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TRUCK NOISE IX
NOISE REDUCTION STUDY OF AN IN-SERVICE DIESEL-POWERED TRUCK
Volume I: Text

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16. Abstract

A series of tests to measure the noise contributions of subsystems were performed on a truck with a conventional short cab, equipped with a Cummins V-903 engine. The data acquired in these tests were used to select retrofittable components which would effectively reduce the total vehicle noise.

The original truck's A-weighted sound level during controlled acceleration tests (SAE J-366) was 90 dBA. The comparable contributions of the systems were 87 dBA for the engine, 84 dBA for the exhaust system, 76 dBA for the cooling system and 72 dBA for the induction system. The interior cab noise was 94 dBA.

A quieted truck test configuration had a sound level of 82 dBA on the left and 81 dBA on the right, with the fan disengaged. This configuration was not commercially feasible or usable on the road.

The final operational retrofitted configuration had a J-366 sound level of 87 dBA. The interior cab noise was 92 dBA.

The final truck had the original induction system, a new single vertical late model muffler, a clutched fan drive and engine covers. All of the retrofitted components are commercially available and in stock.

The total cost of all three changes is between $1000 and $1445 for a 3 dBA noise reduction. A 2 dBA noise reduction could be attained with engine covers only at a cost of from $470 to $770.

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PREFACE

This study of truck component noise contributions provides the United States Department of Transportation and the trucking industry with the alternative approaches and costs of reducing the noise of a group of truck and engine combinations. The study was performed by McDonnell Douglas Astronautics Company under the contractual supervision of the Transportation Systems Center of the U.S. Department of Transportation, Cambridge, Massachusetts, Mr. Robert L. Mason, Technical Monitor.

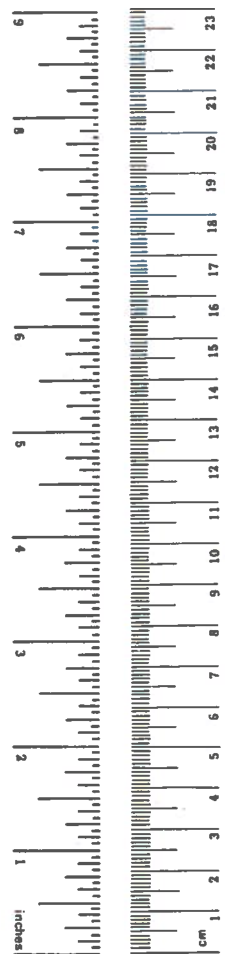
McDonnell Douglas Astronautics Company gratefully acknowledges the assistance of White Motor Corporation and Cummins Engine Company for the information, components and testing they provided. We also thank Stemco Manufacturing Company, Donaldson Company and Horton Industries for providing information and test components.

The author thanks Robert M. Blythe for his assistance in performing the tests and reducing the data.

METRIC CONVERSION FACTORS

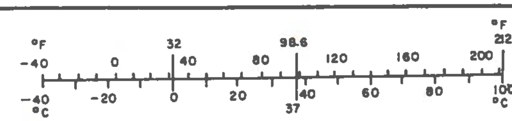
Approximate Conversions to Metric Measures

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



CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

1. INTRODUCTION

The noise issuing from an operating truck is the summation of noises from major subsystems (induction, cooling, exhaust, engine and power train). The relative contribution of each subsystem noise to the total differs as a function of the physical characteristics of the vehicle, the operating conditions of the vehicle, and the geometric and acoustical descriptors used in the noise measuring tests.

A series of tests to measure these subsystem noise contributions were performed on a used truck tractor powered by a Cummins V-903 diesel engine. These measurements, and their analyses, are part of a comprehensive testing program by the United States Department of Transportation/Transportation Systems Center. The program determined for preselected heavy diesel powered trucks, currently in production and/or wide utilization, the level and spectral content of noise emissions from the total vehicle and the engine exhaust, cooling fan and air induction subsystems: provided tested retrofitable designs to reduce these subsystem noise levels; determined the effects of these designs on overall vehicle noise levels, vehicle operation and cost; and published and disseminated, to vehicle operators and purchasers, vehicle modification instruction information regarding side-effects of such modifications and a cost/noise reduction analysis for their consideration as a method to reduce noise emissions from heavy diesel powered trucks.

The performance of these tasks for a specific vehicle is documented in this report.

The acquisition of a test vehicle (body style and engine type selected by the Department of Transportation) and the required mechanical refurbishment and testing were done by the Truck Group of the White Motor Corporation.

The necessary configuring of the test vehicle and the noise measurements and analyses were performed by the Environmental Laboratories of the McDonnell Douglas Astronautics Company.

The following main sections of this report present descriptions of the test vehicle, the configurations of the test vehicle necessary to obtain contributed noise data and the ways in which noise data were acquired, analyzed and presented. The A weighted sound levels for each test configuration and test type are tabulated at the end of the report, in conjunction with the financial data. Sound level histories and one-third octave band spectra are all shown in Appendix A.

2. ORIGINAL VEHICLE

The vehicle acquired for testing was a used truck tractor manufactured by White in 1972, which had logged more than 217,000 miles with apparently no maintenance. Preliminary checks and many leaking gaskets indicated the need of a partial overhaul. This overhaul was performed by the Cummins Engine Company at their facilities in Columbus, Indiana, and included new cylinder wet sleeves, pistons and rings.

The following list describes the major components of the test vehicle.

CHASSIS: White, Model 9564 TDV, S/N 749616, short conventional cab, shown in figures 1 and 2.

DRIVE TRAIN: Fuller RT 910 10 speed transmission and LHRNX116 4.63 ratio rear end.

AIR FILTER: Donaldson FWG 16-0082, dry type 16 inch diameter (figure 3).

RADIATOR: Modine (White #562473A), 5 row.

RADIATOR SHUTTERS: Scovill Vernatherm VD 111800-1W set at 170°F.

SHROUD: Molded F.R.P., ~27-1/2 inch diameter hole (figures 4 and 5).

FAN: 5 bladed, asymmetric, 26 inch diameter, 2.03 inch projected width, running at engine rpm.

Figure 1. Original Vehicle, Right – Hand Side

Figure 2. Original Vehicle, Left -Hand Side

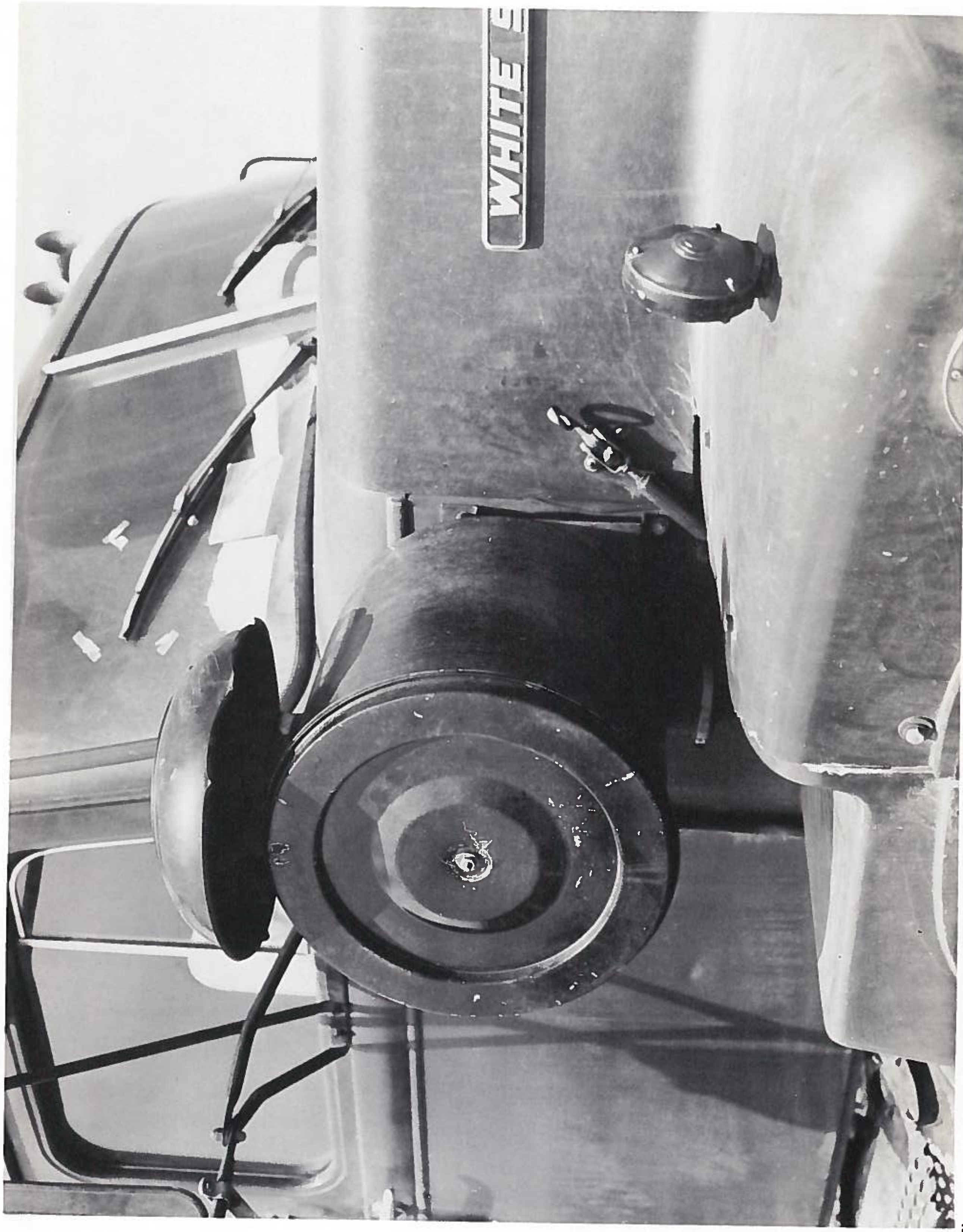


Figure 3. Original Induction Air Filter

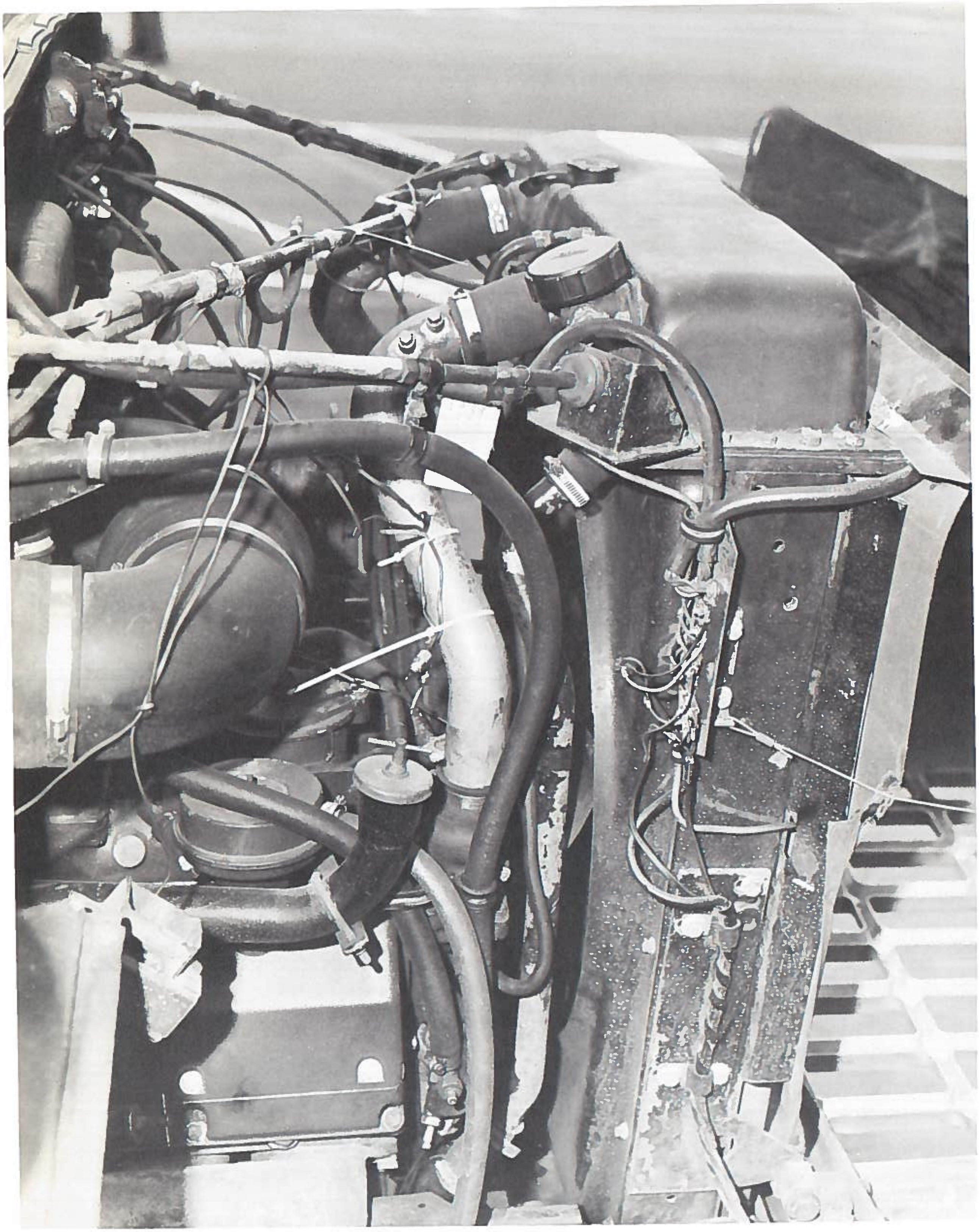


Figure 4. Original Engine Compartment Details, Right Side

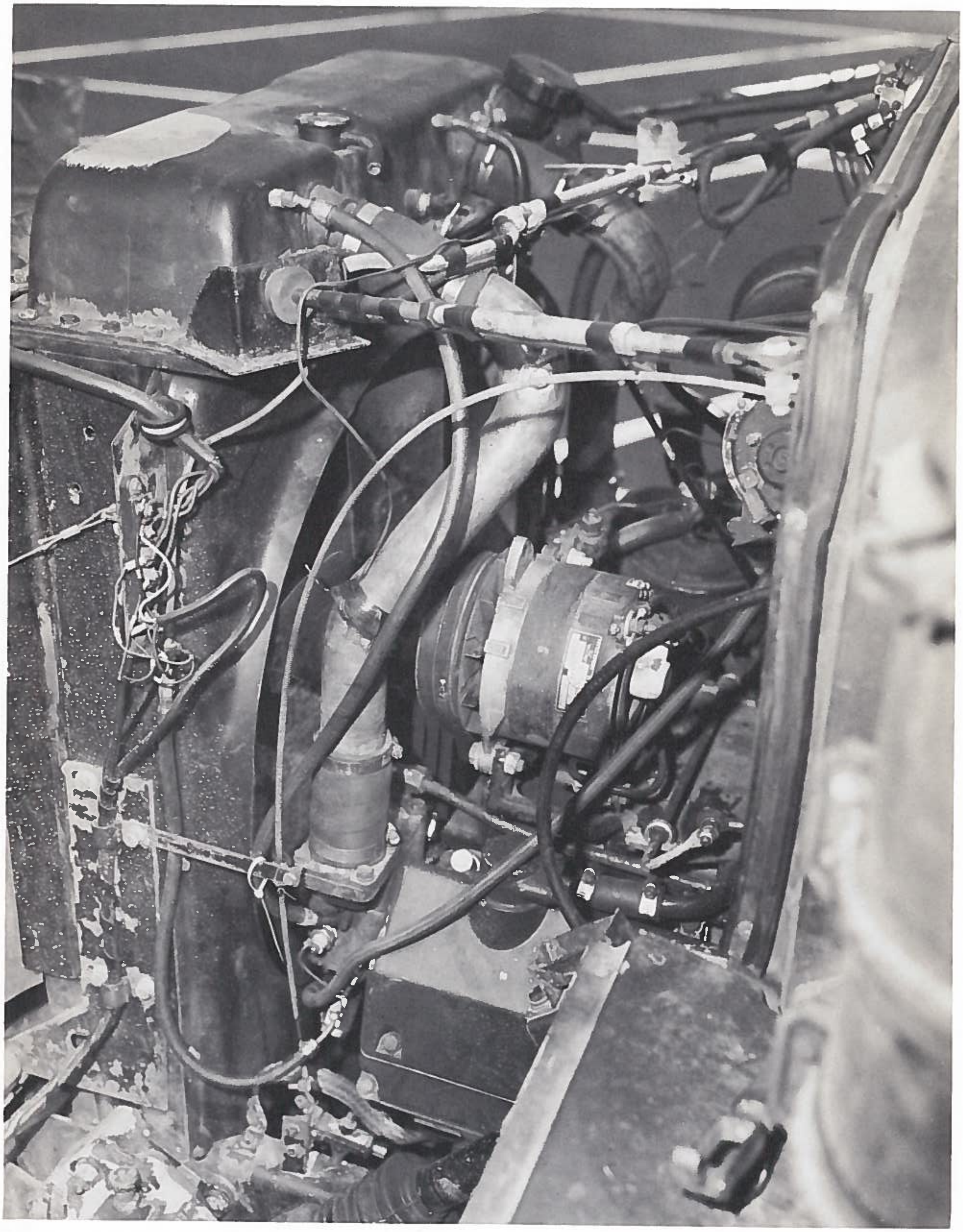


Figure 5. Original Engine Compartment Details, Left Side

EXHAUST SYSTEM: "T" can (White #539404), single horizontal muffler (White #542181), short tail pipe, as shown in figures 6 and 7.

3. CONFIGURATIONS

The determination of noise contributed by various components of a truck requires the selective covering or masking of these or the remaining components. Fourteen configurations (and some variants) were tested, each of these configurations representing a particular combination of covered or disabled components, or specifically exposed component.

The fourteen configurations are described below, identified by number and, in parenthesis, a short descriptor:

CONFIGURATION 1 (BASELINE) This configuration was essentially the original vehicle as described in the previous section, with the exception of positive dashboard controlled radiator shutters (rather than automatic) and a modified dashboard controlled fan-clutch drive (Horton #9817). The latter had a smaller pulley diameter than the original solid pulley, causing the fan to operate at 1.2 times the rpm of the original fan. These two changes permitted positive control of functions normally controlled automatically by coolant temperature, and they also permitted cooling of the engine at idling rpm when necessary.

CONFIGURATION 2 (ENGINE AND TRANSMISSION COVERED) The engine was covered with the Cummins designed and manufactured oil pan covers, shown in figure 8, and the isolated rocker housing and the heat shield shown in figure 9. In addition, the treated engine and the transmission were covered with a minimum of two layers of 1/64 inch lead sheathing separated with 1 inch of Fiberglas insulation. The exhaust manifold remained exposed. The induction system, and the exhaust pipe, T can, muffler and tail pipe were also exposed.

Figure 6. Original T Can and Horizontal Muffler

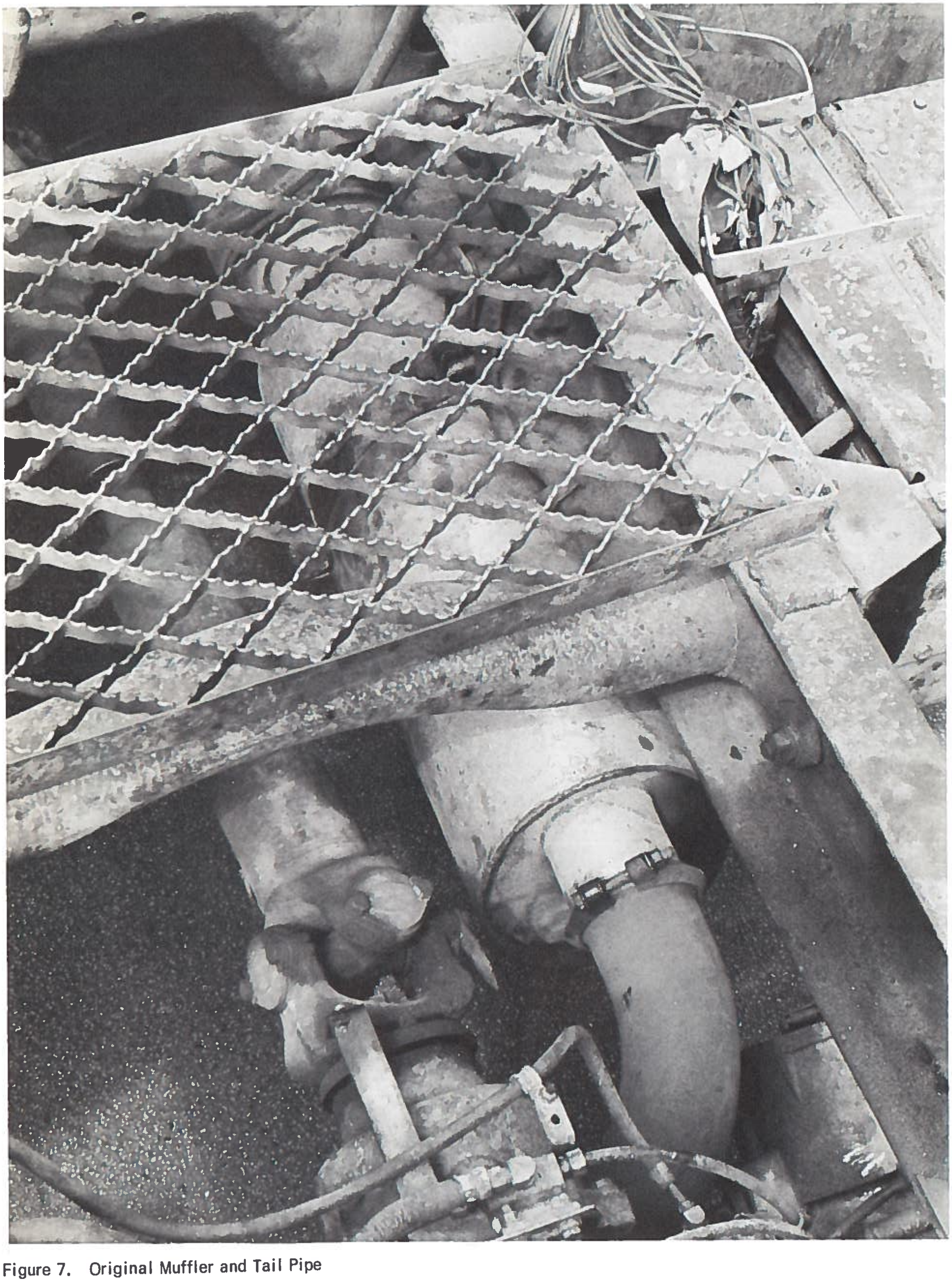
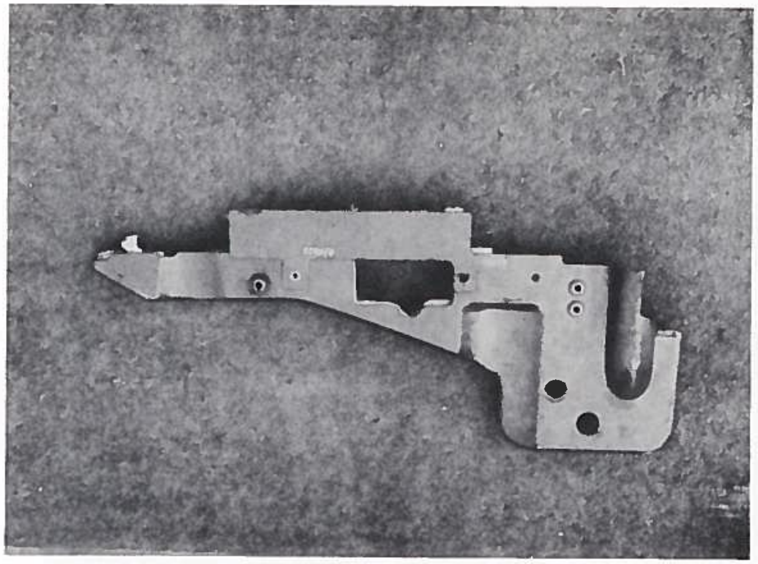
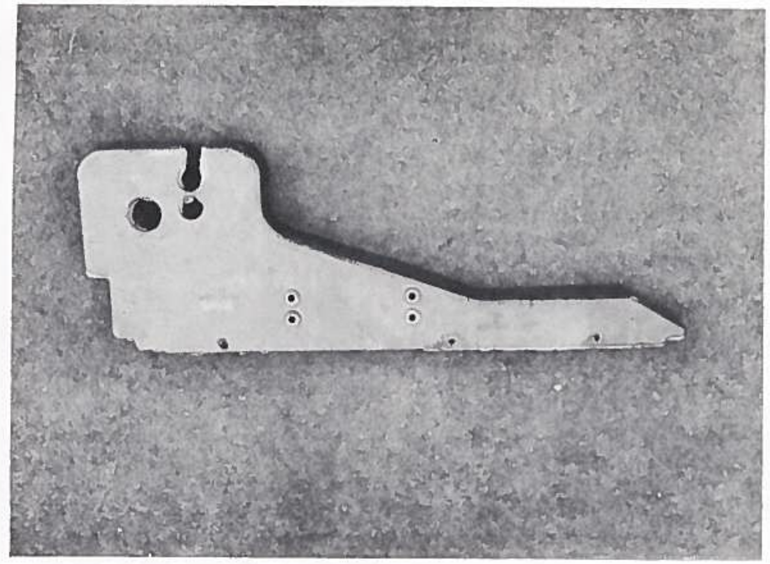


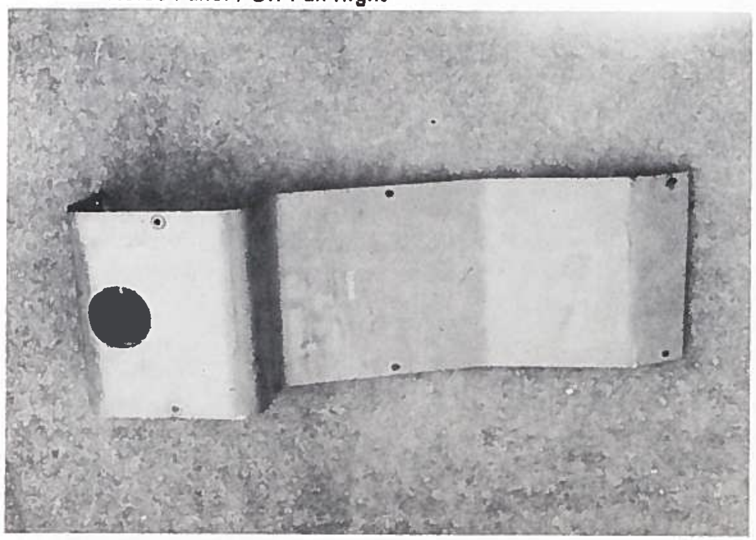
Figure 7. Original Muffler and Tail Pipe



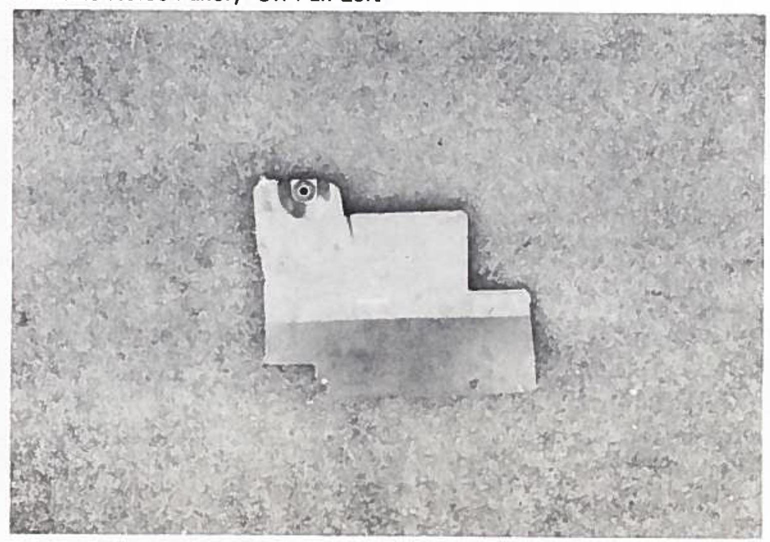
Cummins Noise Panel , Oil Pan Right



Cummins Noise Panel, Oil Pan Left

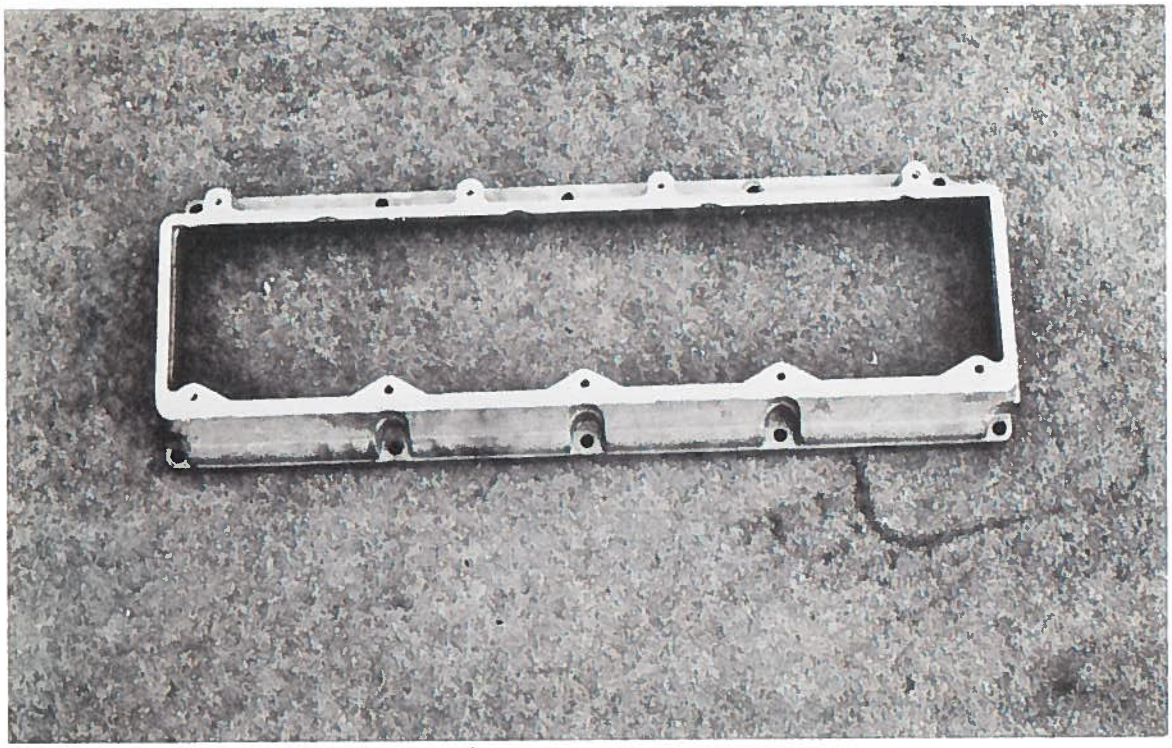


Cummins Noise Panel, Oil Pan Bottom

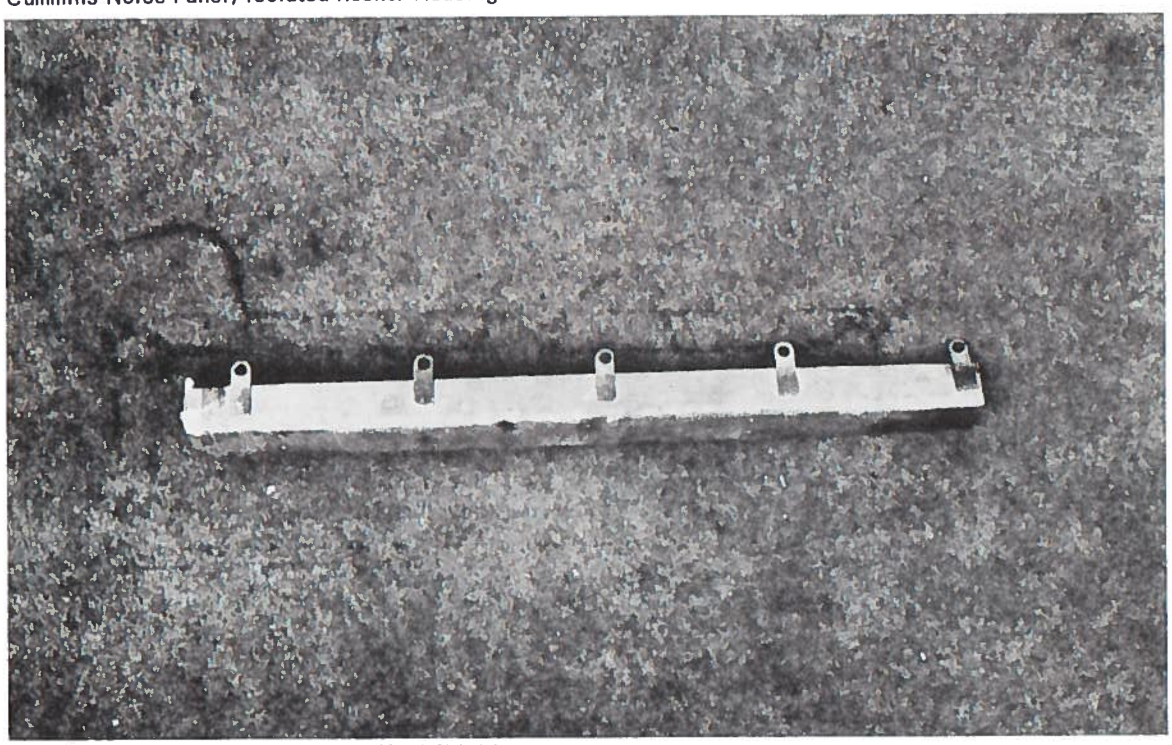


Cummins Noise Panel, Side Panel

Figure 8.



Cummins Noise Panel, Isolated Rocker Housing



Cummins Noise Panel, Exhaust Manifold Shield

Figure 9.

CONFIGURATION 3 (EXHAUST SYSTEM EXPOSED) In this configuration the induction system interior piping was covered by the previously described lead/Figerglas sandwich, and the air filter was covered by a muffler, as detailed in figure 10. Only the exhaust manifold, T can, muffler and tail pipe remained exposed in this configuration.

CONFIGURATION 4 (EXHAUST MANIFOLD EXPOSED) The original muffler was covered with lead and Fiberglas and the exhaust gasses were routed to a second muffler which in turn was covered with a larger muffler, as shown in figure 11 and detailed in figure 12. Only the exhaust manifold remained exposed, up to the clamped joint to the exhaust pipes.

CONFIGURATION 5 (QUIETED TRUCK) was the all covered quieted truck. Figure 13 shows the covered engine and manifold details on the right hand side, the induction system covered, and the air filter muffled. Figure 14 shows left hand side details, including an alternator fan shield, and figure 15 an overall view of the quieted truck.

CONFIGURATION 6 (AIR FILTER EXPOSED) The muffler covering the air filter was removed, leaving the air filter housing exposed. The vehicle was otherwise all covered.

CONFIGURATION 7 (ENGINE WITH COVERS EXPOSED) The engine retained the factory type covers, but not the lead/Fiberglas sandwich covers. The rest of the vehicle remained covered.

CONFIGURATION 8 (WHITE MUFFLER) had a new exhaust system, a single vertical muffler (White #545115 C4) with a 28 inch vertical tail pipe. The single muffler was connected to the original stock T can. The configuration 8 truck retained the lead/Fiberglas covered transmission, the factory engine covers and the lead/Fiberglas covering over the internal ducts of the induction system, but the air filter muffler, and lead/Fiberglas covers over the engine and the air filter rain cap were removed.

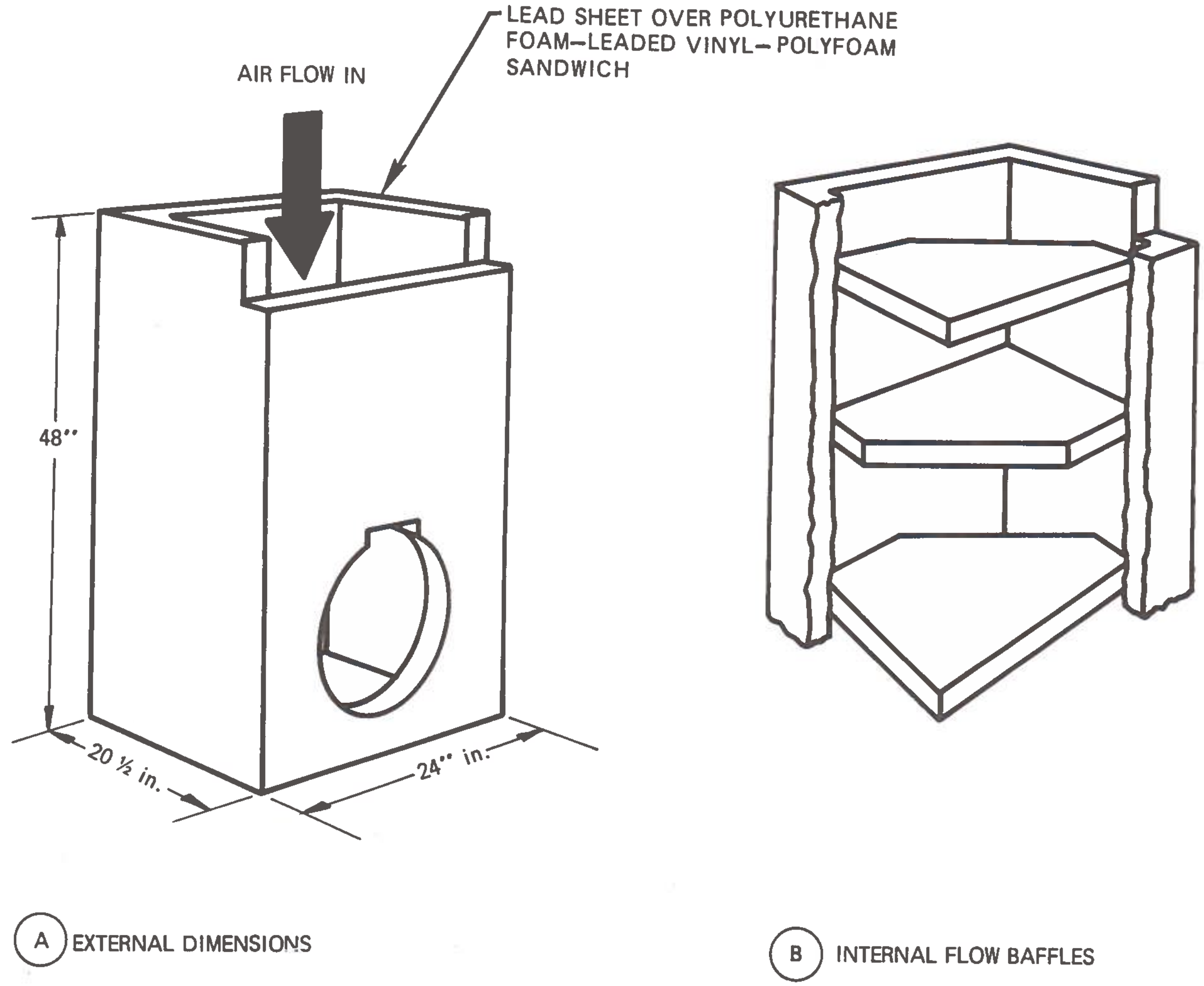


Figure 10. Air Filter Muffler

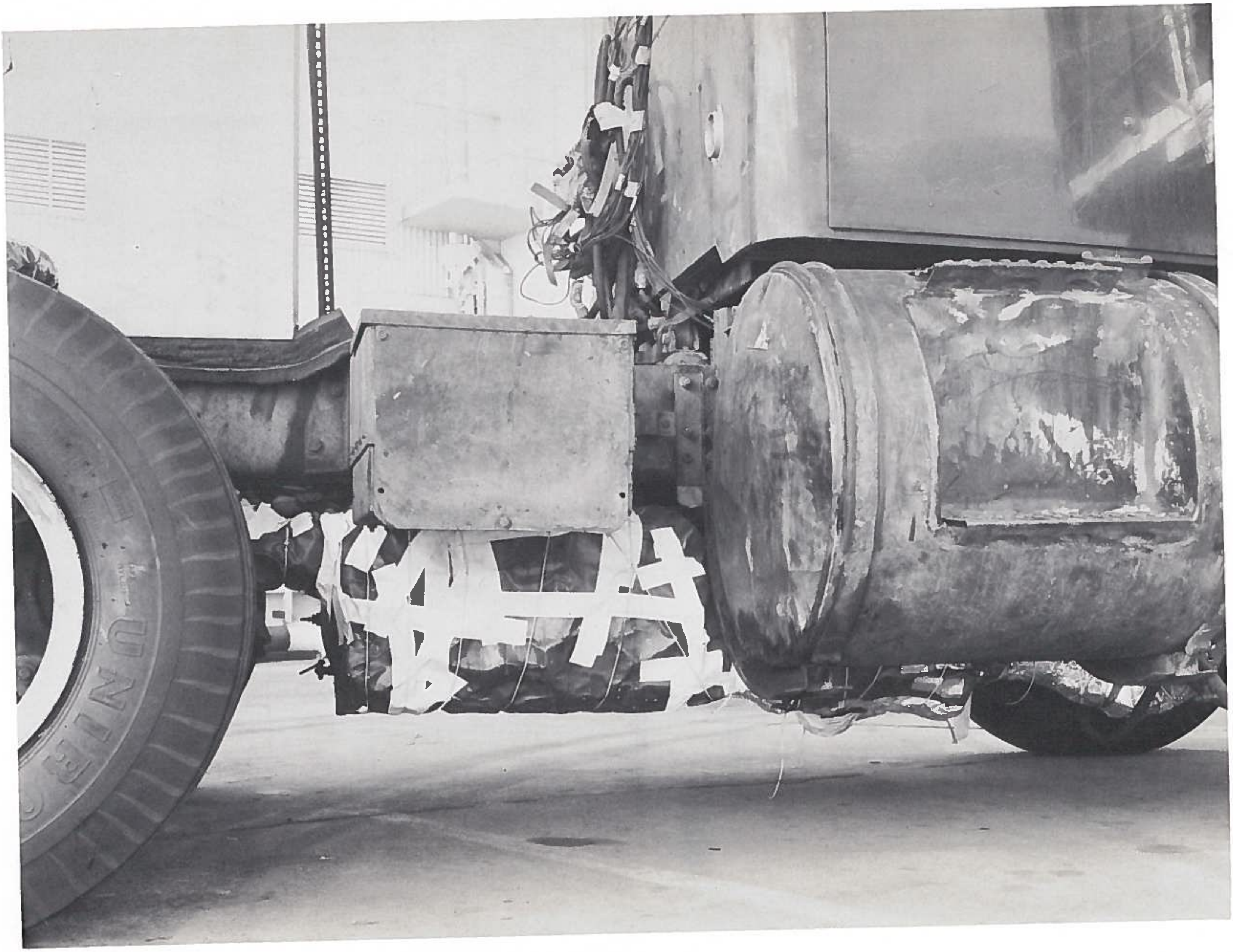
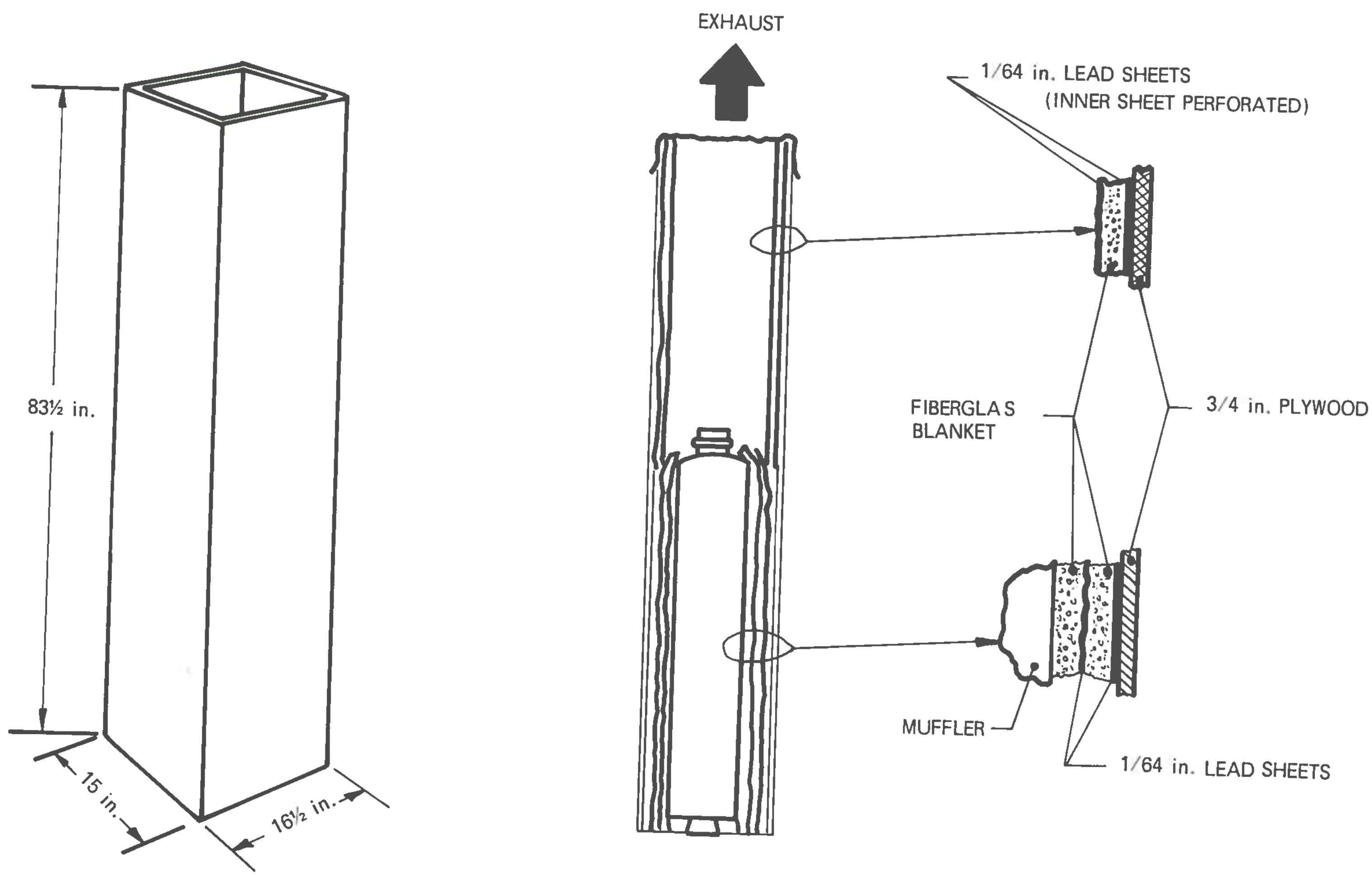


Figure 11 Exhaust System Secondary Muffler and Shroud



(A) EXTERNAL DIMENSIONS

(B) CROSS–SECTION WITH INSULATION DETAILS

Figure 12. Muffler Shroud

Figure 13. Shrouding Details, Right Side

Figure 14. Shrouding Details, Left Side

Figure 15. Quieted Truck Details

CONFIGURATION 9 (NO TAIL PIPE) was identical to configuration 8 except that the 28 inch tail pipe was removed.

CONFIGURATION 10 (STEMCO MUFFLER) This configuration had a Stemco model 9869 single vertical muffler. The transmission and internal induction ducts were covered. The engine, air filter and exhaust manifold were exposed. The clutched fan drive was replaced by a model with a 1:1 pulley ratio (Horton #9816) causing the fan to operate at the same speed as the original fan. The engine retained the Cummins noise covers.

CONFIGURATION 11 (DONALDSON MUFFLER) A Donaldson WKM 10-0064 single vertical muffler replaced the Stemco muffler of configuration 10; no other changes were made.

CONFIGURATION 12 (ALL EXPOSED) In this configuration, all shrouds and covers were removed. The Donaldson single vertical muffler, the engine (without noise covers), the transmission, the complete exhaust and induction systems were all exposed.

CONFIGURATION 13 (RUBBER CURTAINS) was the all exposed truck with the addition of engine compartment side curtains made of 1/2 inch thick rubber, as shown in figures 16 and 17.

CONFIGURATION 14 (FINAL TRUCK) was the final road-ready optimized truck.

The induction system was the original system, with a dry type 16 inch diameter air filter.

The cooling system had the original shroud and five bladed asymmetric fan, but the fan was driven through a thermostatically controlled air operated clutch driven pulley, at the same rpm as the original pulley.

Figure 16. Rubber Curtains, Right Side

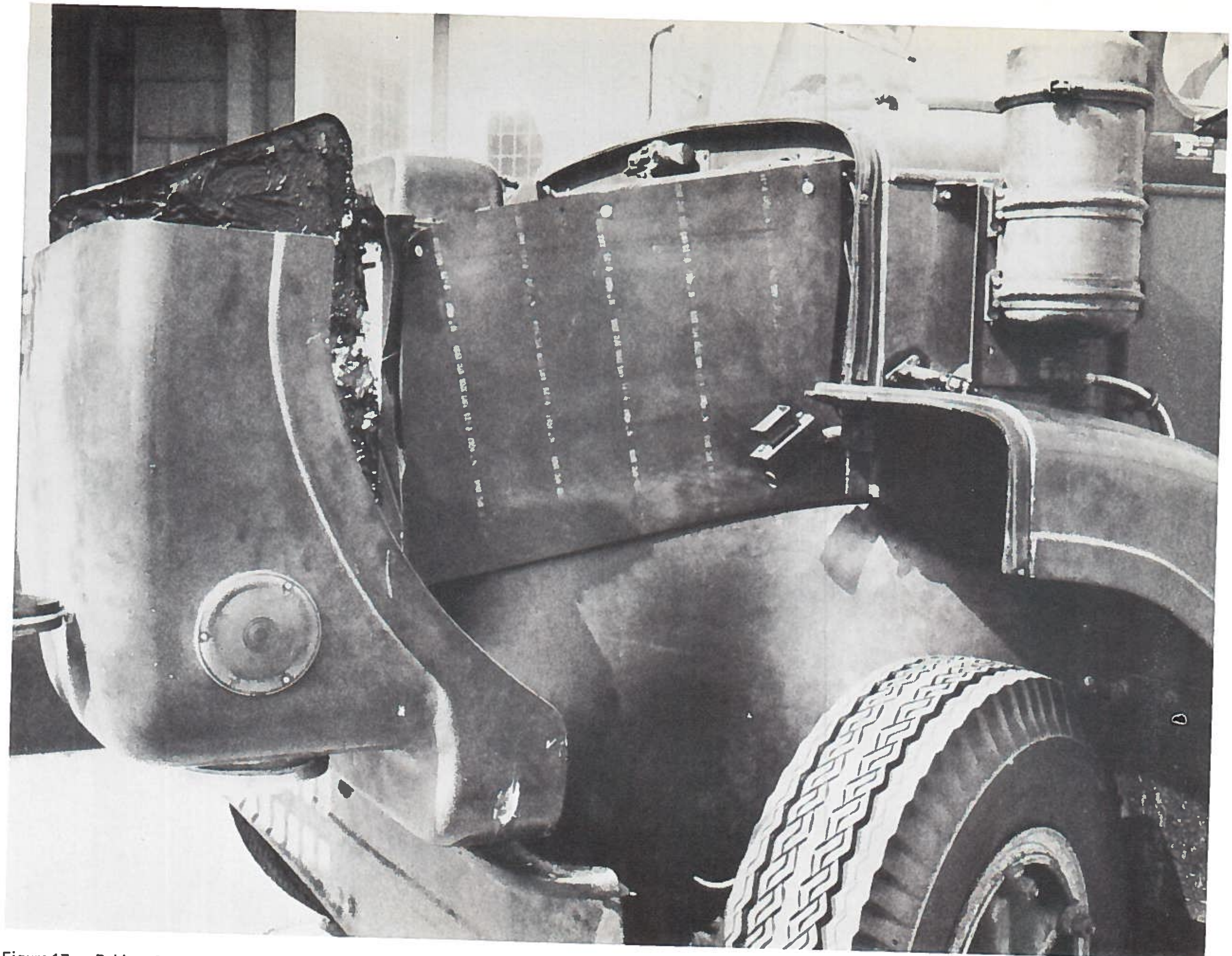


Figure 17. Rubber Curtains, Left Side

The exhaust system differed from the original in using a single, large, double walled vertical muffler (figure 18) instead of a single horizontal muffler.

In addition the engine had the factory noise kit covers installed. Some consecutive noise measurements were made on slight modifications of the configuration 14 truck, as follows:

14 a, air filter rain cap on

14 b, air filter rain cap off

14 c, 6-1/4 inch diameter 51 inch long snorkel on air filter input instead of rain cap (figure 19)

14 d, rubber curtains, like configuration 13.

At the completion of noise measurement tests of configuration 14, the Final Truck was shipped to Cleveland where the Truck Group of White Motors performed mechanical performance tests.

4. TEST REQUIREMENTS

Noise measurements were made in two broad categories: moving tests (accelerating and constant speed) and stationary tests. For both test types the ground of the measuring sites was a flat empty parking area covered with macadam and concrete as shown in figure 20. This site, and an alternate site occasionally used for stationary tests, satisfied the clearance, openness and levelness requirements of the SAE recommended practice J-366, Exterior Sound Levels for Heavy Trucks and Buses.

The acceleration tests were performed in accordance with the procedures of J-366. The acceleration point was passed at 1600 rpm in 5th gear, and the nominal top speed was 21 mph.

The constant speed pass-by at governed rpm was performed in 6th gear at 2800 rpm and a speed of about 30 mph.

Figure 18. Vertical Muffler Installation

Figure 19. Induction System Extension (Snorkel)


Figure 20. Test Site

The stationary tests were performed at governed maximum 2800 rpm, and at 2600, 2350 and 2000 rpm.

In all tests, the microphone was 4 feet above the ground plane and 50 feet from the truck center line.

5. DATA ACQUISITION - ACOUSTICAL

The truck noise was measured with a precision sound level meter set to the "A" weighted sound level, fast response; simultaneously, the signal was recorded on a magnetic tape recorder. Each test run had a pre and post calibration signal on the sound level meter and on the tape recorder.

A minimum of four measurement passes were made for each of the major test configurations to insure repeatability and statistical validity. As a further insurance of statistical significance, identical tests were not run consecutively; rather, complete test cycles were repeated. For example, to obtain 4 measurements of stationary noise at 2600 rpm with the shutters closed and the fan off, a complete cycle of tromp test (IMI), governed 2800 rpm, 2600 rpm, 2000 rpm, with the shutters open and the fan on had to be completed, then again with shutters open and fan off, then again with shutters closed fan on, and finally with the shutters closed fan off, the whole sequence repeated four times. Thus each test tended to be individualized, with the truck operator not attempting to repeat a learned pattern, or the sound level meter observer not trying to match a previous reading. The engine operating parameters also tended to stabilize, without excessive loads or temperatures.

The A weighted sound levels indicated by the sound level meter were entered in data sheets; they are referred to as field data in this report. The broad band unfiltered data recorded on magnetic tape for further analysis are referred to as the recorded data.

6. DATA ACQUISITION - MECHANICAL

Initial cooling and performance tests for the original truck were run at the Cummins Engine Company facilities because the White Motor Corporation's chassis dynamometer and wind tunnel had suffered a breakdown. Due to Cummin's chassis dynamometer roll speed ratio limitations, vehicle performance tests were run in 8th and 9th gear.

The final truck cooling and performance tests were run at the White Motor Corporation's chassis dynamometer, in direct gear.

7. DATA PROCESSING

The field data were averaged to obtain a mean sound level for each of the test configurations.

The recorded data were played back once to obtain sound level histories, by sending the tape player output through an "A" weighting filter and thence to a level recorder. The level recorder paper speed was chosen for convenient inclusion in the report; the pen speed selected (125 mm/s) corresponds to the fast rms setting of a sound level meter, but limits rising slopes to 47 dB/s and descending slopes to 65 dB/s.

Appropriate segments of the recorded data were also analyzed to obtain 1/3 octave band spectra. The analyzer was set to the "Fast random" mode in which the weighted sound level has a time constant of 240 ms (equivalent to rms fast) but the 1/3 octave band sound pressure levels have a time constant of 200 ms above 2 kHz, the time constant increasing to 20 s as the frequency decreases to 20 Hz.

Table 1 lists the equipment used for data acquisition and processing.

TABLE 1. EQUIPMENT LIST

EQUIPMENT	MODEL	MANUFACTURER
Sound Level Meter	2204	Bruel & Kjaer
Calibrator	4220	Bruel & Kjaer
Analyzer	3347/3348	Bruel & Kjaer
Level Recorder	2305	Bruel & Kjaer
Tape Recorder	Nagra IV B	Kudelski

All of this equipment is regularly maintained and the calibration is traceable to NBS standards.

8. DATA PRESENTATION - ACOUSTICAL

The mean values of the field data are presented in tables 2 through 20, listed consecutively in order of configurations, with the exception of table 20, which compares interior sound levels for configurations 1 and 14. Note that the sound levels listed for J-366 test types are mean values, not the maximum sound levels reported when qualifying a vehicle for noise emission.

The sound level histories and corresponding 1/3 octave band spectra are presented in Appendix A, also in consecutive order of configuration. The integral part of Appendix A figure number is the configuration number. Sound level histories of 2600, 2350 and 2000 rpm stationary noise tests are not shown since they are merely straight lines of no analytical value.

Table 21 presents a summary of the configurations for cross reference to tables 2 through 20 and Appendix A.

9. DATA PRESENTATION - MECHANICAL

A comparison of the mechanical and thermal performance of the original and final truck is shown in figures 21 and 22.

TABLE 2. MEAN OF FIELD DATA, BASELINE

CONFIGURATION 1 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS — SHUTTERS CLOSED		SHUTTERS OPEN	
		FAN OFF	FAN ON	FAN ON	FAN OFF
J-366, ACCELERATION.	L	89.8	90.8	89.9	88.9
	R	88.8	90.4	89.0	88.2
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	84.1	89.0	87.3	84.1
	R	83.2	90.1	87.0	83.1
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	87.2	88.5	87.5	87.4
	R	86.6	88.7	87.5	87.7
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	81.5	87.8	85.5	81.0
	R	82.2	89.8	86.8	82.2
2600 RPM, STATIONARY	L	78.8	82.5	83.2	79.2
	R	80.7	87.0	83.8	80.8
2350 RPM, STATIONARY	L	78.2	82.5	81.3	78.0
	R	79.5	84.2	81.3	78.2
2000 RPM, STATIONARY	L	76.2	79.2	78.0	75.8
	R	77.2	80.8	79.0	77.0

TABLE 3. MEAN OF FIELD DATA, COVERED ENGINE

CONFIGURATION 2 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS			
		SHUTTERS CLOSED		SHUTTERS OPEN	
		FAN OFF	FAN ON	FAN ON	FAN OFF
J-366, ACCELERATION.	L	86.1	88.6	88.4	86.3
	R	84.7	88.6	88.6	84.8
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	80.0	88.3	88.7	79.9
	R	79.9	87.8	89.4	79.8
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	83.8	84.8	84.2	83.1
	R	83.5	86.0	85.5	83.5
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	76.0	85.8	86.2	76.3
	R	78.8	85.3	85.5	79.0
2600 RPM, STATIONARY	L	74.7	82.8	83.2	74.5
	R	78.5	85.0	84.0	78.0
2350 RPM, STATIONARY	L	74.0	80.2	80.8	74.2
	R	75.5	82.0	81.5	76.0
2000 RPM, STATIONARY	L	71.7	77.5	77.8	71.5
	R	74.5	78.3	78.0	74.0

TABLE 4. MEAN OF FIELD DATA, EXHAUST SYSTEM

CONFIGURATION ·3 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS SHUTTERS CLOSED FAN OFF	 SHUTTERS CLOSED FAN ON	 SHUTTERS OPEN FAN ON	 SHUTTERS OPEN FAN OFF
J-366, ACCELERATION.	L	-	-	-	-
	R	-	-	-	-
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	-	-	-	-
	R	-	-	-	-
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	82.5	85.5	85.5	82.5
	R	82.5	83.6	83.2	81.8
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	76.0	84.0	84.0	76.0
	R	76.2	84.2	84.0	75.8
2600 RPM, STATIONARY	L	-	-	-	-
	R	74.2	82.8	81.8	74.5
2350 RPM, STATIONARY	L	-	-	-	-
	R	73.7	81.3	79.8	73.3
2000 RPM, STATIONARY	L	-	-	-	-
	R	71.2	77.0	77.0	71.2

TABLE 5. MEAN OF FIELD DATA, EXHAUST MANIFOLD

CONFIGURATION 4 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS SHUTTERS CLOSED FAN OFF	 SHUTTERS CLOSED FAN ON	 SHUTTERS OPEN FAN ON	 SHUTTERS OPEN FAN OFF
J-366, ACCELERATION.	L	-	-	-	-
	R	-	-	-	-
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	-	-	-	-
	R	-	-	-	-
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	78.5	83.0	82.8	78.5
	R	79.7	84.3	83.3	79.7
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	74.3	85.2	86.5	73.3
	R	75.0	84.7	84.0	74.8
2600 RPM, STATIONARY	L	72.2	83.2	83.7	72.5
	R	72.5	84.3	82.0	73.0
2350 RPM, STATIONARY	L	70.8	80.8	80.7	70.5
	R	71.7	81.5	79.2	72.0
2000 RPM, STATIONARY	L	69.3	76.9	77.3	69.5
	R	70.3	77.2	76.5	70.3

TABLE 6. MEAN OF FIELD DATA, QUIET TRUCK

CONFIGURATION 5 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS: SHUTTERS CLOSED, FAN OFF	SHUTTERS CLOSED, FAN ON	SHUTTERS OPEN, FAN ON	SHUTTERS OPEN, FAN OFF
J-366, ACCELERATION.	L	81.5	86.5	87.5	81.9
	R	81.0	87.5	86.6	80.6
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	76.4	83.2	83.9	77.2
	R	76.8	80.9	82.0	76.0
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	77.0	83.8	84.3	77.3
	R	77.5	83.5	84.5	77.3
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	72.5	86.3	86.0	72.7
	R	72.3	83.8	84.5	72.8
2600 RPM, STATIONARY	L	70.8	84.2	84.3	71.3
	R	72.0	84.5	81.8	71.5
2350 RPM, STATIONARY	L	69.3	80.8	81.8	69.8
	R	70.5	80.5	78.5	70.3
2000 RPM, STATIONARY	L	67.5	76.5	76.8	68.2
	R	68.2	76.2	75.3	68.5

TABLE 7. MEAN OF FIELD DATA, AIR FILTER

CONFIGURATION 6 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS: SHUTTERS CLOSED, FAN OFF	SHUTTERS CLOSED, FAN ON	SHUTTERS OPEN, FAN ON	SHUTTERS OPEN, FAN OFF
J-366, ACCELERATION.	L	81.0	83.7	85.9	81.4
	R	81.0	83.4	83.4	80.6
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	77.1	80.4	81.5	77.1
	R	79.1	81.2	82.5	79.0
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	-	-	-	-
	R	78.5	-	-	78.3
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	-	-	-	-
	R	76.4	-	-	76.5
2600 RPM, STATIONARY	L	-	-	-	-
	R	76.5	-	-	76.5
2350 RPM, STATIONARY	L	-	-	-	-
	R	72.5	-	-	72.7
2000 RPM, STATIONARY	L	-	-	-	-
	R	72.7	-	-	72.5

TABLE 8. MEAN OF FIELD DATA, ENGINE WITH NOISE COVERS

CONFIGURATION 7 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS: SHUTTERS CLOSED, FAN OFF	SHUTTERS CLOSED, FAN ON	SHUTTERS OPEN, FAN ON	SHUTTERS OPEN, FAN OFF
J-366, ACCELERATION.	L	83.5	-	-	84.2
	R	83.5	-	-	83.7
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	78.8	-	-	79.0
	R	78.1	-	-	78.8
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	80.8	-	-	81.2
	R	81.3	-	-	81.0
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	76.2	-	-	76.2
	R	75.2	-	-	75.3
2600 RPM, STATIONARY	L	74.3	-	-	74.5
	R	74.2	-	-	74.5
2350 RPM, STATIONARY	L	72.8	-	-	72.7
	R	73.2	-	-	73.5
2000 RPM, STATIONARY	L	71.5	-	-	71.5
	R	71.7	-	-	71.7

TABLE 9. MEAN OF FIELD DATA, WHITE VERTICAL MUFFLER

CONFIGURATION 8 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS SHUTTERS CLOSED FAN OFF	 SHUTTERS CLOSED FAN ON	 SHUTTERS OPEN FAN ON	 SHUTTERS OPEN FAN OFF
J-366, ACCELERATION.	L	85.0	-	-	85.6
	R	85.5	-	-	85.7
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	80.7	-	-	80.7
	R	80.7	-	-	80.7
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	83.0	-	-	83.2
	R	84.2	-	-	84.0
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	77.9	-	-	78.1
	R	79.5	-	-	79.4
2600 RPM, STATIONARY	L	75.9	-	-	75.9
	R	78.6	-	-	78.6
2350 RPM, STATIONARY	L	75.3	-	-	75.2
	R	77.1	-	-	77.0
2000 RPM, STATIONARY	L	-	-	-	-
	R	-	-	-	-

TABLE 10. MEAN OF FIELD DATA, WHITE MUFFLER WITHOUT TAIL PIPE

CONFIGURATION 9 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS			
		SHUTTERS CLOSED		SHUTTERS OPEN	
		FAN OFF	FAN ON	FAN ON	FAN OFF
J-366, ACCELERATION.	L	85.0	-	-	85.7
	R	86.0	-	-	86.5
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	80.9	-	-	81.4
	R	82.0	-	-	82.4
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	-	-	-	-
	R	-	-	-	-
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	-	-	-	-
	R	-	-	-	-
2600 RPM, STATIONARY	L	-	-	-	-
	R	-	-	-	-
2350 RPM, STATIONARY	L	-	-	-	-
	R	-	-	-	-
2000 RPM, STATIONARY	L	-	-	-	-
	R	-	-	-	-

TABLE 11. MEAN OF FIELD DATA, STEMCO VERTICAL MUFFLER

CONFIGURATION 10 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS: SHUTTERS CLOSED, FAN OFF	SHUTTERS CLOSED, FAN ON	SHUTTERS OPEN, FAN ON	SHUTTERS OPEN, FAN OFF
J-366, ACCELERATION.	L	-	-	-	85.1
	R	-	-	-	85.2
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	-	-	-	79.2
	R	-	-	-	80.0
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	83.0	83.2	83.3	83.2
	R	84.5	84.9	84.5	84.5
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	77.5	83.2	80.3	77.3
	R	80.0	83.5	81.8	79.8
2600 RPM, STATIONARY	L	76.0	80.8	79.6	75.5
	R	78.3	81.5	79.5	78.6
2350 RPM, STATIONARY	L	74.9	78.3	76.8	74.6
	R	77.2	79.8	79.2	76.8
2000 RPM, STATIONARY	L	72.8	74.8	74.1	72.8
	R	74.8	77.1	75.6	74.8

TABLE 12. MEAN OF FIELD DATA, DONALDSON VERTICAL MUFFLER

CONFIGURATION 11 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS: SHUTTERS CLOSED, FAN OFF	SHUTTERS CLOSED, FAN ON	SHUTTERS OPEN, FAN ON	SHUTTERS OPEN, FAN OFF
J-366, ACCELERATION.	L	-	-	-	85.3
	R	-	-	-	84.8
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	-	-	-	79.3
	R	-	-	-	80.1
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	82.9	83.7	83.1	82.8
	R	84.3	84.5	84.0	83.9
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	77.2	81.5	80.6	77.3
	R	79.3	82.2	80.9	79.1
2600 RPM, STATIONARY	L	75.9	80.0	78.1	75.5
	R	77.2	79.8	78.8	77.2
2350 RPM, STATIONARY	L	74.6	78.0	76.7	74.2
	R	76.6	78.7	78.0	76.5
2000 RPM, STATIONARY	L	72.5	74.8	74.3	72.5
	R	74.1	76.5	75.3	74.5

TABLE 13. MEAN OF FIELD DATA, ALL EXPOSED

CONFIGURATION 12 SEE TABLE 21FOR DETAILED DESCRIPTION		A WEIGHTED SOUND LEVELS			
		SHUTTERS CLOSED		SHUTTERS OPEN	
TEST TYPES	SIDE	FAN OFF	FAN ON	FAN ON	FAN OFF
J-366, ACCELERATION.	L	88.1	88.5	88.7	88.2
	R	88.1	88.3	88.4	88.4
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	82.9	84.3	83.2	82.7
	R	82.8	84.2	83.4	83.0
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	87.0	87.3	86.8	86.6
	R	87.3	88.0	86.6	87.4
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	81.3	83.4	82.3	81.3
	R	81.8	83.5	83.0	81.7
2600 RPM, STATIONARY	L	77.9	80.5	80.1	78.9
	R	81.5	82.5	81.0	80.5
2350 RPM, STATIONARY	L	77.6	79.1	78.5	77.8
	R	79.0	80.3	79.8	79.7
2000 RPM, STATIONARY	L	75.7	77.2	76.4	75.3
	R	78.0	78.7	78.0	77.5

TABLE 14. MEAN OF FIELD DATA, RUBBER CURTAINS

CONFIGURATION 13 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS: SHUTTERS CLOSED, FAN OFF	SHUTTERS CLOSED, FAN ON	SHUTTERS OPEN, FAN ON	SHUTTERS OPEN, FAN OFF
J-366, ACCELERATION.	L	-	-	-	-
	R	-	-	-	-
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	-	-	-	-
	R	-	-	-	-
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	86.0	86.1	85.7	85.3
	R	86.4	86.5	86.0	86.2
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	80.7	81.9	81.5	80.3
	R	81.2	82.9	82.5	81.4
2600 RPM, STATIONARY	L	77.9	79.3	79.2	77.6
	R	78.9	80.8	80.2	79.1
2350 RPM, STATIONARY	L	77.1	78.3	78.6	76.9
	R	78.3	79.7	79.3	78.5
2000 RPM, STATIONARY	L	74.7	76.2	76.0	74.7
	R	76.5	77.6	76.9	76.4

TABLE 15. MEAN OF FIELD DATA, FINAL TRUCK

CONFIGURATION 14 SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS: SHUTTERS CLOSED, FAN OFF	SHUTTERS CLOSED, FAN ON	SHUTTERS OPEN, FAN ON	SHUTTERS OPEN, FAN OFF
J-366, ACCELERATION.	L	85.9	86.2	86.0	85.7
	R	86.3	86.3	86.1	86.1
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	81.2	82.2	81.7	80.8
	R	81.4	82.5	82.1	81.0
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	83.8	83.9	83.7	83.2
	R	84.5	84.7	84.3	84.1
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	79.0	80.8	80.8	79.0
	R	80.9	81.9	81.3	80.7
2600 RPM, STATIONARY	L	76.4	78.6	78.1	76.3
	R	79.0	79.9	79.5	79.2
2350 RPM, STATIONARY	L	75.5	77.3	77.0	75.1
	R	77.6	79.6	78.6	77.5
2000 RPM, STATIONARY	L	73.8	76.0	75.4	73.4
	R	75.5	77.0	76.1	75.3

TABLE 16. MEAN OF FIELD DATA, AIR FILTER CAP ON

CONFIGURATION 14a SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS			
		SHUTTERS CLOSED		SHUTTERS OPEN	
		FAN OFF	FAN ON	FAN ON	FAN OFF
J-366, ACCELERATION.	L	-	-	-	-
	R	-	-	-	-
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	-	-	-	-
	R	-	-	-	-
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	-	-	-	-
	R	84.1	-	-	-
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	-	-	-	-
	R	80.7	-	-	-
2600 RPM, STATIONARY	L	-	-	-	-
	R	78.7	-	-	-
2350 RPM, STATIONARY	L	-	-	-	-
	R	77.4	-	-	-
2000 RPM, STATIONARY	L	-	-	-	-
	R	75.5	-	-	-

TABLE 17. MEAN OF FIELD DATA, AIR FILTER CAP OFF

CONFIGURATION 14b SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS			
		SHUTTERS CLOSED		SHUTTERS OPEN	
		FAN OFF	FAN ON	FAN ON	FAN OFF
J-366, ACCELERATION.	L	-	-	-	-
	R	-	-	-	-
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	-	-	-	-
	R	-	-	-	-
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	-	-	-	-
	R	84.1	-	-	-
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	-	-	-	-
	R	80.1	-	-	-
2600 RPM, STATIONARY	L	-	-	-	-
	R	78.2	-	-	-
2350 RPM, STATIONARY	L	-	-	-	-
	R	77.3	-	-	-
2000 RPM, STATIONARY	L	-	-	-	-
	R	75.2	-	-	-

TABLE 18. MEAN OF FIELD DATA, SNORKEL

CONFIGURATION 14c SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS: SHUTTERS CLOSED, FAN OFF	SHUTTERS CLOSED, FAN ON	SHUTTERS OPEN, FAN ON	SHUTTERS OPEN, FAN OFF
J-366, ACCELERATION.	L	-	-	-	-
	R	-	-	-	-
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	-	-	-	-
	R	-	-	-	-
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	-	-	-	-
	R	84.6	-	-	-
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	-	-	-	-
	R	80.5	-	-	-
2600 RPM, STATIONARY	L	-	-	-	-
	R	78.0	-	-	-
2350 RPM, STATIONARY	L	-	-	-	-
	R	77.3	-	-	-
2000 RPM, STATIONARY	L	-	-	-	-
	R	75.2	-	-	-

TABLE 19. MEAN OF FIELD DATA, RUBBER CURTAINS

CONFIGURATION 14d SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS SHUTTERS CLOSED FAN OFF	 SHUTTERS CLOSED FAN ON	 SHUTTERS OPEN FAN ON	 SHUTTERS OPEN FAN OFF
J-366, ACCELERATION.	L	-	-	-	-
	R	-	-	-	-
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	-	-	-	-
	R	-	-	-	-
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	-	-	-	-
	R	84.5	84.5	84.4	84.6
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	-	-	-	-
	R	81.5	82.6	82.0	81.3
2600 RPM, STATIONARY	L	-	-	-	-
	R	79.4	80.5	80.0	79.5
2350 RPM, STATIONARY	L	-	-	-	-
	R	77.7	79.2	78.7	77.9
2000 RPM, STATIONARY	L	-	-	-	-
	R	75.9	77.5	76.3	75.7

TABLE 20. MEAN OF FIELD DATA, INTERIOR NOISE

CONFIGURATION 1 & 14 INTERIOR SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	CONFIGURATION	A WEIGHTED SOUND LEVELS			
		SHUTTERS CLOSED		SHUTTERS OPEN	
		FAN OFF	FAN ON	FAN ON	FAN OFF
J-366, ACCELERATION.	1	94.0	95.0	94.0	93.3
	14	91.8	91.8	91.6	91.4
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	1	89.0	95.3	92.3	88.8
	14	87.1	88.4	87.5	87.3
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	1	93.0	94.0	92.2	92.5
	14	91.9	92.1	92.0	91.8
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	1	88.8	94.5	92.2	88.3
	14	87.6	88.6	87.8	87.3
2600 RPM, STATIONARY	1	86.7	90.7	90.3	86.8
	14	85.6	86.8	86.3	85.2
2350 RPM, STATIONARY	1	86.0	89.5	88.7	86.3
	14	85.9	87.1	86.0	85.2
2000 RPM, STATIONARY	1	84.2	86.7	84.8	84.3
	14	84.7	85.7	84.6	84.6

TABLE 21 CONFIGURATION SUMMARY

configuration	induction system: air filter housing	induction system: ducts	cooling system: 1:1 fan	cooling system: 2:1 fan	exhaust system: exhaust manifold	exhaust system: t can & pipe	exhaust system: muffler	exhaust system: tail pipe	power system: transmission hous.	power system: stock engine	power system: noise kit engine	notes
												X=exposed or engaged C=covered or shrouded O=removed or inoperative A= alternating on & off
1	X	X		A	X	X	X	X	X	X		BASELINE
2	X	X		A	X	X	X	X	C		C	engine and transmission covered
3	C	C		A	X	X	X	X	C		C	only exhaust manifold exposed
4	C	C		A	X	C	C	C	C		C	only exhaust system exposed
5	C	C		A	C	C	C	C	C		C	QUIETED TRUCK
6	X	C		A	C	C	C	C	C		C	only air filter exposed
7	C	C		O	C	C	C	C	C		X	only engine with noise kit exposed
8	X	X		O	X	X	X	X	C		X	White single vertical muffler
9	X	X		O	X	X	X	O	C		X	tail pipe removed
10	X	X	A		X	X	X	X	C		X	Stemco muffler 1:1 fan
11	X	X	A		X	X	X	X	C		X	Donaldson muffler
12	X	X	A		X	X	X	X	X	X		ALL EXPOSED
13	X	X	A		X	X	X	X	X	X		rubber curtains added
14	X	X	A		X	X	X	X	X		X	FINAL TRUCK
14*	X	X	O		X	X	X	X	X		X	*a: cap on, *b: cap off *c: snorkel, *d: curtains

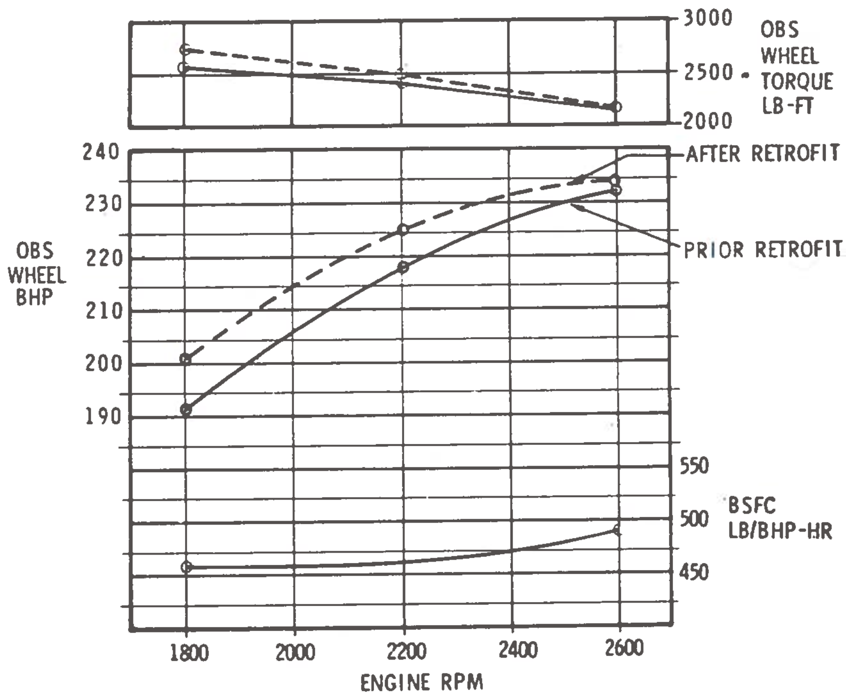


Figure 21. Engine Mechanical Performance

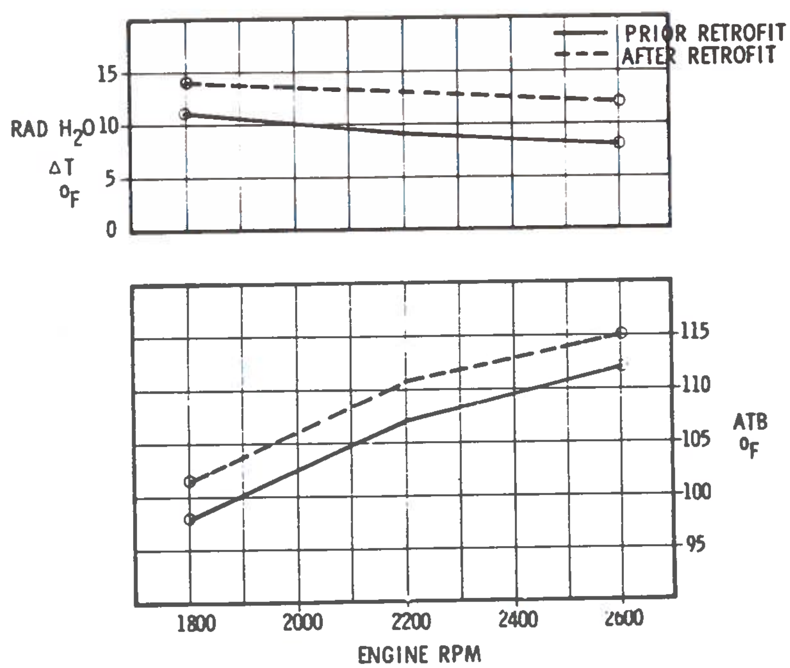


Figure 22. Engine Thermal Performance

The final truck was equipped with a Horton #9816 fan clutch and at 90°F ambient wind tunnel temperature, the clutch cycled off at 186°F and on at 191°F radiator top tank temperature during full load operation. The off cycle was approximately 15 seconds in duration. Observed fan horsepower at 2600, 2200 and 1800 engine rpm's was measured at 10.3, 8.6 and 4.6, respectively by observing the difference in wheel horsepower during the fan off/on cycle.

10. DATA ANALYSIS

In addition to the data shown in tables 2 through 20, the sound levels contributed by some components can be derived by calculation. For example, the contribution of fan noise to the total noise can be derived from the data shown in table 15 by calculating the sound level which would raise the fan-off sound levels to the fan-on sound levels.

In other instances, upper and lower bound sound levels can be deduced. For example the data in table 8 represent an upper bound for the engine with noise covers installed, since the rest of the truck, although reasonably well covered and muffled, still radiates some sound. On the other hand, calculating the quiet truck (table 6) contribution to the total yields a lower bound, since it assumes the extra covering of the engine to totally eliminate engine noise; this lower bound of engine noise is shown in table 22. The average of the lower and upper bound sound levels can be assumed to be the probable sound level of the engine alone.

In a similar manner, the noise contributions of other truck components were calculated; these calculated sound levels, with excerpts of appropriate original data, are listed in table 23 for the four test conditions which yield maximal sound levels. These sound levels and relations are characteristic of this particular truck and engine combination only.

The sound levels shown in table 23 serve as a basis for selection of strategy in reducing total truck noise. Note that in all cases, the

TABLE 22. ENGINE WITH NOISE COVERS. LOWER BOUND OF SOUND LEVELS

CONFIGURATION "7 MINUS 5" SEE TABLE 21 FOR DETAILED DESCRIPTION TEST TYPES	SIDE	A WEIGHTED SOUND LEVELS: SHUTTERS CLOSED, FAN OFF	SHUTTERS CLOSED, FAN ON	SHUTTERS OPEN, FAN ON	SHUTTERS OPEN, FAN OFF
J-366, ACCELERATION.	L	79.2	-	-	80.3
	R	79.9	-	-	80.8
CONSTANT SPEED AT GOVERNED MAXIMUM RPM	L	75.1	-	-	74.3
	R	72.2	-	-	75.6
MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP	L	78.5	-	-	78.9
	R	79.0	-	-	78.6
MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY	L	73.8	-	-	73.6
	R	72.1	-	-	71.7
2600 RPM, STATIONARY	L	71.7	-	-	71.7
	R	70.2	-	-	71.5
2350 RPM, STATIONARY	L	70.2	-	-	69.6
	R	69.9	-	-	70.7
2000 RPM, STATIONARY	L	69.3	-	-	68.8
	R	69.1	-	-	68.9

TABLE 23. . NOISE CONTRIBUTIONS (dBA)

NOISE SOURCE	J		K		I		G	
	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
Baseline (1.2X Fan)	91	90-½	89	90	88-½	88-½	88	90
Baseline (no fan)	89-½	88-½	84	83	87-½	87	81-½	82
Quiet Truck (no fan)	81-½	81	77	76-½	77	77-½	72-½	72-½
FINAL truck (1:1 fan)	86	86	82	82-½	84	84-½	81	81-½
FINAL truck (no fan)	86	86	81	81	83-½	84-½	79	81
Orig. Exhaust system	82-½	82	75	74	82	81-½	74	72-½
New exhaust system	80	81	73-½	75-½	79-½	80-½	73	76-½
Exhaust manifold*	77	79	73	74	75-½	78	71	73
1:1 fan	74-½	75	75	76	71	71	76	73-½
1.2:1 fan	84-½	85	85-½	85	81	83	85-½	85
Induction system	71	77	71	77-½	71	75	71	75-½
Original engine	86	85-½	81-½	79	85	84-½	77-½	77-½
Engine with noise covers	82	82	77	76	80	80	75	73-½
Transmission*	77	77	74	74	71	71	75	75

NOTES

All sound levels rounded to nearest ½ dB

— Extrapolated

*Includes engine noise radiation

J=J-366 acceleration

K= Constant speed at governed maximum rpm

I=Maximum instantaneous peak, stationary tromp

G=Maximum governed speed, 2800 rpm, stationary engine noise predominates and controls the overall sound level. Exhaust system noise is very engine-load sensitive, whereas fan noise is only rpm sensitive. Thus, during J-366 tests, or acceleration, or pulling loads up grades, the second most significant noise source is the exhaust system. During low load pulling, constant speed running, down slope running, fan noise becomes the second most significant noise source. The exhaust system noise is relatively insignificant during low load operation, and the intake system noise is relatively insignificant at all times.

The calculated sound levels on the left side of the truck incorporating a single change, double change and triple change are shown in tables 25 through 28 for the acceleration (J) and constant speed (K) moving tests and for the tromp (I) and governed (G) maximum rpm stationary tests. The effectiveness of the changes is also shown in table 24, showing the calculated sound level reductions in the Final Truck.

TABLE 24. CALCULATED SOUND LEVEL REDUCTIONS (dBA)

TEST TYPE →	J	K	I	G
SINGLE CHANGE:				
a. NOISE KIT ON ENGINE	1.8	1.9	2.1	0.7
b. REVISED EXHAUST SYSTEM	0.5	0.2	0.6	0.1
c. DISENGAGED FAN	0.2	0.6	0.0	1.1
DOUBLE CHANGE:				
a. + b.	2.6	2.1	3.1	0.8
a. + c.	2.1	2.8	2.3	2.0
b. + c.	0.7	0.8	0.6	1.3
TRIPLE CHANGE:				
a. + b. + c.	2.9	3.1	3.3	2.2

J = J-366 acceleration
K = Constant speed at governed maximum rpm
I = Maximum instantaneous peak, stationary tromp
G = Maximum governed speed, 2800 rpm, stationary

TABLE 25. CALCULATED SOUND LEVELS OF VARIOUS CONFIGURATIONS, ACCELERATION (dBA)

TESTS: J-366 ACCELERATION "J" LEFT	TOTAL VEHICLE NOISE	ORIGINAL ENGINE	REVISED ENGINE	ORIGINAL EXHAUST	REVISED EXHAUST	FAN ON	FAN OFF	INDUCTION SYSTEM	TRANSMISSION	EXHAUST MANIFOLD
DATA FROM TABLE 3 →		86	82	82.5	80	74.5	0	71	77	77
ORIGINAL CONFIGURATION	88.6	X		X		X		X	X	X
SINGLE CHANGE:										
a. NOISE KIT ON ENGINE	86.8		ⓧ	X		X		X	X	X
b. REVISED EXHAUST SYSTEM	88.1	X			ⓧ	X		X	X	X
c. DISENGAGED FAN	88.4	X		X			ⓧ	X	X	X
DOUBLE CHANGE:										
a. + b.	86.0		ⓧ		ⓧ	X		X	X	X
a. + c.	86.5		ⓧ	X			ⓧ	X	X	X
b. + c.	87.9	X			ⓧ		ⓧ	X	X	X
TRIPLE CHANGE:										
a. + b. + c.	85.7		ⓧ		ⓧ		ⓧ	X	X	X

TABLE 26. CALCULATED SOUND LEVELS OF VARIOUS CONFIGURATIONS, CONSTANT SPEED (dBA)

TESTS: CONSTANT SPEED AT MAXIMUM GOVERNED 2800 RPM "K" LEFT	TOTAL VEHICLE NOISE	ORIGINAL ENGINE	REVISED ENGINE	ORIGINAL EXHAUST	REVISED EXHAUST	FAN ON	FAN OFF	INDUCTION SYSTEM	TRANSMISSION	EXHAUST MANIFOLD
DATA FROM TABLE 3 →		81.5	77	75	73.5	75	0	71	74	73
ORIGINAL CONFIGURATION	84.2	X		X		X		X	X	X
SINGLE CHANGE:										
a. NOISE KIT ON ENGINE	82.3		(X)	X		X		X	X	X
b. REVISED EXHAUST SYSTEM	84.0	X			(X)	X		X	X	X
c. DISENGAGED FAN	83.6	X		X			(X)	X	X	X
DOUBLE CHANGE:										
a. + b.	82.1		(X)		(X)	X		X	X	X
a. + c.	81.4		(X)	X			(X)	X	X	X
b. + c.	83.4	X			(X)		(X)	X	X	X
TRIPLE CHANGE:										
a. + b. + c.	81.1		(X)		(X)		(X)	X	X	X

TABLE 27. CALCULATED SOUND LEVELS OF VARIOUS CONFIGURATIONS, STATIONARY PEAKS (dBA)

TESTS: MAXIMUM INSTANTANEOUS PEAK, STATIONARY TROMP "I" LEFT	TOTAL VEHICLE NOISE	ORIGINAL ENGINE	REVISED ENGINE	ORIGINAL EXHAUST	REVISED EXHAUST	FAN ON	FAN OFF	INDUCTION SYSTEM	TRANSMISSION	EXHAUST MANIFOLD
DATA FROM TABLE 3 →		85	80	82	79.5	71	0	71	71	75.5
ORIGINAL CONFIGURATION	87.3	X		X		X		X	X	X
SINGLE CHANGE:										
a. NOISE KIT ON ENGINE	85.2		(X)	X		X		X	X	X
b. REVISED EXHAUST SYSTEM	86.7	X			(X)	X		X	X	X
c. DISENGAGED FAN	87.3	X		X			(X)	X	X	X
DOUBLE CHANGE:										
a. + b.	84.2		(X)		(X)	X		X	X	X
a. + c.	85.0		(X)	X			(X)	X	X	X
b. + c.	86.7	X			(X)		(X)	X	X	X
TRIPLE CHANGE:										
a. + b. + c.	84.0		(X)		(X)		(X)	X	X	X

TABLE 28. CALCULATED SOUND LEVELS OF VARIOUS CONFIGURATIONS, STATIONARY GOVERNED. (dBA)

TESTS: MAXIMUM GOVERNED SPEED, 2800 RPM, STATIONARY "G" LEFT	TOTAL VEHICLE NOISE	ORIGINAL ENGINE	REVISED ENGINE	ORIGINAL EXHAUST	REVISED EXHAUST	FAN ON	FAN OFF	INDUCTION SYSTEM	TRANSMISSION	EXHAUST MANIFOLD
DATA FROM TABLE 3 →		77.5	75	74	73	76	0	71	75	71
ORIGINAL CONFIGURATION	82.5	X		X		X		X	X	X
SINGLE CHANGE:										
a. NOISE KIT ON ENGINE	81.8		(X)	X		X		X	X	X
b. REVISED EXHAUST SYSTEM	82.4	X			(X)	X		X	X	X
c. DISENGAGED FAN	81.4	X		X			(X)	X	X	X
DOUBLE CHANGE:										
a. + b.	81.7		(X)		(X)	X		X	X	X
a. + c.	80.5		(X)	X			(X)	X	X	X
b. + c.	81.2	X			(X)		(X)	X	X	X
TRIPLE CHANGE:										
a. + b. + c.	80.3		(X)		(X)		(X)	X	X	X

The single most effective change for J, K and I tests, as indicated in the respective tables, is the installation of the noise covers on the engine, while for the G test disengagement of the fan is the most effective single step.

The second most effective single change, for "J" and "I", is the new exhaust system; but for "K" disengaging the fan is a more effective change.

The second most effective single step improvement can also be seen to provide no more than 1/2 dB improvement over the original configuration. As a corollary, the best of the double changes is slightly more effective than the optimum single change, and the triple change is typically less than a dB improvement over the best single change. Note however from table 20 that the fan noise is a strong contributor of internal cab noise.

Thus a clear cut decision on making a quieter truck is also linked to a specific operating condition. Nevertheless, in order to obtain a quietest operating truck, with a V-903 engine and a configuration similar to the tested Final Truck, all three changes should be incorporated: the Cummins engine covers, a state-of-the-art vertical muffler and a clutched fan drive. Vehicle cooling and mechanical performance is not affected by the installation of the noise attenuation hardware.

A significant source of noise is the exhaust manifold area, radiating both from the manifold surface and from the engine block surface behind the manifold. Although part of the exhaust system, the manifold surface noise is unaffected by muffler performance and may well represent a noise floor for exhaust noise, regardless of future improvements in mufflers. There are not at present any shields or devices commercially available to attenuate the exhaust manifold and exhaust pipe noise.

The engine covers commercially available from Cummins do not cover the engine block surface behind the manifold, but their installation in the Final Truck provided a most significant sound level lowering of 4 dBA for the engine, resulting in a 2 dBA reduction for the truck during loaded operation.

The cost analysis in the next section is based on the use of the Cummins noise covers, a Donaldson muffler and a Horton fan clutch, as installed in the Final Truck.

The Cummins noise covers are the only commercially available noise reduction covers for the V-903 engine, but the Donaldson muffler is representative of a class of modern, well designed and effective mufflers. For example, tables 9, 11 and 12 show the similarity in truck noise with three different modern mufflers. Similarly, the Horton fan clutch is representative of a class of devices which perform essentially the same function, incidentally saving fuel costs, thus amortizing the cost of the device.

The reduction in V-903 powered truck noise, as documented in this report, can be achieved with any effective muffler and fan clutch.

11. COST ANALYSIS

Costs for the following components are based on prices charged retail customers of White Branches. Labor costs are based on rates prevailing in the Cleveland, Ohio area in the second quarter, 1975. These costs will vary since the selling rate of mechanic's labor varies from about $13.00 to $22.00 per hour across the country. In addition, the parts costs may vary due to shipping charges and marketing practices. Taxes are not included.

As part of this retrofit, additional parts may have to be replaced, including muffler clamps, exhaust pipes, flex hose, fan belts, lubricants, and similar items. Although the cost of these items has not been included in the estimates, they may reasonably be expected to be incurred by the vehicle owner. In addition, labor costs may be expected to vary from vehicle to vehicle, depending on the condition of the truck and the skill and experience of the mechanic.

No reduction in cost should be attributed to the removal of usable parts from an in-service vehicle since there is a limited salvage value associated with these components.

Complete Engine Noise Kit for a Cummins V-903

The engine noise kit contains the following parts, described with Cummins part numbers:

Engine Cover, LH	AR 11610	$ 23.44
Engine Cover, RH	AR 11611	33.97
Rocker Covers (2)	AR 11624	192.98
Oil Sump Covers	AR 11623	189.57
Flat Side Oil Pan (New)	AR 11625	244.20
	Total Material Cost	$684.16

In addition to the cost of the noise panels, a cost of approximately $85.05 will be incurred for the installation of these panels on an in-service vehicle.

Muffler and T-Can

The costs of the muffler and T-can are as follows:

Muffler	Donaldson WKM 10-0064	$ 86.40
T-Can	White 539404	50.36
	Total Material Cost	$136.76

The estimated retail cost of the labor involved in replacing a muffler is $23.63 in the Cleveland area.

Horton Fan Drive, Model 9816

The Horton fan drive is priced at $440.00 per unit, including controls. The estimated labor cost for its installation is $63.00.

Total Cost

Engine Noise Package	- Material	$ 684.16		
	- Labor (5.4 hrs.)	85.05		
			$769.21	
Muffler Package	- Material	149.80		
	- Labor (1.5 hrs.)	23.63		
			173.43	
Fan Drive Package	- Material	440.00		
	- Labor (4.0 hrs.)	63.00		
			503.00	
	Total Material	$1,273.96		
	Total Labor	171.68		
	Total Cost			$1,445.64

12. CONCLUSIONS

For a truck with a geometry similar to the White short cab conventional, powered with a Cummins V-903 engine, the most significant reduction in maximum sound level (∿ 2 dBA) is achieved by installing the Cummins engine covers (noise kit). An additional dBA of noise reduction can be obtained from either a state-of-the-art muffler or a fan clutch drive, depending on the operating condition of the truck. Installing engine covers, muffler and fan clutch insures a total noise reduction of 2.2 to 3.3 dBA for stationary tests and 2.9 to 3.1 dBA for moving tests.

Installation of these devices causes no degradation in performance. The fan clutch reduces fuel consumption and obviates the need for and cost of radiator shutters.

The cost of the engine covers, with installation, ranges up to $770, the muffler up to $175, the fan clutch about $500, for a total of $1445.

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