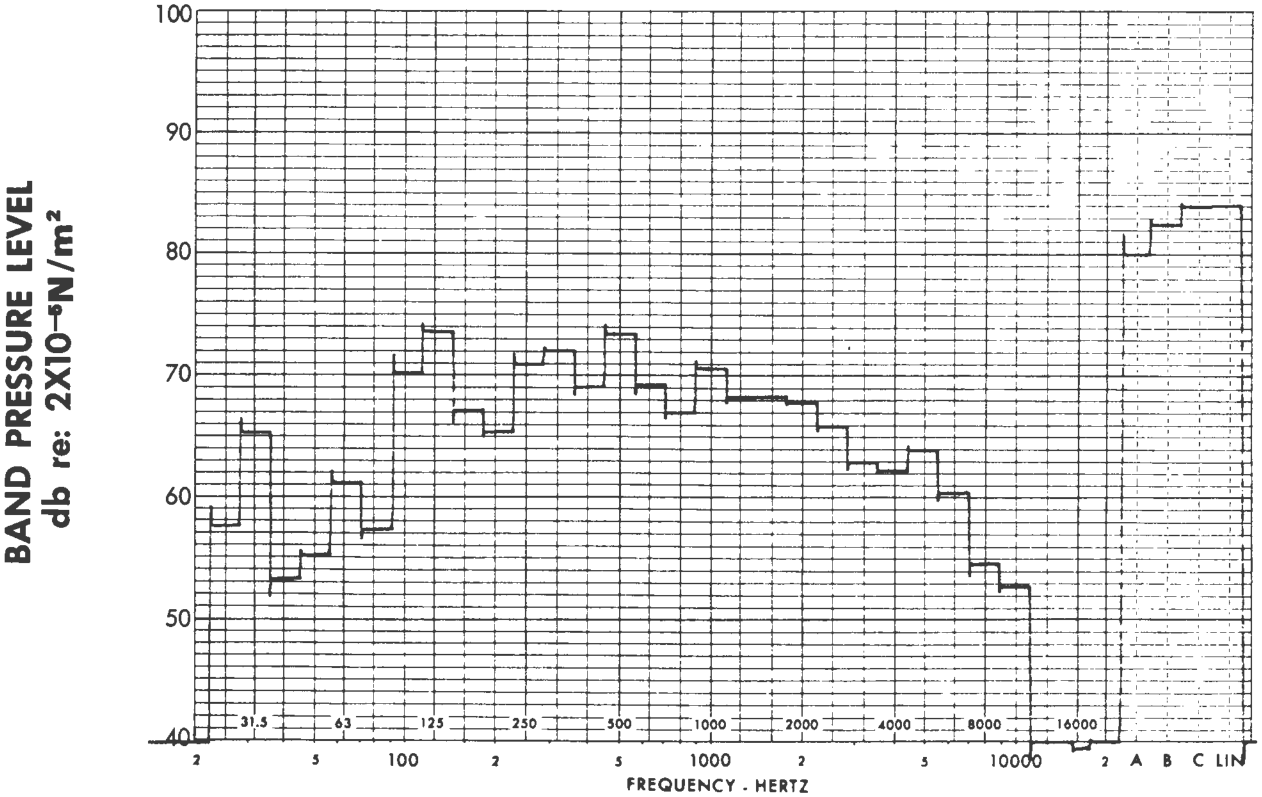


VEHICLE MODEL: DH9502
ENGINE SIDE SHIELDS

RIGHT SIDE



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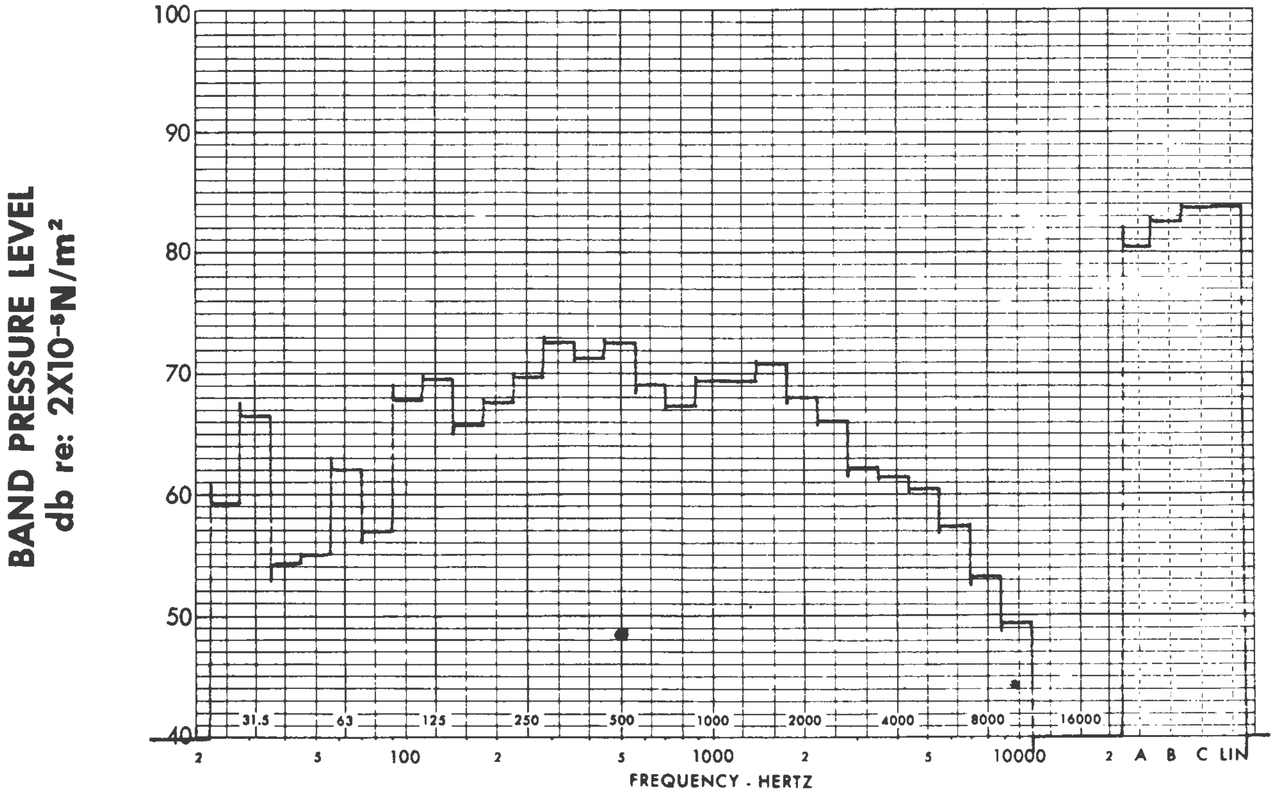
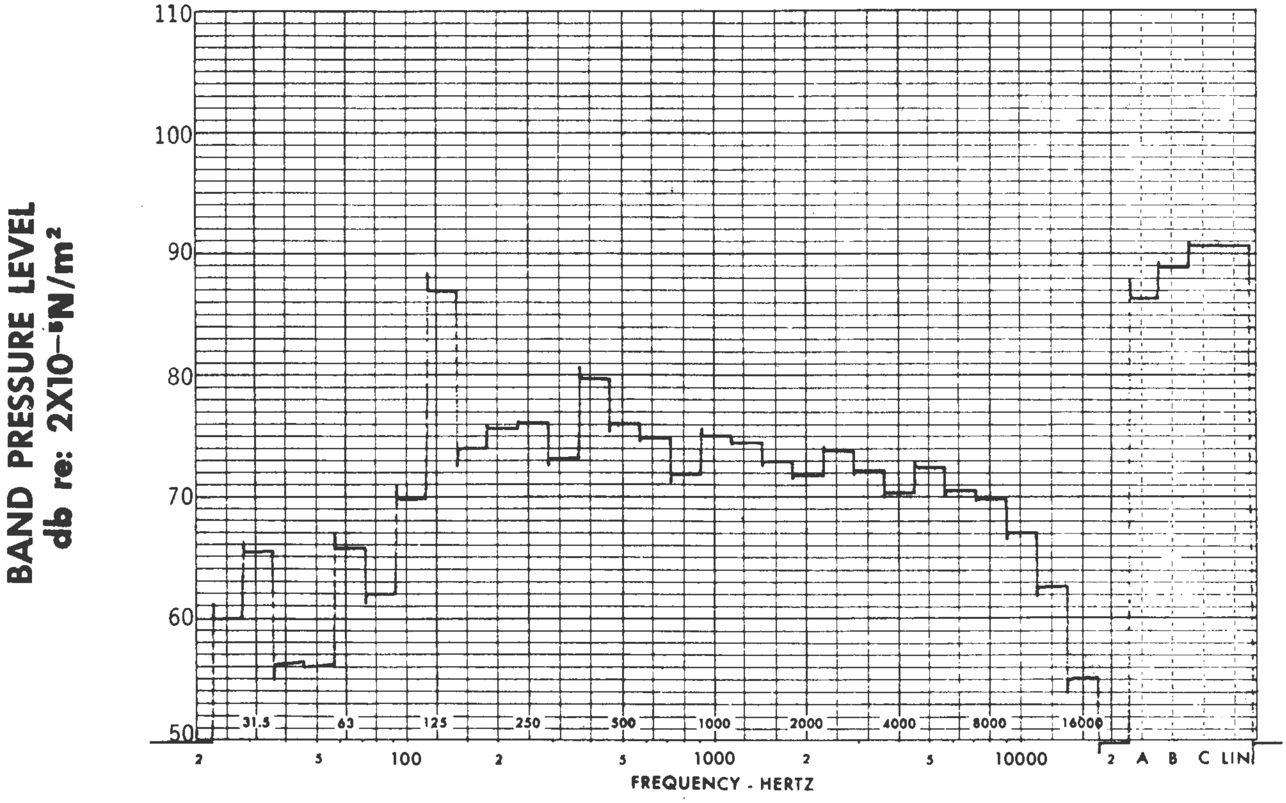
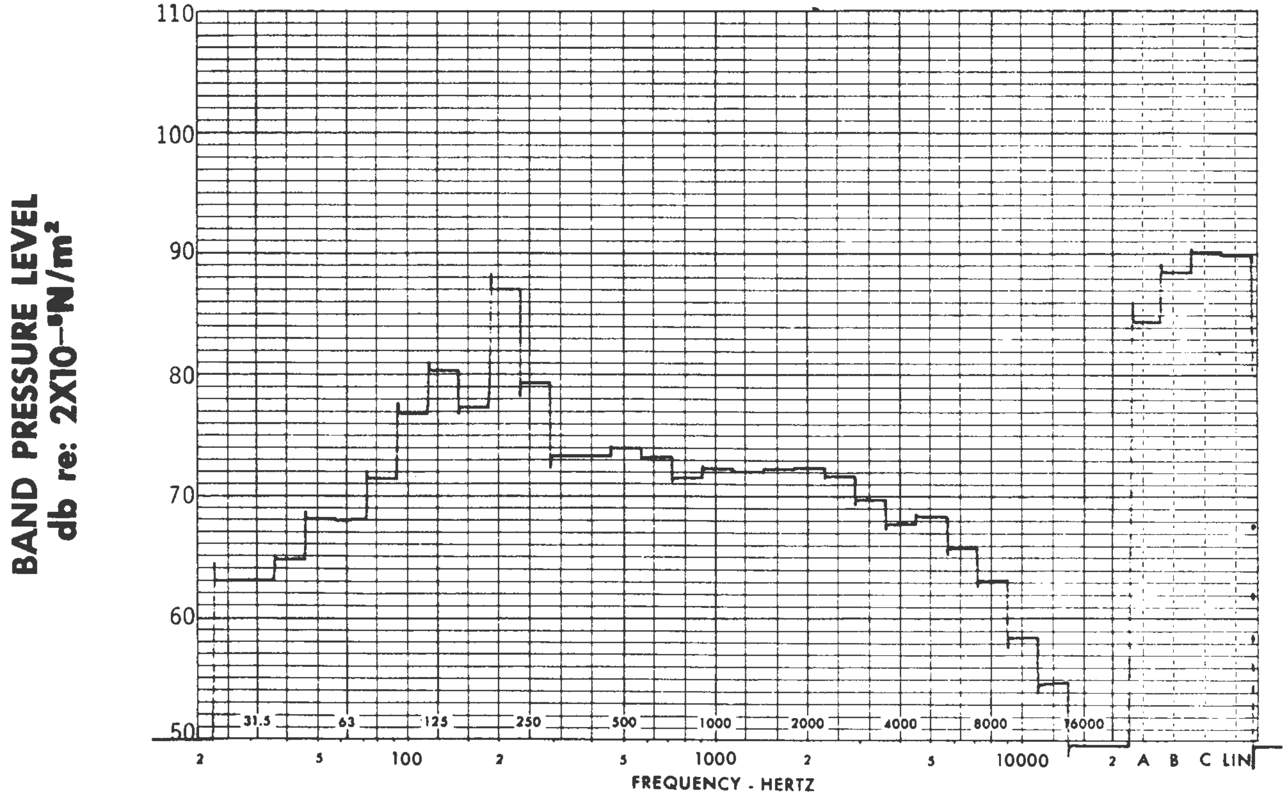


VEHICLE MODEL: DH9502
TOTAL VEHICLE NOISE

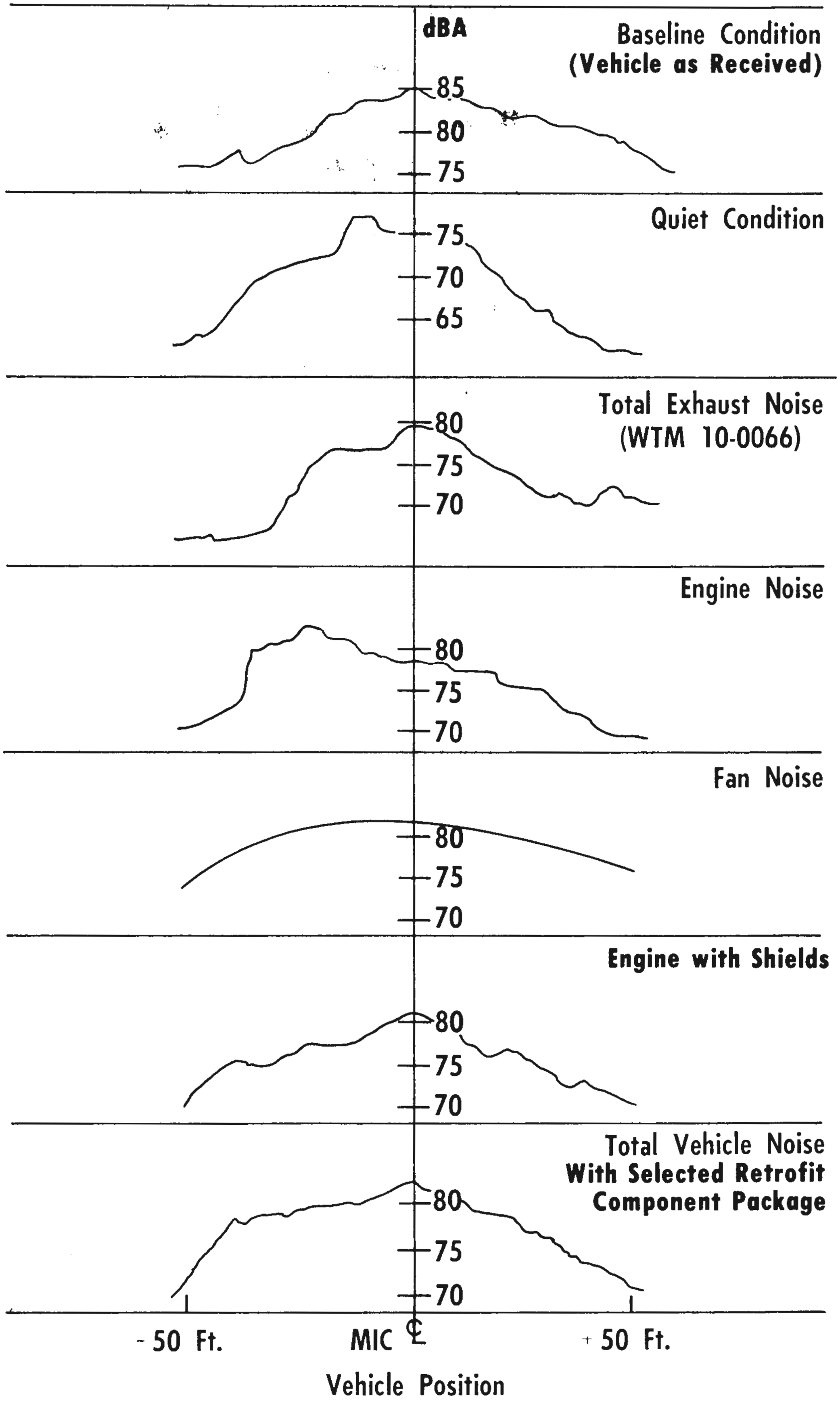
RIGHT SIDE



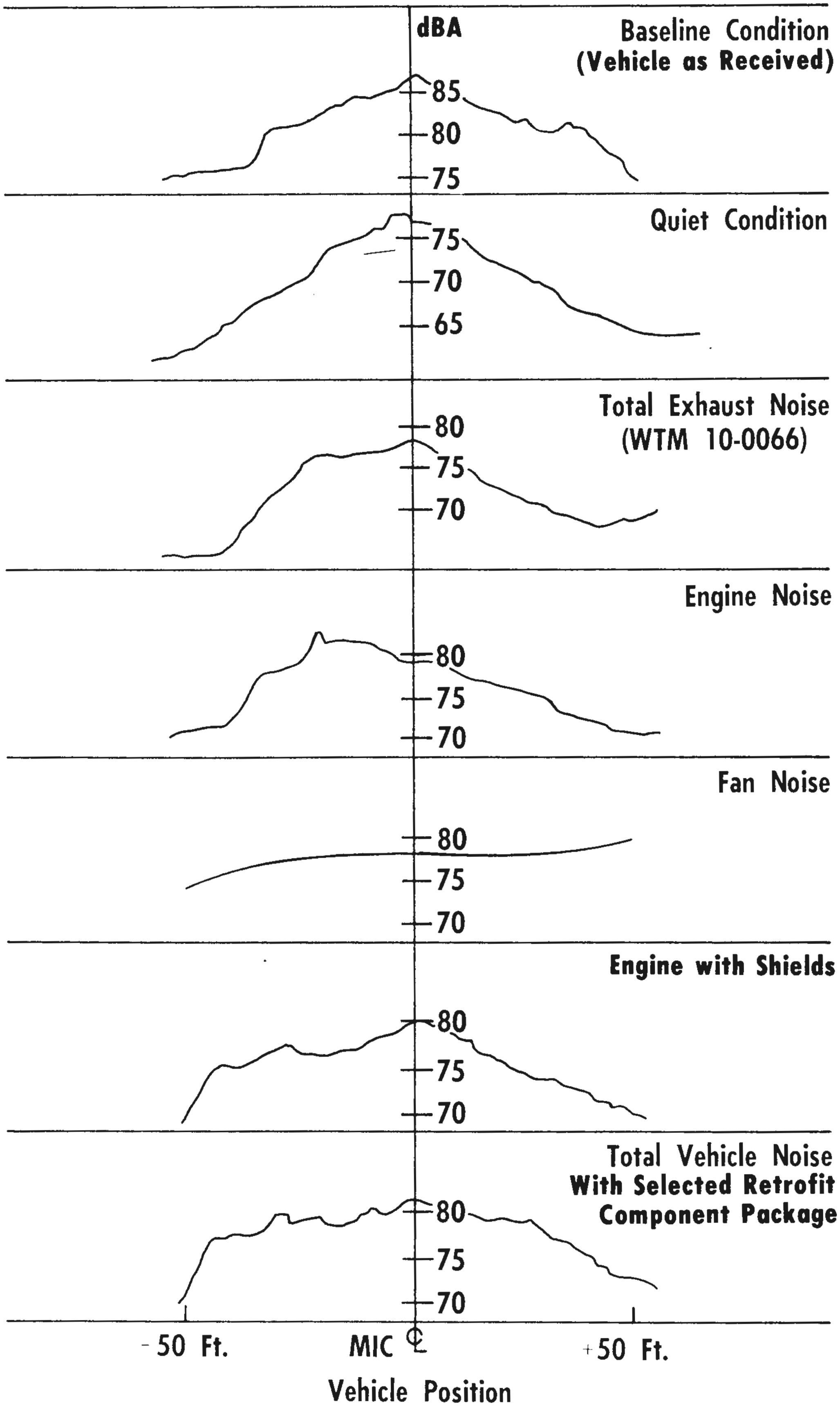
LEFT SIDE



JN9500 RIGHT SIDE

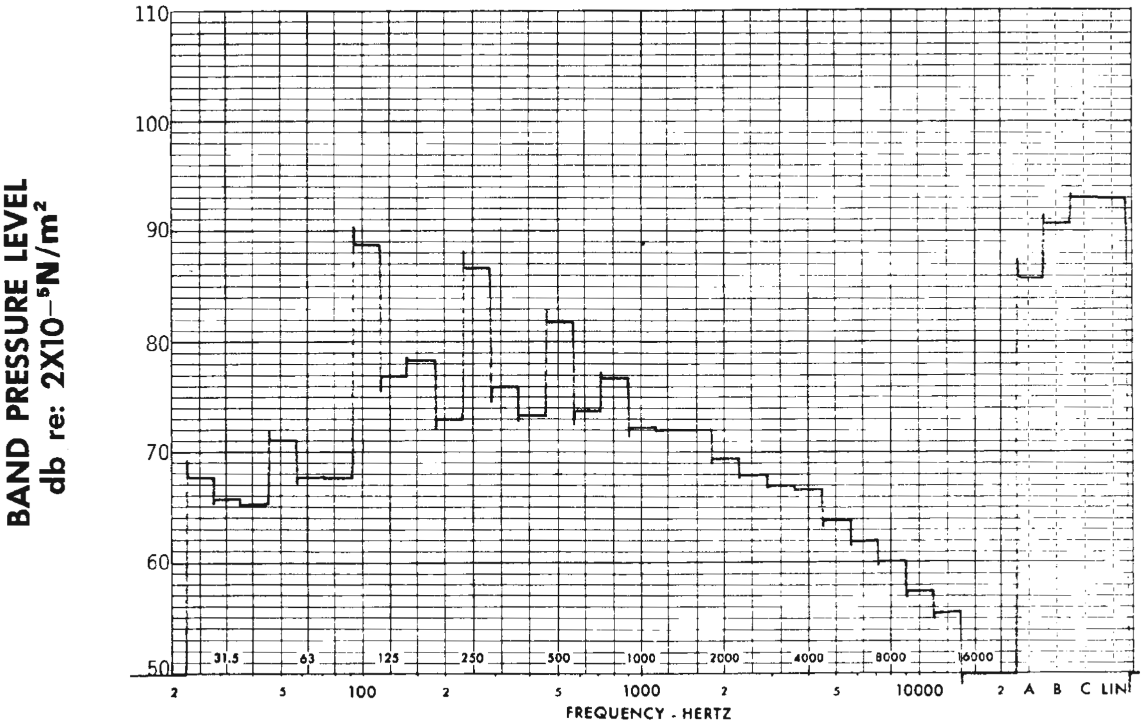


JN9500 LEFT SIDE



VEHICLE MODEL: JN9500
BASELINE TOTAL VEHICLE NOISE

RIGHT SIDE



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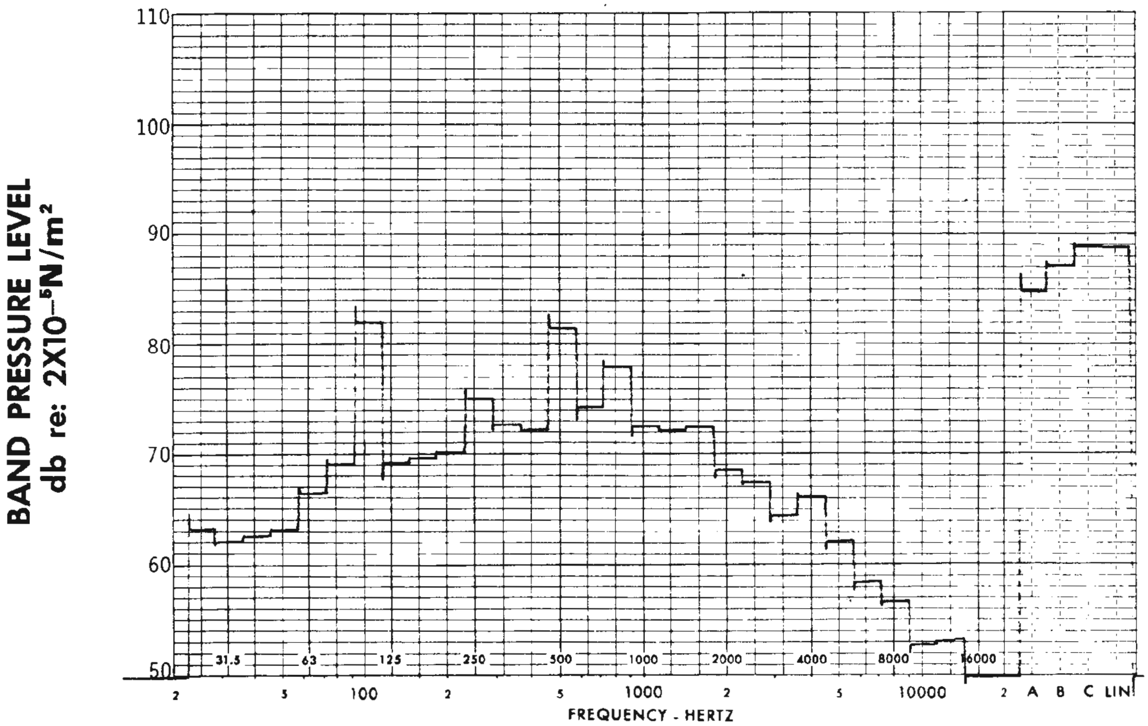
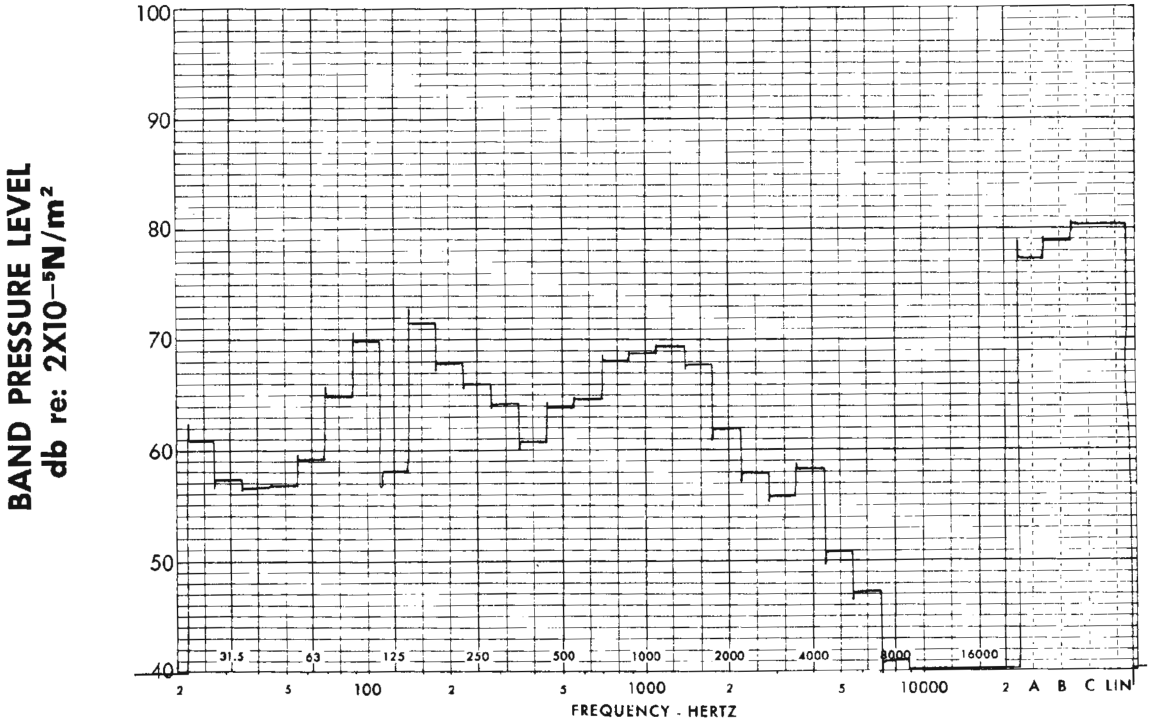


VEHICLE MODEL: JN9500
TOTAL QUIET

RIGHT SIDE



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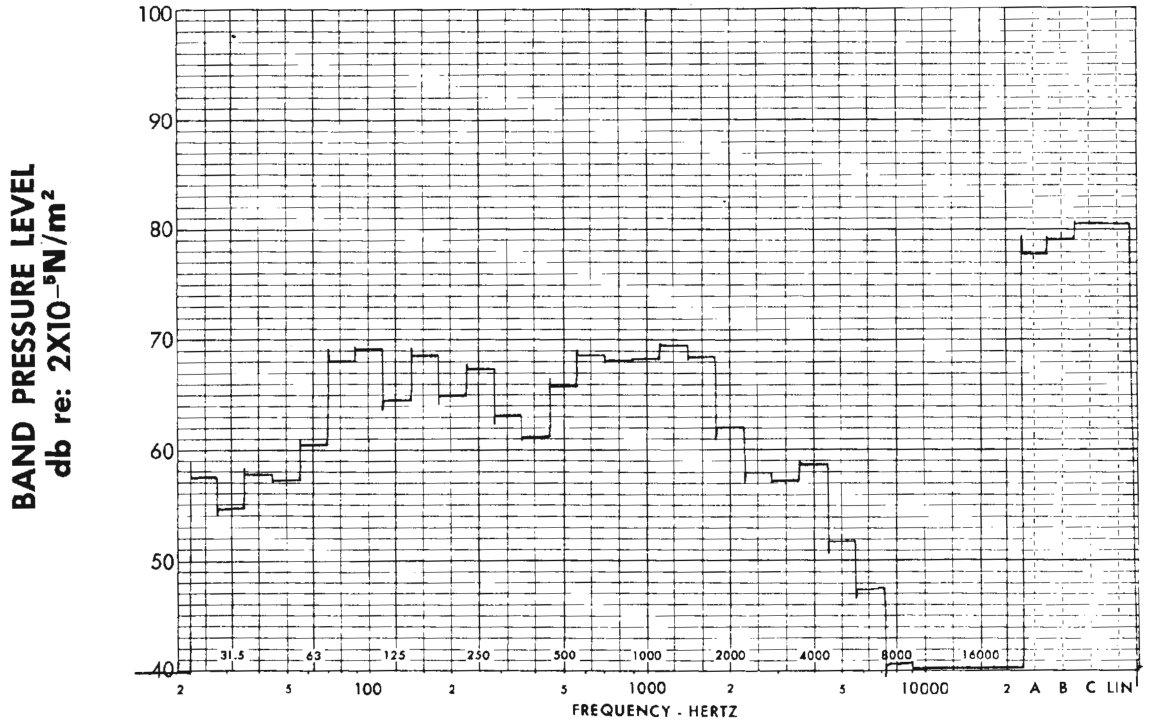
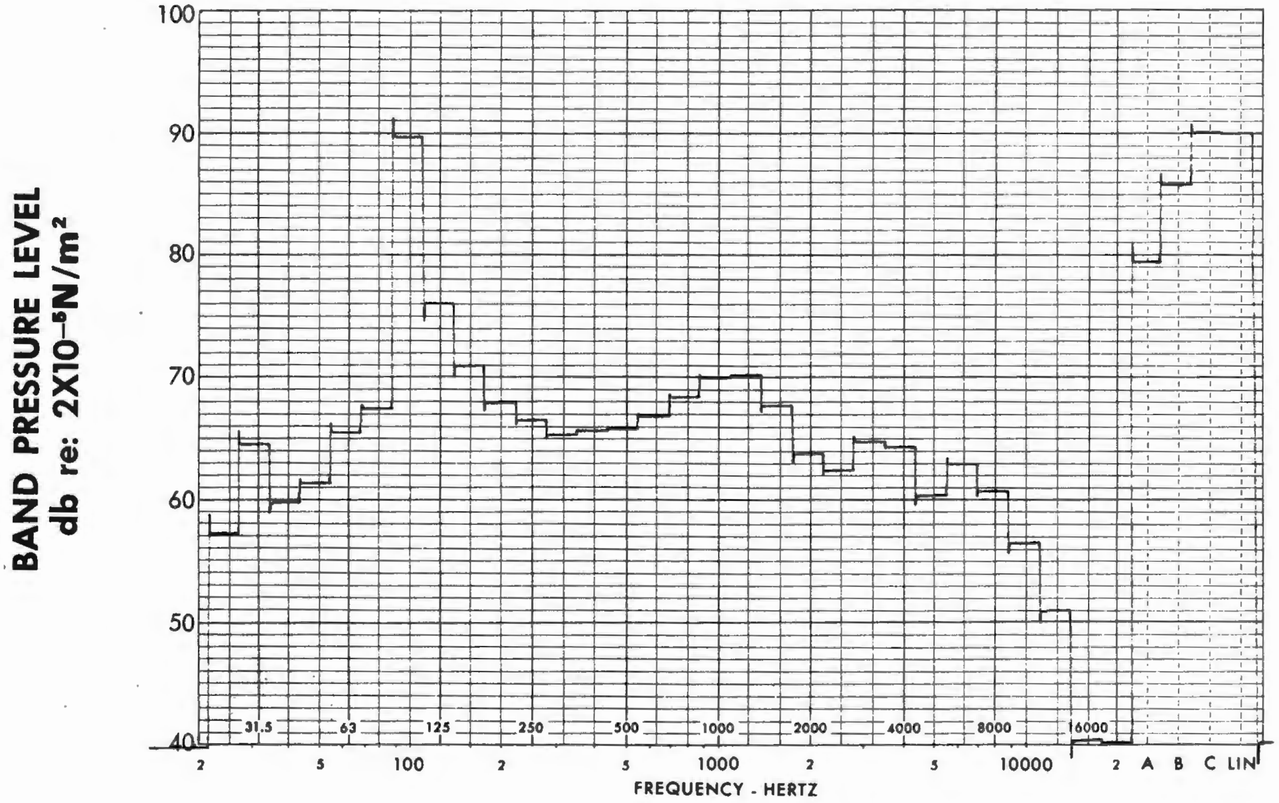


VEHICLE MODEL: JN9500
EXHAUST NOISE WTM 10-0066

RIGHT SIDE



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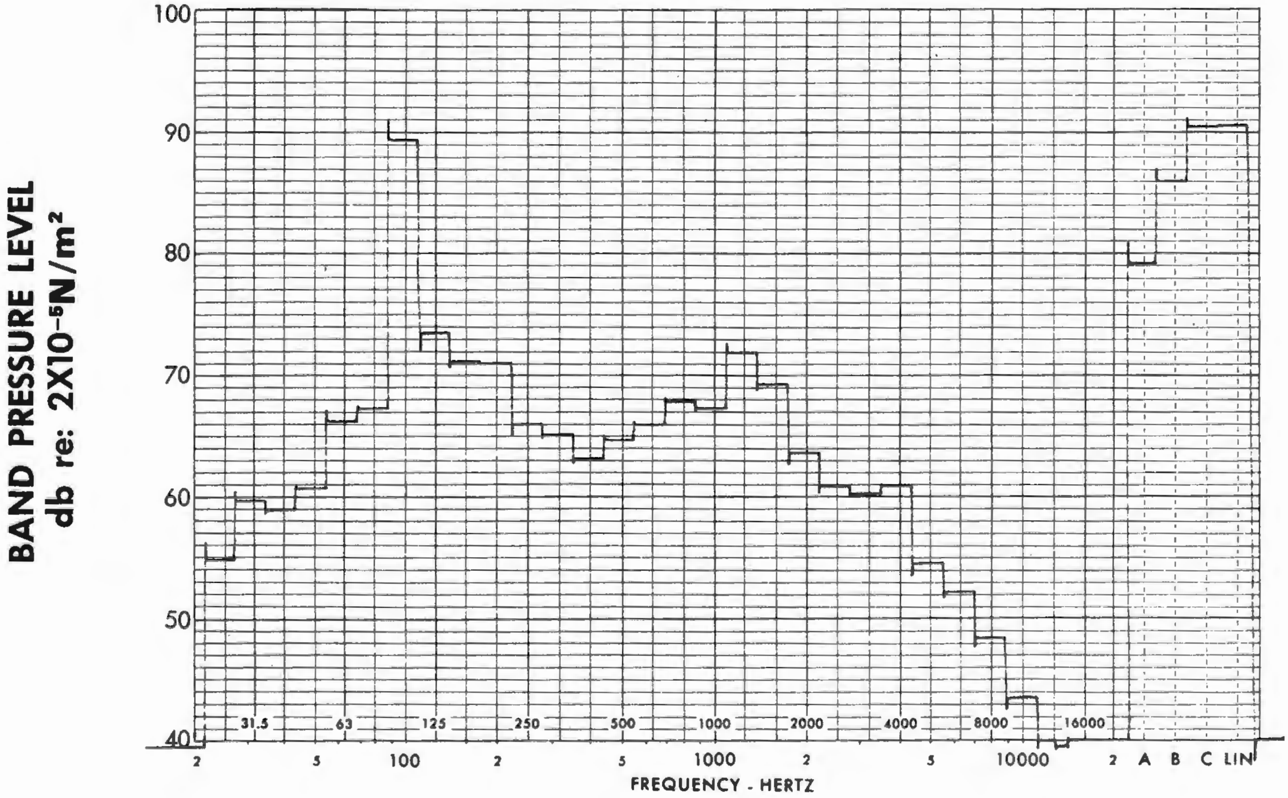
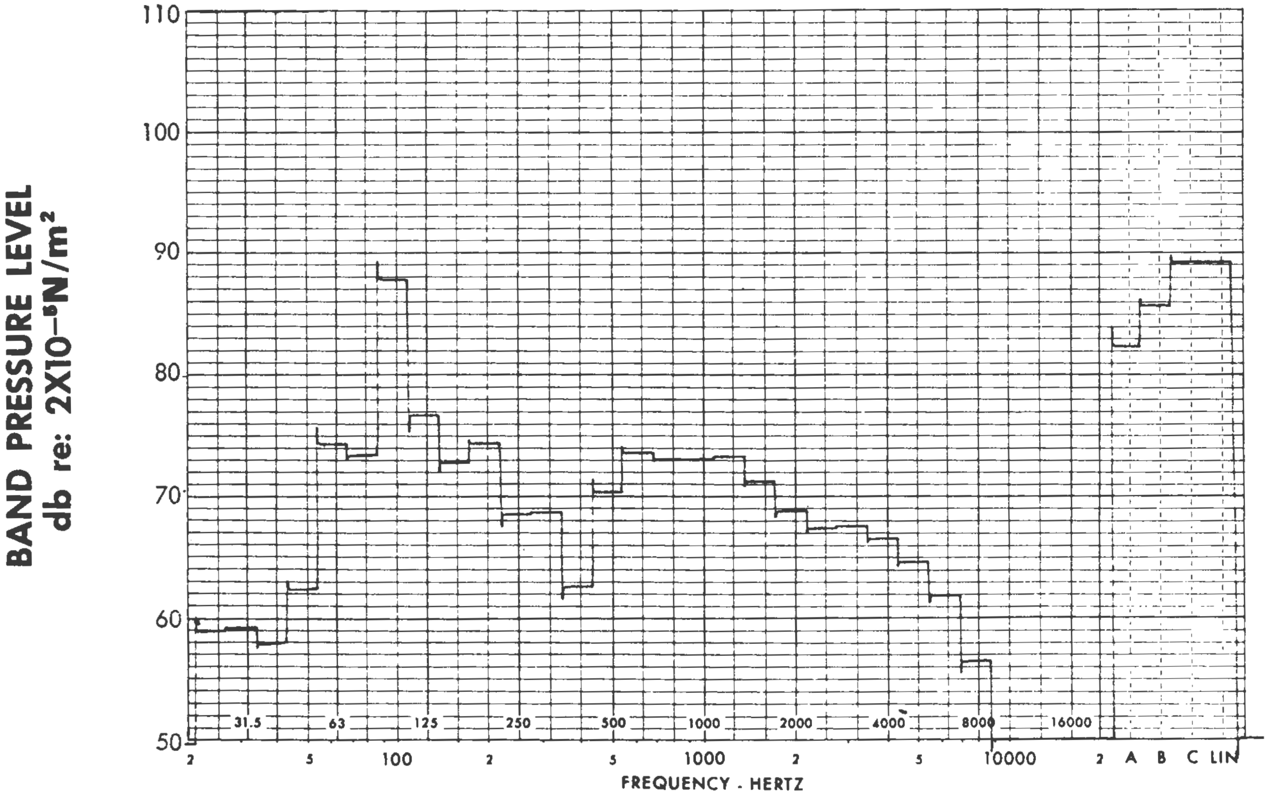


VEHICLE MODEL: JN9500
EXHAUST NOISE - STEMCO 9400



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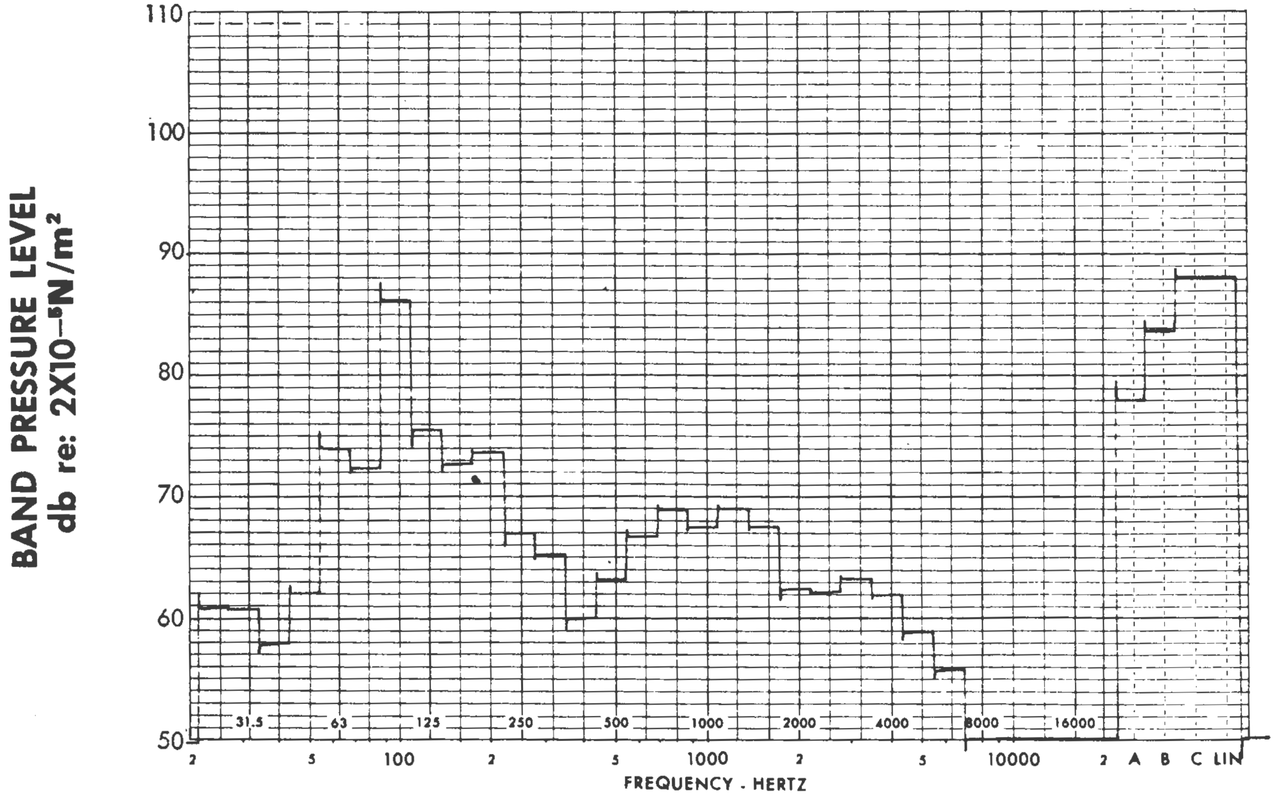
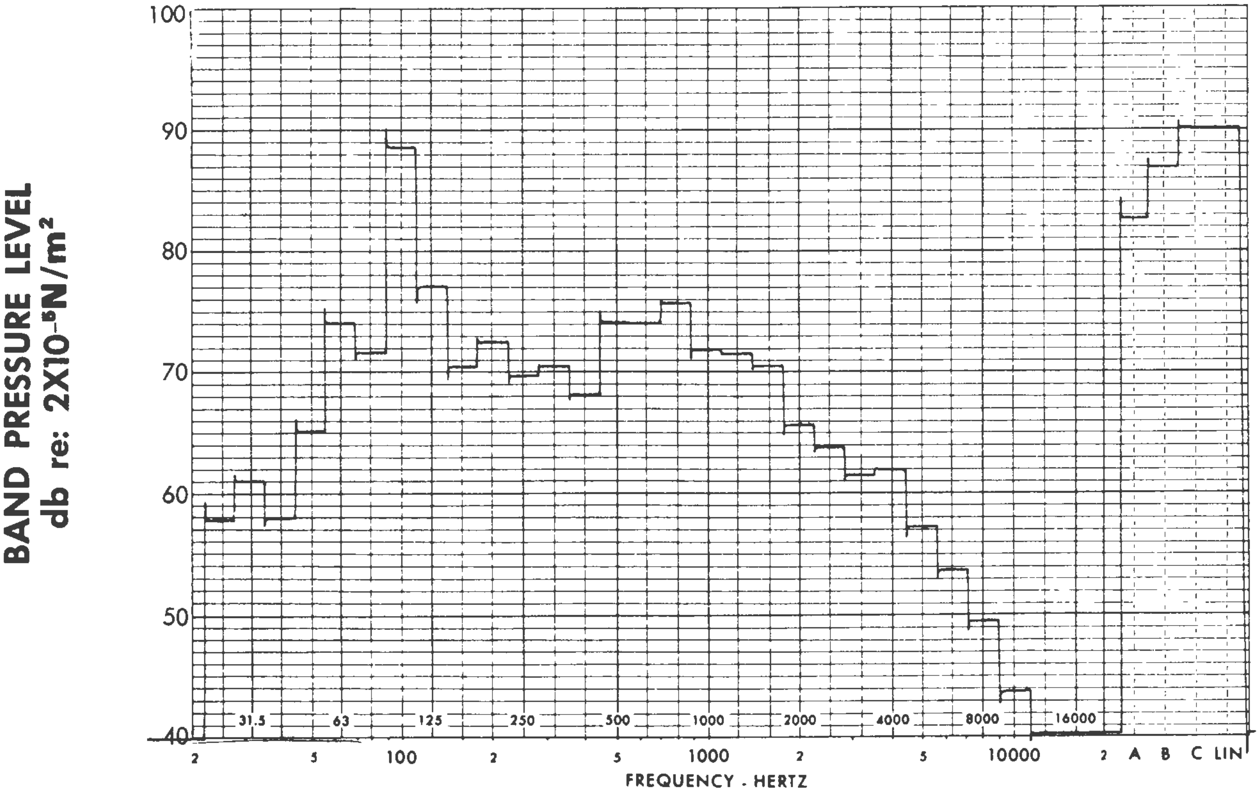


LEFT SIDE

VEHICLE MODEL: JN9500
EXHAUST NOISE - PRODUCTION

RIGHT SIDE



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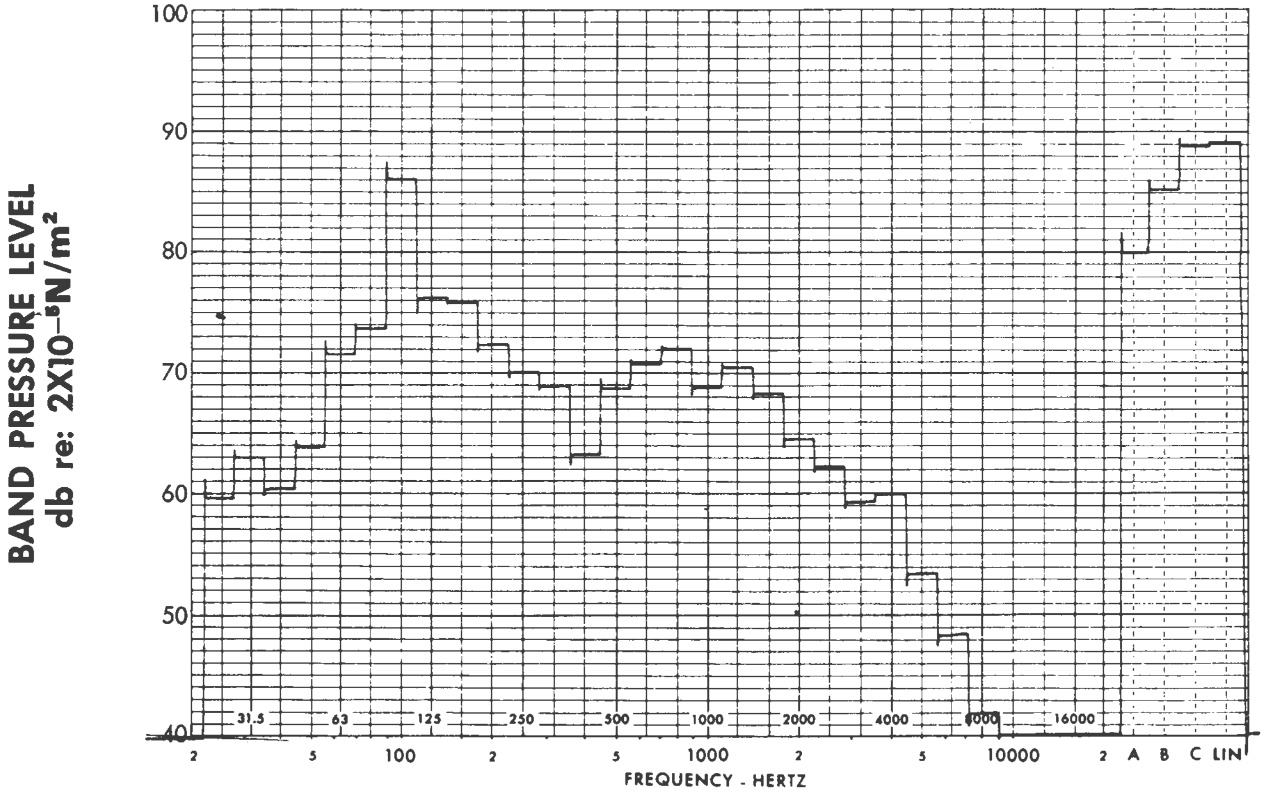
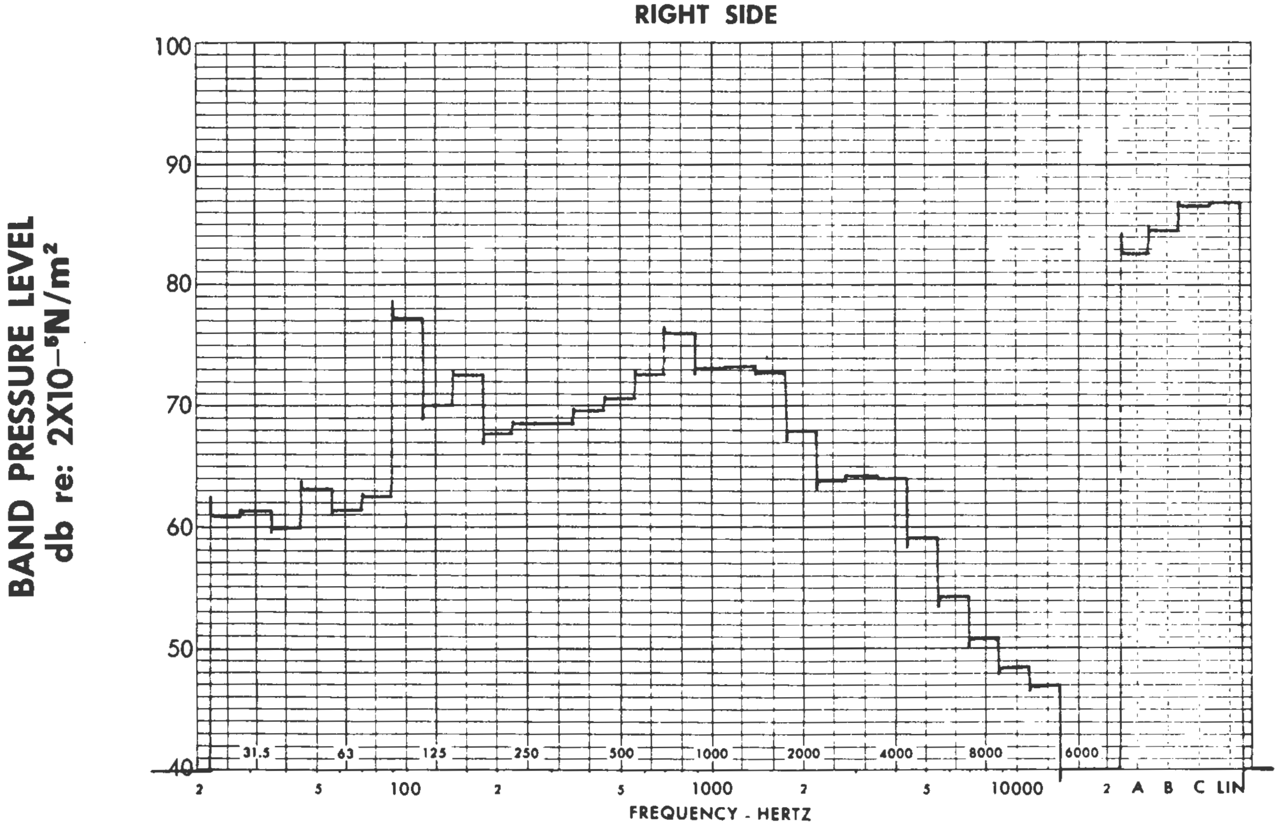
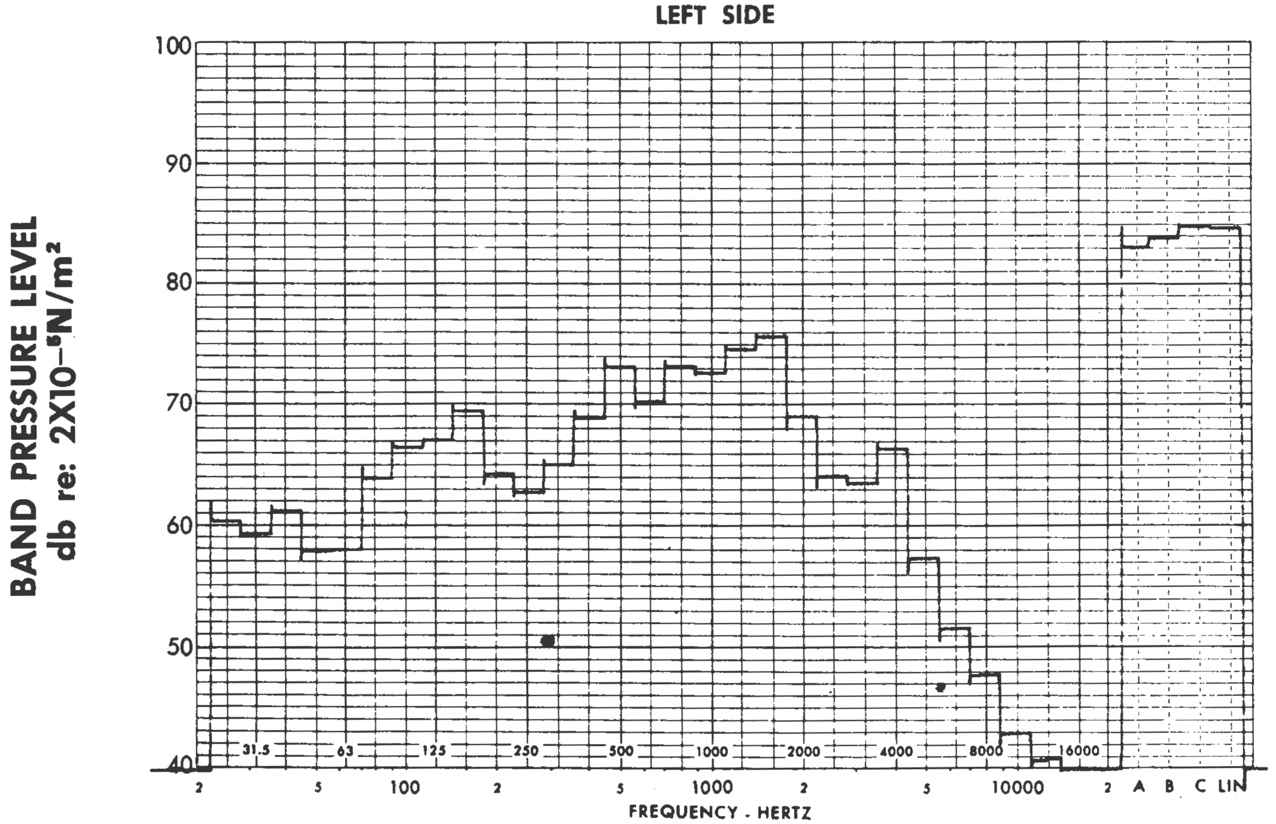


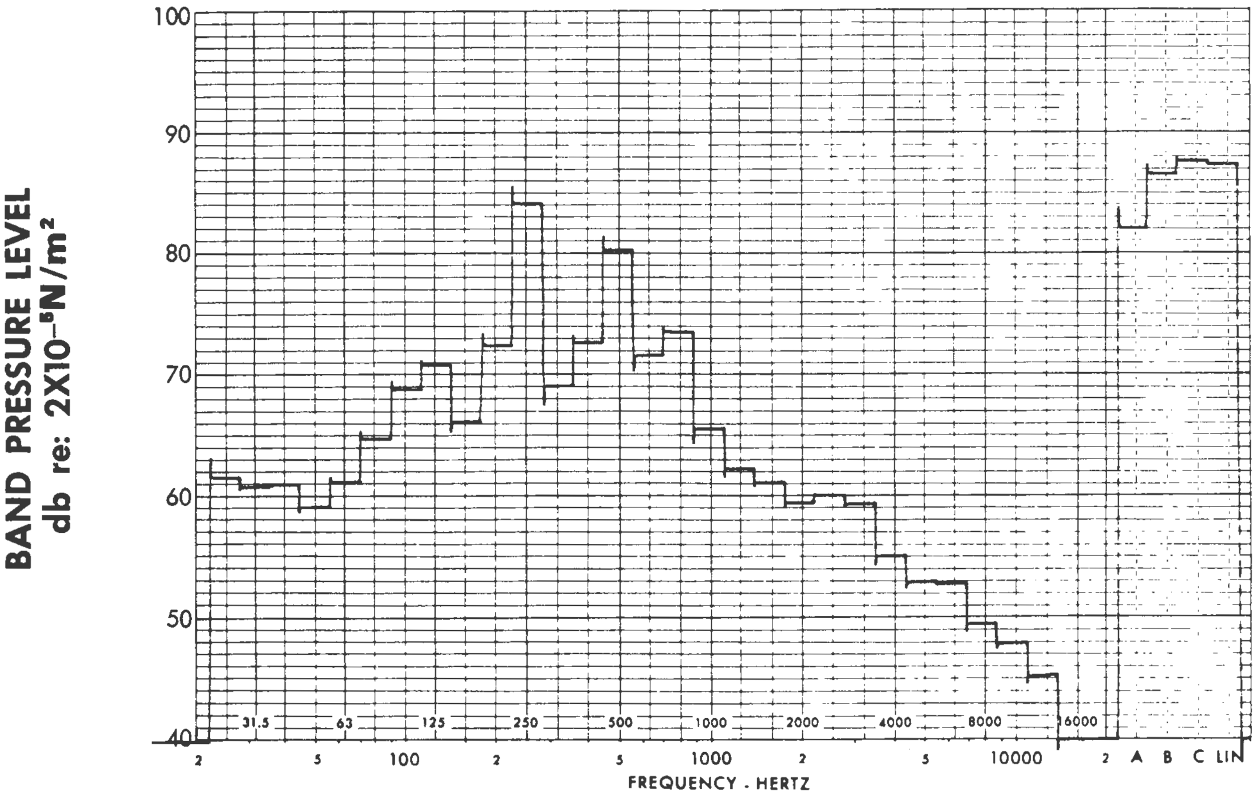
VEHICLE MODEL: JN9500
ENGINE NOISE





VEHICLE MODEL: JN9500
FAN NOISE

RIGHT SIDE



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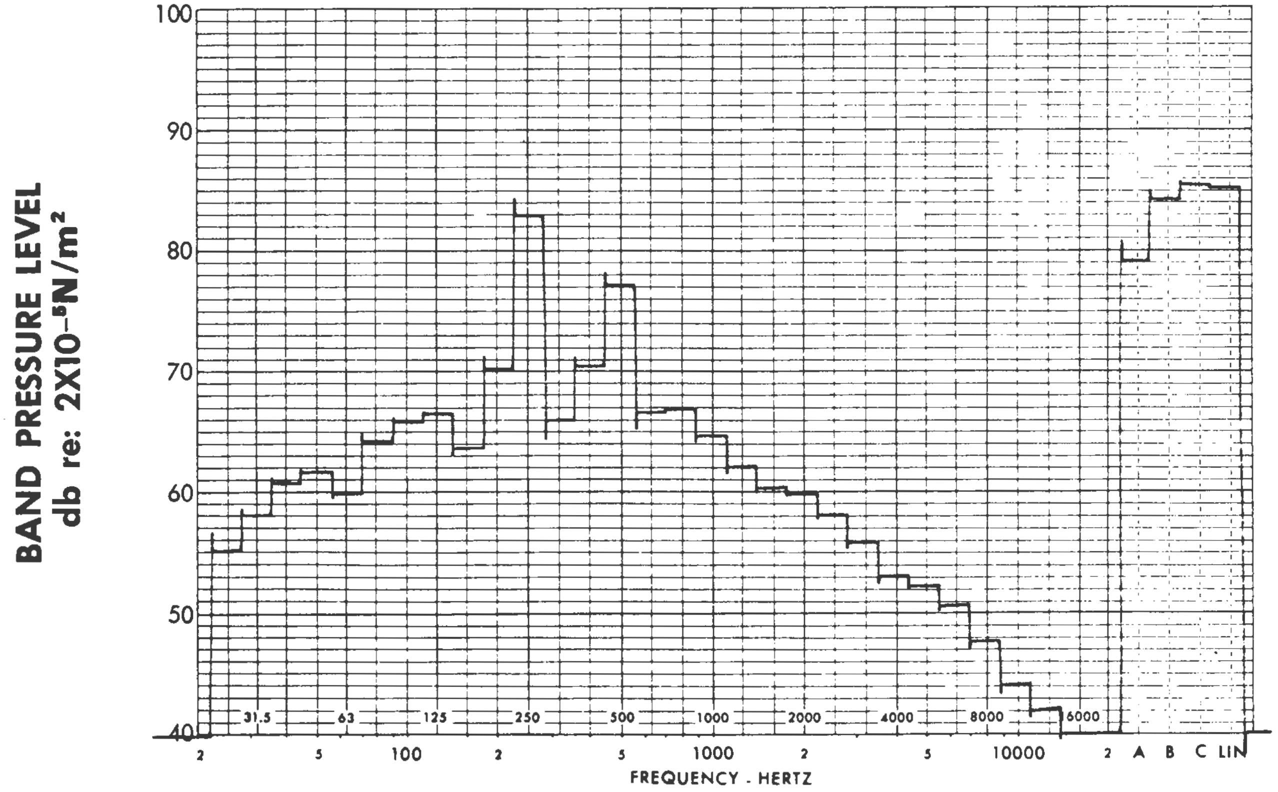
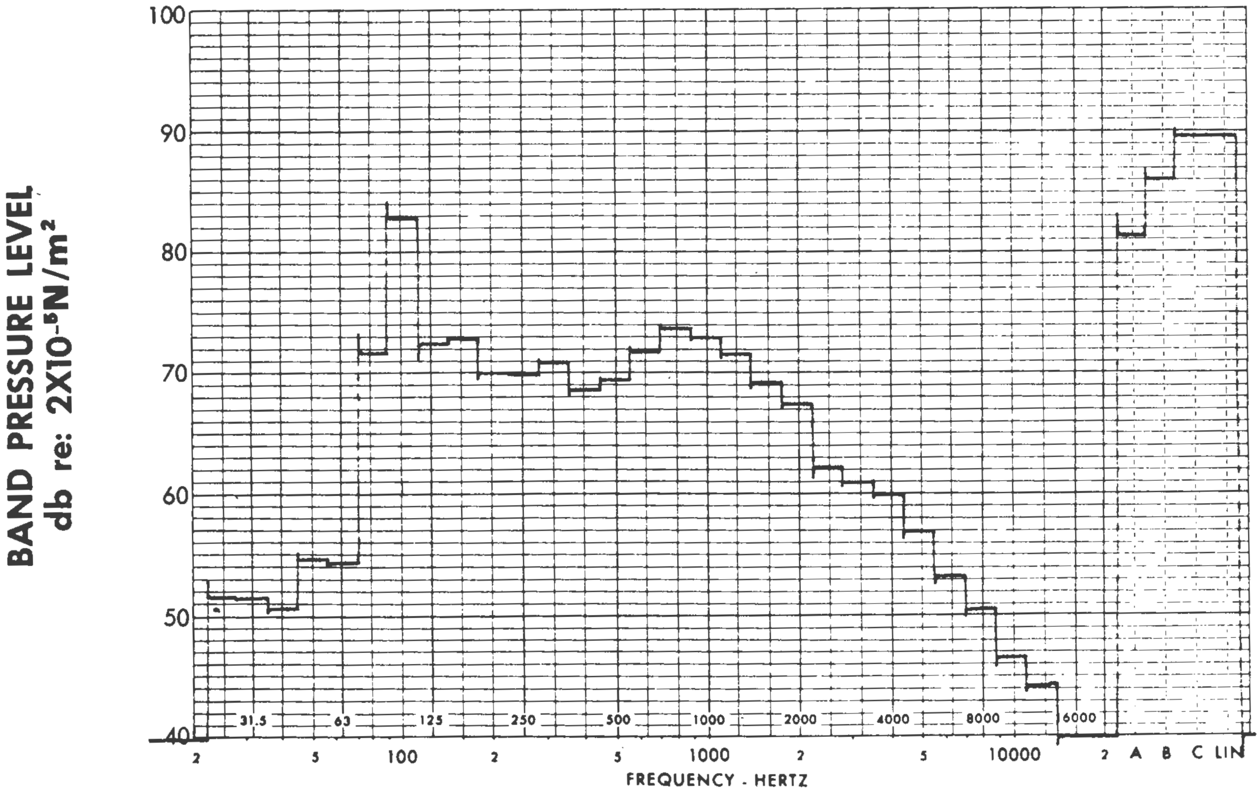
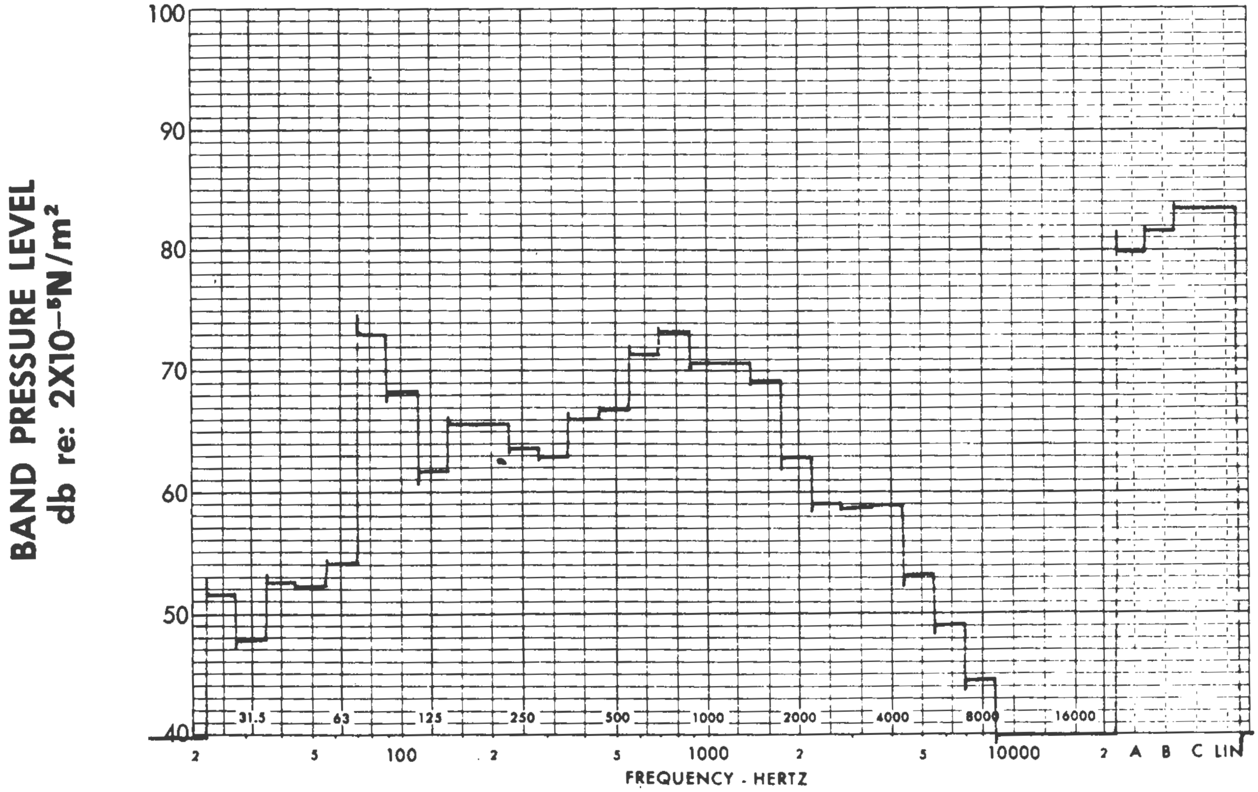


VEHICLE MODEL: JN9500
CUMMINS ENGINE SHIELDS

RIGHT SIDE

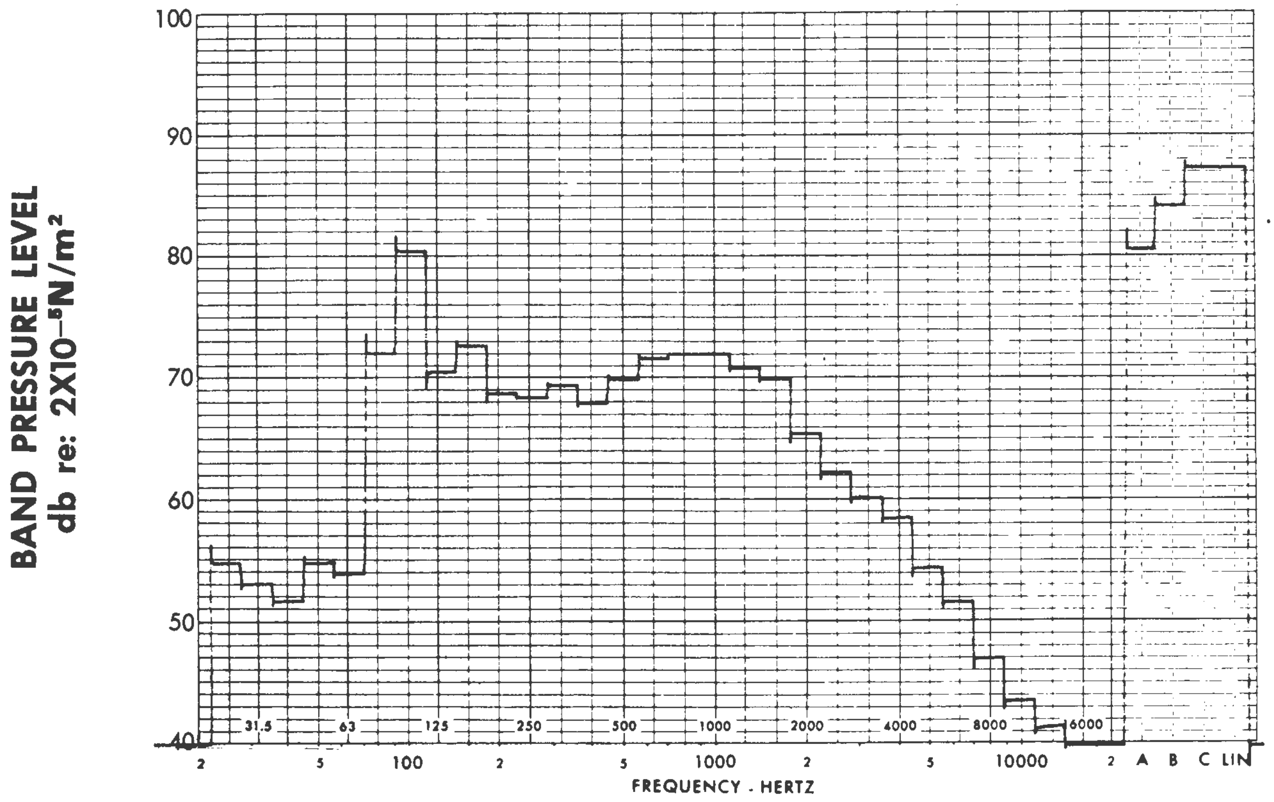


LEFT SIDE



VEHICLE MODEL: JN9500
ENGINE SIDE SHIELDS

RIGHT SIDE



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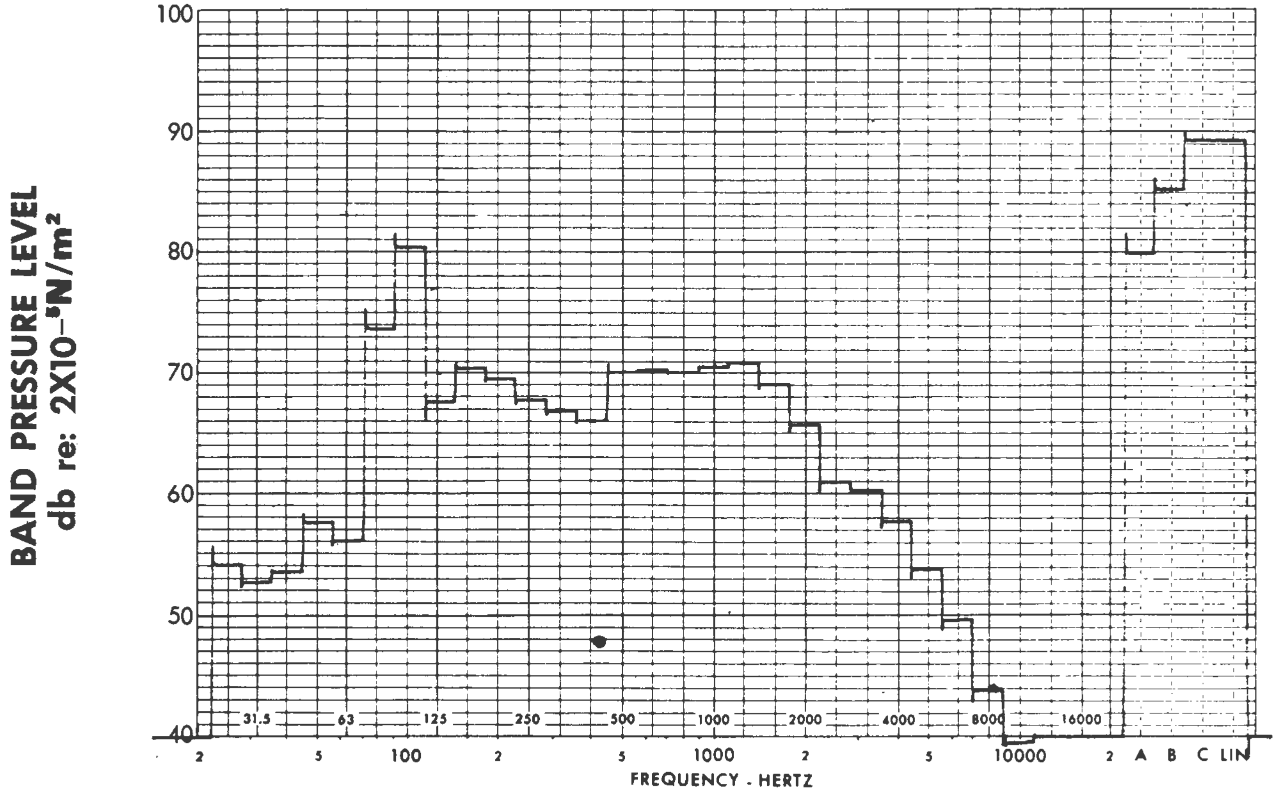
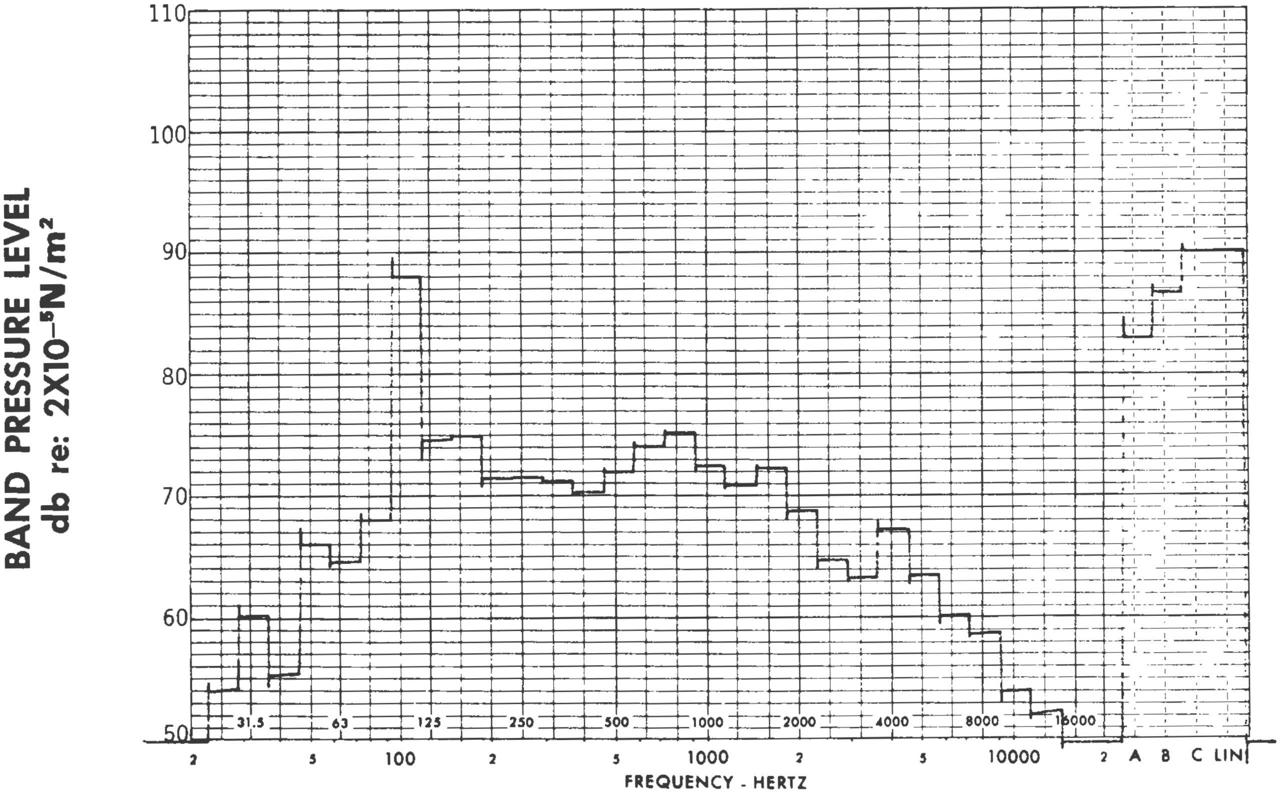
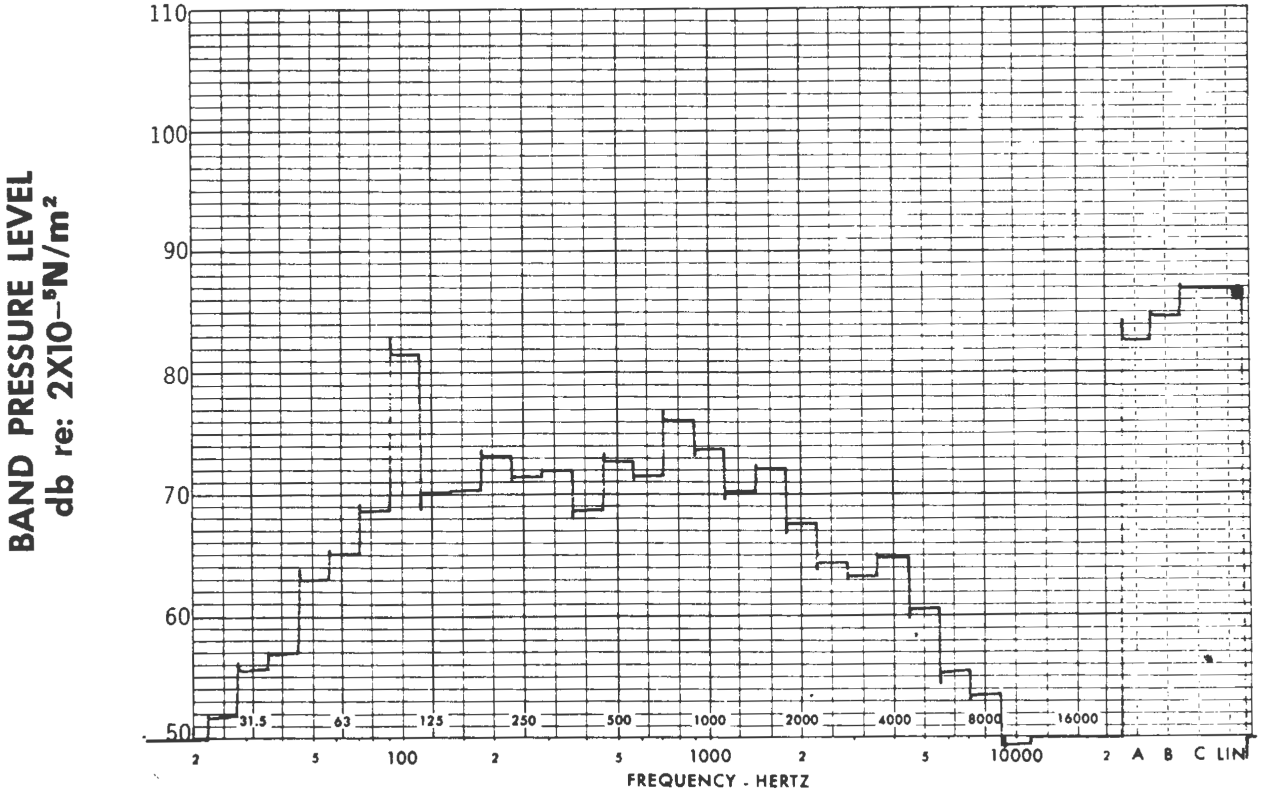


VEHICLE MODEL: JN9500
TOTAL VEHICLE NOISE

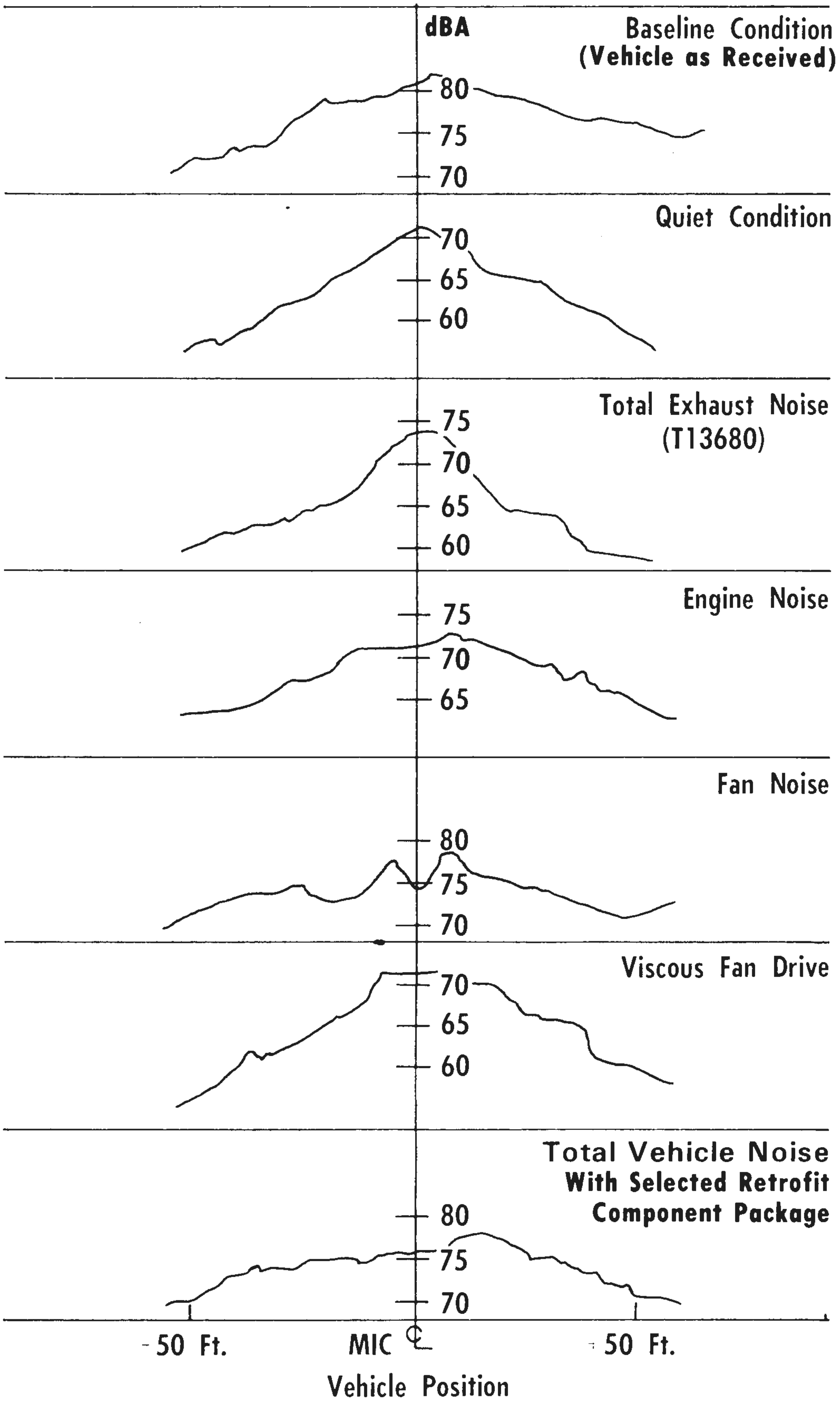
RIGHT SIDE



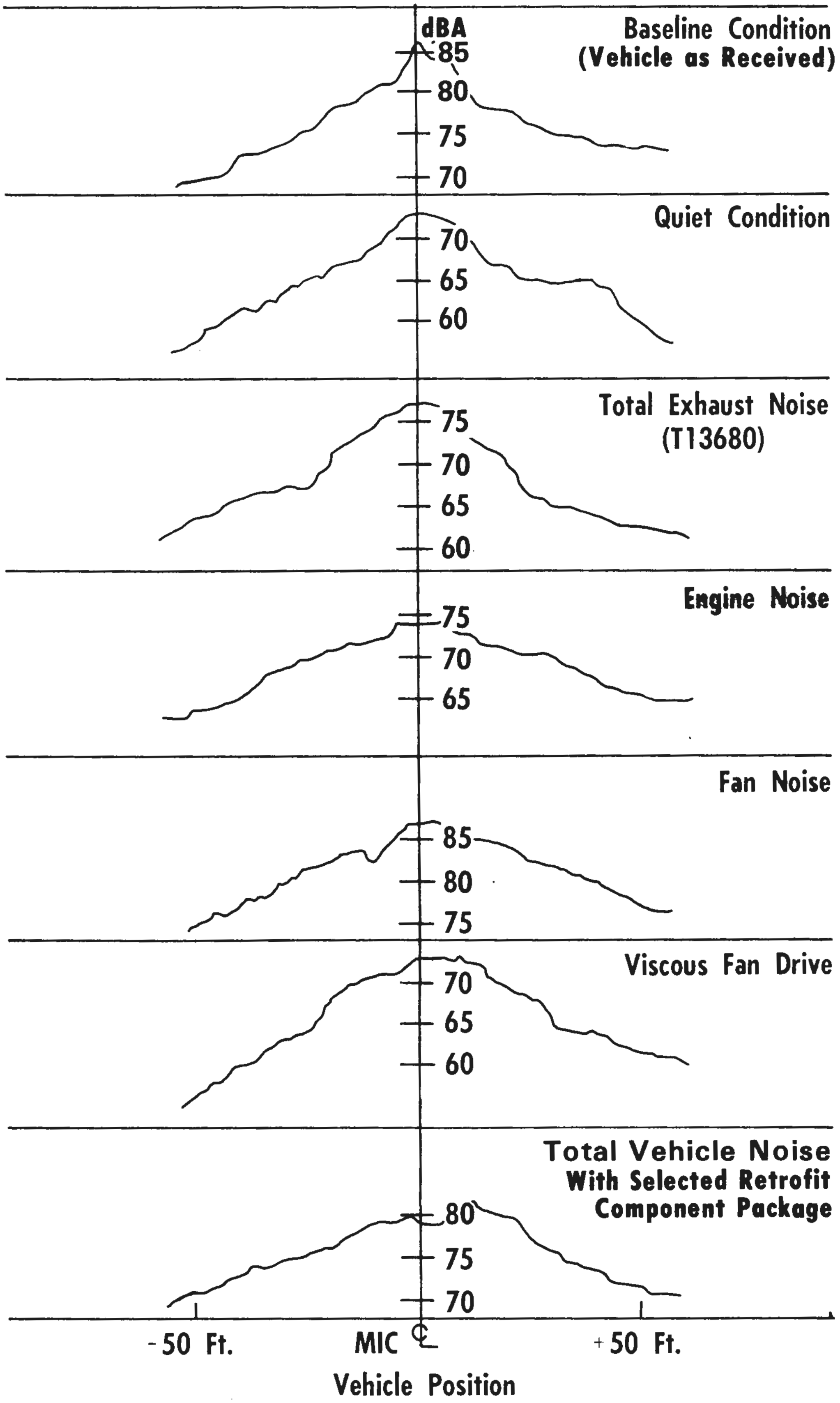
LEFT SIDE



T8H5305 RIGHT SIDE

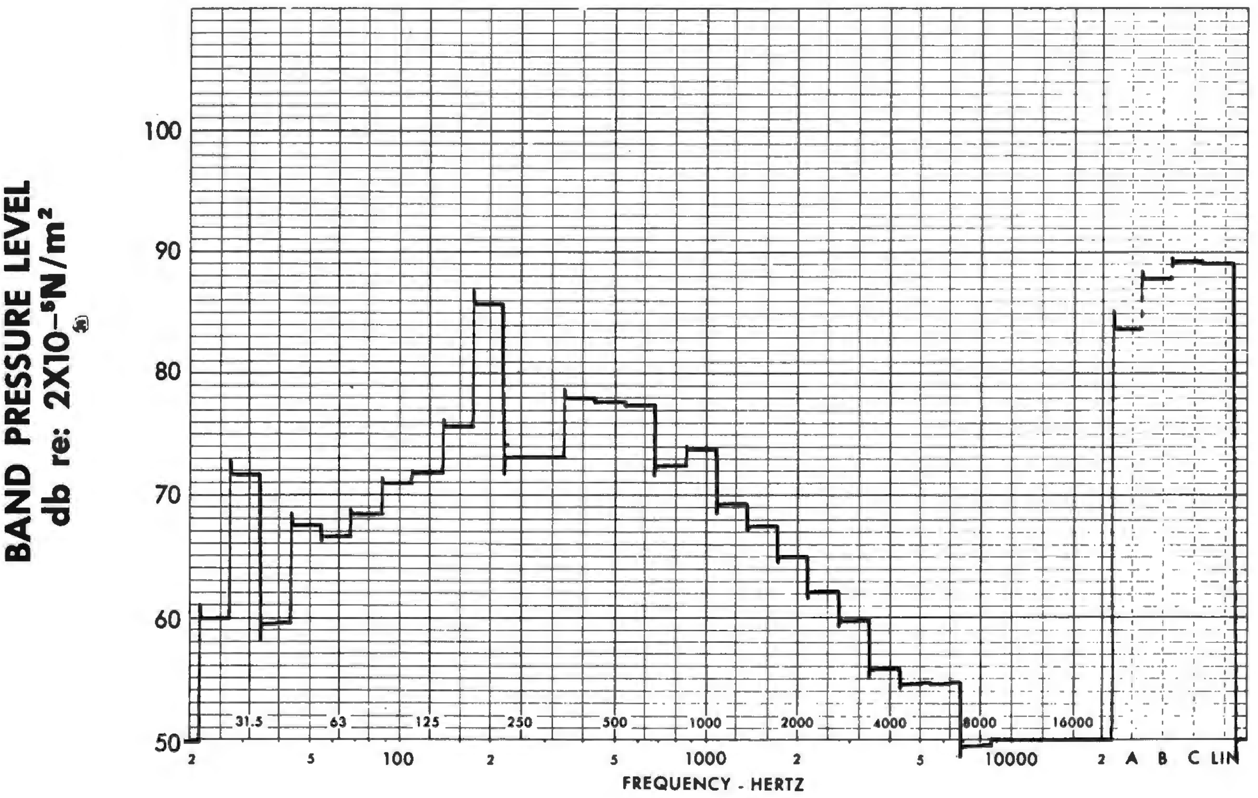


T8H5305 LEFT SIDE

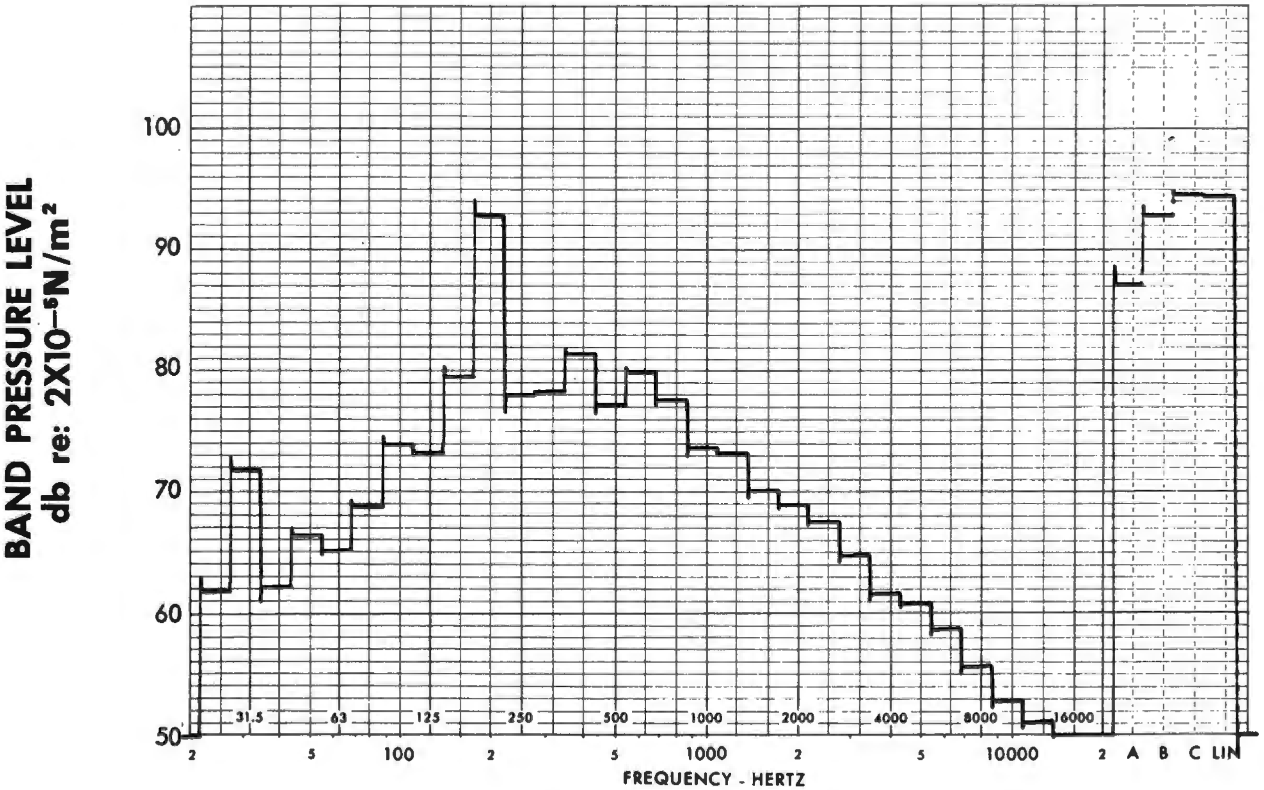


VEHICLE MODEL: T8H5305
TOTAL VEHICLE NOISE

RIGHT SIDE

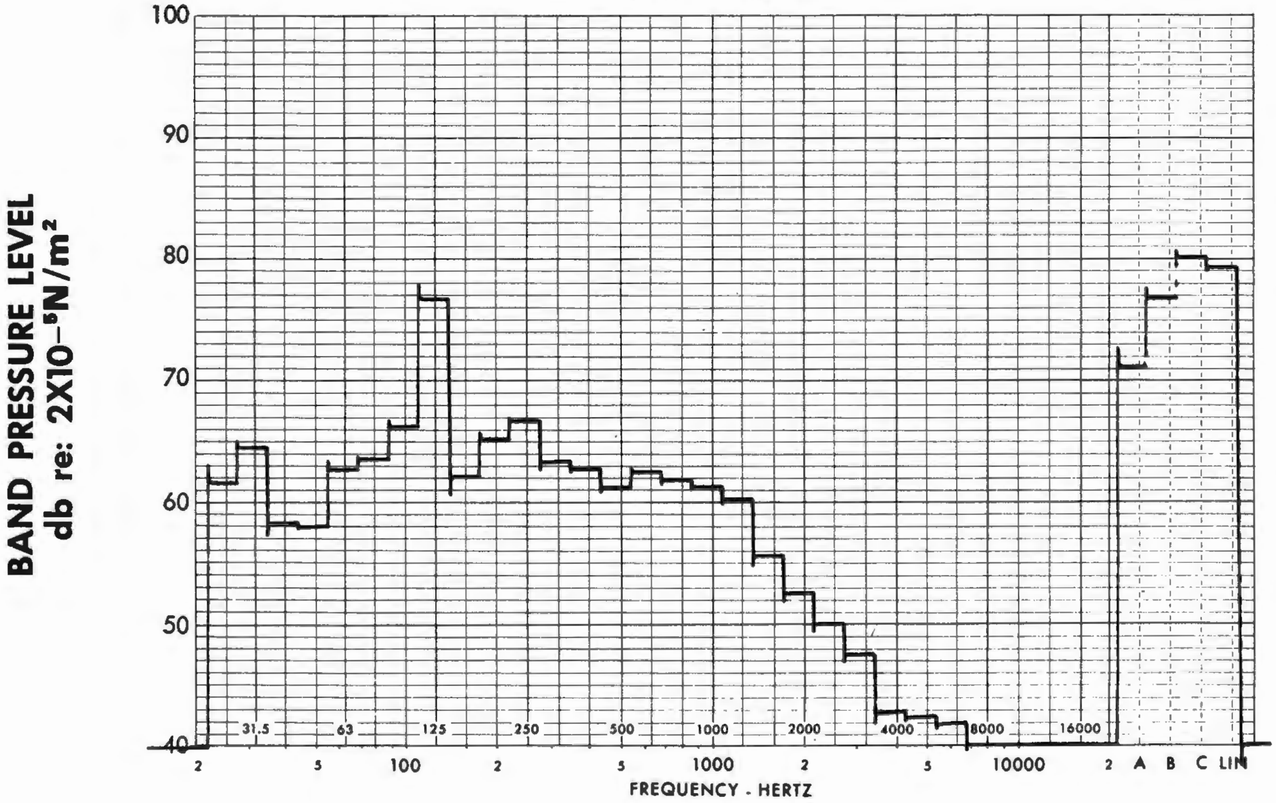


LEFT SIDE



VEHICLE MODEL: T8H5305
TOTAL QUIET

RIGHT SIDE



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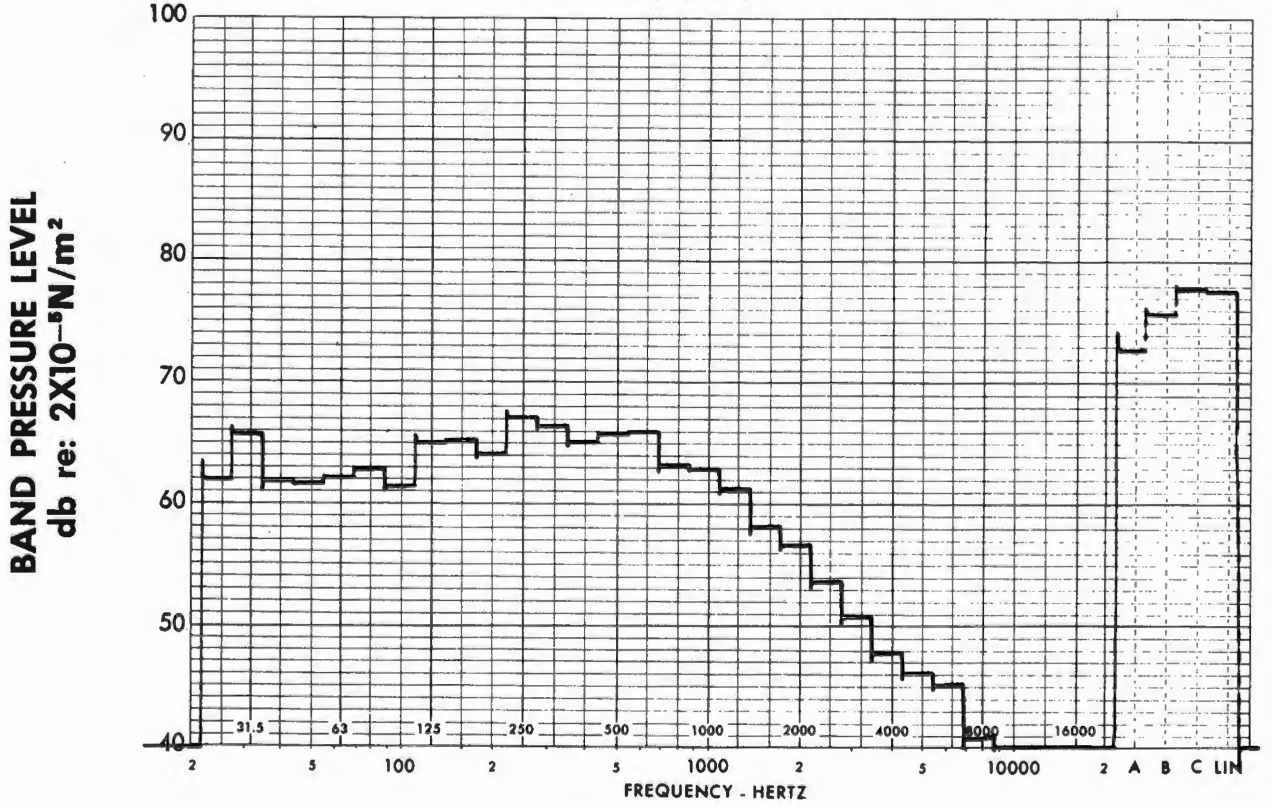
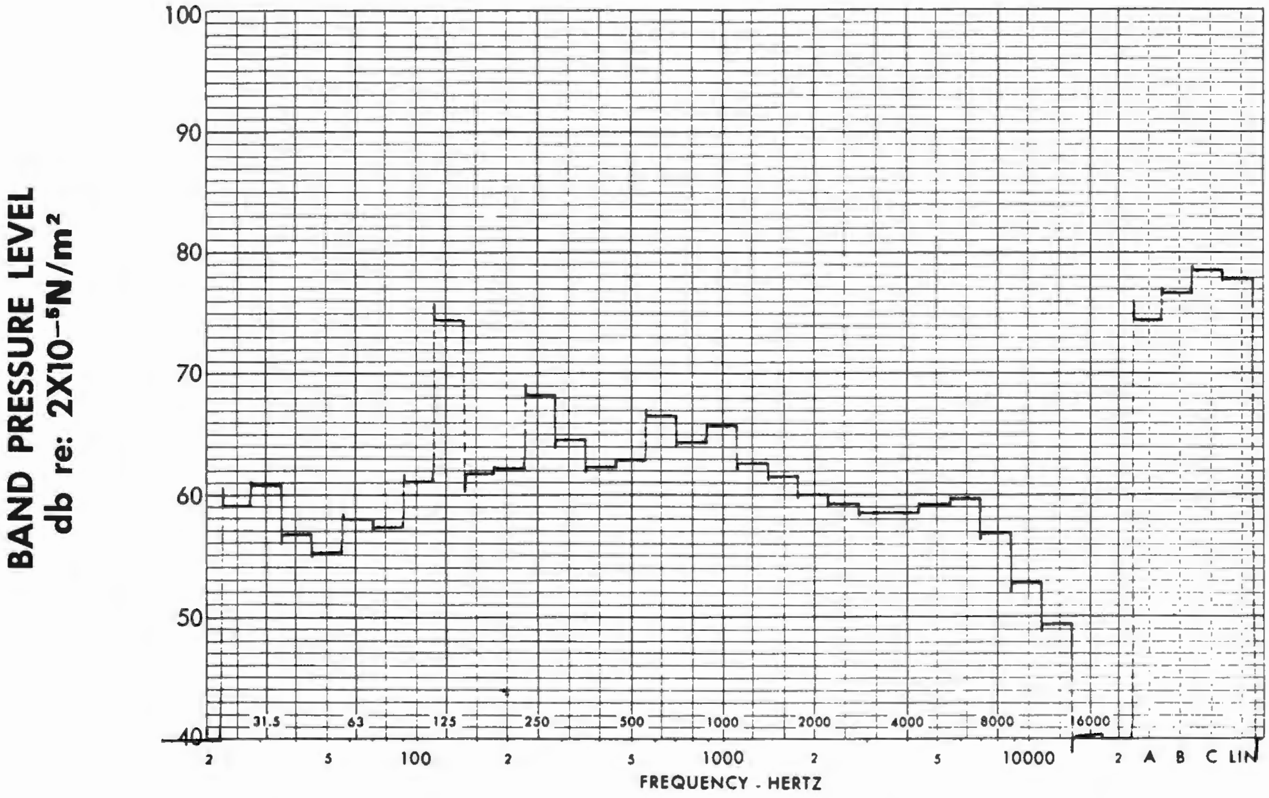
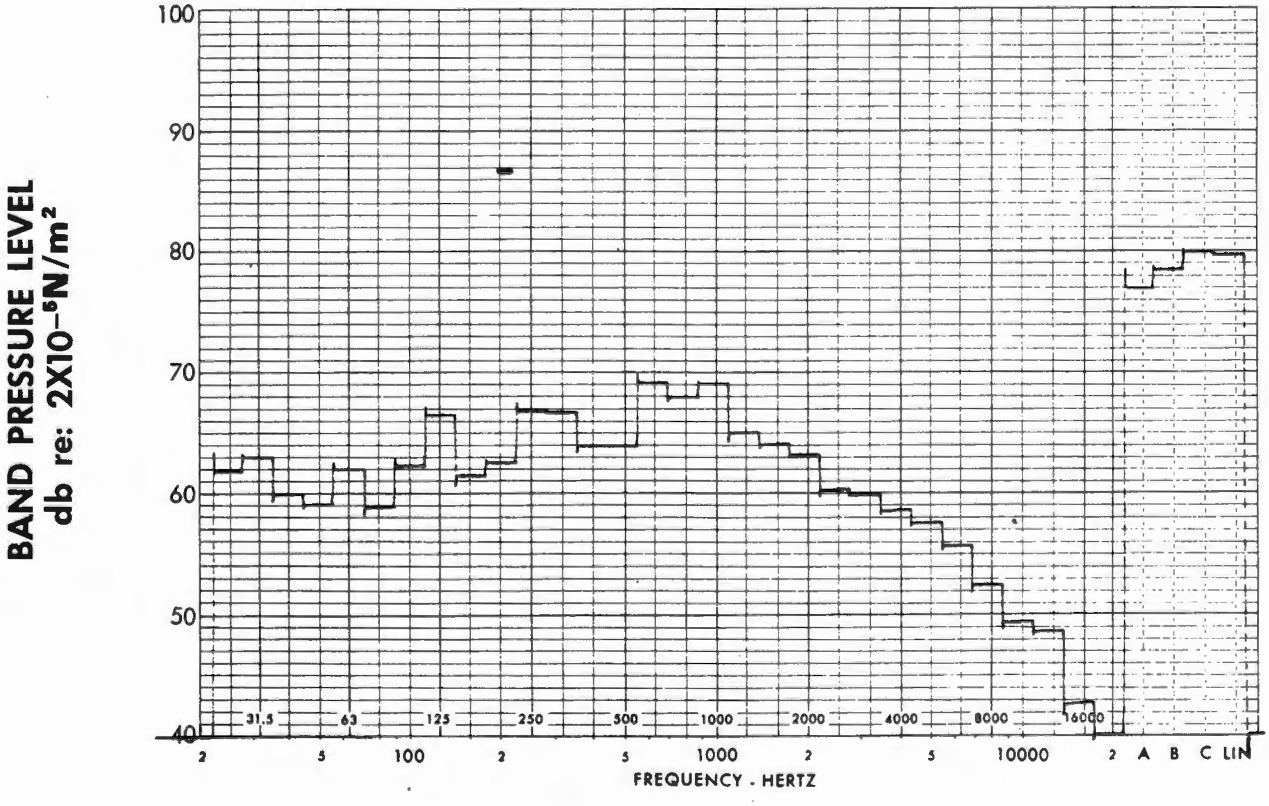


VEHICLE MODEL: T8H5305
EXHAUST NOISE - T13680

RIGHT SIDE

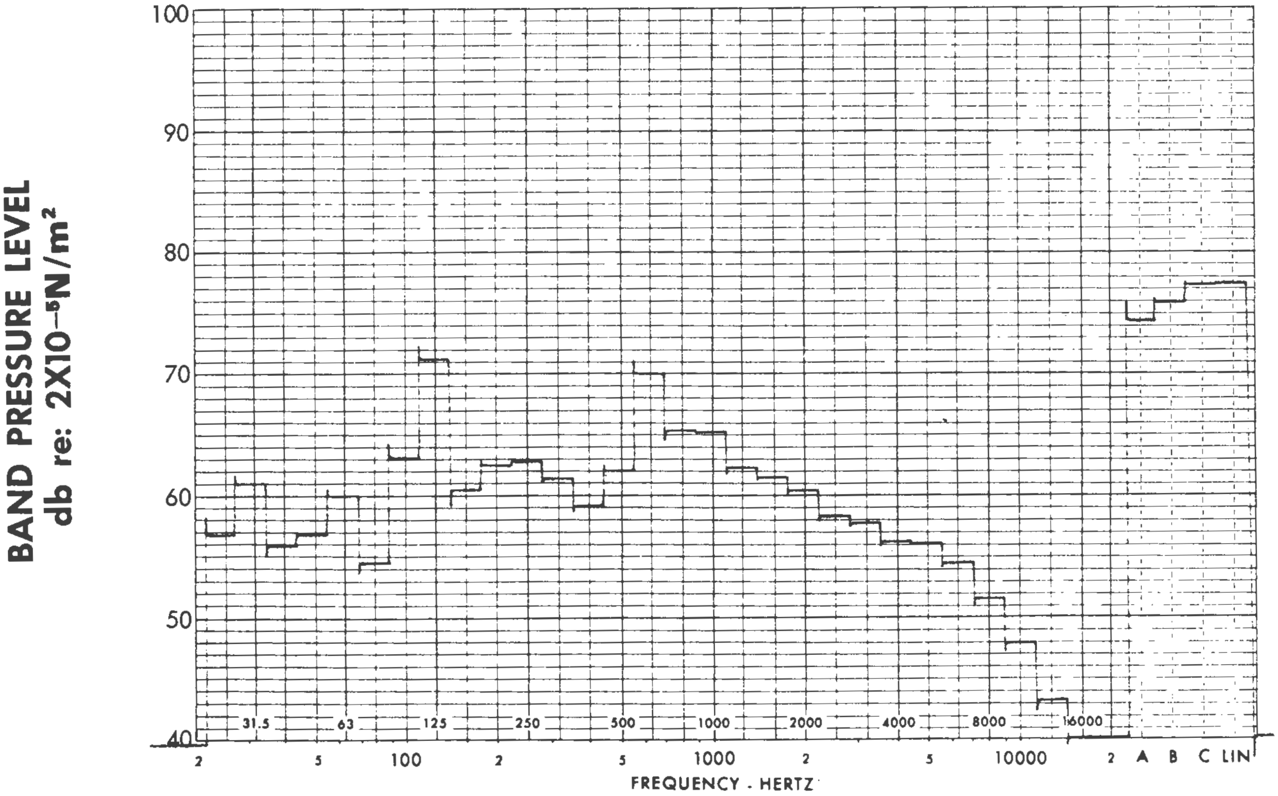


LEFT SIDE



VEHICLE MODEL: T8H5305
EXHAUST NOISE - PRODUCTION

RIGHT SIDE



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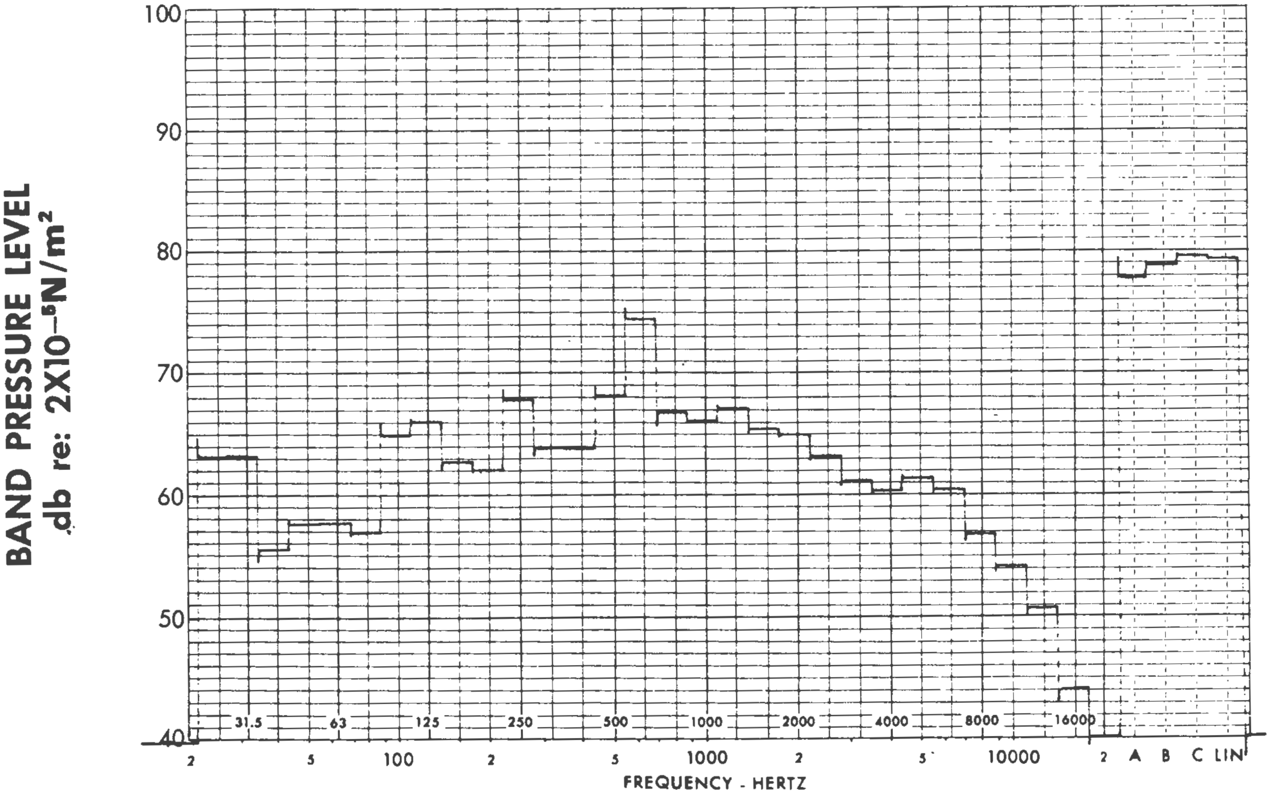
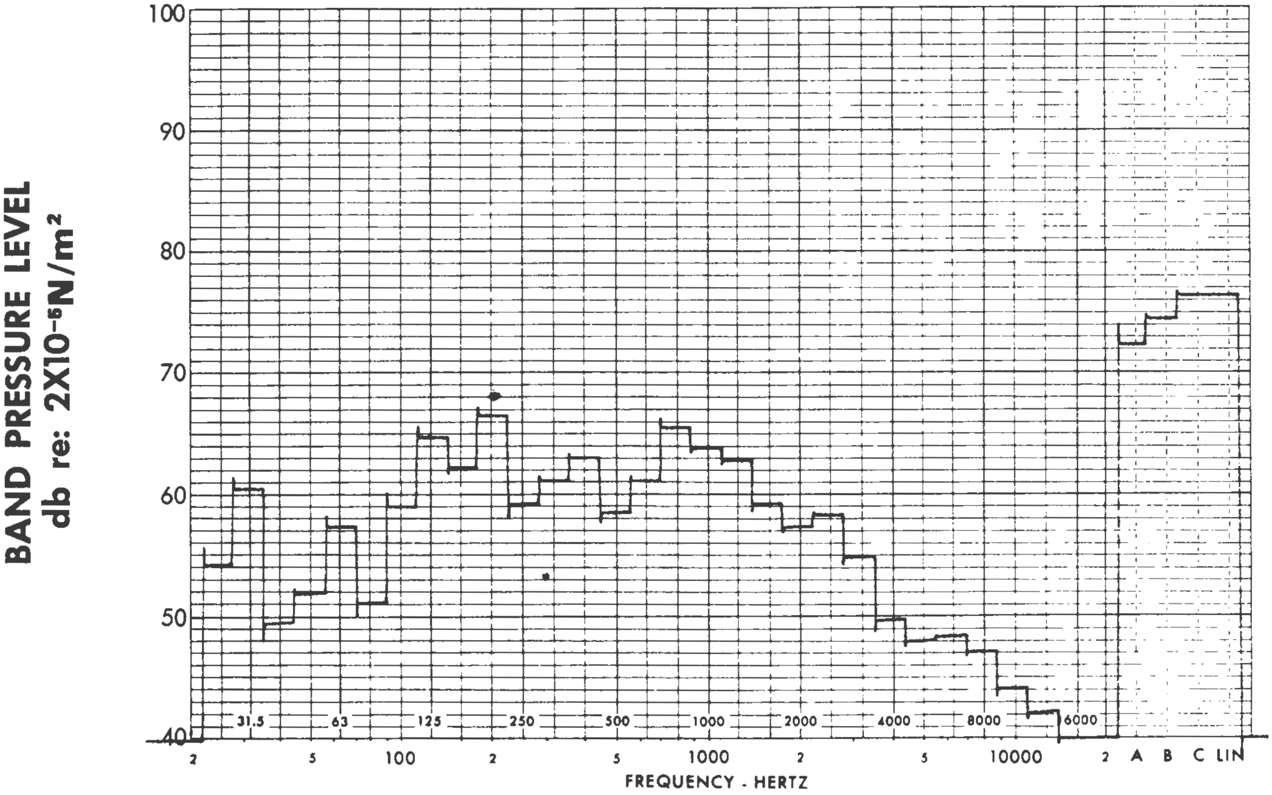


VEHICLE MODEL: T8H5305
ENGINE NOISE

RIGHT SIDE



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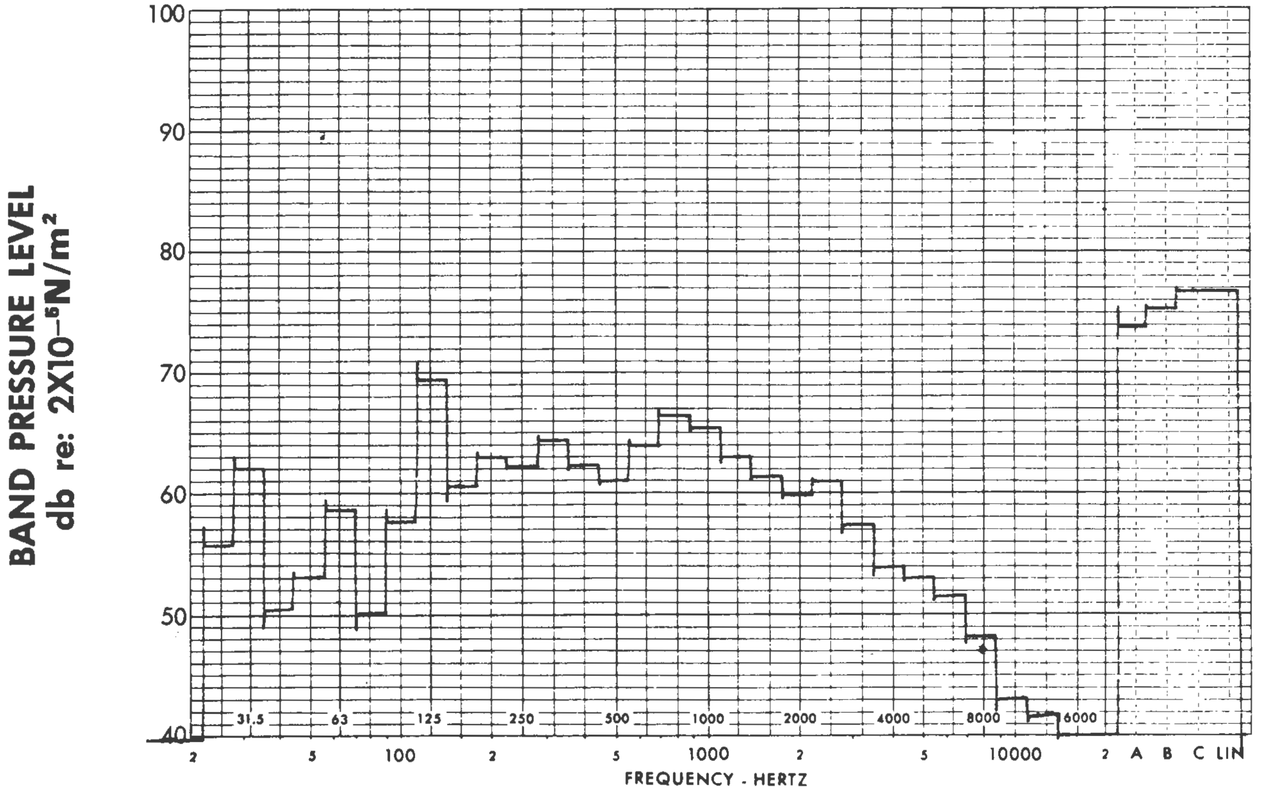
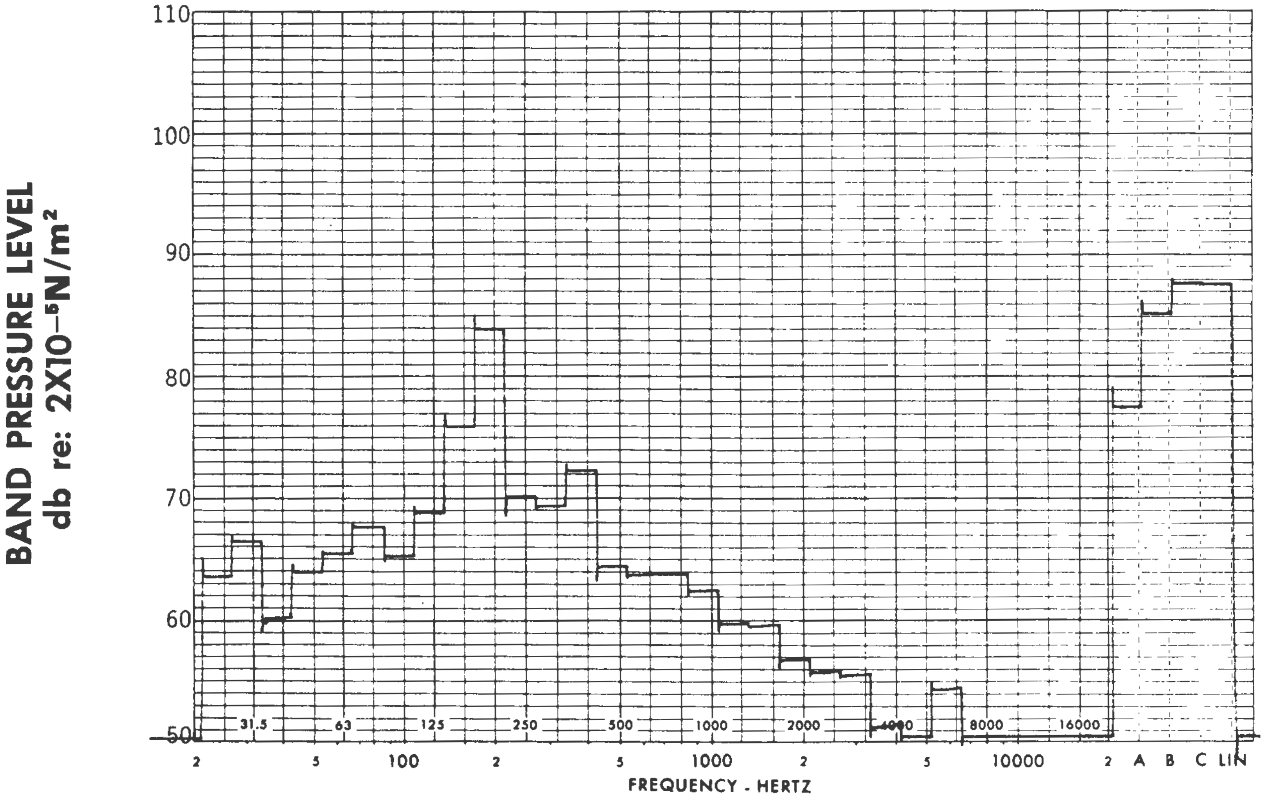


VEHICLE MODEL: T8H5305
FAN NOISE

RIGHT SIDE



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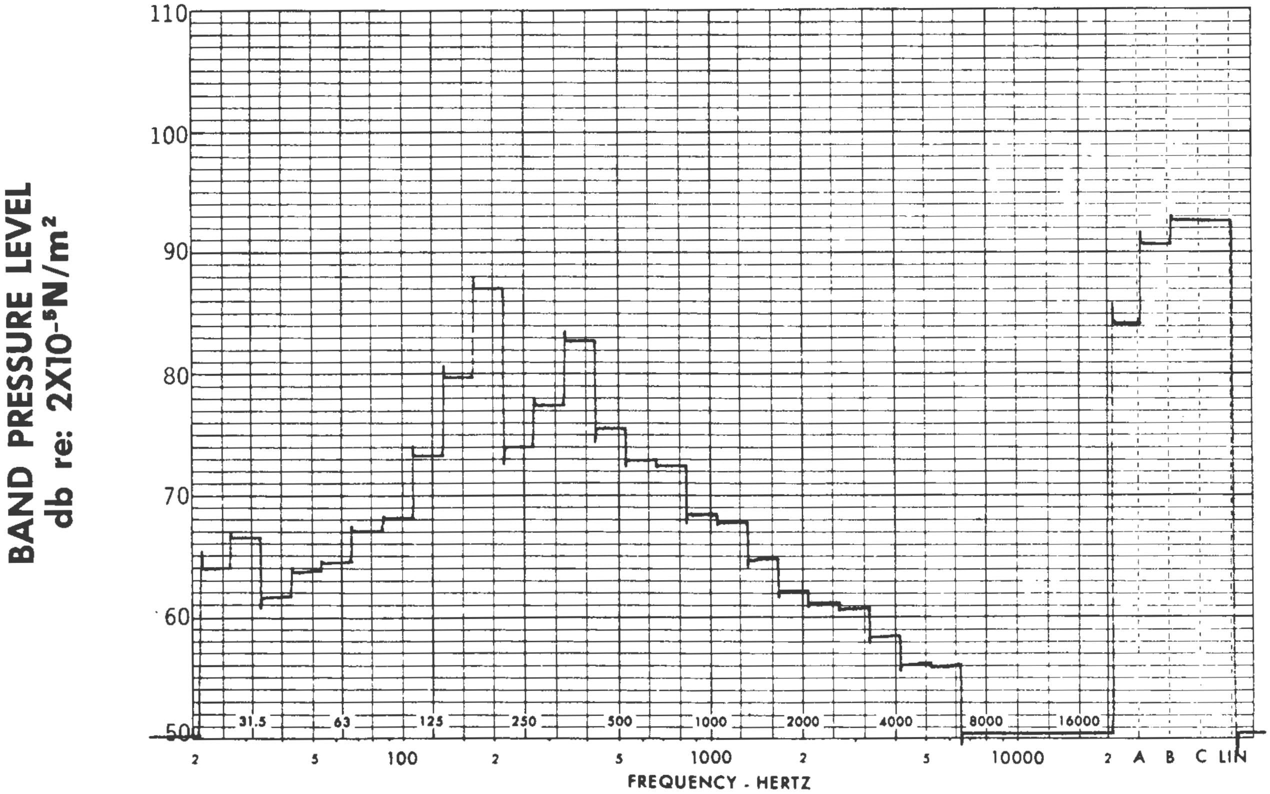
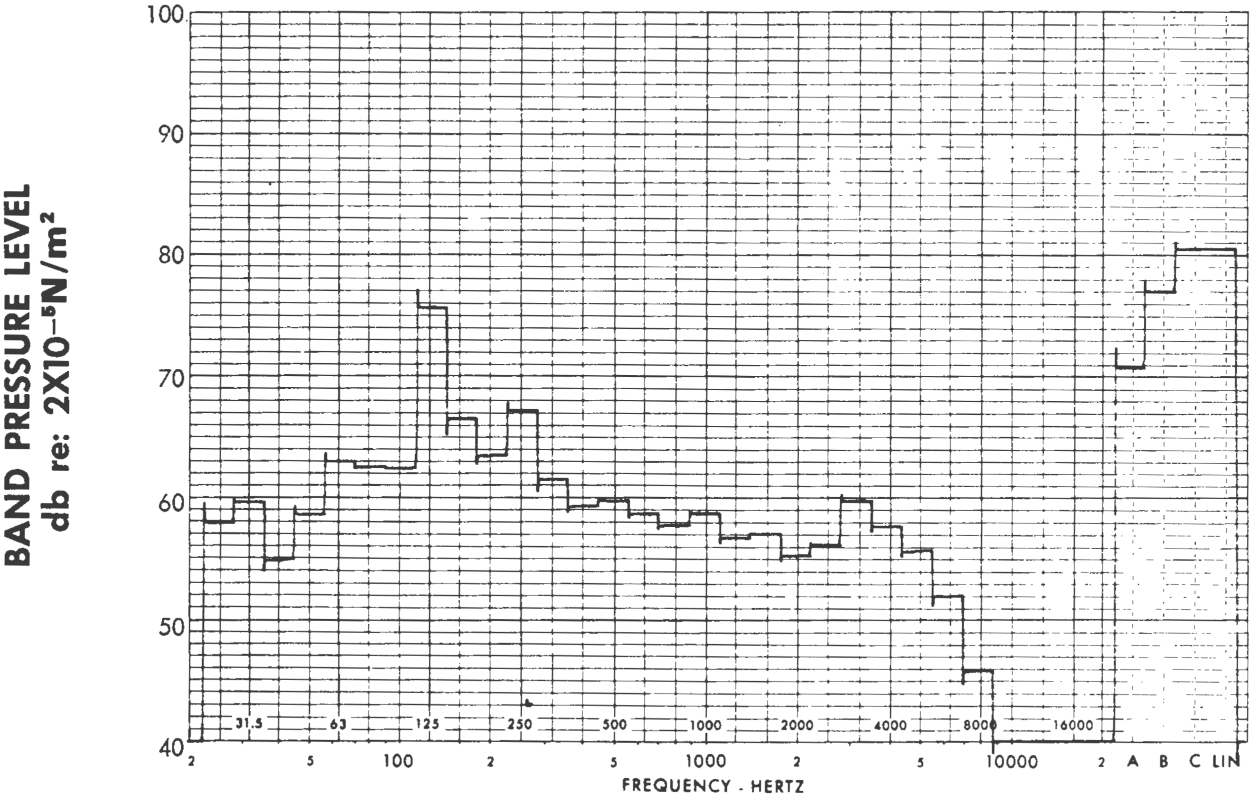
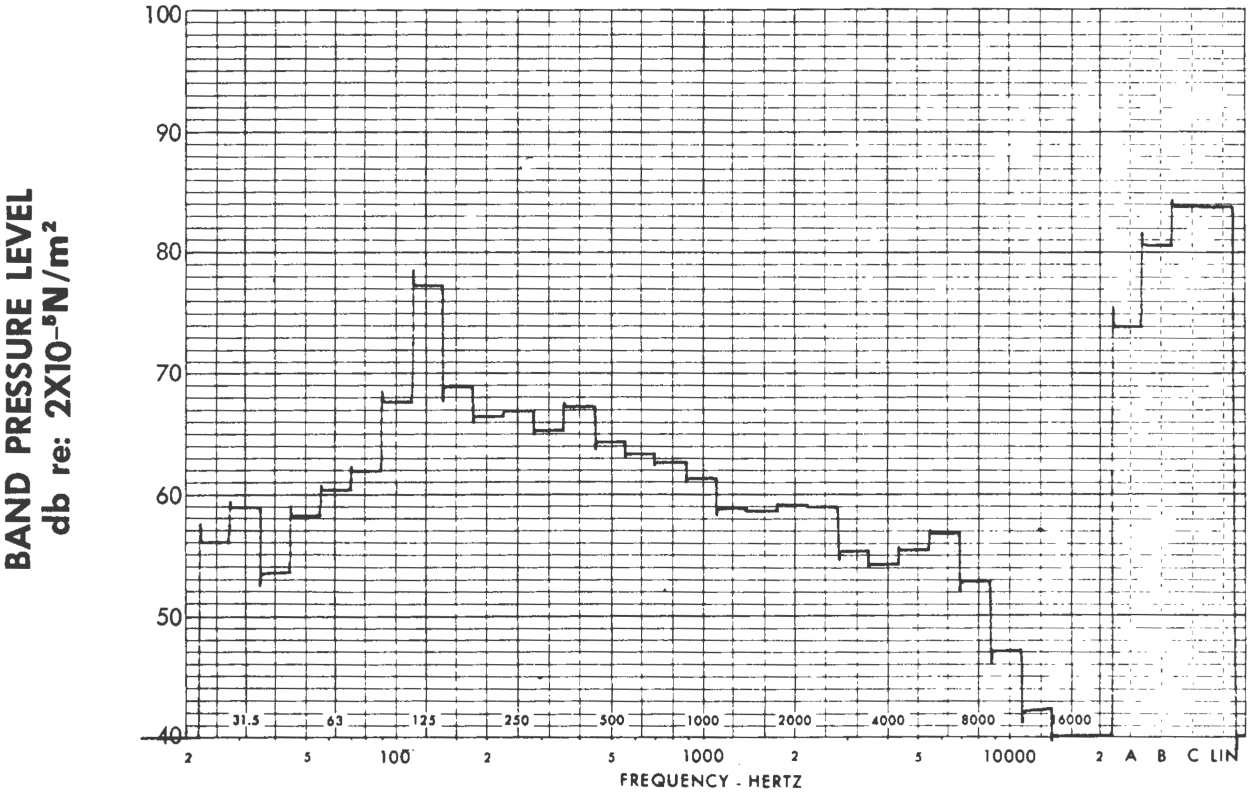


VEHICLE MODEL: T8H5305
VISCOUS FAN NOISE

RIGHT SIDE

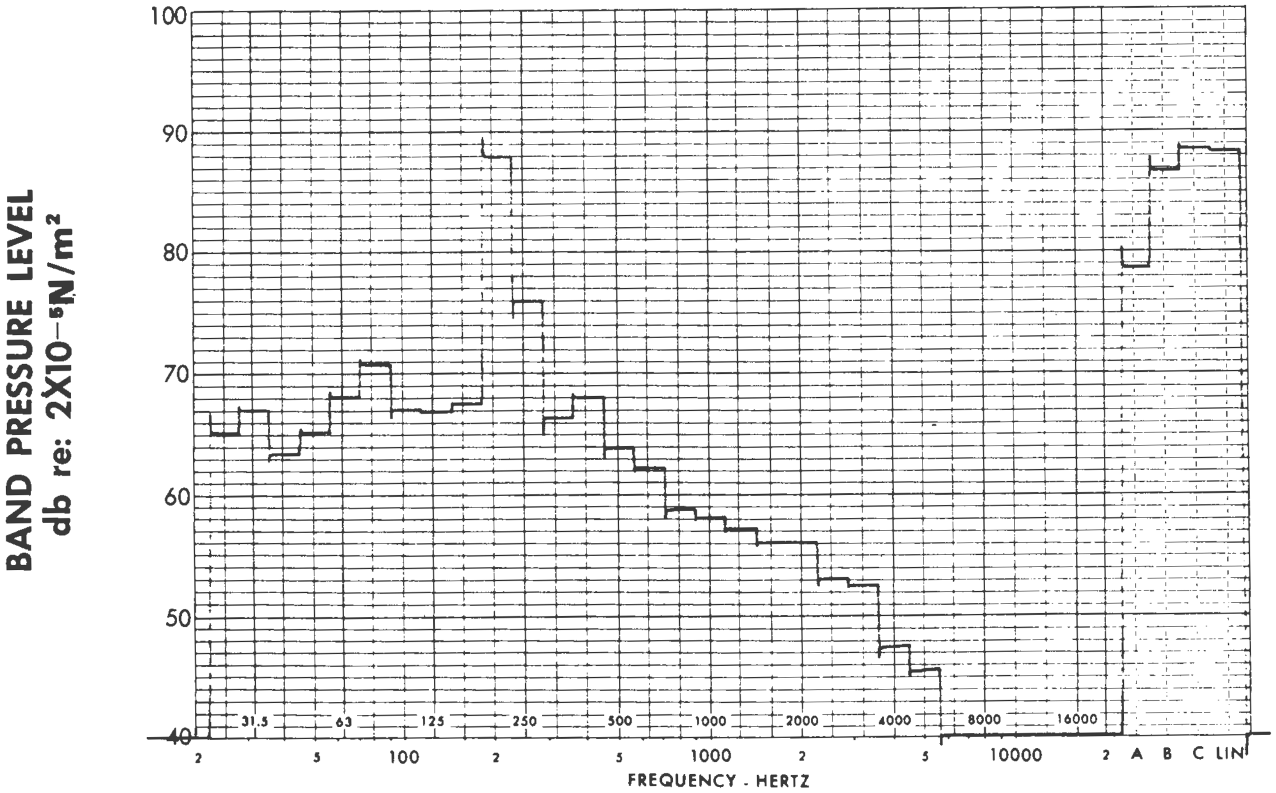


LEFT SIDE

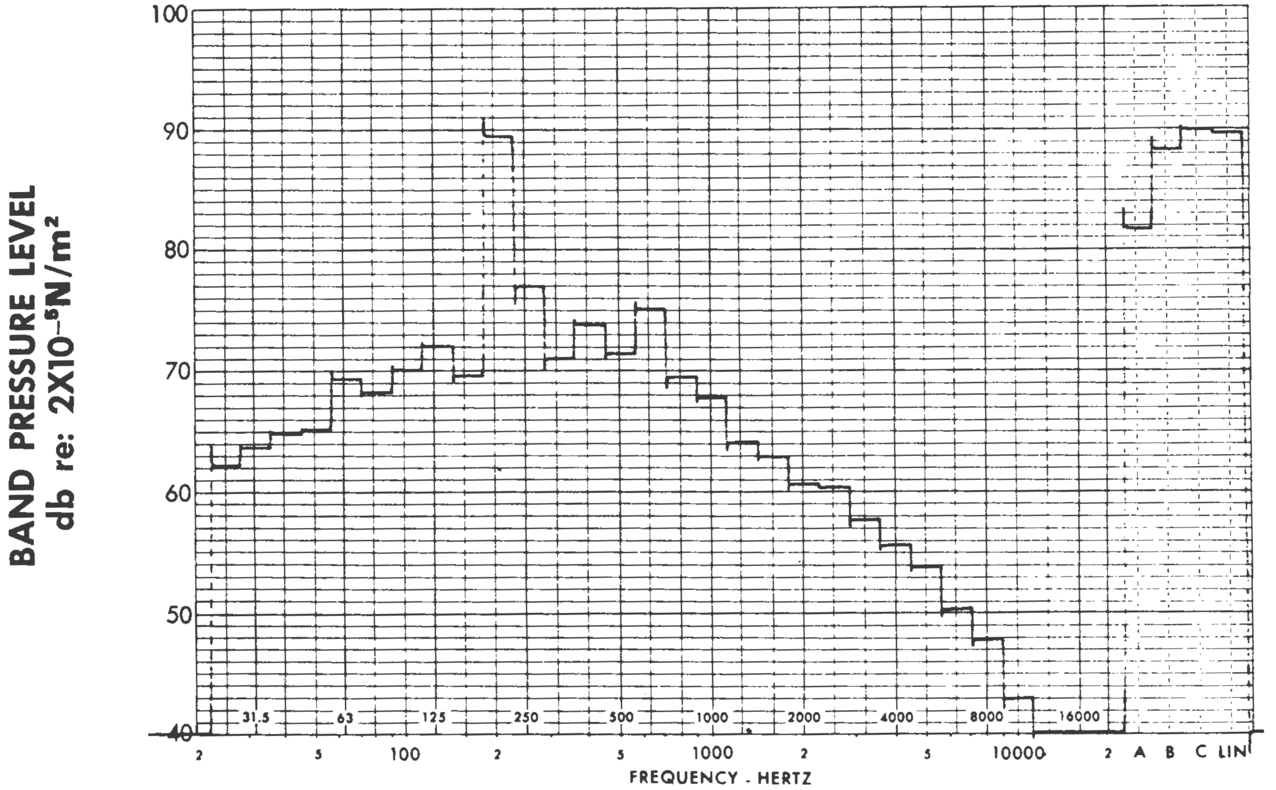


VEHICLE MODEL: T8H5305
TOTAL VEHICLE NOISE

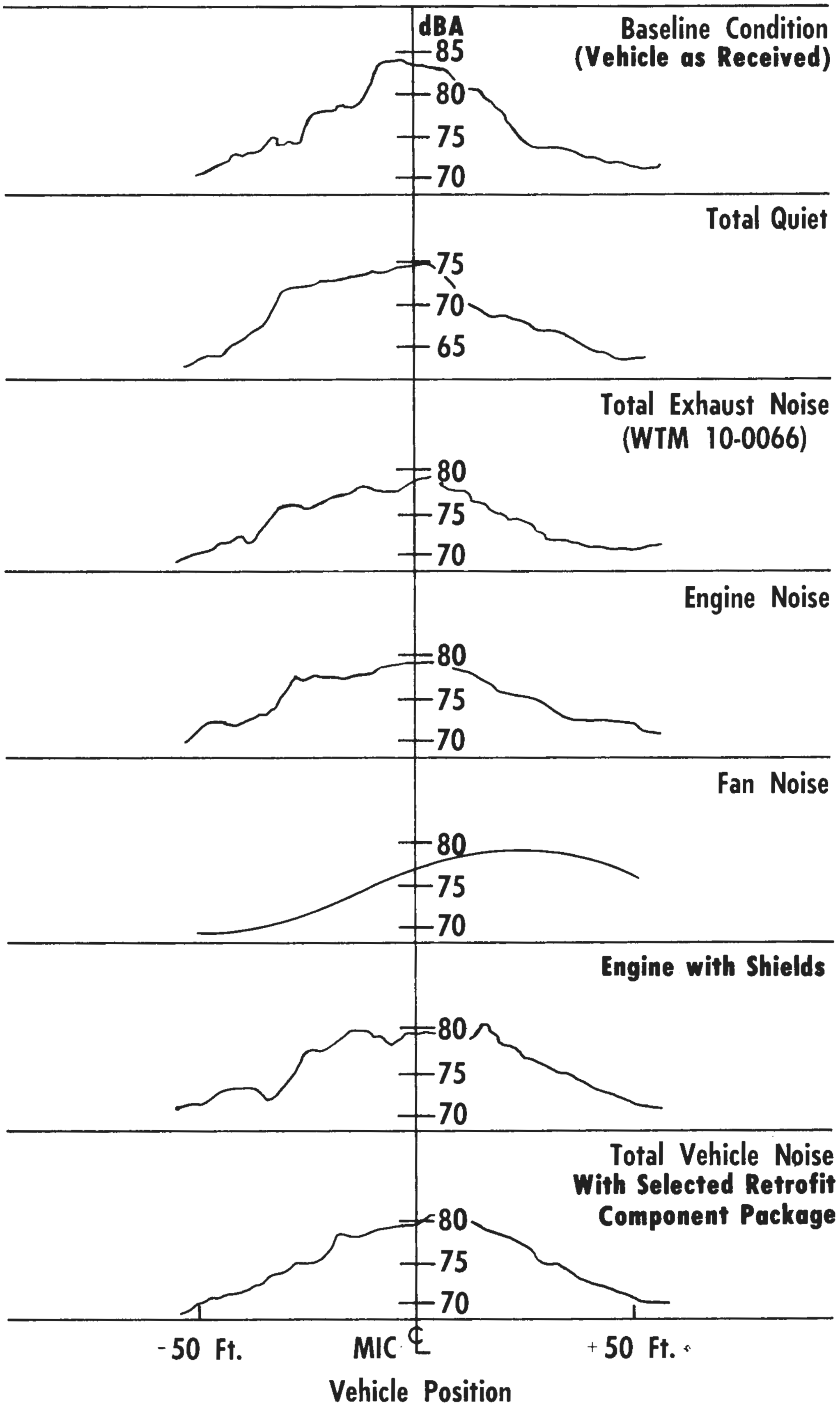
RIGHT SIDE



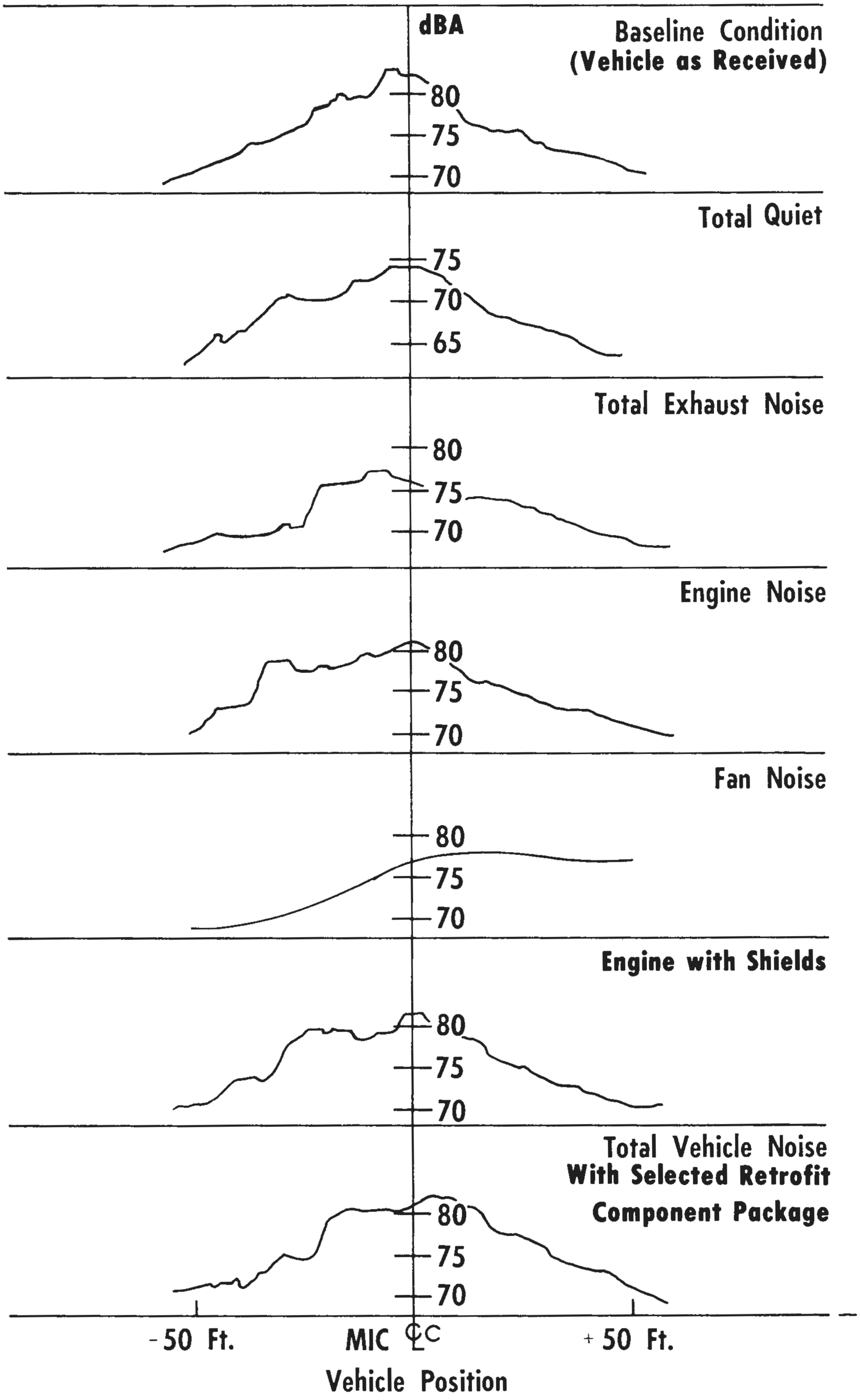
LEFT SIDE



JI9500 RIGHT SIDE

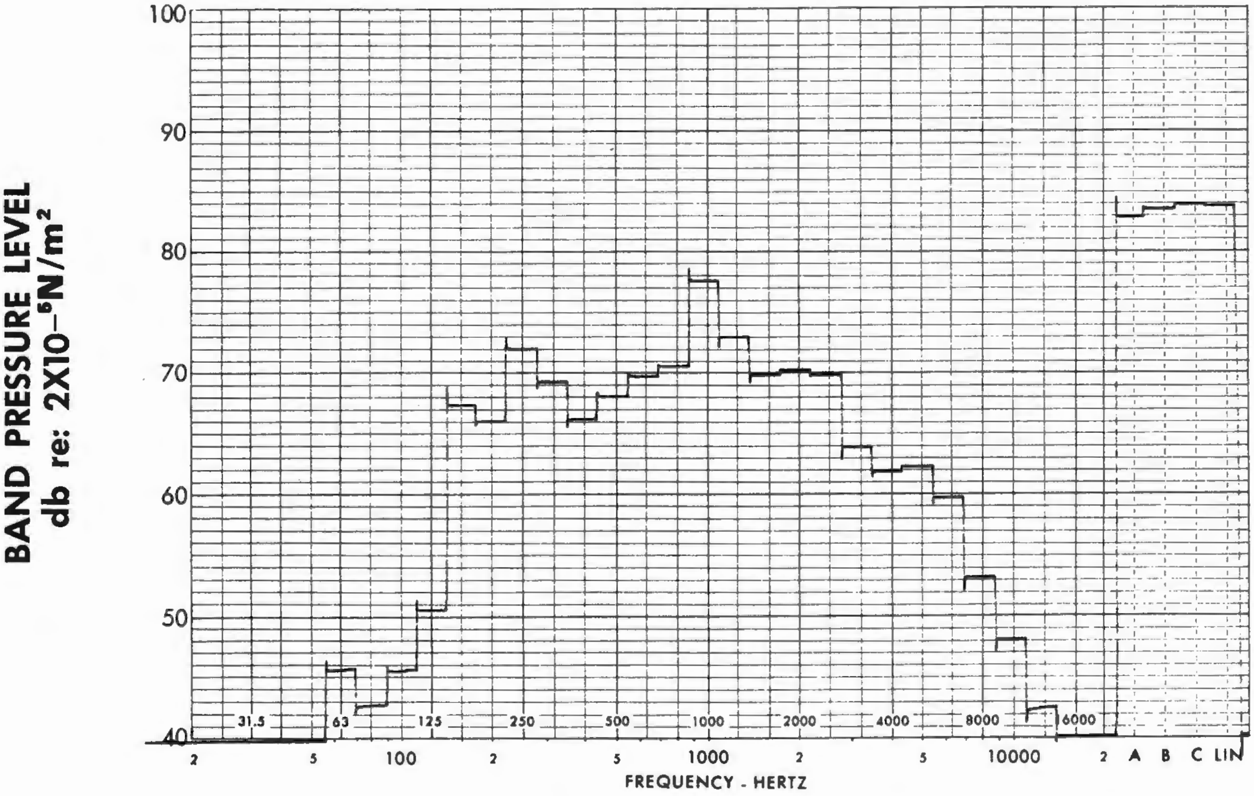


JI9500 LEFT SIDE

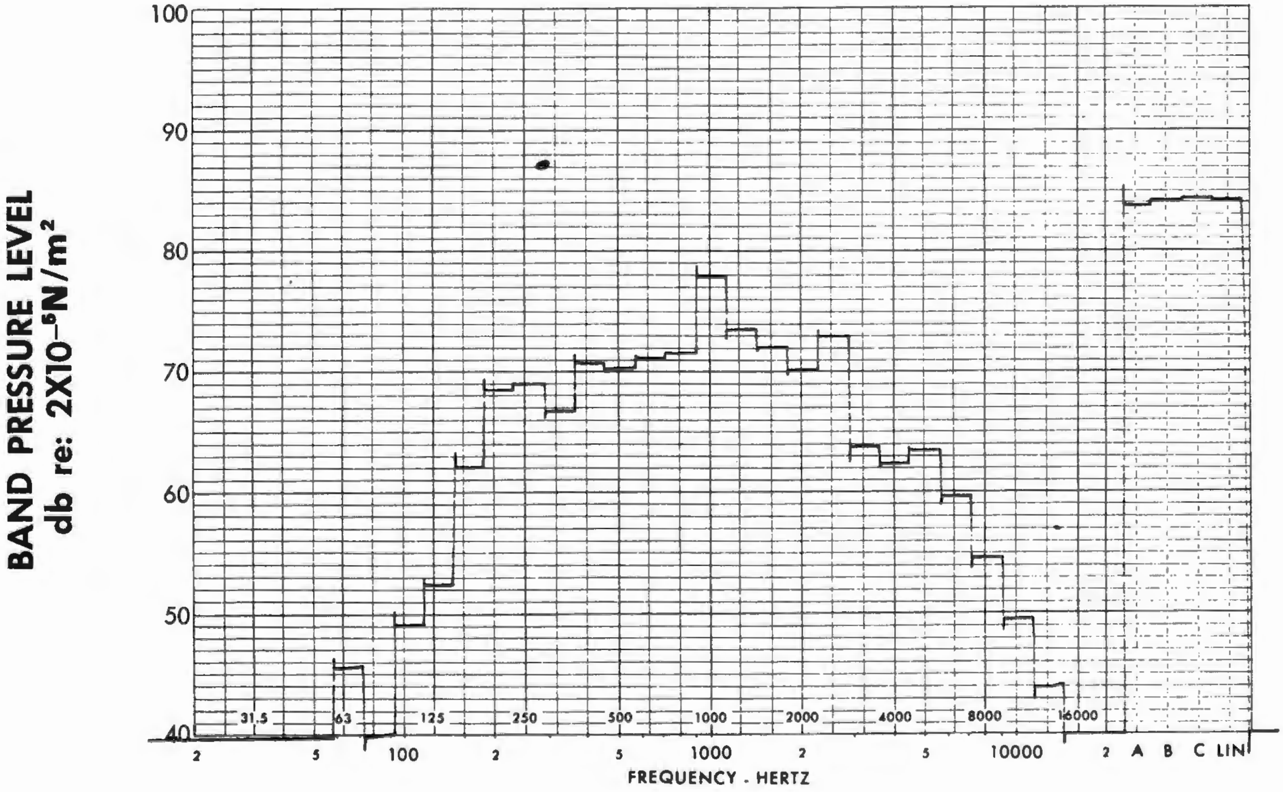


VEHICLE MODEL: J19500
BASELINE TOTAL VEHICLE NOISE

RIGHT SIDE

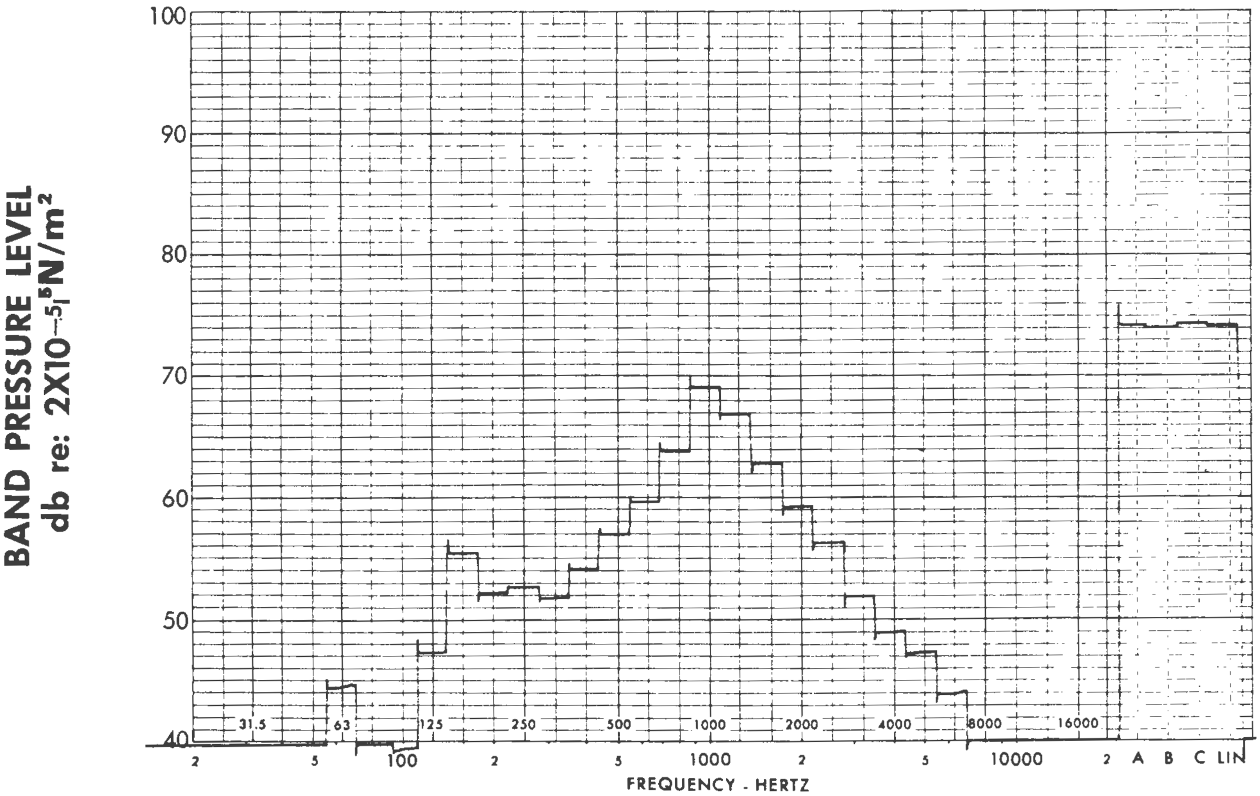


LEFT SIDE

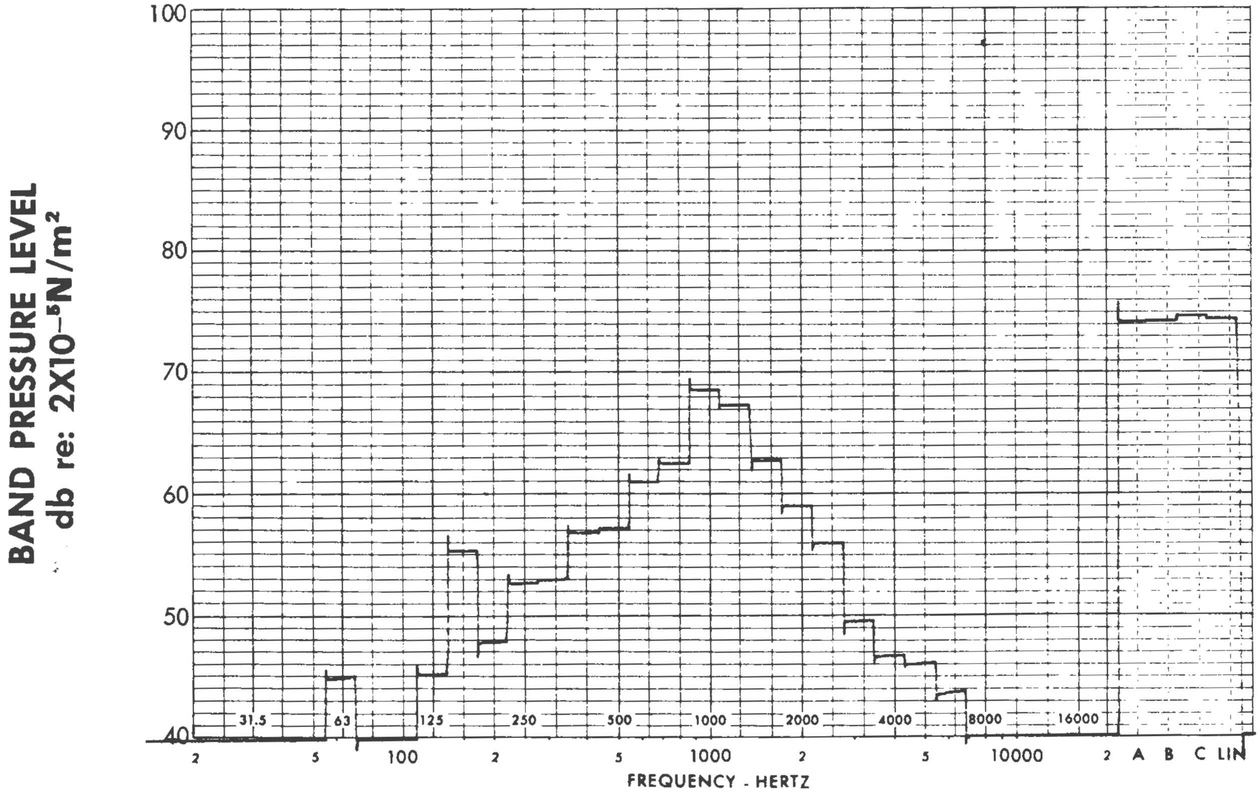


VEHICLE MODEL: JI9500
TOTAL QUIET

RIGHT SIDE

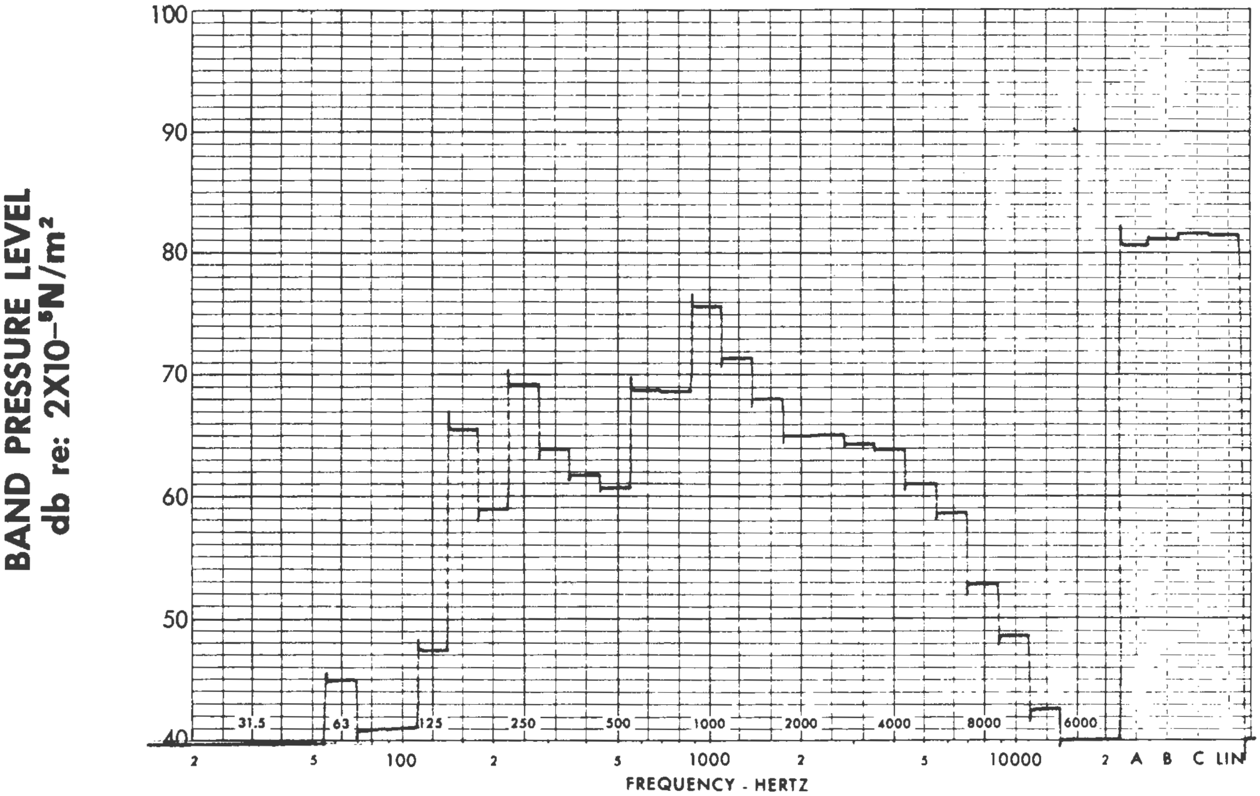


LEFT SIDE



VEHICLE MODEL: JI9500
EXHAUST NOISE - PRODUCTION

RIGHT SIDE



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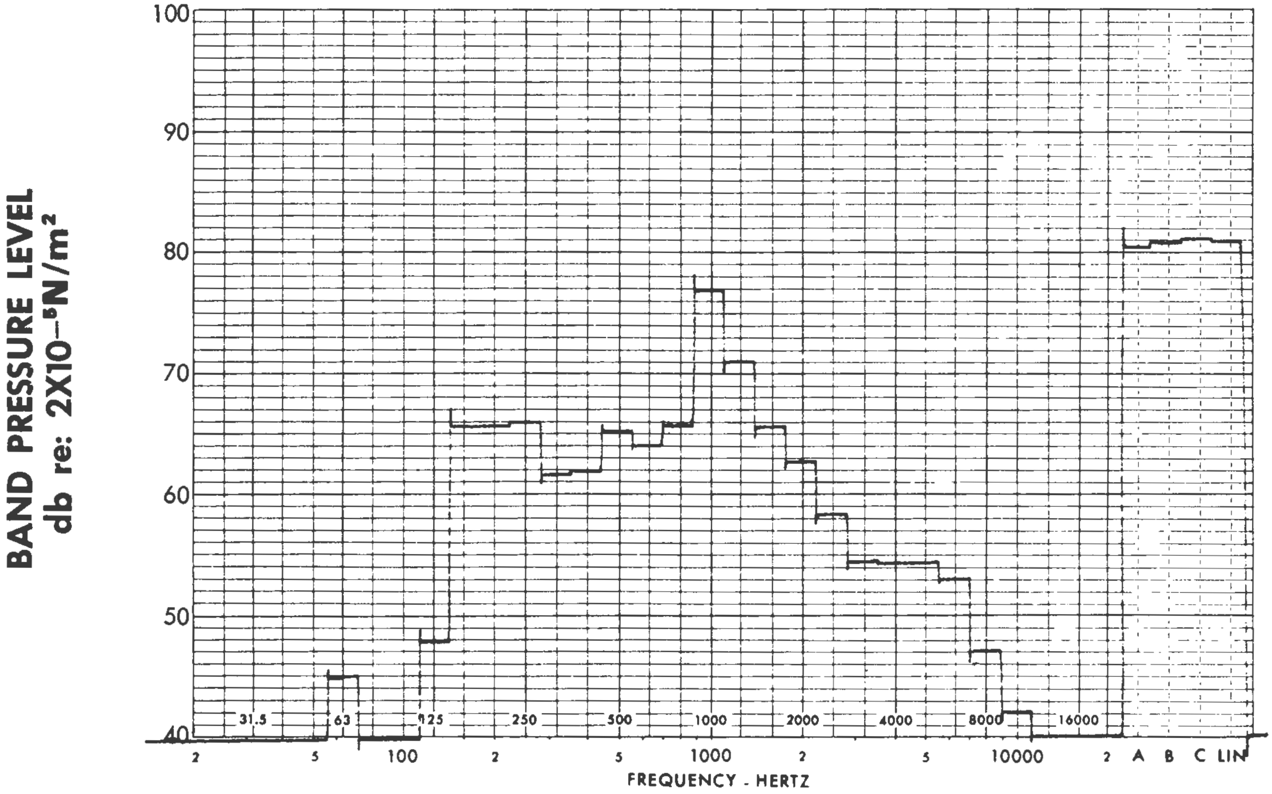
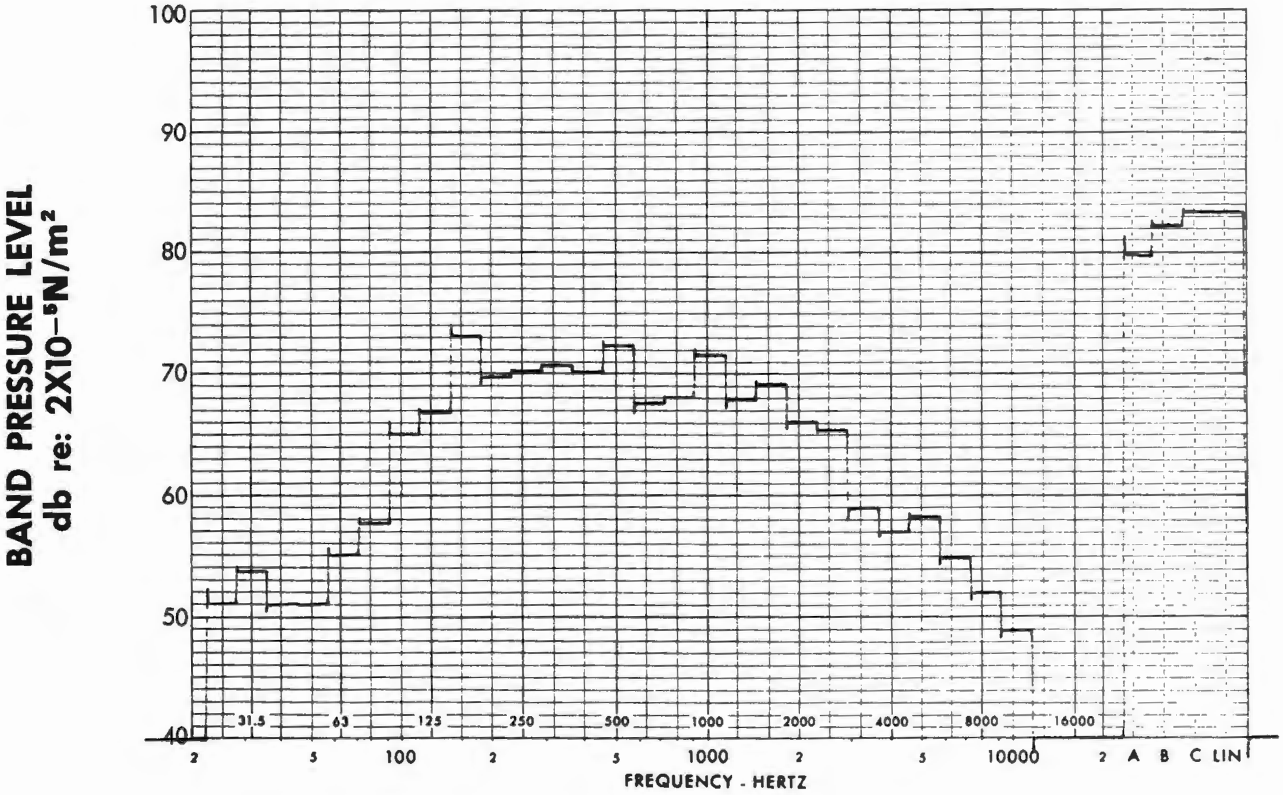
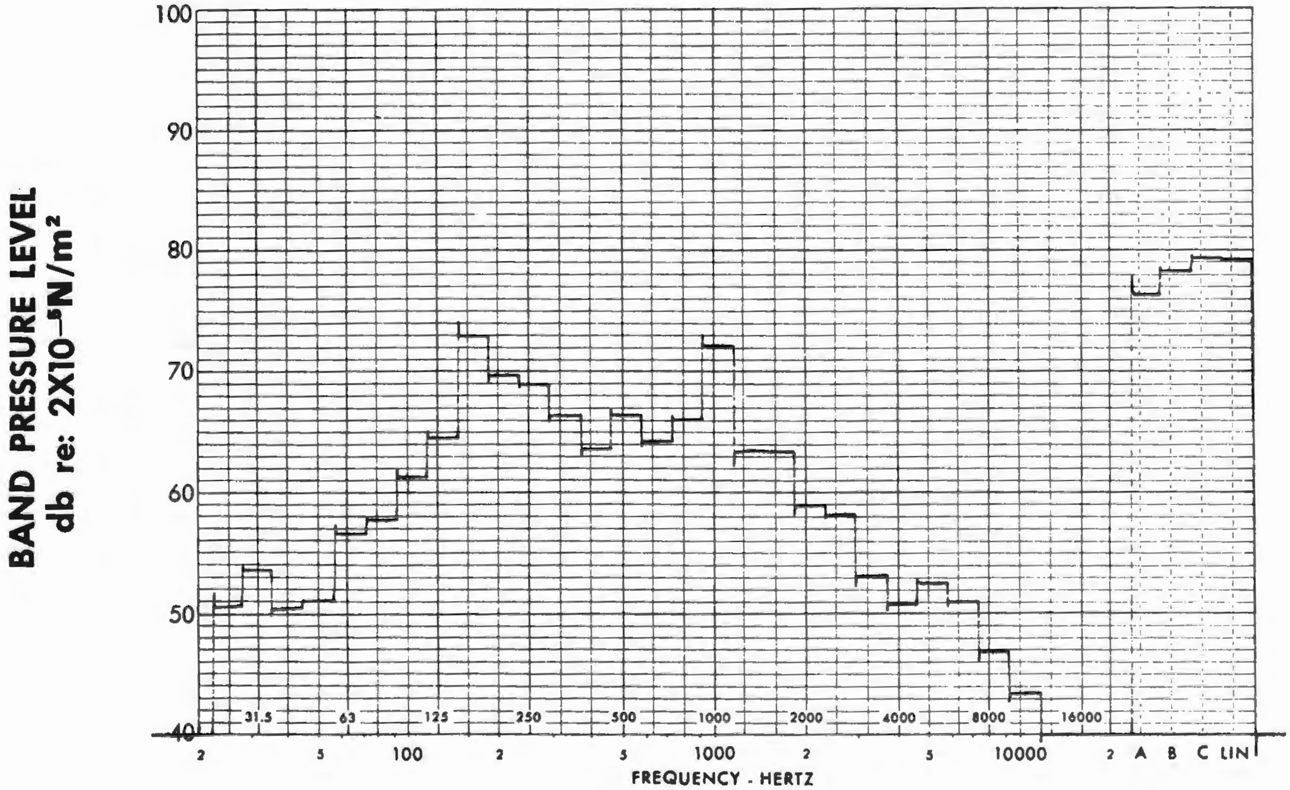


VEHICLE MODEL: J19500
EXHAUST NOISE - WTM 10-0066

RIGHT SIDE

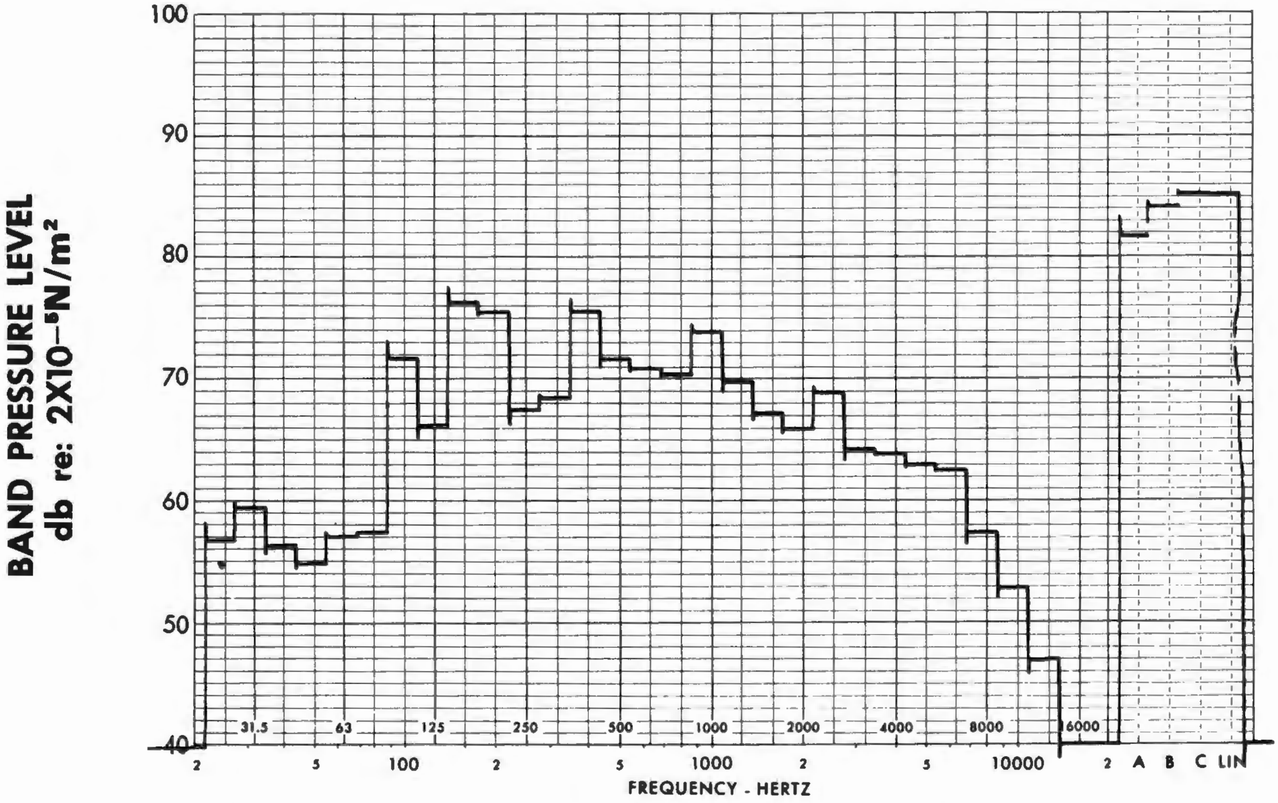


LEFT SIDE



VEHICLE MODEL: JI9500
EXHAUST NOISE - STEMCO 9353

RIGHT SIDE



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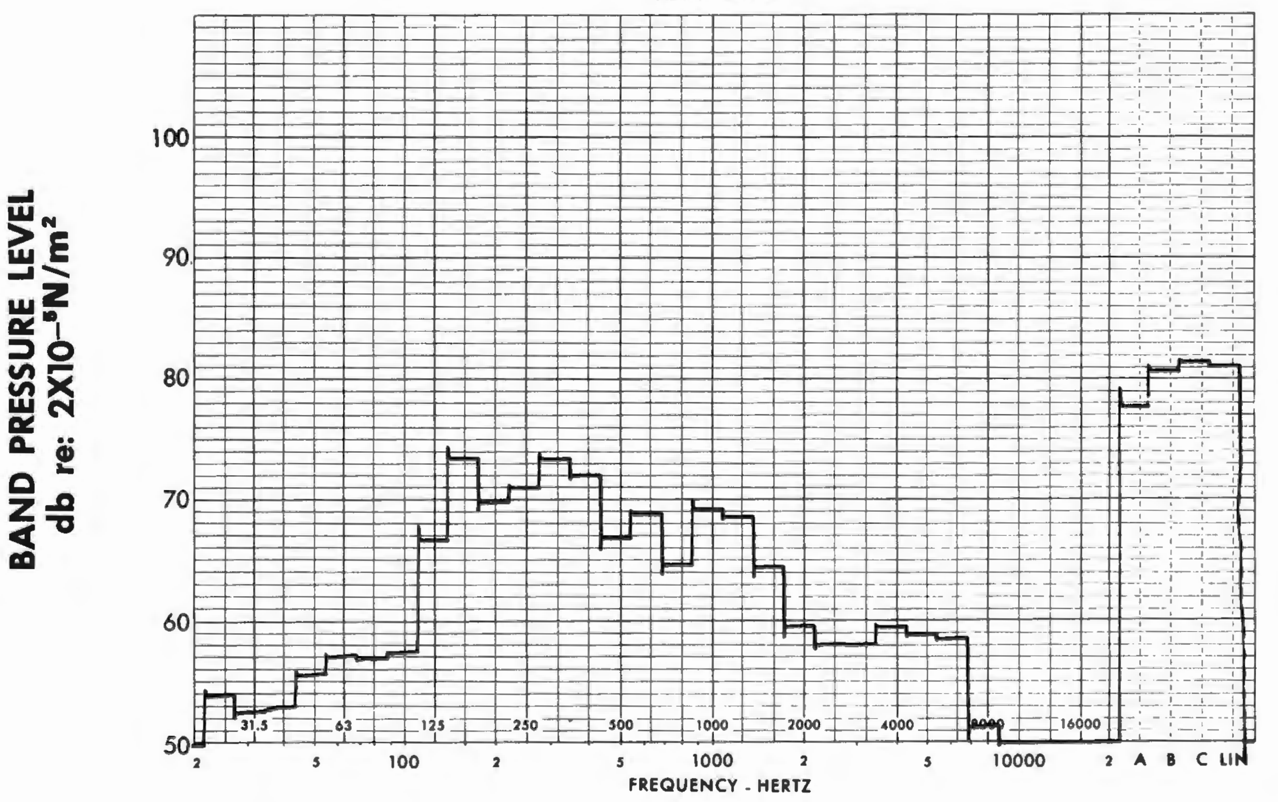
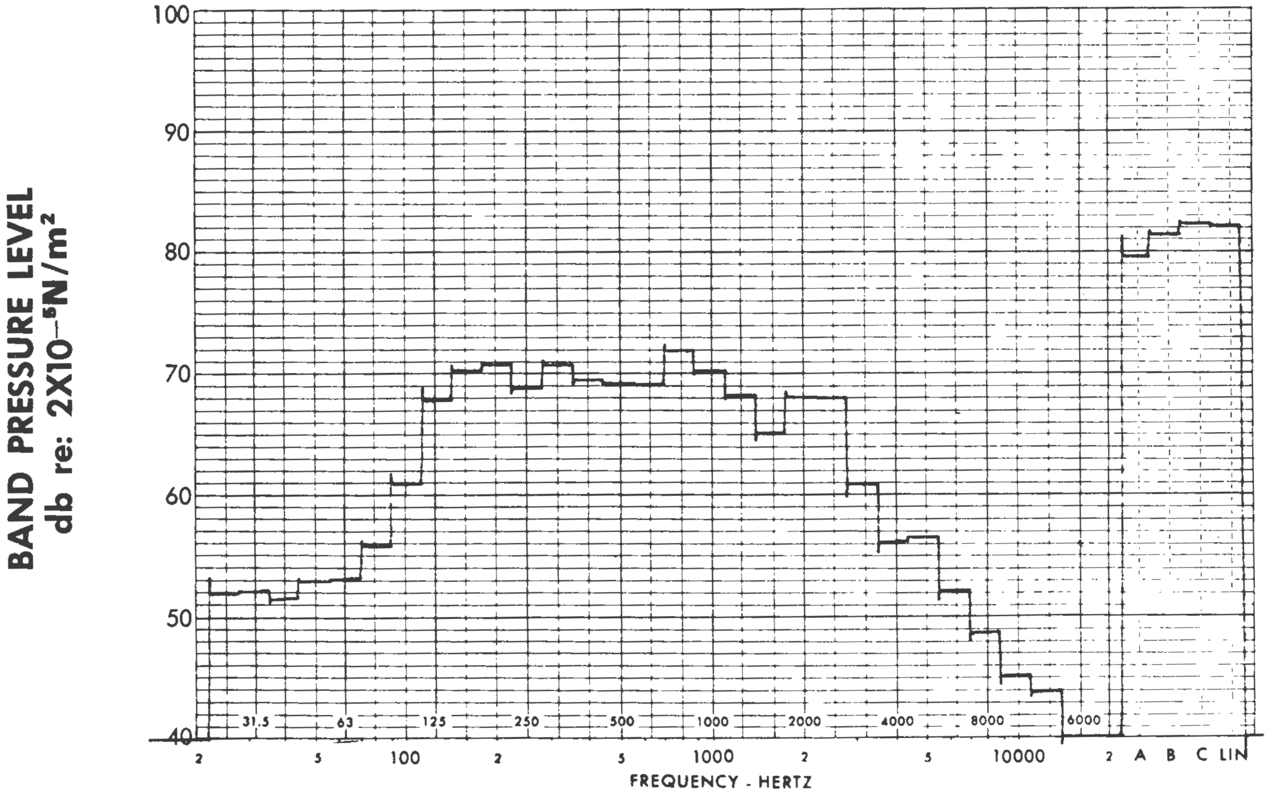
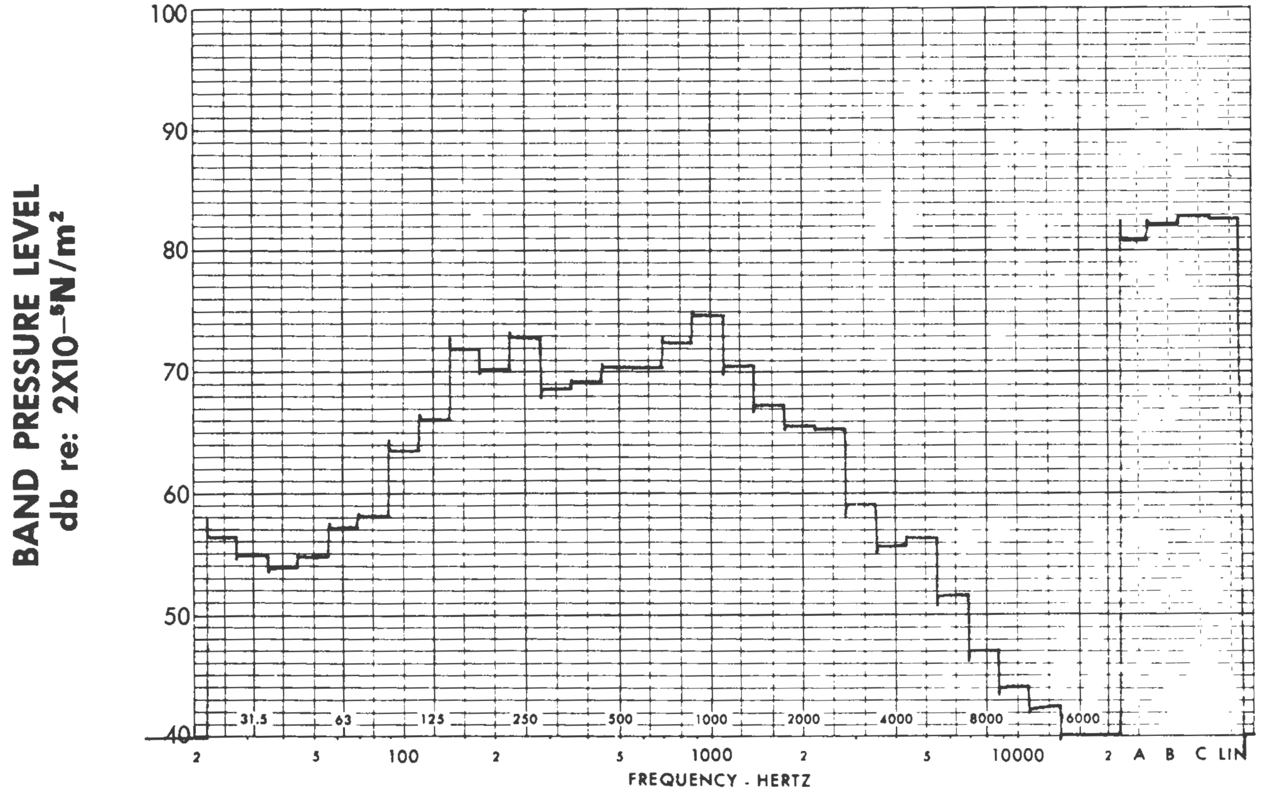


VEHICLE MODEL: J19500
ENGINE NOISE

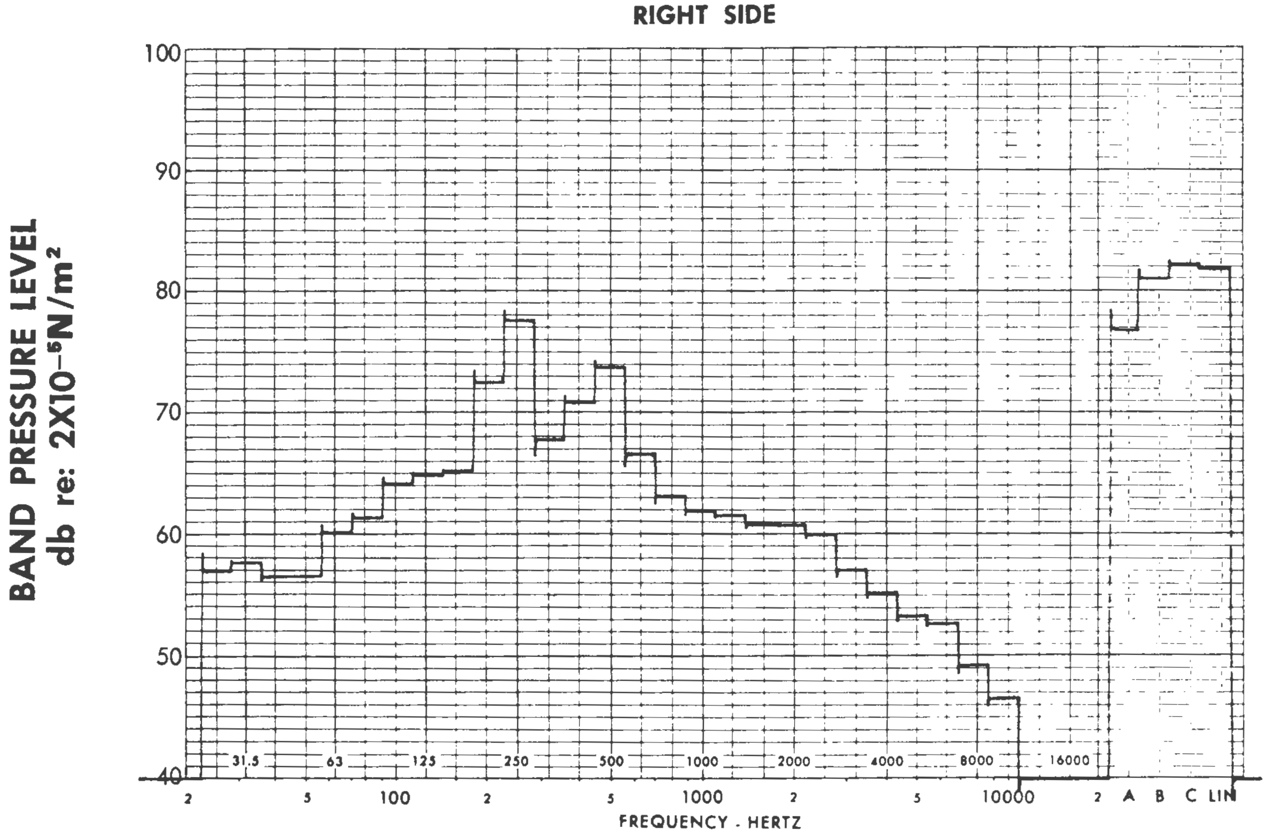
RIGHT SIDE

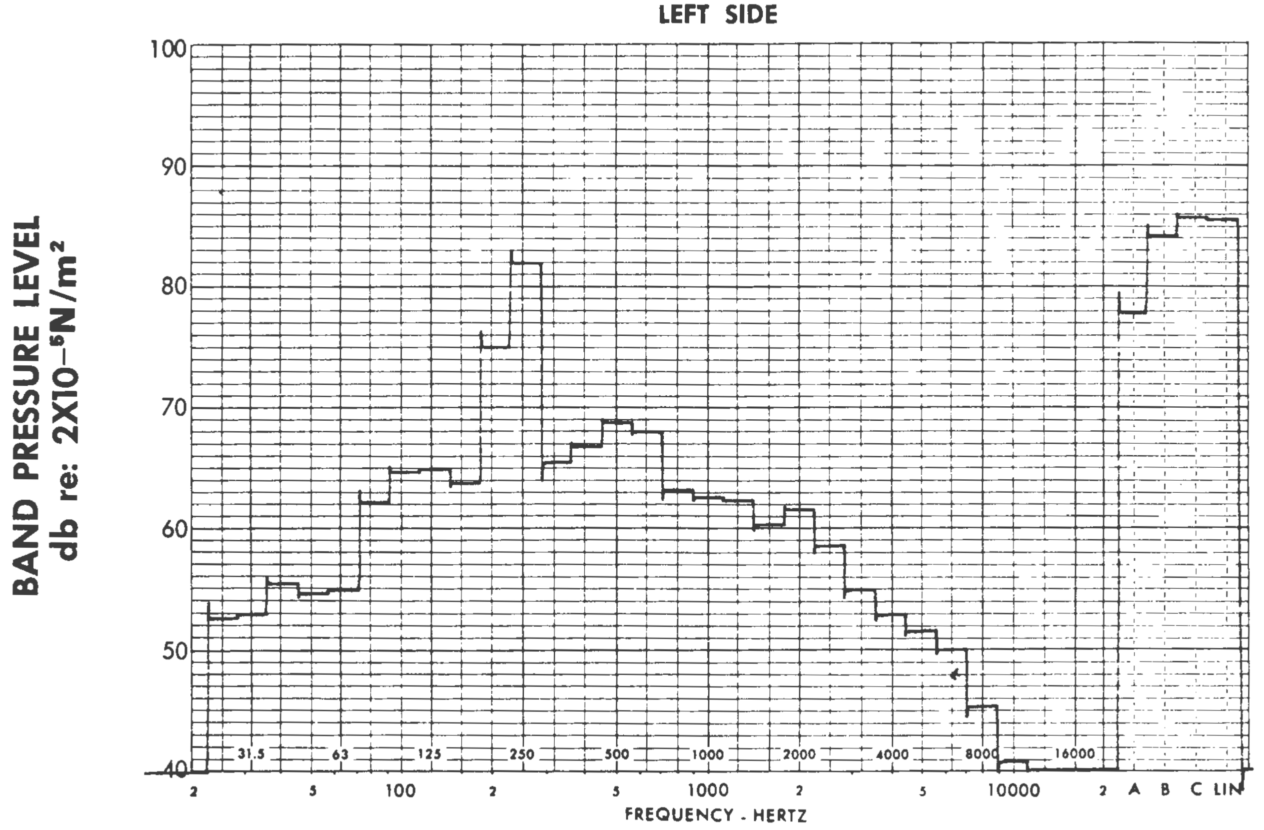


LEFT SIDE



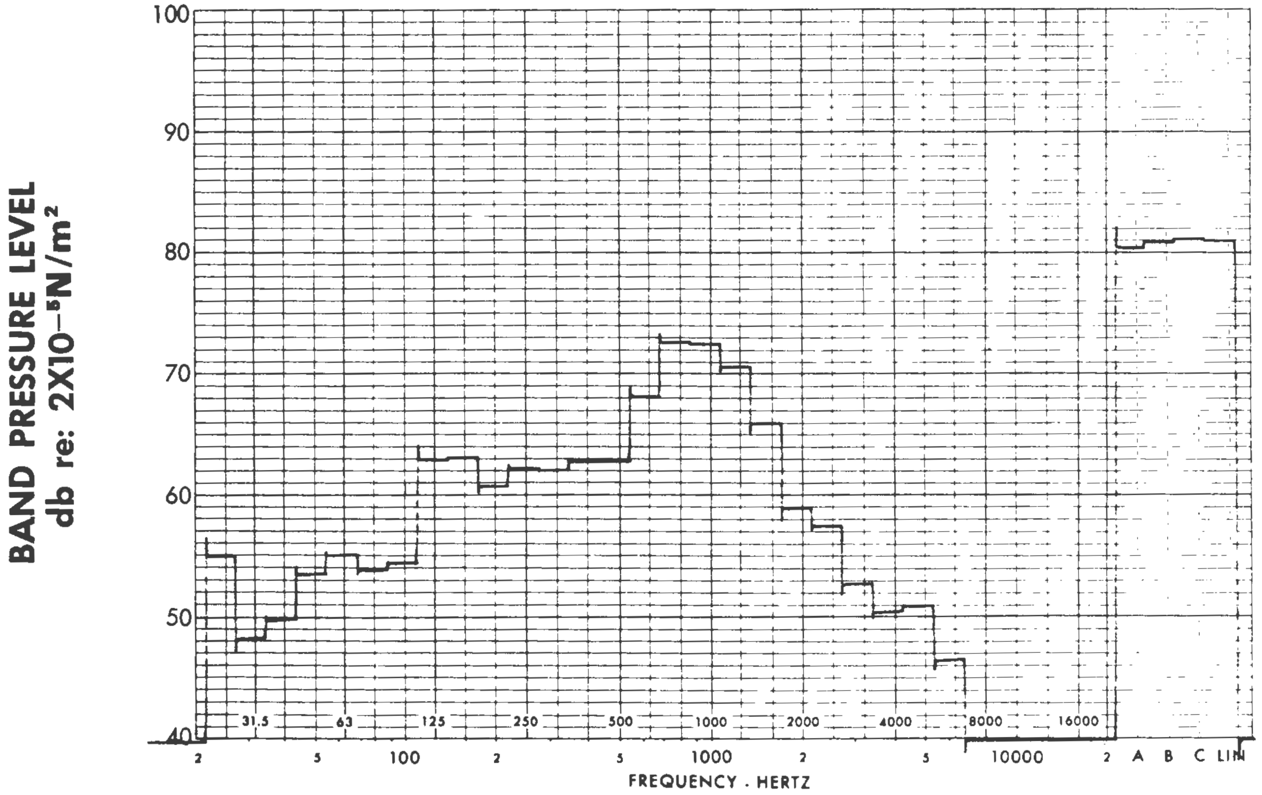
VEHICLE MODEL: J19500
FAN NOISE



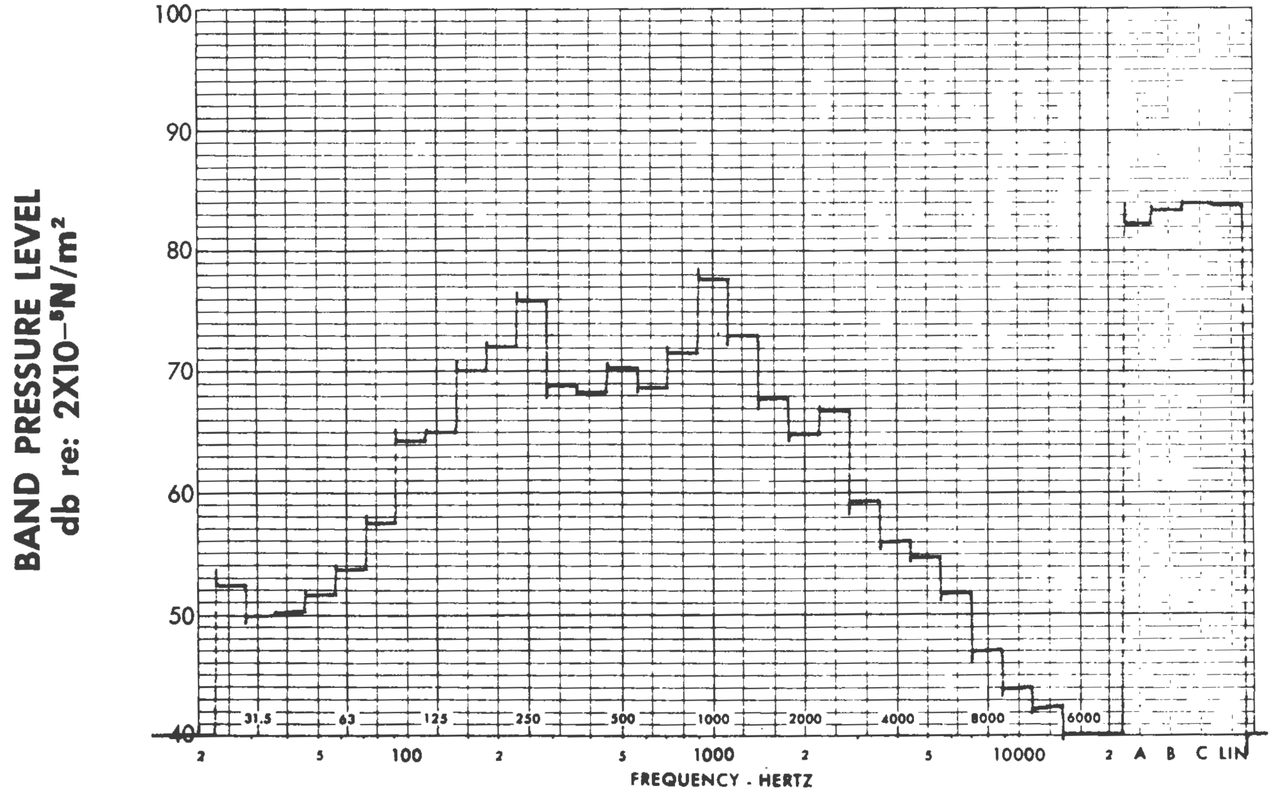


VEHICLE MODEL: J19500
ENGINE SIDE SHIELDS

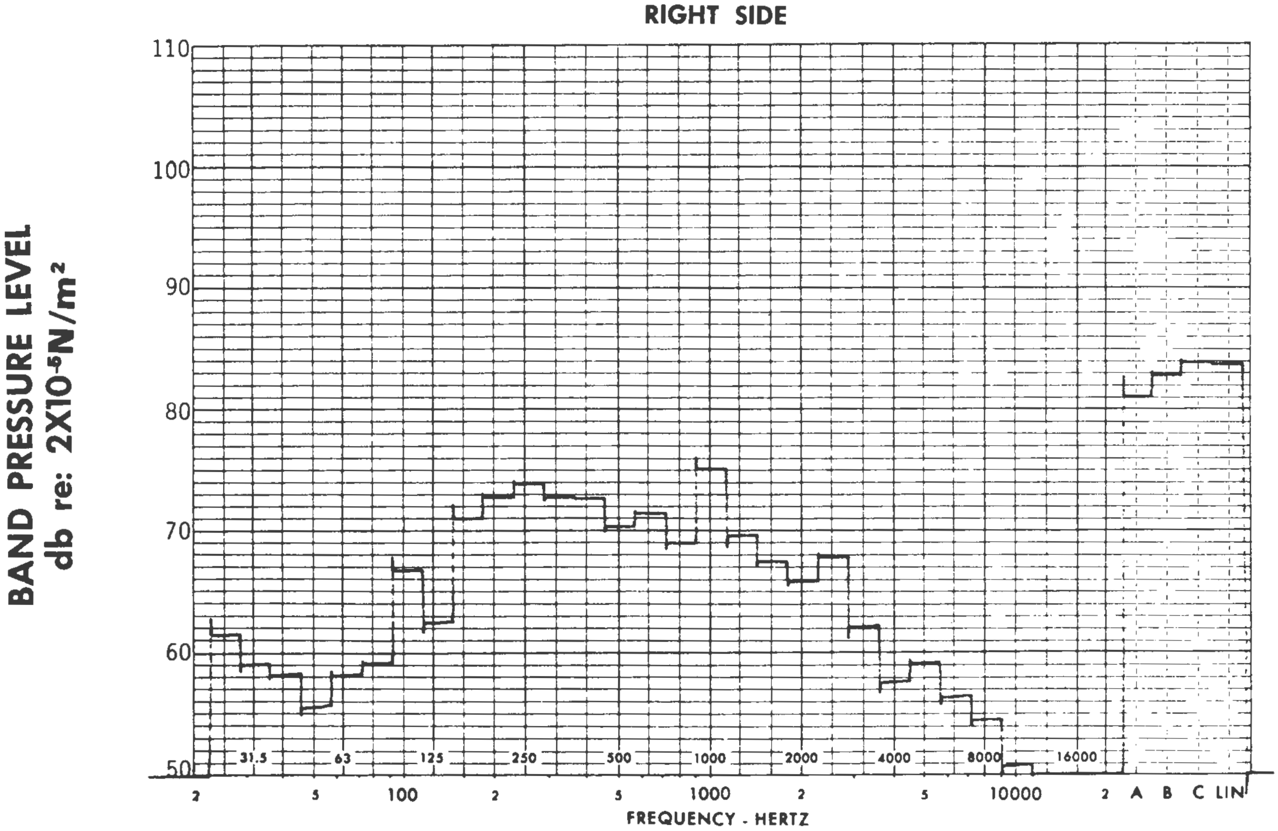
RIGHT SIDE

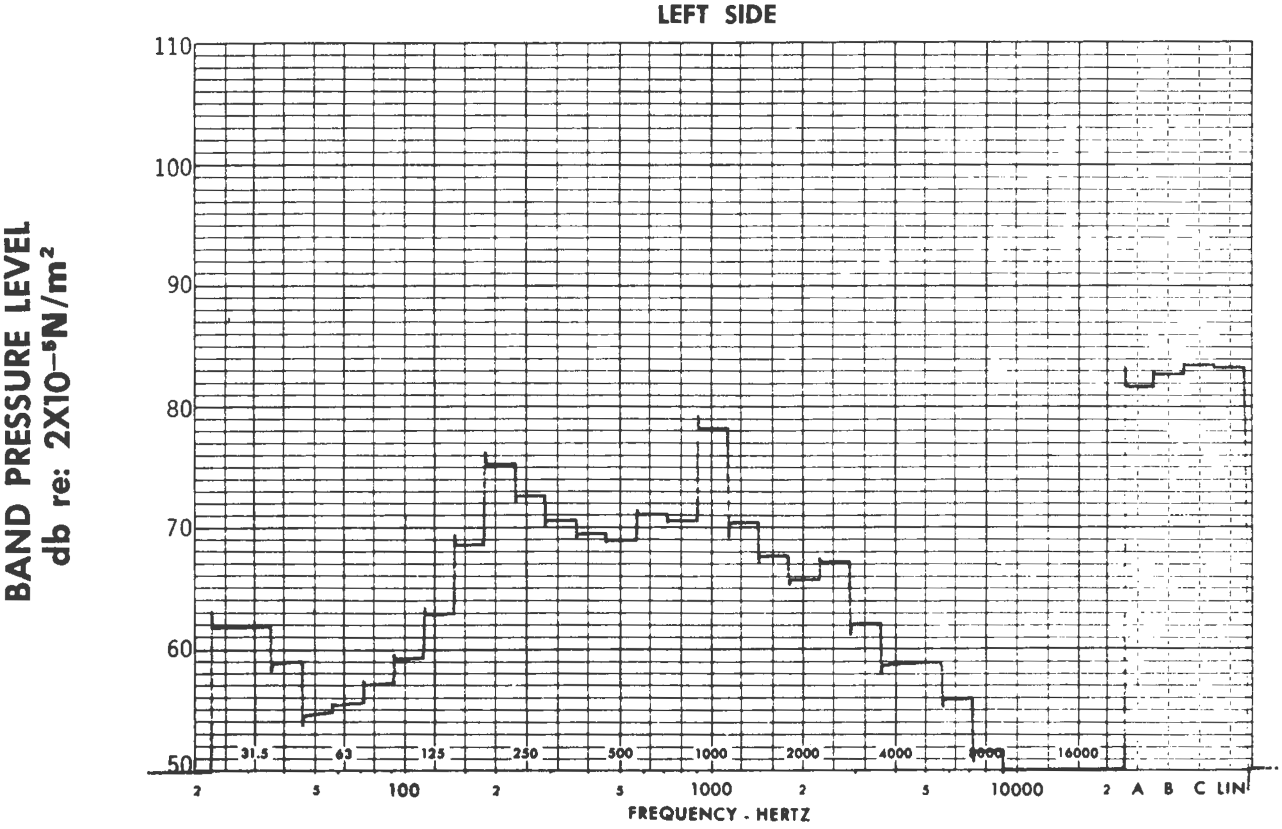


LEFT SIDE



VEHICLE MODEL: JI9500
TOTAL VEHICLE NOISE





APPENDIX C

EVALUATION OF DETROIT DIESEL ALLISON DIVISION'S TWO SPEED GOVERNOR

Supplementary testing was conducted on the DH9502 to evaluate the feasibility of using a two speed governor to reduce passby noise levels. A subjective and objective evaluation of the performance of the components has been analyzed in the following comments.

The dual range governor P/N 5133792 was evaluated on T2568 DH 9502 with 318 DDAD engine and RTO 913 transmission. Exterior vehicle noise level was measured per the SAE J366 passby procedure. Vehicle performance was evaluated as acceleration times for 1/8 and 1/4 mile on the DPG straight away, and total time on a city/country traffic course run from the DPG through Mesa and Tempe. The test load was 72,190 lbs. GCW.

Results of the passby, acceleration, and city/traffic test were:

No Load Governor Setting	Noise Level	1/8 Mile Time	1/4 Mile Time	Traffic Course Time (47 Miles)
2250 RPM	86.9 dB A	25.9 Sec.	40.4 Sec.	97 Min.
Shift Points	2250 - 1700 RPM Lo Range 2250 - 1900 RPM Hi Range w/Splitter			
1850 RPM	85.0 dB A	26.8 Sec.	41.9 Sec.	100 Min.
	dB A = 1.9	t = 3%	t = 4%	t = 3%
Shift Points	1850 - 1400 RPM Lo Range 1850 - 1550 RPM Hi Range w/Splitter			
1650 RPM	83.4 dB A	28.9 Sec.	45.4 Sec.	105 Min.
	dB A = 2.9	t = 12%	t = 12%	t = 8%
Shift Points	1650 - 1350 RPM Lo Range 1650 - 1450 RPM Hi Range w/Splitter			

SUBJECTIVE DRIVEABILITY

The performance and driveability at 2250 RPM maximum governed engine speed was excellent and the exhaust smoke level was very acceptable (Ringelmann No. 1 20% dense).

The performance and driveability at 1850 RPM maximum governed speed was acceptable and noise level in cab was very much improved from the level at 2250 RPM. This was attributed to reduced fan speed which resulted from the lower governed engine speed.

The performance and driveability at 1650 RPM maximum governed speed was not acceptable in city traffic. It was noted that while being operated in a downtown traffic situation, the poor performance of the truck caused the interruption of the flow of traffic. Smoke level was unacceptable (Ringelmann No. 3.5 70% dense). Noise level in the cab was very acceptable.

APPENDIX D

DEALER SERVICE TECHNICAL BULLETIN - TRUCKS

GMC
TRUCKS
SERVICE

Dealer Service Technical Bulletin

GMC TRUCK & COACH DIVISION GENERAL MOTORS CORPORATION

IMPORTANT—All Service Personnel Should Read and Initial

NUMBER: 75-T-13
GROUP: 1-Cab & Body-3
DATE: September, 1975

SUBJECT: EXTERIOR NOISE RETROFITTING

MODELS: ALL 7500-9500 DIESEL MODELS

Prior to the 1975 calendar year, vehicle noise legislation has primarily affected manufacturers of motor vehicles; however, regulations will become effective on October 15, 1975 which will affect operators directly. This bulletin provides a general review of laws as they apply to both manufacturers and operators, plus provides guidelines for retrofit of older GMC trucks.

Regulations Affecting Manufacturer

On January 1, 1973, manufacturers were required by law in several jurisdictions to build vehicles (10,000 GVW and over) which did not exceed the 86 dBA level. GMC trucks built after January 1, 1973 were designed and built to comply with the 86 dBA limit; however, through exhaust system deterioration and alterations, levels may in some cases exceed the limit. Tabulated on pages 9 thru 11 are exhaust, cooling, and shielding components which should be considered as possible fixes to various GMC truck models found to exceed the 86 dBA level.

In addition, various state and local jurisdictions require that certain new trucks manufactured on and after January 1, 1975, sold in these areas, must meet a noise level limit lower than 86 dBA measured at 50 feet (see Figure 1). Such trucks may require the installation of engine shields and fan clutches combined with improved exhaust muffling systems (available as an OEM option) in order to meet these state and local laws.

Area	Gross Vehicle Weight Rating (GVWR) of Trucks Affected	Noise Level Limits For Trucks Manufactured on or After Jan. 1, 1975
Barrington, Illinois	Over 8,000 lbs.	84 dBA
Boston, Massachusetts	Over 10,000 lbs.	84 dBA
California	Over 6,000 lbs.	83 dBA
Chicago, Illinois	Over 8,000 lbs.	84 dBA
Cook County, Illinois	Over 8,000 lbs.	84 dBA
Des Plaines, Illinois	Over 8,000 lbs.	84 dBA
Grand Rapids, Michigan	Over 10,000 lbs.	84 dBA
*Nebraska	10,000 lbs. (Diesel powered)	84 dBA

* Nebraska requires compliance of new diesel powered vehicles *sold* after January 1, 1975 *regardless of manufacture date.* In view of the extensive material and labor modifications necessary, it is not feasible to provide a suitable retrofit package or packages for dealer use in this state to upfit unsold new vehicles in inventory, so the affected vehicle will meet the required Noise Level Limits. Therefore, if you are located in Nebraska, you should take steps to ensure that your transactions are in compliance with these statutes.

Oregon – It should be noted that all 1976 model year trucks (over 6,000 lbs.) sold in Oregon must meet 83 dBA.

It is anticipated that all of the above mentioned state and local manufacturer noise limits will, in the future, be preempted by federal new truck noise standards which will soon be promulgated by the federal Environmental Protection Agency (E.P.A.)

FIGURE 1 AREAS WITH NOISE LEVEL LIMITS

Regulations Affecting Operator

The Interstate Motor Carrier noise emission standards established under the Noise Control Act of 1972, become effective **October 15, 1975**, and cover all motor vehicles weighing over 10,000 lbs. GVW **engaged in interstate commerce**. Enforcement procedures will be enacted through the Department of Transportation and will include the following:

Greater Than 10,000 lbs. GVW
Interstate Commerce

1. 90 dBA at 50 feet at speeds greater than 35 mph.
2. 86 dBA at 50 feet at speeds equal to or less than 35 mph.
3. 88 dBA at 50 feet under stationary run-up tests.
4. Visual Exhaust System Inspection.
5. Visual Tire Inspection.

Exterior noise sources may be categorized as follows:

1. Exhaust system noise can be of two distinct sources, airborne noise coming from the exhaust outlet an vibrational noise radiated from metal surfaces of muffler and piping. Recommendations for the control of airborne and vibrational noise are treated on page 4 in this bulletin.
2. Cooling fan noise can be isolated by removing fan or fan drive belts and noting reduction in overall vehicle noise level. The most effective solution to a fan noise problem is the installation of a thermatically controlled fan drive. Other cooling system recommendations are made later which will not alter cooling system index and will reduce noise. However, the thermatically controlled fan drive may be the most cost effective depending upon the other changes required.
3. Air intake noise is a relatively minor source compared to exhaust and cooling fan noise. An air cleaner of proper design for the vehicle will, in general, solve the majority of the air intake noise conditions.
4. Excessive engine radiated noise can be reduced, in some cases, by installing specially treated oil pans and valve covers. On pages 12 & 13 are pictured cab side shields which reduce the engine mechanical noise radiated.
5. Although tire noise is dependent upon vehicle speed, tread design and wear pattern greatly affect the level of noise produced. Some tread patterns form closed air pockets as they become worn and thus tend to emit more noise as they wear.

   The solution to a tire noise problem is in the selection of a tread design that minimizes the noise level while retaining good wear and traction qualities. The operator should be advised to contact the tire manufacturer for his recommendation.

If the truck does not meet the 86 dBA requirement in its present condition, it is possible that it may achieve the specified noise levels using only a muffler change and exhaust system inspection. The above-35 mph-noise-level requirement may only require a tire change.

Exterior Noise Level Testing

Important items to consider in vehicle testing if accurate noise level measurements are to be obtained are:

1. Noise meter specifications and operating conditions.
2. Noise tests should be made under specifications prescribed by the Society of Automotive Engineers Truck Noise Level Procedure J366b.

Stationary Test

Exterior noise may be measured using either the stationary run-up or the drive-by method. The stationary noise test is the quickest way to measure exterior noise level of the vehicle. This test requires a test site and conditions as follows:

1. Site must be hard surfaced (concrete or **sealed** asphalt) and located in level open space free of reflecting surfaces such as parked vehicles, signboards, buildings within a 50 foot radius (see Figure 2).
2. Microphone located 50 feet from the longitudinal center line of vehicle and 3-1/2 to 4-1/2 feet above ground. Microphone should be in line with a plane passing through the center line of the exhaust outlet, ± 3 feet.
3. Surface of the ground between the microphone and the vehicle should be free of snow, loose soil, etc.
4. No persons other than the driver and the observer who will read the meter should be within 50 feet of the vehicle.
5. The ambient sound level from other sources

should be at least 10 dBA lower than the level of the tested vehicle.

6. Measurements should not be made under any conditions of precipitation.

7. If a vehicle is equipped with an automatic fan drive, the test should be conducted with the fan disengaged. If necessary, the engine should be run at 1,000-1,500 rpm to provide sufficient flow of cooling air to allow fan disengagement.

8. This test is applicable only to vehicles equipped with an engine speed governor (Diesel).

Noise measurement by the stationary test method should involve a vehicle with engine at normal operating temperature and microphone at 50 feet from center line of vehicle travel. The following is a suggested stationary test procedure:

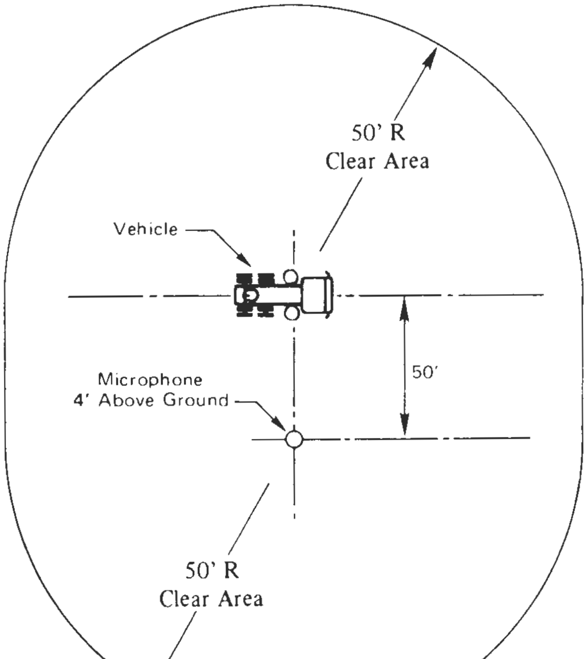


FIGURE 2
STATIONARY EXTERIOR NOISE TEST SITE

1. Sound level meter may be mounted on tripod or hand held. The sound level meter shoud be calibrated and set for "fast" meter response on the "A" network.

2. Parking brakes should be set and transmission should be in neutral. The accelerator is to be floorboarded briskly to attain maximum governed rpm. Record the **peak** meter reading, **not** the stablized noise level. Record this reading and repeat until two readings are obtained which are no more than 2 dBA apart. Average the two highest readings which are within 2 dBA of each other.

3. This test should be performed from both sides of the vehicle, and the results recorded. The highest of the two averages is the acceptable sound level of the truck.

Drive-By Acceleration Test

Exterior sound level measurements for heavy duty trucks, conducted in accordance with SAE J366b, are acceptable. The following is suggested test procedure based on SAE J366b also, see Figure 3.

1. Test site should be a hard surfaced, level, open area free of large reflecting surfaces within 100 feet of microphone.

2. Microphone must be situated 50 feet from center line of vehicle path and 4 feet above the ground.

3. Vehicle must be accelerated at full throttle from a point 50 feet before the microphone line.

4. Proper gear must be selected so that the vehicle reaches governed engine rpm at a speed of 35 mph or less, within a zone beginning 10 feet after the microphone line and ending 50 feet after the microphone line.

5. Surface of the area within measuring site should be free of powdery snow, loose soil, etc.

6. Ambient sound level be at least 10 dBA lower than the level of the test vehicle.

7. Measurements should not be made under any conditions of precipitation.

8. Sound level reading should be taken from both sides of the vehicle. The two highest readings from each side within 2 dBA of each other should be averaged. The highest of the two averages is the accepted sound level of the truck.

NOTE: Dealership testing in the stationary mode should provide close correlation with either drive-by or stationary test modes used by enforcement personnel. It should be the objective of the dealership to reduce the vehicle's noise level as dictated by the amount exceed in the citation.

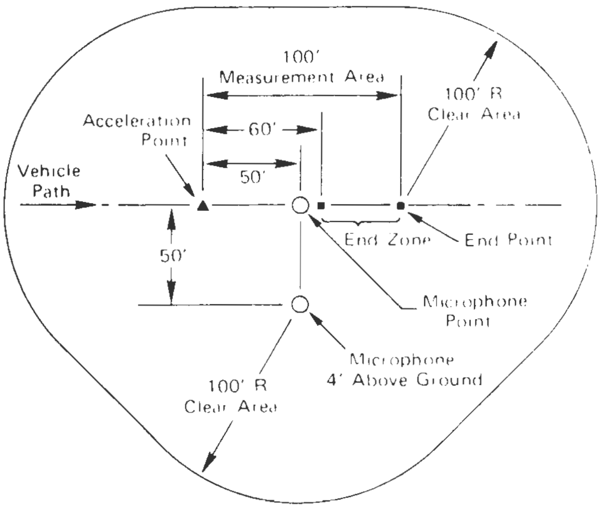


FIGURE 3
DRIVE-BY EXTERIOR NOISE TEST SITE

Tests may be conducted with or without a trailer on the tractor. In most cases, it is more convenient to conduct tests without a trailer due to the difficulty of turn around, etc.

There are a number of practical problems associated with pass-by testing which generally preclude use of this type test by a dealership. Acquisition of land and construction of a pass-by site would be expensive. Use of a public street or highway involves problems of control and interference by other noise sources. For these reasons, it is recommended that the stationary test procedure be used.

Sound Level Meter

The type of meter recommended for vehicle noise testing is the Type II, General Purpose Sound Level Meter. Proper calibration, scale reading, and meter positioning are critical for accurate noise level testing. Refer to Dealer Service Information Letter dated June 1, 1975, "Noise Level Meters", Section 12, Special Tools and Equipment.

Suggested Modifications

To reduce exterior noise levels on various models, exhaust and cooling changes may be necessary. Materials specified in the various model line charts provide part numbers of exhaust, cooling, and shielding components which are used on current production vehicles. This material should be installed only after accurate testing and a check for obvious noise emission points on the vehicle has been performed. Broken or leaking flex pipe and poor connections are two common conditions which can account for a major portion of the vehicle noise level. Altered exhaust systems, not only may increase the exhaust noise emitted, but produce detrimental back pressure effects on the engine. Only recommended mufflers should be installed where a muffler change has been found to be a means to correct the problem. Other areas to check for exhaust leak points are as follows:

Manifolds
Manifold mounting gaskets
Exhaust flange seals
Rigid piping
Resonators (if equipped)

We have found through trial installations that not all recommended components (primarily mufflers) will be a one-for-one fit. The material listed may have increased size and shape which will have to be compensated for by some cutting, welding, and use of flex pipe. However, in most instances, conversion can easily be made using existing bracketry and hardware. Flex pipe should always be replaced with quality grade stainless steel types.

A vehicle fan noise problem can be one of the most difficult to properly solve. The important point to consider is that the cooling ability of the engine cooling system should be not be lowered when correcting a fan noise problem. For this reason, the most desirable solution to a fan noise problem is to install a thermatically controlled or a modulating fan drive. With this system, the fan is engaged a small percent of the time during the normal operation of the vehicle and a major noise source is eliminated. Check with local fan clutch distributor for proper model and application. An alternate solution to engine cooling system noise is installation of the recommended components listed in Chart F. It is not necessary to make these modifications in addition to a fan clutch.

The following charts, by model type, specify exhaust, cooling, and shielding requirements necessary for retrofitting certain past models of GMC trucks. On models other than those listed on the conversion charts which are tested and found to exceed the specified noise levels, the operator may be able to utilize some of the recommended material and procedures to bring his vehicle into compliance.

It is suggested that before making initial test, check the following:

1. Ensure that the engine is running correctly.

2. Engine governed rpm setting.

3. Exhaust leaks.

4. Correct parts in exhaust and cooling areas.

Vehicle modification should be performed according to the following sequences:

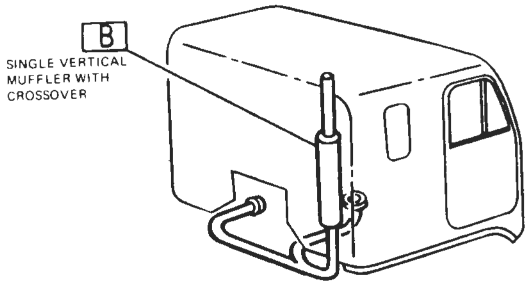
1. Muffler - retest

2. Cooling changes – if required, retest

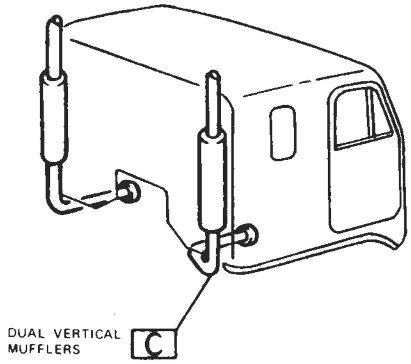
3. Shielding

In some instances, not all of the recommended material will be required since a revised muffler may be all that is needed. Shown on pages 5-8 are the various exhaust systems of which the proper component application chart should be referred to.

The information contained in this bulletin is provided for information purposes only. Our intention in publishing this bulletin is to make service personnel generally aware of noise laws affecting our products. This bulletin is no substitute for legal counsel, and it is recommended that if you or one of your customers has a question regarding the applicability of, or compliance with, federal, state or local noise laws, please consult an attorney, further, our specific recommendations because of variations in conditions of use, deterioration, maintenance, etc. for the reduction of sound levels on in-service GMC vehicles should not be considered a guarantee or warranty by GMC that if our recommendations are followed, individual vehicles will meet certain noise levels.



ASTRO - REFER TO CHART A



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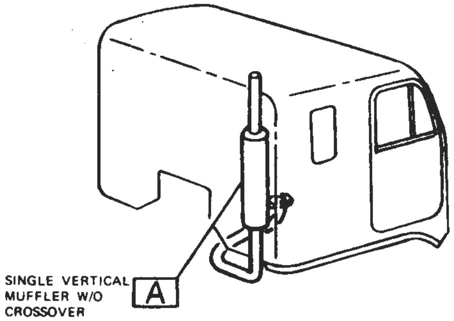

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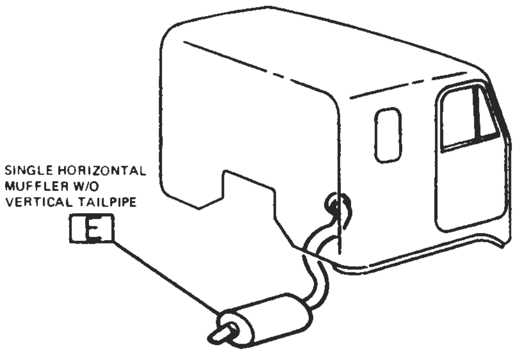

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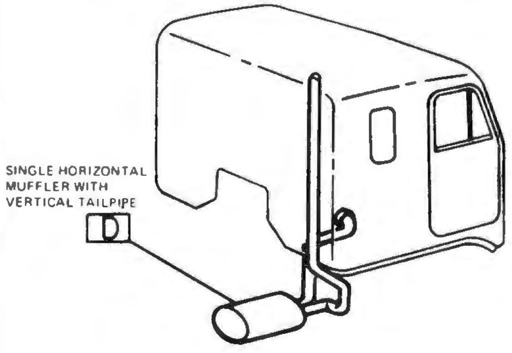


ASTRO - REFER TO CHART A

The single horizontal muffler, vertical tailpipe system will require conversion to a single vertical muffler system. Shown below are various cab – air intake combinations which require conversion to the single vertical system using the parts listed.

FH, DH Model
86" Cab (Sleeper)
Horizontal Muffler System
Snorkle Air Intake

Part Requirements

Part Number	Description
721497	Muffler
717433	Strap (2)
687644	Pipe Upper R.H.
687643	Pipe Upper L.H.
718531	Wye Pipe
5137619	Clamps (2)
658692	Locator
658801	Stak Extension
716643	Flex Pipes (2)
687646	Flex Pipe Bracket

DH, FH
86" Cab (Sleeper)
Frontal Air (RPO KJ9)
Single Horizontal Muffler System)

Part Requirements

Part Number	Description
721497	Muffler
713093	Straps (2)
718530	Support Bracket
687644	Pipe
687644	Pipe
687643	Pipe
718531	Pipe
5137619	Clamp (2)
658801	Stack Extension
716643	Flex Pipe (2)
687646	Bracket

FH, DH 9500
54" Cab Non-Sleeper
Snorkle Air Intake
Single Horizontal Muffler, Vertical Tailpipe

Part Requirements

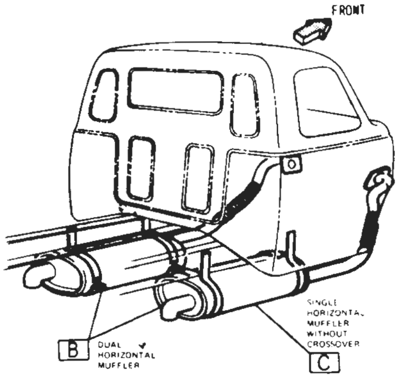
Part Number	Description
721497	Muffler
717433	Straps (2)
658692	Muffler Locator
648688	Upper Pipe L.H.
658489	Upper Pipe R.H.
5137619	Manifold Clamp (2)
648484	Lower Pipe L.H.
658808	Lower Pipe R.H.
648480	Crossmember U-Bolt (2)
9421042	Washer (4)
103321	Washer (4)
9418931	Nut (4)
718517	Muffler Inlet Pipe
716643	Flex Tube (2)
658801	Stack Extension
2378620	4" Pipe Clamp (AR)

FH, DH 9500
Non-Sleeper Cab
Frontal Air Intake (RPO KJ9)

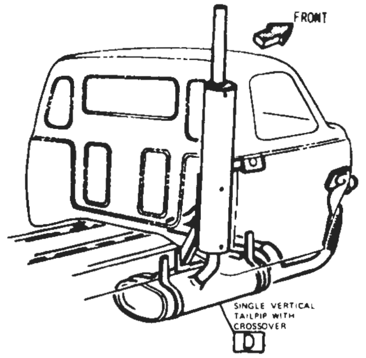
Part Requirements

Part Number	Description
721497	Muffler
5127794	Manifold (R.H.)
718533	Support Bracket
713093	Straps (2)
648484	Lower Pipe
648488	Upper Pipe
716643	Flex Pipe (2)
5137619	Clamps (2)
679209	Manifold Adapter
5100147	Gasket
9426323	Support Bracket Bolts (13) DH
9426323	Support Bracket Bolts (3) DH
9422332	Support Bracket Bolts (8) FH
2436165	Washer (6) DH
2436165	Washer (16) FH
9422301	Nut (3) DH
658801	Stack Extension
658808	Muffler Pipe
658692	Locator Bracket
9419073	Manifold Adapter Bolt (4)
103328	Manifold Adapter Washer (4)
9422301	Nut (8) FH

HEAVY-DUTY CONVENTIONAL -
REFER TO CHART B



HEAVY-DUTY CONVENTIONAL -
REFER TO CHART B



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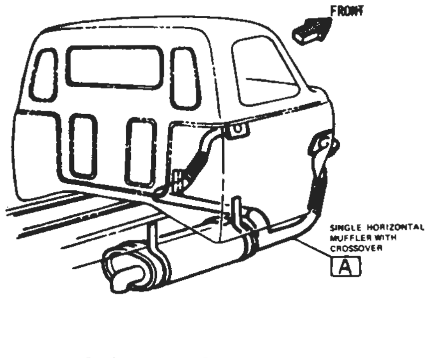

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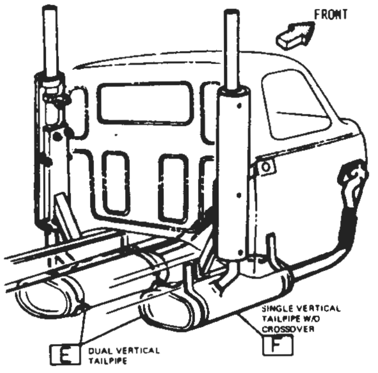

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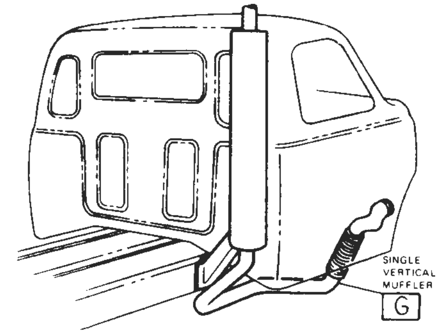

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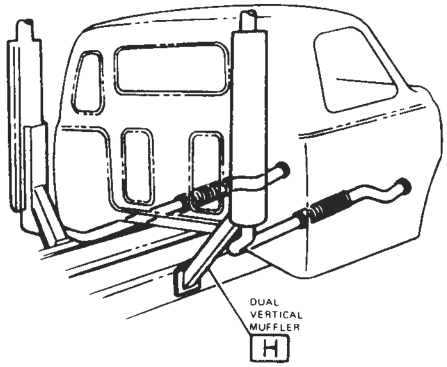

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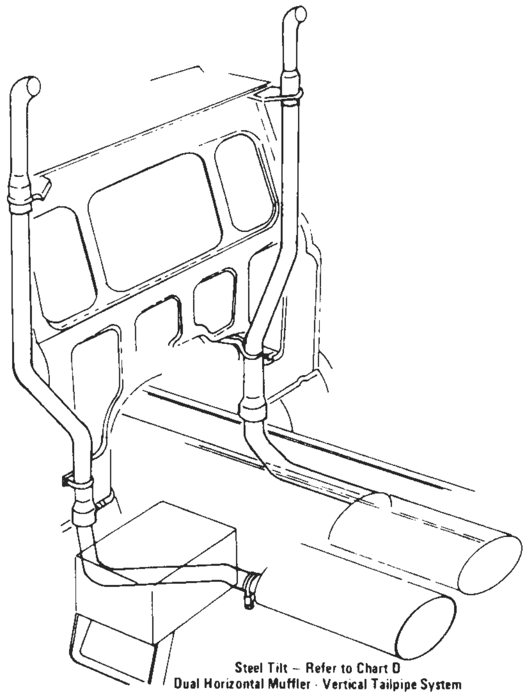
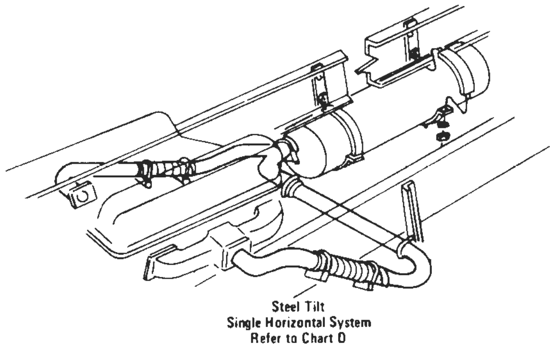


STEEL TILT – REFER TO CHART D
DUAL HORIZONTAL MUFFLER - VERTICAL TAILPIPE SYSTEM



STEEL TILT – REFER TO CHART D
SINGLE HORIZONTAL SYSTEM

CHART A
ASTRO MODEL
EXHAUST MODIFICATIONS

SYSTEM	MODEL	YEAR	ENGINE	EXH. SYSTEM TYPE	ORIG. MUFFLER	REPL. MUFFLER	ALTERNATE MUFFLER
C	DI,FI	69-72	6-71	SVTP	651997 or 651998	713061	
		73-74	"	"	697602	713061	
D		69-72	"	SH	2483764 or 2482972	717202	
		73-74	"	"	695424	717202	
A,B		69-72	"	SV	660901 or 2182970	717217	STEMCO – 9353
A,B		73-74	"	SV	695423	717217	STEMCO – 9353
C	DH,FH	69-72	8V-71	SVTP	651996 or 651995	SEE CAB –	EXHAUST LAYOUT FOR SVTP
AB		69-74	"	SV	685217 or 704305	721497	STEMCO – 9869
E		69-74	"	DV	676533 or 691318	717214	2005343 A.R.
E	DP9502	71-72	12V-71	DV	663283	717217	STEMCO – 9353[1]
		73-74	12V-71	"	695423	717217	STEMCO – 9353[1]
E	OB9502	72-74	V-903	DV	676533 or 691318	717217	
C	DN,FN	71-72	NH250	SVTP	651996 or 651995	2005343 A.R.	
C		73	"	SVTP	695421	2005343 A.R.	
D		71-73	"	SH	679399	717202	
A,B		71-72	"	SV	660901 or 2482970	2005341 A.R.	
A,B		73	"	SV	685217	2005341 A.R.	
A,B	DC,FC	71-72	NTC270 NTC335	SV	663284 or 663283	713064	
A,B		73-74	"	"	695419	713064	

A.R. ORDER PART ON AN "AS REQUIRED" BASIS.

[1] REQUIRES 4" TO 5" ADAPTER

SVTP – SINGLE VERTICAL TAILPIPE

SH – SINGLE HORIZONTAL MUFFLER

SV – SINGLE VERTICAL MUFFLER

DV – DUAL VERTICAL MUFFLERS

CHART B
HEAVY DUTY CONVENTIONAL
EXHAUST MODIFICATIONS

SYSTEM	MODEL	EXH. SYSTEM	EXISTING MUFFLER DIMENSIONS	REPL. MUFFLER	MAKE	MANF. NO.	REPL. DIMENSIONS
A,C	HC,JC	SH	36.0 x 10.12	713031[1]	D	WOM12-0201	36.0 x 10.0 x 15.0
G		SV	44.5 x 9.0	717308	D	MPM09-0197	44.5 x 9.0
A,C	HN,JN	SH	26.0 x 10.0 x 15.0	717202	D	WOM12-0203	36.0 x 10.0 x 15.0
D,F		SVTP	26.0 x 10.0 x 15.0	717202	D	WDM12-0203	36.0 x 10.0 x 15.0
G		SV	44.5 x 9.0	2005341 A.R.	S	9349	44.0 x 9.0
A,C	HI,HI	SH	28.0 x 10.12	717202[2]	D	WOM12-0203	36.0 x 10.0 x 15.0
D,F		SVTP	28.0 x 10.12	2488077	N	T-9396	28.0 x 10.12
G		SV	44.5 x 9.0	2005341 A.R.	S	9349	45.00 x 9.0
B	HH,JH	DH	28.0 x 10.12	717209[3]	O	WOM12-0209	36.0 x 10.0 x 15.0
E		OVTP	28.0 x 10.12	682154	D	MAM10-0062	28.0 x 10.12
H		OV	44.5 x 9.0	2005343 A.R.	S	9352	45.0 x 9.12
D,F	MC	SV	44.5 x 9.0	717308	D	MPM09-0197	44.5 x 9.0
H	JB,MB	DV	44.5 x 9.0	691318	D	MSM09-0194	44.5 x 9.0
B	CH,MH	OH	28.0 x 10.12	717209[3]	O	WOM12-0209	36.0 x 10.0 x 15.0
E		DVTP	28.0 x 10.12	717209	D	WOM12-0209	36.0 x 10.0 x 15.0
H		DV	44.5 x 9.0	2005343 A.R.	S	9352	45.0 x 9.12
A,C	HV,JV	SH	28.0 x 10.12	717202[4]	O	WOM12-0203	36.0 x 10.0 x 15.0
B		DH	28.0 x 8.5	2005340 A.R.	D	WOM09-0159	26.0 x 8.75 x 12.0
D,F		SVTP	28.0 x 10.12	2005342 A.R.	S	9851	38.5 x 10.0

A.R. ORDER PART ON AN "AS REQUIRED" BASIS

[1] [3] [2] [4] REFER TO CHART C FOR ASSOCIATED BRACKETRY REQUIRED

CHART C
HEAVY DUTY CONVENTIONAL
BRACKETRY

	MODEL	EXH. SYSTEM	REPL. MUFFLER	MUFFLER BRKT.	QTY.	MUFFLER STRAP	QTY.
1	HC,JC	SH *	713031	713029	2	683142	2
2	HI,JI	SH	717202	718957	2	683142	2
3	HH,JH	DH,DVTP	717209	717298	4	708482	4
4	HV,JV	SH,DH	717202	721114	2	683142	2

* HARDWARE REQUIRED ON 1972 AND PRIOR MODELS

CHART D
STEEL TILT
EXHAUST MODIFICATIONS

MODEL	YEAR	ENGINE	EXHAUST SYSTEM	ORIG. MUFFLER	REPL. MUFFLER	HARDWARE
TV,WV	65-75	6V-53	DVTP[1]	(20.0 x 11.0 x 8.2) 2385995	(26.0 x 11.5 x 8.5) 2005340 A.R.	2403262 – Pipe (2) 2358415 – U-Bolt
TV,WV	65-73	6V-53	DH	2385995	2005340 A.R.	
TV,WV	73-75	6V-53	SH	695424 (28.0 x 10.12)	717202 (36.0 x 15.1 x 10.1)	720800 – Brkt. 721114 – Brkt.

[1] ALL DUAL HORIZONTAL MUFFLER-VERTICAL TAILPIPE SYSTEMS SHOULD BE CONVERTED TO THE DUAL HORIZONTAL SYSTEM

CHART E
FLEX PIPE & U-CLAMPS

FLEX PIPE	PART NO.	U-CLAMP	PART NO.
3.0 x 13.0	719236	3"	791784
4.0 x 14.0	716643	3-1/2"	791785
4.0 x 12.0	717231	4"	791786
5.0 x 16.0	716645	4-1/2"	791787
5.0 x 14.0	716644	5"	791788

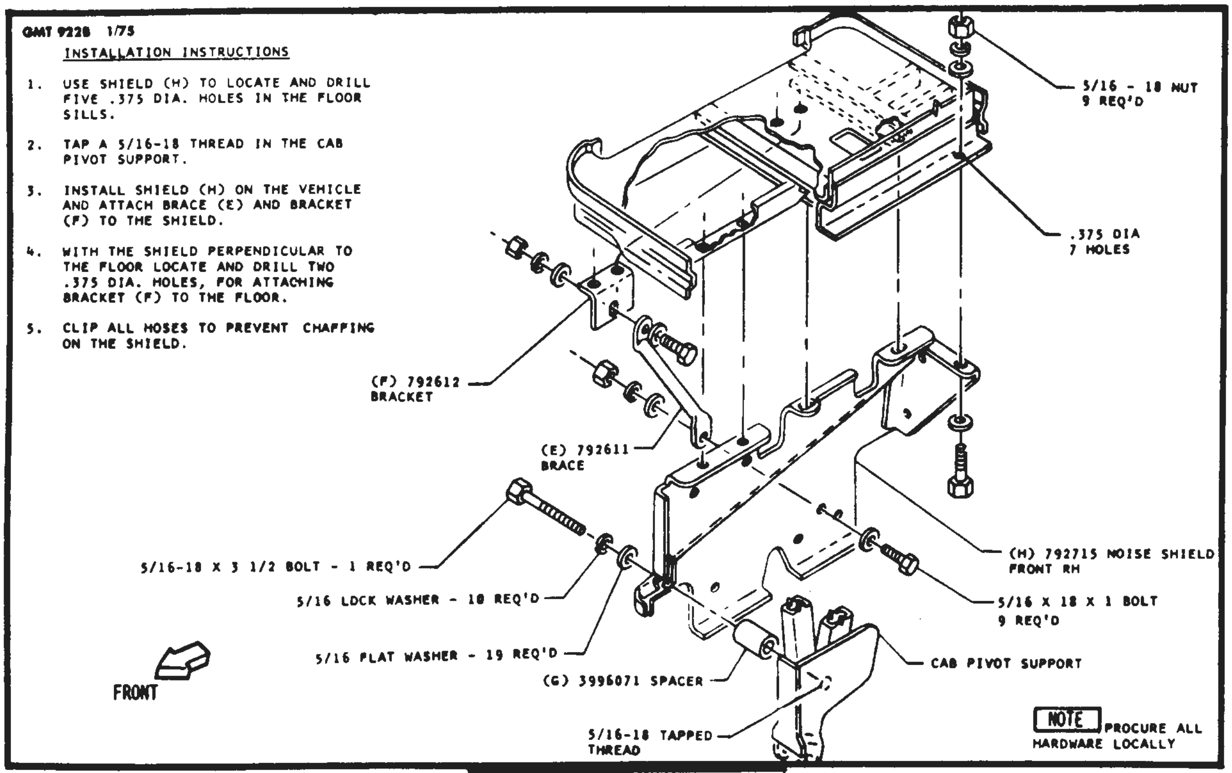
CHART F
COOLING MODIFICATIONS
ALL MODELS

MODEL	ENGINE	EXISTING FAN	REPL. FAN	ASSOCIATED PARTS
HI,JI	6-71	28" 6 BLADE	2005390	NO FAN CHANGE IF EXISTING IS 26" 6 BLADE
HH,JH	8V-71	6 BLADE	2005390	
HN,JN	SUPER 250 NH-250 NH-230	28" PRIOR TO 1973	2005390	FAN PULLEY – CUMMINS NO. 211845 BELT SET – CUMMINS NO. 178443
		26" PRIOR TO 1973	2005390	FAN PULLEY – CUMMINS 211845 BELT SET – CUMMINS 178443 RADIATOR (1100 SQ. IN.) – 684235 SHROUD – 704784, LOWER HOSE – 693313
HC,JC	NTC-270 NTC-290 NTC-335	28"	707490	SHROUD – 796236 BELT SET – 178466 FAN PULLEY – CUMMINS 216885
JB,MB	V-903	26"	2005390	SHRDUD – 719233 FAN PULLEY – 217198 BELT SET – 204481 ALTERNATOR BELT – 697076 A/C COMP. BELT – 9433898
TW,WW	6V-71 8V-71	IF 28"	2005390	
DI,FI	6-71	SAME AS HI,JI		
DH,FH	8V-71	IF 28"	2005390	
DH,FH	8V-71T	30" NO RETROFIT REQUIRED		
		28" 6 BLADE USE HORTON OR SCHWITZER FAN CLUTCH		
DN,FN	NH-230 NH-250	28" PRIOR TO 1973	2005390	FAN PULLEY – CUMMINS 211845 BELT SET – CUMMINS 200328
DC,FC	NTC-270 NTC-290	28" PRIOR TO 1973	2005390	FAN PULLEY – CUMMINS 211845 BELT SET – CUMMINS 200328
	NTC-335		669381	FAN PULLEY – CUMMINS 211845 BELT SET – CUMMINS 200328
DB,FB	V-903	SAME AS JB,MB		
DP95	12V-71		708338 32"	SHROUD (LH) – 711809 SHROUD (RH) – 711810 SHROUD (UPPER) – 711811 SHROUD (LOWER) – 711814 CRANK PULLEY – 5122482 BELT SET – 5134591

MODELS WITH NO COOLING SYSTEM CHANGES REQUIRED

MODEL	ENGINE	MODEL	ENGINE	MODEL	ENGINE
EG,SG	DH478	HV,JV	6V-53	TJ,WJ	DH637
HG,JG	DH478	MC95	NTC-350	TV,WV	6V-53
HJ,JJ	DH637	TG,WG	DH478	DC,FC	NTC-350

ASTRO CAB SHIELD INSTALLATION



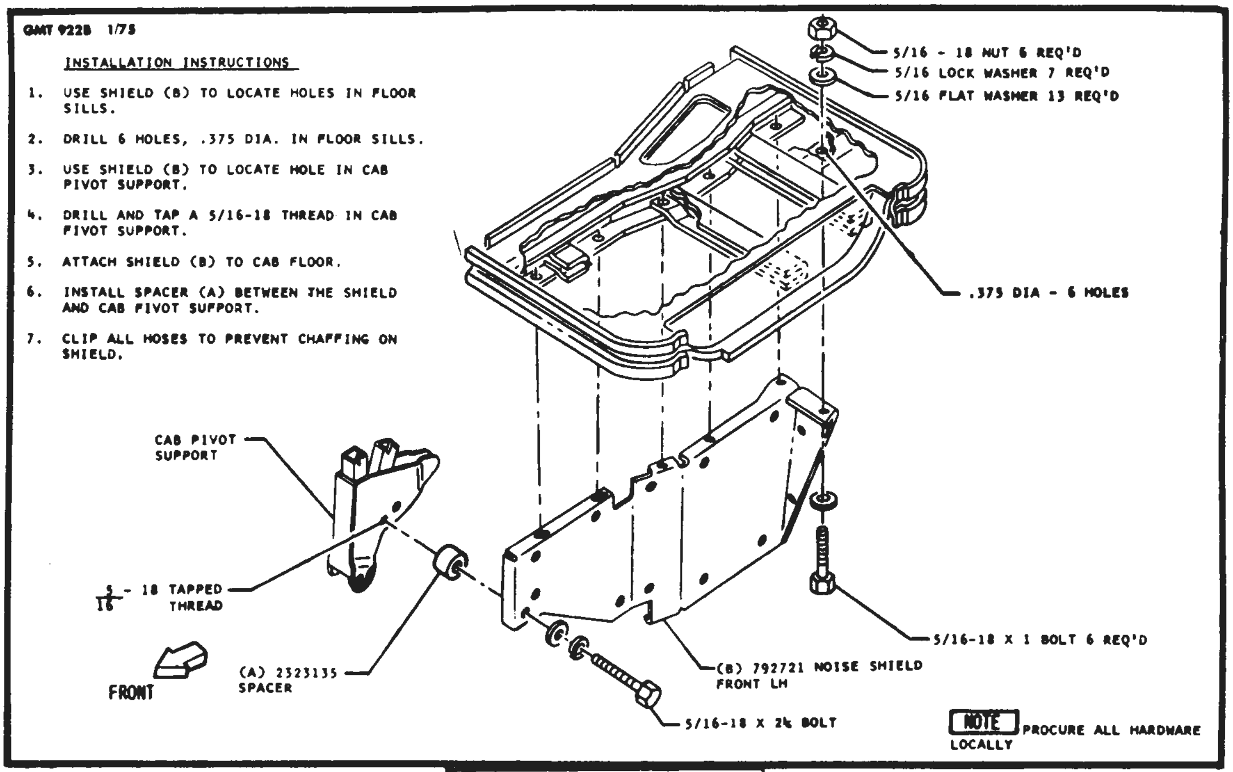
GMT 9228 1/75

INSTALLATION INSTRUCTIONS

1. USE SHIELD (H) TO LOCATE AND DRILL FIVE .375 DIA. HOLES IN THE FLOOR SILLS.
2. TAP A 5/16-18 THREAD IN THE CAB PIVOT SUPPORT.
3. INSTALL SHIELD (H) ON THE VEHICLE AND ATTACH BRACE (E) AND BRACKET (F) TO THE SHIELD.
4. WITH THE SHIELD PERPENDICULAR TO THE FLOOR LOCATE AND DRILL TWO .375 DIA. HOLES, FOR ATTACHING BRACKET (F) TO THE FLOOR.
5. CLIP ALL HOSES TO PREVENT CHAFFING ON THE SHIELD.

NOTE PROCURE ALL HARDWARE LOCALLY

TM DH/FM 9 (54",74", 86" CABS)
RH FRT ENG NOISE SHIELD



GMT 9228 1/75

INSTALLATION INSTRUCTIONS

1. USE SHIELD (B) TO LOCATE HOLES IN FLOOR SILLS.
2. DRILL 6 HOLES, .375 DIA. IN FLOOR SILLS.
3. USE SHIELD (B) TO LOCATE HOLE IN CAB PIVOT SUPPORT.
4. DRILL AND TAP A 5/16-18 THREAD IN CAB FIVOT SUPPORT.
5. ATTACH SHIELD (B) TO CAB FLOOR.
6. INSTALL SPACER (A) BETWEEN THE SHIELD AND CAB FIVOT SUFPORT.
7. CLIP ALL HOSES TO PREVENT CHAFFING ON SHIELD.

NOTE PROCURE ALL HARDWARE LOCALLY

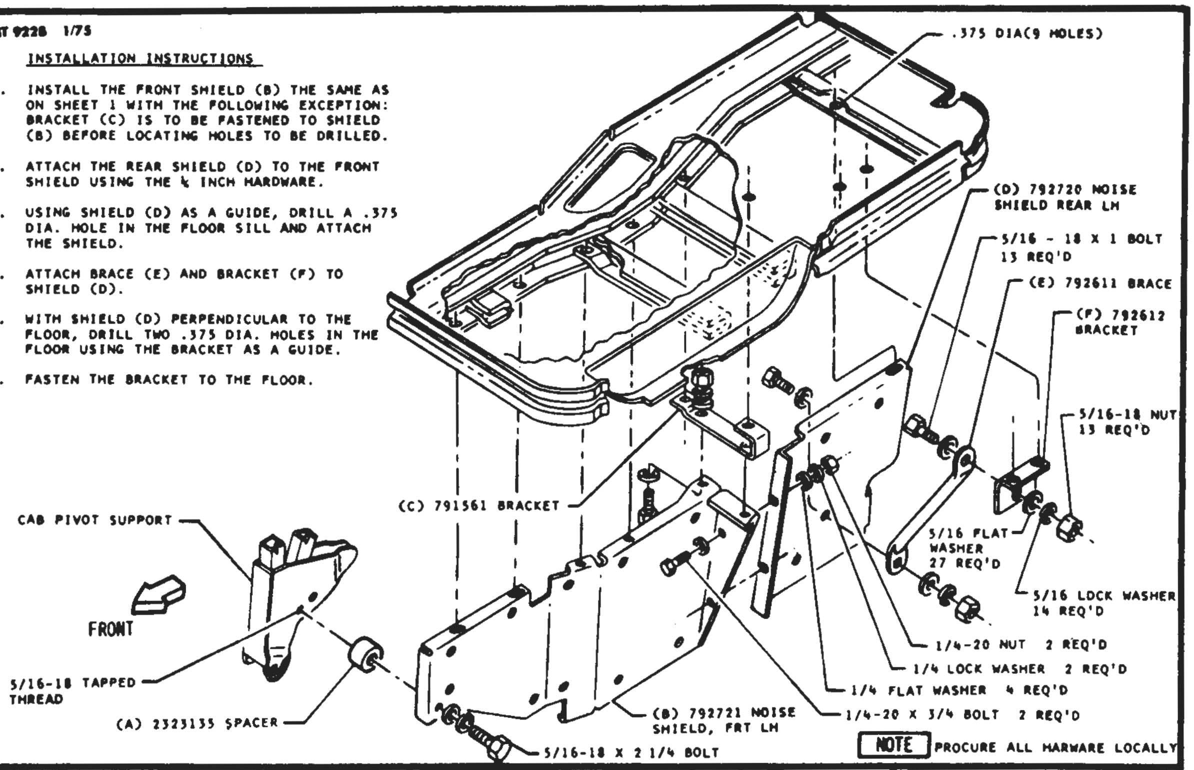
TM DH/FM 9(54" CAB)
LH FRONT ENG NOISE SHIELD

ASTRO CAB SHIELD INSTALLATION

GMT 9228 1/75

INSTALLATION INSTRUCTIONS

1. INSTALL THE FRONT SHIELD (B) THE SAME AS ON SHEET 1 WITH THE FOLLOWING EXCEPTION: BRACKET (C) IS TO BE FASTENED TO SHIELD (B) BEFORE LOCATING HOLES TO BE DRILLED.
2. ATTACH THE REAR SHIELD (D) TO THE FRONT SHIELD USING THE ¼ INCH HARDWARE.
3. USING SHIELD (D) AS A GUIDE, DRILL A .375 DIA. HOLE IN THE FLOOR SILL AND ATTACH THE SHIELD.
4. ATTACH BRACE (E) AND BRACKET (F) TO SHIELD (D).
5. WITH SHIELD (D) PERPENDICULAR TO THE FLOOR, DRILL TWO .375 DIA. HOLES IN THE FLOOR USING THE BRACKET AS A GUIDE.
6. FASTEN THE BRACKET TO THE FLOOR.



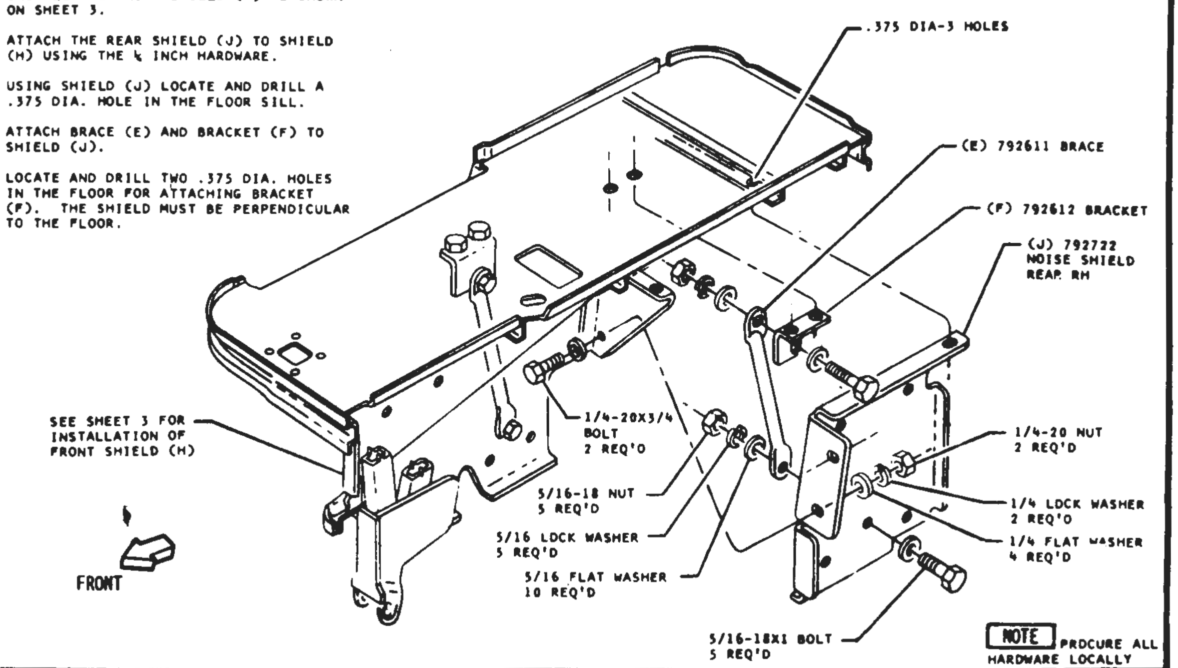
NOTE PROCURE ALL HARWARE LOCALLY

TM DH/FH 9(74 & 86" CABS)
LH ENG NOISE SHIELDS
(FRONT & REAR)

GMT 9228 1/75

INSTALLATION INSTRUCTIONS

1. INSTALL THE FRONT SHIELD (H) AS SHOWN ON SHEET 3.
2. ATTACH THE REAR SHIELD (J) TO SHIELD (H) USING THE ¼ INCH HARDWARE.
3. USING SHIELD (J) LOCATE AND DRILL A .375 DIA. HOLE IN THE FLOOR SILL.
4. ATTACH BRACE (E) AND BRACKET (F) TO SHIELD (J).
5. LOCATE AND DRILL TWO .375 DIA. HOLES IN THE FLOOR FOR ATTACHING BRACKET (F). THE SHIELD MUST BE PERPENDICULAR TO THE FLOOR.



NOTE PROCURE ALL HARDWARE LOCALLY

TM DH/FH 9(74" & 86" CABS)
RH REAR ENGINE NOISE SHIELD

APPENDIX E

GENERAL MOTORS TRUCK AND COACH DIVISION BULLETIN

This bulletin was compiled by General Motors Truck & Coach Division expressly for the purpose of fulfilling the requirements of United States Government Contract DOT-TSC-699 and is based upon the limited testing conducted thereunder. This bulletin may be revised at a later date with respect to parts, procedures, or any other particular at the sole discretion of General Motors Corporation.

Coach Service Technical Bulletin

GMC COACHES SERVICE

GMC TRUCK & COACH DIVISION GENERAL MOTORS CORPORATION

IMPORTANT—All Service Personnel Should Read and Initial

NUMBER:

GROUP:

DATE:

SUBJECT: Exterior Noise *

MODELS: T8H-5305

Coach retrofit requires the following changes be made:

1. Muffler

2. Belly Pan Insulation

3. Hydraulic Fan Drive

Muffler Replacement

The exhaust muffler is strap mounted longitudinally between the engine bulkhead and the bulkhead at rear of axle. Remove the existing muffler according to the service procedure outlined in X-7126, Sec. 8, page 298. Replace the muffler using the following muffler: Nelson T13680

Engine Belly Pans

The engine belly pans or dust shields below the power plants require the installation of fiberglass insulation to the inner surface. The following procedure may be followed:

1. Remove the engine dust shields.

2. Clean the engine side of the shields using suitable solvent.

3. Using three (3) pieces of insulation material, P/N 720214, trim material to appropriate size and adhere to the dust shields using 3M type No. 76 adhesive or similar. (Note: The insulation should be installed with the PVC treated side to the shield.)

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4. Bolts with large flat washers may be used to improve the insulation material retention.

5. Reinstall the dust shields on the vehicle.

Hydraulic Fan Drive

A coach equipped with the direct drive type fan drive may be replaced with thermostatically controlled fluid drive fan to further reduce the operating noise level. The speed this fan operates depends upon engine operating temperature which affects the amount of oil retained in the drive and driven torus housing. Oil from the engine crankcase is used to fill the torus housing to operate the fan.

To convert a direct drive type fan to a torus drive fan, the following procedure should be followed:

Replacement of the fan drive housing will be required for conversion since the torus drive shaft differs between the direct drive and the torus drive type fans. Replacement of both the accessory drive gear and the fan drive shaft is required since gear wear and mesh should be observed. For this reason, the entire fan drive housing should be replaced up to the engine front cover drive attachment (see Figure E-1).

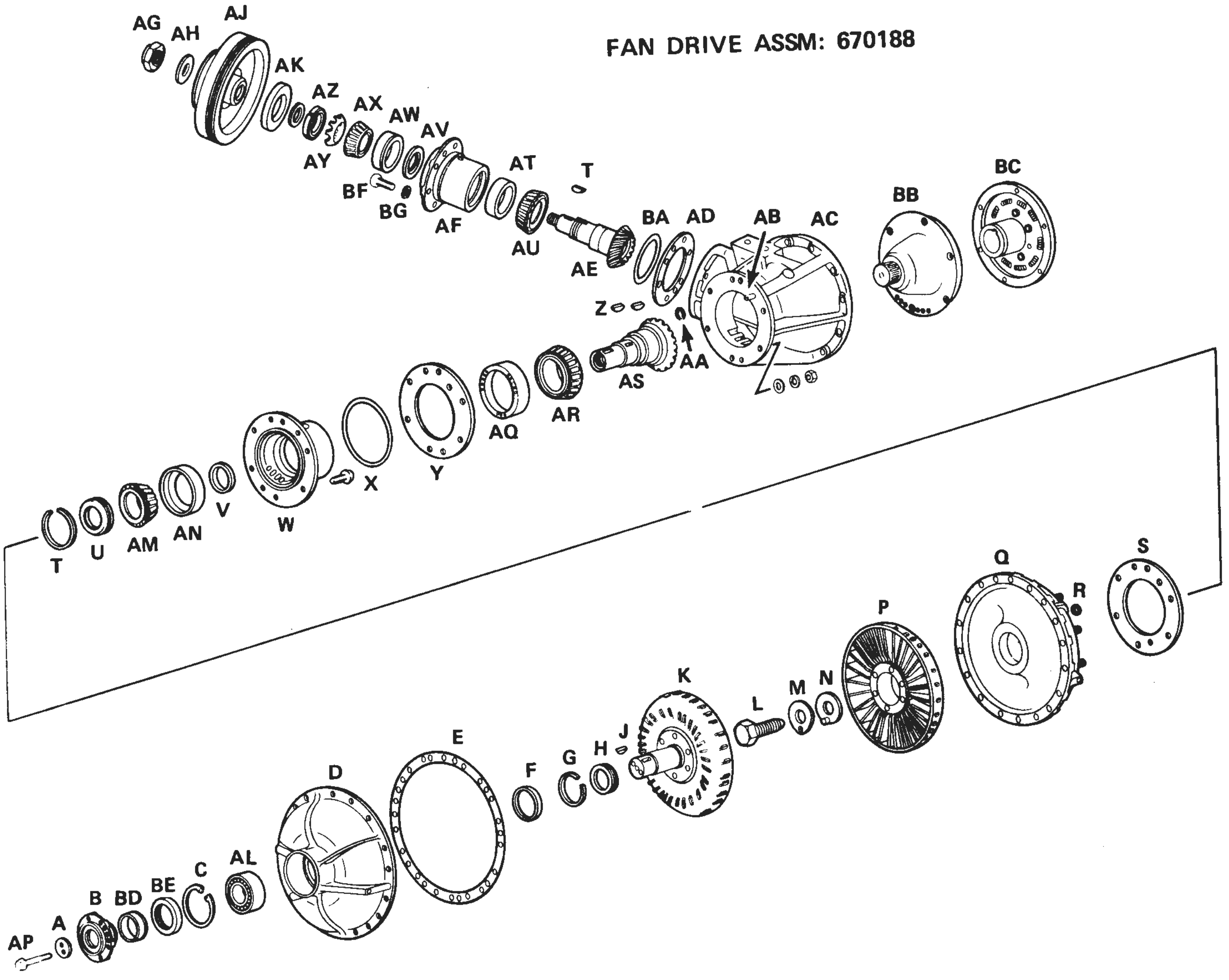

FIGURE E-1 HYDRAULIC FAN DRIVE ASSEMBLY

KEY TO FLUID FAN DRIVE (WITH AIR COND.)

KEY	PART NO.	DESCRIPTION
A	2356816	WASHER
B	688464	HUB ASSY
C	9422066	RING - retaining
D	711370	HOUSING
E	2385763	GASKET
F	2356813	BUSHING
G	5111492	RING
H	2357326	CARRIER
J	113782	KEY
K	2386785	TORUS ASSY
L	271676	BOLT - plain - (7/8-14 x 1-3/4)
M	2389705	PLATE - lock
N	2389706	WASHER ASSY
P	2386783	TORUS ASSY
Q	670172	HOUSING
R	060441	STUD
S	2386781	GASKET
T	5111492	RING - seal
U	2370833	CARRIER
V	See text	SPACER
W	2386366	RETAINER
X	2386642	"O" RING

KEY	PART NO.	DESCRIPTION
Y	See text	SHIM
Z	2411326	KEY
AA	2386640	"O" RING
AB	2414033	PIN
AC	668724	HOUSING
AD	See text	SHIM
AE	2417847	PINION
AF	2386371	RETAINER
AG	2426440	NUT
AH	2389355	WASHER
AJ	688466	PULLEY
AK	688034	SEAL ASSY
AL	905508	BEARING ASSY
AM	9414134	CONE - outer
AN	455272	CUP - outer
AP	----	BOLT - (5/16-18 x 78)
AQ	443696	CUP - inner
AR	7451072	CONE - inner
AS	See text	GEAR ASSY - (w/pinion)
AT	454460	CUP - inner
AU	9414131	CONE - inner

KEY TO FLUID FAN DRIVE (WITH AIR COND.)
(CONT.)

KEY	PART NO.	DESCRIPTION
AV	See text	SPACER
AW	455272	CUP - outer
AX	455271	CONE - outer
AY	----	WASHER - (1-13/32 ID x 2-1/4 OD)
AZ	----	NUT - (1-3/8-18)
BA	NPN	RING
BB	2386365	COUPLING
BC	2450537	DAMPER
BD	688081	SEAL-TORUS
BE	691978	SEAL-HUB
BF	----	BOLT - (3/8-16 x 1-1/8
BG	----	WASHER - (3/8)

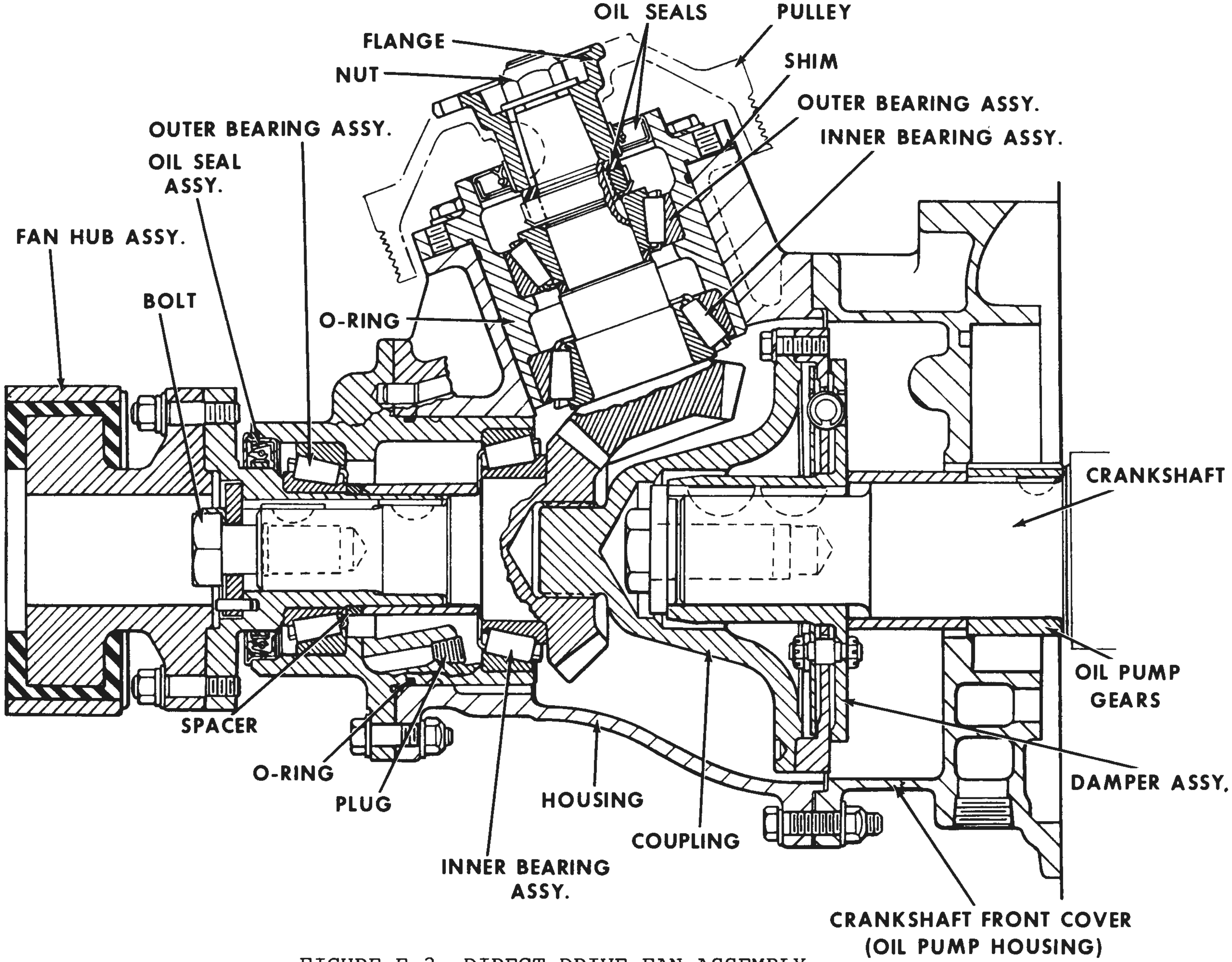

FIGURE E-2 DIRECT DRIVE FAN ASSEMBLY

In addition, a Vernatherm thermostatic control valve will be required to regulate oil flow to the torus assembly.

Vernatherm Part Number:	2353084
Engine Coolant Outlet Pipe:	8879749

Connection to the fluid fan, Vernatherm and crankcase should be made by using braided stainless oil lines.

Service and installation instructions for the Hydraulic fluid drive fan, refer to Service Manual X-7328. (See Figure E-2)

APPENDIX F

REPORT OF INVENTIONS

This document was prepared by GMC Truck and Coach Division, General Motors Corporation, Pontiac, Michigan under Contract DOT-TSC-699. General Motors Corporation does not claim to have made any innovation, discovery, improvement or invention as a result of the work performed under this contract.

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