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EVALUATION OF DIESEL ENGINE PERFORMANCE WITH INTAKE AND EXHAUST SYSTEM THROTTLING

Volume I: Text and Appendixes A through H

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16. Abstract The diesel engine itself is an important source of diesel powered vehicle noise, and becomes dominant after proper treatment of intake/exhaust and cooling system noise at vehicle speeds below fifty miles per hour. An investigation was conducted to quantify the effects of intake and exhaust restrictions, and load-speed scheduling on the radiated noise from four diesel truck engines, produced by different manufacturers. Sound power measurements were made in an accoustically modified engine performance test cell. The noise associated with intake, exhaust, cooling and their respective ducting systems were appropriately abated to permit quantification of engine radiated noise. Exhaust emission data including temperature and performance data were also monitored. Engine radiated noise was not significantly affected by intake pressure restrictions up to 60 inches H_2O or exhaust restrictions up to 90 inches H_2O. The precombustion chamber turbocharged engine exhibited lower sound output than the naturally aspirated engine with respect to the mechanical power available under various load-speed conditions. Calculated engine sound pressure levels projected to fifty feet, gave noise levels ranging from 77 to 83 dB (A) at rated engine speed.

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PREFACE

This report summarizes and concludes the interagency effort on U.S. Department of Transportation agreement RA-73-2, Noise Reduction in Diesel Truck Engines Intake and Exhaust System Throttling. Contract activities began in November, 1972 and continued through May 1974. Objectives of the contract were (1) to make detailed measurements of exhaust emissions, exhaust temperatures, performance and radiated noise on typical truck diesel engines in order to quantify the effects of intake and exhaust restrictions for exhaust silencing treatment requirements; (2) to quantify diesel engine radiated noise as a function of load, speed and engine type.

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1. INTRODUCTION

In accordance with the Department of Transportation (DOT) contract provisions, the objective of the study was to characterize effects of diesel engine intake and/or exhaust system restrictions on engine performance, emissions, and noise. The report presents experimental results of tests using four test-stand-mounted diesel truck engines operated at varied speeds and loads with both intake and exhaust system restrictions controlled as test variables. Performance parameters measured included: speed, torque, air consumption, fuel consumption and oil and exhaust temperatures. The emissions measured were carbon monoxide, hydrocarbon, oxides of nitrogen, and smoke. Noise radiated from the engine was measured in dBA and the sound level signal was recorded on tape and provided to DOT personnel for sound spectral analysis. Neither an engine cooling fan nor a transmission were used in the test setup and insofar as practicable the sound radiated from intake and exhaust systems was isolated from the test cell and from the microphone. Noise and performance measurements were made at three speed-load combinations: full load at manufacturer's rated speed, speed for maximum torque development, and at an intermediate speed at full load.

2. DESCRIPTION OF TEST EQUIPMENT

Engines, Test Cell, Intake-Exhaust System, Fuel

Four diesel engines were made available by the manufacturers; these were:
-- a naturally aspirated 4-cycle direct-injection engine, Cummins NHC-250
-- a turbocharged 4-cycle direct-injection engine, Mack ENDT-675
-- a turbocharged 4-cycle precombustion chamber engine, Caterpillar 1673C, and
-- a 2-cycle direct-injection blower scavenged engine, Detroit Diesel 6-71.
Descriptive data are given in Table 1.

The test cell was 14 ft x 19 ft x 10 ft in dimension and was equipped with two power absorbing dynamometers. The test cell and engine installation are shown pictorally in Figure 1; schematically in Figure 2. The associated control and measuring equipment were located in an adjacent room. The engine mounting base consisted of I beams mounted in 24 x 36 x 78-inch concrete block supported on 8-inch concrete piers to 4 feet below floor level. A 1/2-inch expansion joint was provided between the mounting base and the room floor. The dynamometer base was of similar but lighter construction. Following sound level measurement evaluation and upon recommendation of the DOT's noise measurement consultant, the cell walls were sealed with a hard surface Epoxy paint to minimize wall absorption. Also sound scattering surfaces were installed in the room corners at the ceiling and at wall-ceiling junctions for mode mixing and elimination of critical room standing modes.

TABLE 1. - Diesel engines used in project to determine effect of intake and exhaust restrictions on performance and noise

Manufacturer.....	Cummins	Mack	Caterpillar	Detroit Diesel
Model.....	NHC-250	ENDT-675	1673-C	6-71[1/]
Type.....	Direct-injection 4-stroke cycle	Direct-injection 4-stroke cycle	Precombustion chamber 4-stroke cycle	Air scavenged direct-injection 2-stroke cycle
Number of cylinders.....	6	6	6	6
Displacement, cu in.....	855	672	638	426
Rated speed, RPM.....	2100	2100	2200	2100
Rated horsepower.....	250	232	250	216
Air induction method.....	Naturally aspirated	Turbocharger 631 GC 487	Turbocharger Garrett Corp.	Blower
Engine serial No.....	623771	8K-5623	6D 1560	

1/ 1972 model with N65 injectors.

The microphone position chosen was five feet from the test engine and toward the center of the room and five feet from the nearest wall at a location four feet above the floor level (Figures 1 and 2).

Filtered air was supplied the engines through a 10-1/4-inch x 12-inch pleated paper air filter cartridge (Fram Model CA 240 PL). The air intake and filter were located outside the test cell as was a flow measuring venturi and a pulsation damping chamber. The air was conducted to the engine through a 4-inch diameter by 1/16-inch wall pipe. Located in this pipe was a remote controlled servo-operated butterfly valve. This valve was used to restrict the flow to the engine. The static pressure on the engine side of the butterfly restriction valve was taken from a tap mounted on the engine side of the valve. The pressure differential from atmospheric was measured using water and/or Hg manometers. See Figures 3 through 6.

The exhaust system conducted the engine exhaust outside the cell through a 4 or 5-inch by 1/16-inch wall pipe. The exhaust system piping configuration varied with engines (see Figures 3 through 6). The portion of the piping system within the test cell was covered with 2 or 3 inches of preformed calcium silicate and a 24-gauge aluminum jacket outer covering.

Measurements made by the DOT consultant established that this exhaust pipe insulation served as sufficient sound barrier for the purpose of the experiment. Initial operation of the engines without a muffler was attempted, but the sound levels outside the test facility were objectionable to the neighbors. Therefore, a Donaldson muffler, 10-inch x 15-inch x 26-inch model MOM 12 0108 with offset 5-inch inlet and outlet was installed. Additional variable exhaust restriction was provided by a remote controlled butterfly valve on the engine side of the muffler. Static pressure in the exhaust line was measured on the engine side of the restriction by the use of water and/or mercury manometers.

A commercially available high cetane number diesel fuel was used for all tests. Table 2 provides a listing of fuel properties.

3. TEST PROCEDURES

3.1 Selection of Operating Parameters

The engine to be tested was mounted on the test stand. If a new engine, it was broken-in following the manufacturer's recommended speed, load, and time. Prior to making sound level measurements, emission measurements--carbon monoxide (CO), hydrocarbon (HC), oxides of nitrogen (NO_x), and smoke--were made using a 13-mode cycle.

TABLE 2. - Typical fuel properties

Distillation, °F:	
IBP	330
5%	372
10%	388
20%	420
30%	440
40%	460
50%	476
60%	494
70%	516
80%	538
90%	572
95%	600
EP	614
Recovery	98%
Specific gravity	0.8459
API	35.8
Kinematic viscosity:	
100°F	2.21
Sulfur, wt %	.15
FIA, vol %:	
Aromatic	31
Olefin	5
Flash point	132°F

These tests were then repeated at the completion of the experiment so that any major change in engine emissions could be detected. Following this, the engine was operated using restricted exhaust and/or intake systems to establish working and maximum ranges of restrictions for use in the experiment. The maximum values used were well beyond those recommended by the manufacturer for normal operation. This was done to assist in establishing pressure, power, and sound level relationship. The criteria used to set maximum limits of restriction were (1) exhaust temperatures at the manifold or turbocharger were not to exceed short period temperatures in excess of those arrived at in discussion with the manufacturer's representatives. (2) Smoke levels in excess of approximately 20 percent opacity were not to be exceeded at any test condition. The experiment test plan is shown below.

Speed	Intake restriction level	Exhaust restriction level
Maximum torque	A	a
	A	b
	A	c
Intermediate	B	a
	B	b
	B	c
Rated	C	a
	C	b
	C	c

NOTE.-A,B,C, and a,b,c represent different levels of pressure in the intake or exhaust system.

Triplicate tests were made at most of the test conditions. The speed and restriction levels varied for each engine; values are listed in Tables 3, 4, 5, and 6.

3.2 Engine Performance Measurements

Measurements were made for speed, torque, air flow, fuel flow, and for temperatures of air, coolant, exhaust, and oil.

A 300-horsepower induction dynamometer provided with speed and current controls was used to load the engine. Torque measurement was made using a Baldwin Lima Hamilton load cell with electronic digital strain gauge meter. The engine speed was measured by direct-current tachometer generator and meter. The speed measuring system calibration was checked frequently with a stroboscope.

TABLE 3. - Summary of Cummins NHC-250 data

Exhaust ΔP, "H_2O 1/	Intake ΔP, "H_2O 2/	Barometer, mmHg	Power, bhp 3/	Air flow, lb/hr	Fuel flow, lb/hr	A/F	BSFC, lb/bhp-hr	Oil temp., °F	Exhaust temp., °F	Smoke, pct opacity	Intake temp., °F	Pressure		BSER, g/bhp-hr 5/			S.P.L. 6/ dBA	Smoke limited throttle
												Intake (dry), mmHgA 4/	Exhaust, mmHgA	CO	HC	NO_x as NO_2		
1,400 RPM																		
26	19.9	742.1	166.6	1,243	71.0	17.5	0.426	213	1,345	7.0	79	699.4	785	6.4	0.08	7.9	105.9	No
25	40.1	742.1	155.9	1,153	71.3	16.2	.457	222	1,465	10.5	82	661.5	783	3.4	.13	7.3	105.9	No
25	60.7	743.4	137.9	1,021	60.7	16.8	.440	218	1,284	20.0	81	623.0	784	9.5	.02	6.6	104.9	Yes
56	20.2	741.6	162.3	1,236	71.2	17.4	.439	222	1,385	3.0	85	699.4	841	3.7	.05	7.4	105.0	No
55	40.0	741.6	152.7	1,150	71.5	16.1	.468	222	1,490	11.0	85	661.7	839	5.2	.09	7.0	105.8	No
56	59.3	743.4	139.0	1,001	63.4	15.8	.456	220	1,400	19.0	80	625.6	841	3.6	.01	6.3	105.2	Yes
85	20.2	741.5	159.5	1,216	71.3	17.1	.447	224	1,418	2.5	88	698.7	896	2.7	.06	7.4	105.2	No
84	39.8	740.4	149.2	1,156	72.0	16.1	.482	214	1,490	21.0	78	662.0	894	3.0	.10	6.6	106.1	No
85	60.7	743.4	134.5	991	63.3	15.7	.470	220	1,415	18.0	80	623.0	896	3.2	.01	5.9	104.5	Yes
1,750 RPM																		
27	21.3	743.4	205.9	1,500	87.5	17.1	0.425	230	1,390	15.0	80	696.8	787	4.5	0.01	6.4	107.8	No
26	40.9	743.4	194.9	1,384	88.2	15.7	.453	237	1,500	18.5	81	660.0	785	2.0	.01	6.4	108.2	No
25	60.0	743.4	176.6	1,305	79.6	16.4	.451	234	1,432	18.0	82	624.4	784	3.2	.01	6.3	107.6	Yes
55	21.4	743.4	204.1	1,489	87.6	17.0	.429	236	1,403	14.0	83	696.5	840	3.7	.01	6.4	107.5	No
56	40.3	753.0	191.1	1,412	88.8	15.9	.465	225	1,482	13.5	66	661.2	841	1.9	.20	7.0	107.9	No
53	60.3	752.0	176.4	1,303	84.1	15.5	.477	233	1,520	19.0	70	623.9	839	2.0	.15	6.6	107.5	No
87	20.7	751.3	198.0	1,487	87.8	16.9	.443	227	1,407	10.0	75	698.0	899	3.5	.20	7.4	106.4	No
87	43.2	742.4	181.1	1,382	85.3	16.2	.471	229	1,477	18.0	76	655.8	899	2.2	.21	6.4	107.8	Yes
82	63.3	742.0	169.2	1,286	82.1	15.7	.485	234	1,535	20.0	77	618.1	889	1.9	.13	6.1	107.7	Yes
2,100 RPM 7/																		
28	20.3	740.2	232.4	1,847	101.0	18.3	0.435	238	1,374	11.2	80	698.6	794	6.0	0.08	6.6	109.3	No
28	40.2	740.2	224.0	1,713	101.4	16.9	.452	240	1,474	14.0	85	661.4	790	2,8	.09	6.3	109.2	No
26	60.1	740.2	213.4	1,594	100.6	15.8	.472	246	1,568	17.8	86	624.2	787	1.9	.10	5.9	110.7	No
57	20.3	740.2	231.4	1,812	99.9	18.2	.432	246	1,402	13.5	86	698.6	844	4.5	.07	6.8	108.5	No
57	40.2	740.2	221.1	1,687	100.0	16.9	.452	247	1,493	18.0	85	661.4	844	2.4	.08	6.4	109.2	No
58	58.8	740.2	207.4	1,581	96.5	16.4	.466	244	1,524	19.0	86	626.4	844	2.4	.10	5.9	109.2	Yes
88	20.2	740.2	226.0	1,800	99.2	18.2	.440	246	1,407	12.5	85	698.8	900	3.3	.08	6.6	108.9	No
88	40.1	740.2	214.6	1,676	99.6	16.8	.464	247	1,505	16.0	85	661.6	900	2.2	.08	6.2	108.9	No
85	59.6	740.6	199.8	1,563	97.6	15.9	.494	246	1,592	19.8	85	625.2	896	1.8	.10	5.8	109.6	Yes

1/ Exhaust ΔP ("H_2O) above 736.6 mmHgA.
2/ Intake ΔP ("H_2O) below 736.6 mmHgA corrected for water vapor in the intake air.
3/ Corrected for temperature using SAE-J816-B engine test code. C_D = ((intake temperature, R)/545)$^{0.7}$.
4/ Intake pressure, mmHgA, corrected to dry basis = intake pressure, mmHgA less intake water vapor pressure, mmHgA.
5/ BSER is brake specific emission rate, g/bhp-hr.
6/ S.P.L. is sound pressure level near engine.
7/ All values at 2,100 rpm (except Noise, dBA) are an average of two tests; Noise dBA is a single test value.

TABLE 4. - Summary of Mack ENDT 675 data[1]

Exhaust ΔP, "H_2O [2]	Intake ΔP, "H_2O [3]	Barometer, mmHg	Power, bhp [4]	Air flow, lb/hr	Fuel flow, lb/hr	A/F	BSFC, lb/bhp-hr	Oil temp., °F	Exhaust temp., °F [12]	Smoke, pct opacity	Intake temp., °F	Pressure: Intake (dry), mmHgA [5]	Pressure: Exhaust, mmHgA	BSER, g/bhp-hr [6]: CO	BSER: HC	BSER: NO_x as NO_2	S.P.L. [7] dBA
1,500 RPM																	
30.8	20.1	744.2	208.0	1,804	76.8	23.5	0.369	218	1,041	3.5	85	698.9	794.1	2.30	0.45	11.90	102.8
30.8	41.1	744.2	202.2	1,675	76.6	21.8	.379	219	1,103	5.0	85	659.7	794.1	3.33	.37	11.57	102.5
30.8	60.8	744.2	197.0	1,563	76.9	20.3	.390	219	1,165	7.6	86	622.7	794.1	4.75	.28	11.19	102.2
30.8	80.8	744.2	154.0	1,229	[8]/63.2	19.4	.410	215	1,154	9.6	87	585.5	794.1	6.09	.36	10.72	101.1
50.4	19.9	744.2	203.0	1,721	76.0	22.6	.374	217	1,079	3.8	89	699.4	830.9	2.68	.45	11.47	102.5
50.7	40.7	744.2	198.0	1,610	76.5	21.0	.386	219	1,142	5.8	89	660.2	831.4	4.10	.36	11.19	102.1
50.7 [9]	59.5	743.0	179.1	1,421	[8]/71.7	19.8	.400	217	1,172	7.7	91	625.3	831.5	5.12	.25	10.55	101.2
50.4	80.4	744.0	135.1	1,114	[8]/55.9	19.9	.414	214	1,132	9.5	91	586.1	830.9	6.27	.44	10.71	100.7
70.7	19.7	744.0	199.5	1,655	75.9	21.8	.380	218	1,118	4.5	92	699.7	868.8	3.33	.33	10.32	102.1
70.4	41.0	743.5	194.1	1,543	77.0	20.0	.396	218	1,181	7.1	91	659.6	868.3	4.78	.22	10.50	101.8
70.2	60.7	743.5	155.0	1,247	[8]/62.4	19.9	.403	216	1,154	8.3	93	623.0	867.9	5.57	.34	9.73	99.9
70.4	80.9	743.5	124.9	1,035	[8]/52.8	19.6	.423	213	1,136	10.0	94	585.2	868.3	6.75	.42	9.42	101.1
1,800 RPM																	
30.7	21.1	743.1	211.0	2,237	80.8	27.6	0.383	220	954	1.6	79	697.0	793.9	1.40	0.71	11.22	103.6
30.4	41.0	743.1	207.2	2,092	80.9	25.8	.390	221	1,006	2.5	80	659.8	793.5	1.87	.66	11.47	103.6
30.4	60.3	743.1	204.5	1,955	81.3	24.0	.397	221	1,061	3.1	81	623.8	793.5	2.65	.52	11.04	103.5
30.7	80.3	743.1	200.9	1,818	81.6	22.3	.406	222	1,131	4.8	81	586.3	793.9	3.47	.32	10.78	103.2
50.4	21.1	743.1	210.1	2,155	81.7	26.3	.389	221	990	1.8	83	697.0	830.8	1.75	.71	11.30	103.9
50.4	40.8	743.6	206.8	2,017	81.9	24.6	.396	221	1,045	3.1	83	660.2	830.9	2.42	.57	10.85	103.3
50.4	60.3	743.6	203.9	1,883	82.0	22.9	.402	221	1,106	4.1	84	623.6	830.9	2.99	.44	10.58	103.2
50.3	80.1	743.6	193.5	1,704	[8]/78.9	21.5	.407	221	1,162	5.8	86	586.6	830.7	3.90	.31	10.31	103.1
70.4 [10]	21.3	743.6	210.1	2,069	81.4	25.4	.387	221	1,031	2.1	89	696.7	868.4	2.04	.62	11.07	103.5
70.5	40.0	743.1	207.7	1,945	81.7	23.8	.393	221	1,088	3.3	89	661.6	868.4	2.69	.49	10.78	103.1
70.2	60.1	743.1	202.7	1,805	81.4	22.1	.399	223	1,152	4.8	91	624.2	868.0	3.67	.36	10.39	103.0
70.1 [9]	80.0	742.7	171.5	1,535	[8]/71.9	21.3	.419	220	1,160	7.5	87	586.8	867.8	4.81	.37	9.61	102.7
2,100 RPM																	
35.0 [9]	20.1	744.8	203.7	2,416	86.6	27.9	0.425	226	1,008	2.0	88	699.1	802.0	2.27	0.92	8.28	105.5
32.6 [9]	40.0	744.8	199.8	2,278	85.1	26.8	.426	226	1,046	3.0	88	661.7	797.6	2.52	.73	9.28	105.5
31.2 [9]	60.2	744.8	196.6	2,140	85.8	25.0	.436	226	1,095	3.5	88	624.0	795.0	2.94	.54	8.98	105.5
30.7 [9]	81.1	745.0	198.4	2,006	85.6	23.4	.431	228	1,156	5.2	94	584.9	793.9	3.26	.34	9.57	104.5
51.0 [9]	20.1	744.8	200.2	2,384	85.3	28.0	.426	225	1,014	2.2	90	699.0	831.8	2.28	.74	9.20	105.5
50.3 [9]	40.2	744.2	198.8	2,241	86.2	26.0	.434	226	1,060	2.5	91	661.5	830.6	2.72	.58	9.14	105.4
50.6 [9]	60.2	744.2	196.3	2,102	85.5	24.6	.436	226	1,110	4.0	90	624.0	831.2	3.02	.44	8.83	105.2
51.2 [11]	82.2	746.0	189.9	1,931	[8]/82.7	23.4	.435	227	1,162	6.0	95	582.8	832.4	3.17	.32	8.56	104.0
70.3 [9]	20.2	744.2	200.1	2,352	84.6	27.8	.423	226	1,024	2.8	92	698.9	868.0	2.39	.68	8.90	105.4
70.4	40.0	743.3	200.7	2,201	84.9	25.9	.423	225	1,078	3.3	93	661.7	868.2	2.66	.52	8.57	105.2
70.4	60.1	743.3	191.5	2,029	[8]/83.2	24.4	.434	225	1,125	4.3	94	624.1	868.2	2.98	.42	8.20	104.9

1/ Each value is an average of three replicate tests except as noted.
2/ Exhaust ΔP ("H_2O) above 736.6 mmHgA
3/ Intake ΔP ("H_2O) below 736.6 mmHgA corrected for water vapor in the intake air.
4/ Corrected for temperature using SAE-J816-B engine test code. C_D = ((intake temperature, R)/545)$^{0.7}$
5/ Intake pressure, mmHgA, corrected to dry basis = intake pressure, mmHgA less intake water vapor pressure, mmHgA.
6/ BSER is brake specific emission rate, g/bhp-hr.
7/ S.P.L. is sound pressure level near engine.
8/ Implies aneroid (automatic smoke control) limited fuel rate.
9/ Each value is an average of two tests.
10/ Each value is an average of four tests.
11/ Each value is a single test.
12/ At turbocharger outlet.

TABLE 5. - Summary of Caterpillar 1673C data

Exhaust ΔP, "H_2O 1/	Intake ΔP, "H_2O 2/	Barometer, mmHg	Power, bhp 3/	Air flow, lb/hr	Fuel flow, lb/hr	A/F	BSFC, lb/bhp-hr	Oil temp., °F	Exhaust temp., °F 4/	Smoke, pct opacity	Intake temp., °F	Pressure		BSER, g/bhp-hr 6/			S.P.L. 7/ dBA	Number of observations averaged
												Intake (dry), mmHgA 5/	Exhaust, mmHgA	CO	HC	NO_x as NO_2		
1,600 RPM																		
30.5	10.6	745.8	184	1,674	74.8	22.4	0.407	212	1,149	0.8	92	716.7	793.6	0.34	0.06	4.13	101.0	3
30.5	20.2	745.5	181	1,614	76.0	21.2	.419	212	1,202	1.4	90	698.8	793.7	.53	.07	3.90	100.8	4
30.5	40.3	745.5	174	1,451	77.3	18.8	.444	213	1,303	5.8	91	661.2	793.7	1.36	.03	3.33	100.6	4
30.5	60.2	744.6	156	1,236	76.8	16.1	.488	212	1,390	21.7	92	623.9	793.7	2.66	.03	2.43	100.3	3
50.9	10.5	745.8	182	1,630	75.2	21.7	.412	212	1,183	.8	97	716.9	831.8	.45	.05	4.06	100.9	3
50.7	20.2	745.5	180	1,565	76.1	20.6	.423	212	1,223	1.8	92	698.8	831.5	.68	.04	3.81	100.6	4
50.7	40.3	745.4	171	1,393	77.4	18.0	.452	213	1,339	8.1	93	661.1	831.5	1.61	.03	3.16	100.4	4
70.4	10.5	745.8	182	1,580	75.8	20.8	.417	213	1,216	1.2	97	717.0	868.2	.58	.04	3.88	100.7	3
70.4	20.2	745.4	177	1,503	76.3	19.7	.432	213	1,263	2.9	95	698.8	868.3	.93	.03	3.59	100.6	4
70.4	40.3	745.5	165	1,342	77.5	17.3	.468	213	1,371	11.3	95	661.2	868.3	1.75	.03	2.92	100.3	4
1,900 RPM																		
30.4	11.0	744.8	217	2,154	89.2	24.1	0.411	218	1,143	0.5	94	716.0	793.5	0.22	0.08	5.16	103.6	3
30.5	20.3	743.9	214	2,052	89.3	23.0	.417	218	1,184	.5	94	698.8	793.7	.30	.08	4.96	103.4	4
30.5	40.3	743.9	206	1,840	89.9	20.5	.436	218	1,280	1.1	97	661.2	793.7	.52	.05	4.47	103.0	4
30.5	60.2	743.9	191	1,627	90.3	18.0	.472	219	1,383	4.6	97	623.9	793.7	1.07	.04	3.70	102.5	4
50.6	11.2	744.8	216	2,104	90.0	23.4	.416	219	1,167	.5	98	715.7	831.2	.28	.08	5.15	103.4	3
50.6	20.2	743.9	213	2,018	90.0	22.4	.423	218	1,208	.5	97	698.9	831.2	.35	.07	4.87	103.2	4
50.5	40.3	744.1	204	1,812	90.4	20.0	.444	218	1,306	1.1	98	661.2	831.1	.63	.05	4.41	102.6	4
50.5	60.2	744.0	187	1,591	91.0	17.5	.486	218	1,400	5.3	96	624.0	831.0	1.08	.05	3.57	102.6	2
70.7	10.8	744.8	215	2,039	90.8	22.5	.422	218	1,197	.7	100	716.4	868.9	.31	.06	4.92	103.2	3
70.7	20.2	744.1	210	1,948	90.1	21.6	.429	218	1,232	.5	92	698.9	868.9	.40	.06	4.70	103.0	4
70.7	40.3	744.1	200	1,730	90.5	19.1	.452	218	1,338	2.0	98	661.2	868.9	.73	.04	3.98	102.5	4
2,200 RPM																		
30.8	13.1	744.6	230	2,565	99.4	25.8	0.432	223	1,146	0.5	87	712.1	794.2	0.26	0.08	5.99	105.2	4
30.6	20.4	744.1	229	2,464	99.2	24.8	.433	223	1,180	.6	88	698.5	793.9	.26	.08	5.70	105.1	5
30.6	40.4	744.1	222	2,201	98.8	22.3	.446	223	1,269	.6	90	661.0	793.9	.38	.06	5.33	104.5	5
30.6	60.5	744.1	211	1,938	98.7	19.6	.468	222	1,358	1.2	91	623.5	793.9	.66	.04	4.68	104.2	5
50.3	12.5	744.6	226	2,463	98.3	25.1	.435	223	1,163	.6	91	713.2	830.7	.28	.08	5.76	104.9	4
50.3	20.4	744.1	225	2,363	98.2	24.1	.437	223	1,194	.5	92	698.5	830.7	.31	.07	5.55	104.8	5
50.4	40.3	744.1	217	2,118	98.1	21.6	.453	223	1,275	.6	92	661.3	830.8	.42	.05	5.03	104.3	4
50.4	60.5	744.1	204	1,861	98.3	18.9	.483	222	1,381	1.8	93	673.5	830.8	.73	.04	4.28	103.9	4
70.5	12.2	744.8	222	2,369	97.5	24.3	.438	223	1,172	.5	92	713.7	868.4	.29	.07	5.36	104.7	3
70.6	20.3	744.1	222	2,282	97.5	23.4	.440	223	1,211	.5	94	698.7	868.6	.33	.06	5.21	104.4	4
70.4	40.5	743.8	213	2,037	97.9	20.8	.460	223	1,303	.9	94	660.9	868.2	.50	.05	4.70	104.0	4

1/ Exhaust ΔP ("H_2O) above 736.6 mmHgA.
2/ Intake ΔP ("H_2O) below 736.6 mmHgA corrected for water vapor in the intake air.
3/ Corrected for temperature using SAE-J816-B engine test code. C_D = ((intake temperature, R)/545)$^{0.7}$.
4/ At turbocharger inlet.
5/ Intake pressure, mmHgA, corrected to dry basis = intake pressure, mmHgA less intake water vapor pressure, mmHgA.
6/ BSER is brake specific emission rate, g/bhp-hr.
7/ S.P.L. is sound pressure level near engine.

TABLE 6 . - Summary of Detroit Diesel 6-71 data

Exhaust ΔP, "H_2O 1/	Intake ΔP, "H_2O 2/	Barometer, mmHg	Power bhp 3/	Air flow, lb/hr	Fuel flow, lb/hr	A/F	BSFC, lb/bhp-hr	Oil temp., °F	Exhaust temp., °F 4/	Smoke, pct opacity	Intake temp, °F	Pressure		BSER, g/bhp-hr 6/			S.P.L. 7/ dBA	H_2O vapor, mmHg	Number of observations averaged
												Intake (dry), mmHgA 5/	Exhaust, mmHgA	CO	HC	NO_x as NO_2			
1,400 RPM																			
11.1	7.0	747.1	149	1,798	68.7	26.2	0.462	214	934	10.0	67	737.5	757.3	62.50	0.22	7.73	108.0	14.1	3
30.3	7.2	751.9	149	1,685	69.0	24.4	.464	220	1,013	9.5	72	736.6	793.3	49.50	.17	7.96	106.9	13.6	2
30.7	40.3	744.5	127	1,355	69.0	19.6	.543	219	1,088	19.0	69	676.3	794.0	123.00	.11	7.00	100.0	15.2	2
30.7	59.9	744.5	110	1,155	69.5	16.6	.639	220	1,008	22.5	69	638.8	794.0	247.00	.23	5.86	105.2	14.3	2
50.5	.7	752.3	150	1,694	69.0	24.6	.461	218	1,018	6.5	66	744.8	831.0	42.40	.19	7.61	106.8	9.5	1
50.3	8.2	748.2	147	1,610	69.0	23.3	.470	222	1,048	8.0	72	733.4	830.7	49.20	.17	7.58	106.3	12.2	2
50.4	20.0	747.1	139	1,483	69.0	21.5	.498	220	1,101	11.0	70	712.7	830.9	61.90	.11	7.75	106.1	13.7	3
50.3	30.0	748.2	129	1,341	69.0	19.4	.535	221	1,183	17.0	75	691.9	830.1	67.30	.05	6.98	105.7	11.5	2
50.4	40.3	744.5	124	1,300	69.0	18.8	.558	221	1,121	19.0	73	676.0	830.9	57.00	.25	7.17	105.5	15.2	2
50.7	59.8	745.0	100	1,056	69.5	15.2	.697	220	964	18.0	67	640.2	831.3	-	.40	5.65	104.3	15.6	1
50.6	80.3	745.0	85	936	69.5	13.5	.815	219	905	37.0	69	600.9	831.3	-	-	4.63	103.8	14.6	1
70.5	7.6	744.0	146	1,514	69.0	21.9	.472	220	1,090	9.0	89	737.5	868.4	50.90	.16	7.64	105.9	15.1	1
70.8	20.0	744.5	135	1,405	69.0	20.3	.511	222	1,143	14.5	80	715.4	870.0	61.50	.09	8.18	105.4	16.1	2
70.5	29.7	744.0	126	1,277	69.0	18.5	.547	223	1,187	18.0	92	695.4	868.4	63.00	.04	6.96	105.0	14.3	1
70.8	40.3	744.5	115	1,195	69.0	17.3	.598	220	1,108	23.0	82	676.3	869.0	125.00	.12	6.95	104.7	15.2	2
1,700 RPM																			
11.2	11.8	743.6	181	2,181	77.3	28.2	0.428	218	964	6.6	68	729.9	757.3	33.50	0.26	10.39	109.2	15.3	3
31.1	7.9	746.5	182	2,153	79.0	27.3	.435	223	980	7.0	68	734.4	794.8	25.70	.27	10.38	108.0	12.6	1
30.7	19.7	743.6	176	2,005	78.3	25.6	.446	222	1,027	8.3	69	714.6	793.9	32.20	.24	10.40	108.3	15.0	3
30.8	29.1	745.4	168	1,861	79.3	23.5	.471	222	1,083	10.5	64	695.7	794.2	38.30	.15	9.87	107.7	13.6	2
30.7	39.8	743.6	163	1,748	78.7	22.2	.483	224	1,133	13.0	70	676.3	793.9	45.20	.14	9.21	107.4	14.2	3
30.3	59.3	740.0	156	1,642	77.0	21.3	.493	225	1,185	16.0	79	640.8	793.3	-	.07	8.73	106.5	15.2	1
49.4	7.6	746.5	181	2,123	79.5	26.7	.439	222	991	5.0	63	734.9	829.1	21.20	.26	10.85	107.5	12.6	1
50.1	19.8	743.6	175	1,953	78.7	24.8	.450	222	1,050	8.2	71	714.6	830.4	29.10	.22	10.00	107.6	14.6	3
50.1	29.2	743.6	169	1,832	78.5	23.3	.466	223	1,097	10.1	71	696.5	830.4	35.00	.18	10.17	107.2	14.6	3
50.2	40.3	743.7	159	1,685	78.9	21.4	.497	225	1,168	14.8	71	675.5	830.4	42.90	.11	9.54	106.8	14.3	4
50.7	52.5	740.0	159	1,651	76.5	21.6	.480	224	1,180	13.0	81	653.9	831.4	-	.07	9.27	106.8	15.5	1
70.6	8.7	745.4	179	2,025	79.3	25.5	.443	224	1,031	7.0	70	734.7	868.5	22.00	.23	11.56	106.8	14.4	2
70.7	19.7	743.6	173	1,891	78.3	24.2	.454	224	1,077	8.7	74	714.6	868.9	27.80	.20	11.09	106.8	15.0	3
70.7	29.2	743.6	166	1,730	78.5	22.1	.474	225	1,128	10.7	75	696.5	868.9	32.90	.16	10.17	106.3	15.0	3
70.7	39.8	743.6	158	1,647	78.5	21.0	.497	226	1,196	13.3	77	676.3	868.9	38.90	.09	9.91	105.8	14.2	3
2,100 RPM																			
13.5	17.2	741.7	211	2,699	90.5	29.8	0.430	225	956	7.0	73	721.0	761.8	22.20	0.18	11.42	109.0	16.5	3
30.8	21.0	741.7	208	2,587	91.0	28.4	.437	227	983	6.3	75	713.7	794.2	23.20	.17	11.61	108.8	16.4	3
31.0	29.9	743.1	202	2,388	91.0	26.2	.452	230	1,032	8.8	75	695.3	794.5	26.00	.31	11.31	108.2	14.8	2
30.8	40.2	741.7	196	2,292	90.2	25.4	.460	226	1,056	10.3	76	676.9	794.2	29.40	.16	11.24	108.7	15.5	3
30.8	60.4	740.2	183	2,047	90.0	22.7	.492	230	1,149	14.5	83	640.7	794.2	40.00	.05	10.71	108.3	17.1	2
50.2	21.5	741.1	205	2,524	90.2	28.0	.440	229	1,000	10.7	80	713.0	830.4	18.00	.23	12.20	108.3	16.6	3
50.3	29.9	743.1	199	2,353	90.0	26.1	.453	230	1,043	14.5	77	695.3	830.7	22.80	.26	11.78	107.8	14.8	2
50.2	40.2	741.1	195	2,248	90.7	24.8	.464	230	1,085	14.0	81	677.1	830.4	27.60	.15	11.37	108.0	15.8	3
50.6	52.7	744.8	180	1,980	91.0	21.8	.507	230	1,180	17.0	67	648.1	831.1	38.50	.15	10.18	107.5	10.0	1
50.0	60.6	739.2	183	2,022	90.5	22.4	.496	230	1,158	17.5	88	640.6	830.0	36.50	.04	10.75	108.1	17.4	2
70.5	17.1	741.4	208	2,528	90.0	28.1	.433	230	1,009	7.0	92	724.2	868.4	15.25	.27	12.71	107.5	19.6	1
70.7	20.2	743.1	205	2,472	90.0	27.5	.440	229	1,021	7.0	81	714.1	868.8	17.21	.24	12.30	107.5	15.2	2
70.7	29.9	743.1	198	2,313	90.5	25.6	.457	230	1,068	8.3	82	695.3	868.8	21.05	.25	12.00	107.3	14.8	2
70.3	40.2	741.4	191	2,203	89.5	24.6	.469	231	1,097	9.3	85	677.1	868.1	24.26	.13	11.84	107.4	15.8	3
70.9	46.7	744.8	182	2,005	90.0	22.3	.495	231	1,183	14.0	76	659.5	869.3	30.34	.15	10.90	107.0	10.2	1

1/ Exhaust ΔP ("H_2O) above 736.6 mmHgA.
2/ Intake ΔP "H_2O below 736.6 mmHgA corrected for water vapor in the intake air.
3/ Corrected for temperature using SAE-J816-B engine test code. $C_D = ((\text{intake temperature,R})/545)^{0.7}$.
4/ At manifold to exhaust pipe.
5/ Intake pressure, mmHgA, corrected to dry basis = intake pressure, mmHgA less intake water vapor pressure, mmHgA.
6/ BSER is brake specific emission rate, g/bhp-hr.
7/ S.P.L. is sound pressure level near engine.

The mass rate of fuel flow was measured with a Flowtron Model 10, type 2, flowmeter and a digital indicator and/or recorder readout. Engine exhaust, coolant, oil, and air intake temperatures were sensed with iron constantan thermocouples and read from a Doric Model 550 digital multipoint indicator. A two-inch throat venturi meter, U tube pressure manometers, mercury barometer, and thermocouples provided the data for calculation of mass air flow. The engine was supplied coolant from an 8-gallon reservoir which was provided make-up water at a rate thermostatically controlled to maintain the reservoir water temperature at 180° F. The flow and inlet and outlet temperature of coolant make-up water was measured for the Cummins engine to provide data on coolant requirements. The flowmeter was not used on the other engines tested.

3.3 Emission Measurements

Emissions of CO, HC, NO_x, and smoke in the exhaust stream were measured using a nondispersive infrared analyzer for carbon monoxide, heated flame ionization for total hydrocarbon, chemiluminesence for oxides of nitrogen, and photoelectric light extinction instruments for smoke. The engine exhaust sample was drawn from the exhaust pipe several feet downstream from the exhaust manifold and ahead of the butterfly restrictor valve. A portion of the sample was taken from the heated sample line directly to the high temperature hydrocarbon analyzer. Another portion of the sample was drawn through an ice-cooled trap and pumped through the CO and NO_x analyzers. Smoke was measured at the outlet of the exhaust muffler (see schematic Figures 3 through 6). A Beckman Smokemeter was used for the tests involving the Cummins, Mack, and Caterpillar engines and a PHS smokemeter for the Detroit diesel engine tests.

3.4 Noise Measurements

Sound pressure level (SPL) measurements were made using a 1-inch General Radio 1560-P6 microphone and a 1560-P40 preamplifier. Overall levels and the dBA levels were recorded on a General Radio Model GR-1523 graphic level recorder with the output signal preconditioned with a model P-1 preamplifier. The microphone was positioned 4 to 5 feet above the floor level and 5 feet from the engine. This microphone position had been selected to represent the location which gave the least variability in sound pressure level from the mean of sound power determinations in the room. In addition, the output signal from the microphone-preamplifier system was recorded on tape cassettes using a Realistic SCT-5B cassette tape recorder. Model GR-1562A microphone calibrator was used to place a

reference signal of 114 dB-1000 Hz on the tape recording and the graphic level recorder prior to each test. These cassettes were then sent to DOT-TSC for spectral breakdown and further analysis along with a preliminary report of the test description and results.

4. EXPERIMENTAL DATA

The engine test data are listed in the tables of Appendices A through E. Some discussion of the units used and corrections applied to some of the items of these tables may be necessary to ready understanding. Definition of the terms is found in Appendix F, and some discussion of the data follows.

5. DISCUSSION OF DATA TABLES

The experimental data that were acquired and results of regression analysis performed during engine testing are presented in this section. Appendices A through E contain copies of computer printout sheets for all tests reported in this project. These data sheets include, among other information: engine identification, ambient conditions, engine operating parameters of intake and exhaust pressures, speed, torque, air and fuel consumption, exhaust and oil temperatures, and emissions. The emissions listed are carbon monoxide, hydrocarbon, oxides of nitrogen, and sound pressure levels. Table 1 is a list describing the engines tested, i.e., manufacturer, model, horsepower, etc. In Tables 3 through 6 a summary of 19 of the more pertinent items from the Appendices A through E is presented. In these tables engine performance, power, fuel consumption, etc., and emissions are averaged for replicate tests and listed for each of the three engine speeds and each combination of intake and exhaust restriction. Table 7 summarizes the "13-mode" emissions test data for the four engines. Tables 8A through 11A contain regression coefficients obtained by treatment of essentially all data represented by Tables 3 through 6 (test data used in the regression analysis are identified in appendix tables A-E). These coefficients enable reconstruction of the test data and comparison of the effects of intake and exhaust pressures in the 11 variables listed. Tables 8B through 11B present data calculated using the equations and coefficients of the regression analysis. In Figures 7 through 17 the data from Tables 8B through 11B are plotted for the rated engine speed. These graphs illustrate the relative effects on each of the four engines of intake and exhaust restriction on the following: horsepower, torque, air flow, fuel flow, brake specific fuel consumption (BSFC), exhaust temperature, smoke, CO, HC, NO_x, and noise.

TABLE 7. - "13-mode" exhaust emissions

Date	Test No.	Emissions, g/bhp-hr			BSFC,[1] lb/bhp-hr	Smoke,[1] percent opacity	Power,[1] bhp	Intake, mmHg	Exhaust, mmHg	Barometer, mmHg	H_2O, VP mmHg
		CO	HC	NO_x							
CUMMINS[2] NHC-250											
03/16/73	4A	4.98	0.61	6.30	0.444	2.2	79.4	736.5	801.2	746.0	5.3
03/20/73	7A	4.88	.70	6.45	.455	3.1	79.3	734.0	905.0	743.7	5.7
03/20/73	8A	4.51	.69	5.94	.462	4.0	76.2	661.8	793.7	745.4	4.4
03/21/73	9A	4.29	.69	6.26	.485	4.5	73.3	655.8	894.9	740.0	5.6
MACK ENDT 675											
06/18/73	26	3.36	2.14	10.19	0.454	2.2	80.2	710.8	791.2	735.3	20.1
07/18/73	37	3.10	1.85	10.77	.452	2.1	80.0	726.5	799.8	743.9	16.5
CATERPILLAR 1673C											
08/08/73	39	1.21	0.40	5.31	0.451	0.7	85.6	725.2	757.2	742.0	17.7
08/29/73	55	1.16	.36	5.22	.461	.9	82.4	729.1	766.6	745.0	18.4
DETROIT DIESEL 6-71											
09/21/73	58	14.51	1.17	16.35	0.470	1.9	77.2	725.2	762.7	742.4	19.0
10/09/73	69	13.37	.30	16.34	.461	3.1	79.3	722.2	760.1	741.1	19.6

1/ Values are weighted in same manner as the 13-mode gaseous emissions and are presented for comparative purposes only. See individual test data for detailed information.

2/ Data given for Cummins were taken with exhaust restrictions increased above test system minimum.

TABLE 8A. - Regression equation coefficients derived from the data of Caterpillar 1673C tests

$$Y = R + B_1(\Delta pI) + B_2(\Delta pE) + B_3(RPM) + B_4(\Delta pI)^2 + B_5\,\Delta p(RPM)^2$$

Variable (Y)	Regression constant (R)	Coefficient of ΔpI[1/] (B_1)	Coefficient of ΔpE[2/] (B_2)	Coefficient of RPM (B_3)	Coefficient of $(\Delta pI)^2$ (B_4)	Coefficient of $(RPM)^2$ (B_5)	SEE[3/]
Air, lb/hr.....	-1883	-7.526	-3.444	3.1601	-0.05024	-0.0004880	44.9
Fuel, lb/hr.....	- 88.4	.0557	- .0018	.15036	- .000578	- .00002993	1.1
Torque, lb-ft.....	- 156.2	- .5041	- .3995	.89386	- .012268	- .00025498	9.5
Power, bhp.....	- 313.9	- .1213	- .1521	.48908	- .005359	- .00010827	3.2
BSFC, lb/bhp-hr.....	.6596	.000515	.000322	- .0002913	.0000098	.0000000795	.0075
Exhaust, °F.....	1181	4.747	1.234	- .0667	0	0	15.9
Smoke[4/], pct opacity.	14.6	.1236	.0075	- .00847	0	0	3.0
CO[5/], g/bhp-hr.....	11.75	.02008	.00302	- .011348	0	.000002650	.26
HC[6/], g/bhp-hr.....	- .345	- .000804	- .000416	.0004325	0	- .0000001034	.016
NO_x, g/bhp-hr	- 7.72	- .01896	- .01043	.011187	- .0001596	- .000002139	.20
Noise, dBA	73.7	- .0197	- .0113	.02539	0	- .0000049	.24

1/ ΔpI is the intake pressure difference in inches of water corrected for the partial pressure of water vapor in the inlet air and referenced to 736.6 mmHg (29.0 inches)

ΔpI = [736.6 - Bar., mmHg + (1.87 · inlet Δp, inches H_2O) + (K · water vp, mmHg)] ÷ 1.87

$$K = 1 - \frac{1.87 \cdot \text{inlet } \Delta p, \text{ inches } H_2O}{\text{Bar., mmHg}}$$

NOTE.-Inlet Δp used as a positive value.

2/ ΔpE is the exhaust pressure difference in H_2O = (absolute pressure in exhaust after turbocharger, mmHg - 736.6) ÷ 1.87.

3/ SEE is the standard error of estimate. A measure of the precision with which the regression equation predicts (reconstructs) the mean value of Y. Note, this applies to the rpm, ΔpI, and ΔpE limits of the data. For the 122 observations, the predicted values should not differ by more than two times the SEE values of the table.

4/ Prediction equation very poor. Coefficients of equation account for only 48% of variation in Y and SEE is 75% of the standard deviation value for all observations of smoke opacity.

5/ Prediction equation poor. Coefficients account for only 75% of variation in CO and SEE 50% of standard deviation of CO values.

6/ Prediction equation weak. Coefficients account for only 53% of variation in HC and SEE 70% of standard deviation of all HC values.

TABLE 8B. - Calculated noise and emissions from a Cummins NHC-250 diesel engine as determined from a regression analysis of test data at all combinations of speed, and intake and exhaust restrictions

Intake, ΔP, $"H_2O$	1400 RPM			1750 RPM			2100 RPM		
	Exhaust ΔP, $"H_2O$			Exhaust ΔP, $"H_2O$			Exhaust ΔP, $"H_2O$		
	30	50	70	30	50	70	30	50	70
TORQUE, lb-ft									
10	634	625	617	636	628	620	615	607	599
20	615	606	598	617	609	601	596	588	580
40	577	568	560	579	571	563	559	550	542
60	539	530	522	541	533	525	521	512	504
POWER, HP									
10	232.1	229.3	226.4	270.7	267.8	264.9	300.3	297.4	294.6
20	225.7	222.9	220.0	264.3	261.4	258.6	293.9	291.1	288.2
40	213.0	210.1	207.2	251.5	248.6	245.8	281.2	278.3	275.4
60	200.2	197.3	194.4	238.7	235.9	233.0	268.4	265.5	262.6
AIR, lb/hr									
10	1311	1303	1296	1581	1573	1566	1878	1871	1863
20	1254	1246	1239	1523	1516	1509	1821	1813	1806
40	1140	1132	1125	1409	1402	1395	1707	1699	1692
60	1025	1018	1011	1295	1288	1280	1592	1585	1578
BSFC, lb/bhp-hr									
10	0.421	0.427	0.433	0.421	0.428	0.434	0.421	0.427	0.434
20	.429	.435	.442	.429	.436	.442	.429	.435	.442
40	.446	.452	.458	.446	.453	.459	.446	.452	.458
60	.462	.469	.475	.463	.469	.476	.462	.469	.475
EXHAUST TEMPERATURE, °F									
10	1275	1292	1308	1277	1293	1310	1321	1338	1354
20	1324	1340	1357	1325	1342	1358	1370	1386	1403
40	1421	1438	1454	1423	1439	1456	1467	1484	1500
60	1518	1535	1551	1520	1536	1553	1565	1581	1598
SMOKE, percent opacity									
10	6.5	6.5	6.5	8.1	8.1	8.1	9.6	9.6	9.6
20	8.7	8.7	8.7	10.2	10.2	10.2	11.8	11.8	11.8
40	13.0	13.0	13.0	14.6	14.6	14.6	16.1	16.1	16.1
60	17.3	17.3	17.3	18.9	18.9	18.9	20.4	20.4	20.4
CARBON MONOXIDE, g/bhp-hr									
10	7.0	6.4	5.8	6.1	5.5	4.9	6.0	5.4	4.8
20	6.2	5.6	5.1	5.3	4.7	4.2	5.2	4.6	4.0
40	4.7	4.1	3.5	3.8	3.2	2.6	3.7	3.1	2.5
60	3.2	2.6	2.0	2.3	1.7	1.1	2.2	1.6	1.0
HYDROCARBONS, g/bhp-hr									
10	0.02	0.04	0.05	0.04	0.05	0.07	0.03	0.05	0.06
20	.03	.05	.06	.05	.06	.08	.05	.06	.08
40	.06	.07	.09	.07	.09	.10	.07	.09	.10
60	.08	.10	.11	.10	.11	.13	.10	.11	.13
OXIDES OF NITROGEN, g/bhp-hr									
10	8.1	8.1	8.1	7.8	7.8	7.8	7.5	7.5	7.5
20	7.9	7.9	7.9	7.6	7.6	7.6	7.3	7.3	7.3
40	7.4	7.4	7.4	7.2	7.2	7.2	6.9	6.9	6.9
60	7.0	7.0	7.0	6.7	6.7	6.7	6.5	6.5	6.5
SOUND PRESSURE LEVEL, dBA									
10	106.0	105.9	105.7	108.3	108.1	108.0	110.1	110.0	109.8
20	106.1	105.9	105.8	108.4	108.2	108.0	110.2	110.0	109.9
40	106.2	106.1	105.9	108.5	108.3	108.2	110.3	110.2	110.0
60	106.4	106.2	106.0	108.6	108.5	108.3	110.5	110.3	110.2

TABLE 9A. - Regression equation coefficients derived from the data of the Mack ENDT-675 tests (with fuel limited test data withheld) 1/

$$Y = R + B_1(\Delta pI) + B_2(\Delta pE) + B_3(RPM) + B_4(RPM)^2$$

Variable (Y)	Repression constant (K)	Coefficient of				SEE 4/
		ΔpI 2/ (B_1)	ΔpE 3/ (B_2)	RPM (B_3)	$(RPM)^2$ (B_4)	
Air, lb/hr.....	-3099	-6.74	-3.33	5.1440	-0.0011419	30.0
Fuel, lb/hr.....	34.6	0	- .012	.0382	- .0000065	.9
Torque, lb-ft.....	988	- .49	- .27	- .0547	- .0000777	7.5
Power, bhp.....	- 77.3	- .166	- .088	.3291	- .0000916	2.4
BSFC, lb/bhp-hr.....	.723	.00031	.00011	- .0004612	.000000149	.005
Exhaust, °F.....	3024	2.76	1.55	-2.2870	.0006021	15.7
Smoke, pct opacity..	62	.060	.021	- .06521	.0000169	.6
CO 5/, g/bhp-hr.....	34.9	.032	.016	- .03649	.0000096	.4
HC 5/, g/bhp-hr.....	- 4.24	- .0068	- .0036	.005387	- .00000137	.09
NO_x 5/, g/bhp-hr.....	- 12.7	- .0117	- .0173	.03128	- .00000964	.71
Noise, dBA.....	105.6	- .013	- .010	- .00632	.00000317	.32

1/ Data taken when the fuel flow was reduced by engine's smoke limiting device was not included in determining the regression equations.

2/ ΔpI is the intake pressure difference in inches of water corrected for the partial pressure of water vapor in the inlet air and references to 736.6 mmHg (29.0 inches)
ΔpI = [736.6 - Bar., mmHg + (1.87 · inlet Δp, inches H_2O) + (K · water vp, mmHg)] ÷ 1.87

$$K = 1 - \frac{1.87 \cdot \text{inlet } \Delta p, \text{ inches } H_2O}{\text{Bar., mmHg}}$$

NOTE.--Inlet Δp used as a positive value.

3/ ΔpE is the exhaust pressure difference in H_2O = (absolute pressure in exhaust after turbocharger mmHg - 736.6) ÷ 1.87.

4/ SEE is the standard error of estimate. A measure of the precision with which the regression equation predicts (reconstructs) the mean value of Y. Note, this applies to the rpm, ΔpI, and ΔpE limits of the data. For the 81 observations the predicted values should not differ by more than two times the SEE values of the table.

5/ Prediction equations weak. Coefficients of equation account for only 70-80 pct of variation in Y and SEE is from 48-58 pct of the standard deviation of all Y values.

TABLE 98. - Calculated noise and emissions from a Mack ENDT 675 diesel engine as determined from a regression analysis of test data at all combinations of speed, and intake and exhaust restrictions

Intake, ΔP, "H_2O	1500 RPM			1800 RPM			2100 RPM		
	Exhaust ΔP, "H_2O			Exhaust ΔP, "H_2O			Exhaust ΔP, "H_2O		
	30	50	70	30	50	70	30	50	70
TORQUE, lb-ft									
10	718	713	707	625	619	614	517	512	507
20	713	708	702	620	614	609	513	507	502
40	703	698	693	610	605	599	503	497	492
60	694	688	683	600	595	589	493	488	482
POWER, HP									
10	206.0	204.2	202.4	214.0	212.2	210.5	205.6	203.8	202.0
20	204.3	202.5	200.8	212.3	210.6	208.8	203.9	202.1	200.4
40	201.0	199.2	197.5	209.0	207.3	205.5	200.6	198.8	197.1
60	197.7	195.9	194.1	205.7	203.9	202.2	197.3	195.5	193.7
AIR, lb/hr									
10	4979	4913	4846	5392	5325	5259	5599	5532	5466
20	4912	4845	4779	5324	5258	5191	5532	5465	5398
40	4777	4710	4644	5190	5123	5056	5397	5330	5264
60	4642	4576	4509	5055	4988	4922	5262	5195	5129
FUEL, lb/hr									
10	76.9	76.7	76.4	81.9	81.7	81.5	85.8	85.6	85.3
20	76.9	76.7	76.4	81.9	81.7	81.5	85.8	85.6	85.3
40	76.9	76.7	76.4	81.9	81.7	81.5	85.8	85.6	85.3
60	76.9	76.7	76.4	81.9	81.7	81.5	85.8	85.6	85.3
BSFC, lb/bhp-hr									
10	0.373	0.375	0.377	0.382	0.384	0.386	0.418	0.420	0.422
20	.376	.378	.380	.385	.387	.390	.421	.423	.426
40	.382	.384	.387	.391	.394	.396	.427	.430	.432
60	.388	.391	.393	.398	.400	.402	.434	.436	.438
EXHAUST TEMPERATURE, °F									
10	1022	1053	1084	932	963	994	951	982	1013
20	1050	1081	1112	960	991	1022	978	1009	1040
40	1105	1136	1167	1015	1046	1077	1033	1064	1095
60	1160	1191	1222	1070	1101	1132	1089	1120	1151
SMOKE, percent opacity									
10	3.4	3.9	4.3	0.6	1.0	1.4	0.8	1.2	1.7
20	4.0	4.5	4.9	1.2	1.6	2.0	1.4	1.8	2.3
40	5.2	5.7	6.1	2.4	2.8	3.2	2.6	3.0	3.5
60	6.4	6.9	7.3	3.6	4.0	4.4	3.8	4.2	4.7
CARBON MONOXIDE, g/bhp-hr									
10	2.6	2.9	3.2	1.1	1.4	1.8	1.4	1.7	2.0
20	2.9	3.2	3.5	1.4	1.8	2.1	1.7	2.0	2.4
40	3.5	3.8	4.2	2.1	2.4	2.7	2.4	2.7	3.0
60	4.2	4.5	4.8	2.7	3.0	3.4	3.0	3.3	3.6
HYDROCARBONS, g/bhp-hr									
10	0.58	0.51	0.44	0.84	0.77	0.70	0.86	0.78	0.71
20	.51	.44	.37	.77	.70	.63	.79	.72	.64
40	.38	.31	.23	.64	.57	.49	.65	.58	.51
60	.24	.17	.10	.50	.43	.36	.52	.44	.37
OXIDES OF NITROGEN, g/bhp-hr									
10	11.9	11.5	11.2	11.7	11.4	11.0	9.8	9.5	9.1
20	11.8	11.4	11.1	11.6	11.3	10.9	9.7	9.4	9.0
40	11.5	11.2	10.9	11.4	11.0	10.7	9.5	9.1	8.8
60	11.3	11.0	10.6	11.1	10.8	10.5	9.3	8.9	8.6
SOUND PRESSURE LEVEL, dBA									
10	102.8	102.6	102.4	104.1	103.9	103.7	105.9	105.7	105.5
20	102.7	102.5	102.3	103.9	103.7	103.5	105.7	105.5	105.3
40	102.4	102.2	102.0	103.7	103.5	103.3	105.5	105.3	105.1
60	102.2	102.0	101.8	103.4	103.2	103.0	105.2	105.0	104.8

TABLE 10A. - Regression equation coefficients derived from the data of Caterpillar 1673C tests

$$Y = R + B_1(\Delta pI) + B_2(\Delta pE) + B_3(RPM) + B_4(\Delta pI)^2 + B_5\,\Delta p(RPM)^2$$

Variable (Y)	Regression constant (R)	Coefficient of ΔpI[1/] (B_1)	Coefficient of ΔpE[2/] (B_2)	Coefficient of RPM (B_3)	Coefficient of $(\Delta pI)^2$ (B_4)	Coefficient of $(RPM)^2$ (B_5)	SEE[3/]
Air, lb/hr.....	-1883	-7.526	-3.444	3.1601	-0.05024	-0.0004880	44.9
Fuel, lb/hr.....	- 88.4	.0557	- .0018	.15036	- .000578	- .00002993	1.1
Torque, lb-ft.....	- 156.2	- .5041	- .3995	.89386	- .012268	- .00025498	9.5
Power, bhp.....	- 313.9	- .1213	- .1521	.48908	- .005359	- .00010827	3.2
BSFC, lb/bhp-hr.....	.6596	.000515	.000322	- .0002913	.0000098	.0000000795	.0075
Exhaust, °F.....	1181	4.747	1.234	- .0667	0	0	15.9
Smoke[4/], pct opacity.	14.6	.1236	.0075	- .00847	0	0	3.0
CO[5/], g/bhp-hr.....	11.75	.02008	.00302	- .011348	0	.000002650	.26
HC[6/], g/bhp-hr.....	- .345	- .000804	- .000416	.0004325	0	- .0000001034	.016
NO_x, g/bhp-hr	- 7.72	- .01896	- .01043	.011187	- .0001596	- .000002139	.20
Noise, dBA	73.7	- .0197	- .0113	.02539	0	- .0000049	.24

1/ ΔpI is the intake pressure difference in inches of water corrected for the partial pressure of water vapor in the inlet air and referenced to 736.6 mmHg (29.0 inches)
ΔpI = [736.6 - Bar., mmHg + (1.87 · inlet Δp, inches H_2O) + (K · water vp, mmHg)] ÷ 1.87

$$K = 1 - \frac{1.87 \cdot \text{inlet } \Delta p, \text{ inches } H_2O}{\text{Bar., mmHg}}$$

NOTE.-Inlet Δp used as a positive value.

2/ ΔpE is the exhaust pressure difference = (absolute pressure in exhaust after turbocharger, mmHg - 736.6) ÷ 1.87

3/ SEE is the standard error of estimate. A measure of the precision with which the regression equation predicts (reconstructs) the mean value of Y. Note, this applies to the rpm, ΔpI, and ΔpE limits of the data. For the 122 observations, the predicted values should not differ by more than two times the SEE values of the table.

4/ Prediction equation very poor. Coefficients of equation account for only 48% of variation in Y and SEE is 75% of the standard deviation value for all observations of smoke opacity.

5/ Prediction equation poor. Coefficients account for only 75% of variation in CO and SEE 50% of standard deviation of CO values.

6/ Prediction equation weak. Coefficients account for only 53% of variation in HC and SEE 70% of standard deviation of all HC values.

TABLE 10B. - Calculated noise and emissions from a Caterpillar 1673C diesel engine as determined from a regression analysis of test data at all combinations of speed, and intake and exhaust restrictions

Intake, ΔP, "H_2O	1600 RPM			1900 RPM			2200 RPM		
	Exhaust ΔP, "H_2O			Exhaust ΔP, "H_2O			Exhaust ΔP, "H_2O		
	30	50	70	30	50	70	30	50	
TORQUE, lb-ft									
10	603	595	587	603	595	587	558	550	542
20	594	586	578	595	587	579	549	541	533
40	569	561	553	570	562	554	524	516	508
60	535	527	519	535	527	519	490	482	474
POWER, HP									
10	185.1	182.1	179.1	218.2	215.1	212.1	231.7	228.7	225.7
20	182.3	179.3	176.2	215.4	212.3	209.3	228.9	225.9	222.8
40	173.5	170.4	167.4	206.5	203.5	200.4	220.1	217.0	214.0
60	160.3	157.3	154.2	193.4	190.3	187.3	206.9	203.9	200.8
AIR, lb/hr									
10	1740	1671	1603	2176	2107	2038	2524	2455	2386
20	1650	1581	1512	2086	2017	1948	2433	2364	2296
40	1439	1370	1301	1875	1806	1737	2223	2154	2085
60	1188	1119	1050	1624	1555	1486	1972	1903	1834
FUEL, lb/hr									
10	76.0	76.0	75.9	89.7	89.6	89.6	98.0	97.9	97.9
20	76.4	76.3	76.3	90.1	90.0	90.0	98.4	98.3	98.3
40	76.8	76.8	76.7	90.5	90.4	90.4	98.8	98.7	98.7
60	76.8	76.7	76.7	90.4	90.4	90.4	98.7	98.7	98.7
BSFC, lb/bhp-hr									
10	0.413	0.419	0.426	0.409	0.415	0.422	0.419	0.426	0.432
20	.421	.427	.434	.417	.423	.430	.427	.434	.440
40	.443	.449	.456	.439	.446	.452	.450	.456	.462
60	.473	.479	.486	.469	.475	.482	.479	.486	.492
EXHAUST TEMPERATURE, °F									
10	1159	1183	1208	1139	1163	1188	1119	1143	1168
20	1206	1231	1256	1186	1211	1236	1166	1191	1216
40	1301	1326	1351	1281	1306	1331	1261	1286	1311
60	1396	1421	1445	1376	1401	1425	1356	1381	1405
SMOKE, percent opacity									
10	2.5	2.7	2.8	0	0.1	0.3	- 2.6	- 2.4	- 2.3
20	3.7	3.9	4.0	1.2	1.4	1.5	- 1.3	- 1.2	- 1.0
40	6.2	6.4	6.5	3.7	3.8	4.0	1.1	1.3	1.4
60	8.7	8.8	9.0	6.1	6.3	6.4	3.6	3.8	3.9
CARBON MONOXIDE, g/bhp-hr									
10	0.7	0.7	0.8	0	0.1	0.2	- 0.1	0	0
20	.9	.9	1.0	.2	.3	.4	.1	.2	.2
40	1.3	1.3	1.4	.6	.7	.8	.5	.6	.6
60	1.7	1.7	1.8	1.1	1.1	1.2	.9	1.0	1.0
HYDROCARBONS, g/bhp-hr									
10	0.06	0.05	0.05	0.08	0.07	0.07	0.09	0.08	0.07
20	.05	.05	.04	.07	.07	.06	.08	.07	.06
40	.04	.03	.02	.06	.05	.04	.06	.05	.04
60	.02	.01	0	.04	.03	.03	.05	.04	.03
OXIDES OF NITROGEN, g/bhp-hr									
10	4.2	4.0	3.8	5.3	5.1	4.9	6.0	5.8	5.6
20	3.9	3.7	3.5	5.1	4.8	4.6	5.8	5.6	5.4
40	3.4	3.2	3.0	4.5	4.3	4.1	5.2	5.0	4.8
60	2.7	2.5	2.3	3.8	3.6	3.4	4.5	4.3	4.1
SOUND PRESSURE LEVEL, dBA									
10	101.2	101.0	100.8	103.7	103.5	103.3	105.3	105.1	104.9
20	101.0	100.8	100.6	103.5	103.3	103.1	105.1	104.9	104.7
40	100.7	100.4	100.2	103.1	102.9	102.7	104.7	104.5	104.3
60	100.3	100.0	99.8	102.7	102.5	102.3	104.3	104.1	103.9

TABLE IIA. - Regression equation coefficients derived from the data of Detroit Diesel 6-71 tests

$$Y = R + B_1(\Delta pI) + B_2(\Delta pE) + B_3(RPM) + B_4(\Delta pI)^2 + B_5\,\Delta p(RPM)^2$$

Variable (Y)	Regression constant (R)	Coefficient of					SEE[4]
		ΔpI[1] (B_1)	ΔpE[2] (B_2)	RPM (B_3)	$(\Delta pI)^2$[3] (B_4)	$(RPM)^2$ (B_5)	
Air, lb/hr.....	-1273	-14.014	-2.873	2.871	-	-0.0003740	42.4
Fuel, lb/hr.....	12.5	-	-	.0467	-	- .00000454	.83
Torque, lb-ft.....	48.4	- 2.26	-2.41	.613	-	- .0001720	10.6
Power, bhp.....	- 166.7	- .739	- .0727	.316	-	- .00006195	2.90
BSFC[5], lb/bhp-hr.....	1.166	.00219	.000197	- .000777	-	.00000019	.015
Exhaust[5],.....	1099	4.685	1.301	- .118	-	-	30.3
Smoke[6], pct opacity..	92.3	.319	- .00212	- .0953	-	.00002483	3.2
CO[5], g/bhp-hr.....	576.6	.851	- .153	- .566	-	.00014014	9.1
HC[7], g/bhp-hr.....	- .099	- .000393	- .000397	.000231	-	-	.045
NO_x, g/bhp-hr.....	- 33.2	- .0444	.0147	.0436	-	- .00001047	.36
Noise[5], dBA.....	93.1	- .0261	- .0339	.0160	-	- .00000373	.43

1/ ΔpI is the intake pressure difference in inches of water corrected for the partial pressure of water vapor in the inlet air and referenced to 736.6 mmHg (29.0 inches)
$\Delta pI = [736.6 - Bar.,\ mmHg + (1.87 \cdot inlet\ \Delta p,\ inches\ H_2O) + (K \cdot water\ vp,\ mmHg)] \div 1.87$

$$K = 1 - \frac{1.87 \cdot inlet\ \Delta p,\ inches\ H_2O}{Bar.,\ mmHg}$$

NOTE.--Inlet Δp used as a positive value.

2/ ΔpE is the exhaust pressure difference = (absolute pressure in exhaust after turbocharger, mmHg - 736.6) ÷ 1.87.

3/ Coefficients not significant at 2 · t level.

4/ SEE is the standard error of estimate. A measure of the precision with which the regression equation predicts (reconstructs) the mean value of Y. Note, this applies to the rpm, ΔpI, and ΔpE limits of the data. For the 78 observations, the predicted values should not differ by more than 2.7 times the SEE values of the table at the 95% confidence level.

5/ Prediction equation weak. Coefficients account for only 83% to 85% of variation in emissions and SEE 41% to 43% of standard deviation of all emission values.

6/ Prediction equation very poor. Coefficients of equation account for only 64% of variation in Y and SEE is 62% of the standard deviation value for all observations of smoke opacity.

7/ Prediction equation poor. Coefficients account for only 69% of variation of HC and SEE 56% of standard deviation of HC values.

TABLE IIB. - Calculated noise and emissions from a Detroit 6-71 diesel engine as determined from a regression analysis of test data at all combinations of speed, and intake and exhaust restrictions

Intake, ΔP, $"H_2O$	1400 RPM Exhaust ΔP, $"H_2O$			1700 RPM Exhaust ΔP, $"H_2O$			2100 RPM Exhaust ΔP, $"H_2O$		
	30	50	70	30	50	70	30	50	70
TORQUE, lb-ft									
10	540	535	530	564	559	554	547	543	538
20	517	512	507	541	536	531	525	520	515
40	472	467	462	496	491	486	480	475	470
60	427	422	417	451	446	441	434	430	425
POWER, HP									
10	144.7	143.3	141.8	181.9	180.4	179.0	214.1	212.7	211.2
20	137.3	135.9	134.4	174.5	173.0	171.6	206.7	205.3	203.8
40	122.5	121.1	119.6	159.7	158.3	156.8	192.0	190.5	189.1
60	107.8	106.3	104.8	144.9	143.5	142.0	177.2	175.7	174.3
AIR, lb/hr									
10	1661	1604	1546	2148	2090	2033	2691	2634	2577
20	1521	1463	1406	2007	1950	1892	2551	2494	2436
40	1241	1183	1126	1727	1670	1612	2271	2214	2156
60	960	903	845	1447	1389	1332	1991	1933	1876
FUEL, lb/hr									
10	67.2	67.2	67.2	76.1	76.1	76.1	86.5	86.5	86.5
20	67.2	67.2	67.2	76.1	76.1	76.1	86.5	86.5	86.5
40	67.2	67.2	67.2	76.1	76.1	76.1	86.5	86.5	86.5
60	67.2	67.2	67.2	76.1	76.1	76.1	86.5	86.5	86.5
BSFC, lb/bhp-hr									
10	0.478	0.482	0.486	0.422	0.426	0.430	0.400	0.404	0.408
20	.500	.504	.508	.444	.448	.452	.422	.426	.430
40	.544	.548	.552	.488	.492	.496	.466	.470	.474
60	.588	.592	.596	.532	.536	.539	.510	.514	.517
EXHAUST TEMPERATURE, °F									
10	1020	1046	1072	984	1010	1036	937	963	989
20	1067	1093	1119	1031	1057	1083	984	1010	1036
40	1160	1186	1212	1125	1151	1177	1078	1104	1130
60	1254	1280	1306	1219	1245	1271	1171	1197	1223
SMOKE, percent opacity									
10	10.7	10.6	10.6	5.2	5.1	5.1	4.8	4.8	4.7
20	13.9	13.8	13.8	8.4	8.3	8.3	8.0	7.9	7.9
40	20.2	20.2	20.2	14.7	14.7	14.7	14.4	14.3	14.3
60	26.6	26.6	26.5	21.1	21.1	21.0	20.7	20.7	20.7
CARBON MONOXIDE, g/bhp-hr									
10	62.7	59.6	56.6	23.2	20.2	17.1	9.8	6.8	3.7
20	71.2	68.1	65.1	31.7	28.7	25.6	18.3	15.3	12.2
40	88.2	85.2	82.1	48.8	45.7	42.6	35.4	32.3	29.2
60	105.2	102.2	99.1	65.8	62.7	59.7	52.4	49.3	46.3
HYDROCARBONS, g/bhp-hr									
10	0.21	0.20	0.19	0.28	0.27	0.26	0.37	0.36	0.35
20	.20	.20	.19	.27	.27	.26	.37	.36	.35
40	.20	.19	.18	.27	.26	.25	.36	.35	.34
60	.19	.18	.17	.26	.25	.24	.35	.34	.33
OXIDES OF NITROGEN, g/bhp-hr									
10	7.3	7.6	7.9	10.7	11.0	11.2	12.2	12.5	12.8
20	6.9	7.2	7.5	10.2	10.5	10.8	11.7	12.0	12.3
40	6.0	6.3	6.6	9.3	9.6	9.9	10.9	11.1	11.4
60	5.1	5.4	5.7	8.4	8.7	9.0	10.0	10.3	10.6
SOUND PRESSURE LEVEL, dBA									
10	106.9	106.2	105.6	108.2	107.6	106.9	109.0	108.3	107.6
20	106.7	106.0	105.3	108.0	107.3	106.6	108.7	108.0	107.4
40	106.1	105.5	104.8	107.5	106.8	106.1	108.2	107.5	106.8
60	105.6	104.9	104.3	106.9	106.3	105.6	107.7	107.0	106.3

6. SPECIAL TESTS

Several special tests were conducted at the request of project officers to indicate the magnitude of the effect on sound or performance levels with changes in engine operating conditions.

One of the special tests was designed to establish a non-firing (motoring) noise level of the engine and accessory equipment. Since the dynamometer available did not provide a means of driving the diesel engines, a measure of sound level versus engine speed was made during deceleration on fuel shutoff. Tests on the first engine were made by recording a sound level and speed signal on the tape cassette. This recording for the Cummins engine was provided DOT for their analysis. The other three engines were tested in a similar manner, but using a graphic level recorder available at that time. Figure 18 is a plot of engine RPM on coast-down with fuel off versus sound level in dBA. The data from this figure will serve to compare non-firing SPL levels with engine operating levels over the range shown. A much more sophisticated test and equipment would be required to obtain data for use in separating firing and non-firing (i.e., combustion) noise. Figure 19 is a presentation of the sound level in the room with the Detroit Diesel engine operating at various loads and speeds. The data for this figure are found in test No. 60 of Appendix D.

A second special test was conducted using the Caterpillar engine to examine the sound pressure levels in the room with the engine operated normally but at part load as compared to the engine operated with the turbine removed from the turbocharger. The data are in tables 43A and 43B, 56A and 56B of Appendix C. Simple removal of the turbocharger results in increased noise radiated from the engine. Without the engine being properly adapted to operation without the turbocharger, the operating parameters of the two sets of tests could not be matched. However, as a comparison of Figure 20 with Figure 21 exhibits, there is a definite increase in sound levels at intermediate speeds even with the non-turbocharged operation at part load.

A different comparison was made of turbocharger effect using the Mack engine. For this test the microphone was removed from the test cell and located three feet from the open exhaust outlet on the building roof. The muffler had previously been disconnected at this point. With the engine operating at the condition shown in test No. 33, Appendix B, 2,100 RPM, the noise level was 109 dBA for the turbocharged operation compared to 123.5 for the operation with the turbocharger turbine and compressor blades removed from their housing.

The effect of thermal insulation on the coolant requirements was examined for the Cummins engine. The engine was blanketed with 1-inch thick, 1/2 lb density, fiberglass Kraft foil-backed insulation. This material's maximum temperature range did not permit blanketing the exhaust manifold. Test No. 10, Appendix A, lists the data of this single experiment. The difference in cooling load is insignificant, which was expected with the exhaust manifold not included within the engine blanketing. There was a slight 5° F increase in oil temperature. This experiment was not followed further to establish effects of enclosure of the exhaust manifold.

Other special tests were conducted at the Project Officer's request and reported in monthly letter reports to DOT for their aid in interpretation of sound spectrum data from the data recorded on magnetic tapes.

7. FUEL EFFECTS

A minor portion of the effort of the project was a scheduled investigation of fuel effects on combustion noise in the diesel engine. Some initial work was accomplished; however, time, personnel, and fund requirements of the main project resulted in discontinuance of the study of fuel effects. A contributing factor to the dropping of this work was learning that a more sophisticated engine and instrumentation than that available would be required to obtain meaningful results.

In exploratory work on the effect of fuel a CFR ante-chamber variable compression cetane rating engine was set up and instrumented to measure injection time, ignition delay, rate of pressure rise and sound pressure levels. Using this engine and associated equipment, drastic variations in fuel composition did not result in significant differences in combustion associated noise external to the engine. It was decided that a direct-injection combustion chamber would be more useful in a study of fuel effects and that injector spray patterns would need to be modified. As indicated above, this further extension of the study was not appropriate within priorities as then determined by the project officer, and the study was discontinued.

For purposes of record, the rationale of the experimental approach intended for the investigation is discussed in Appendix G.

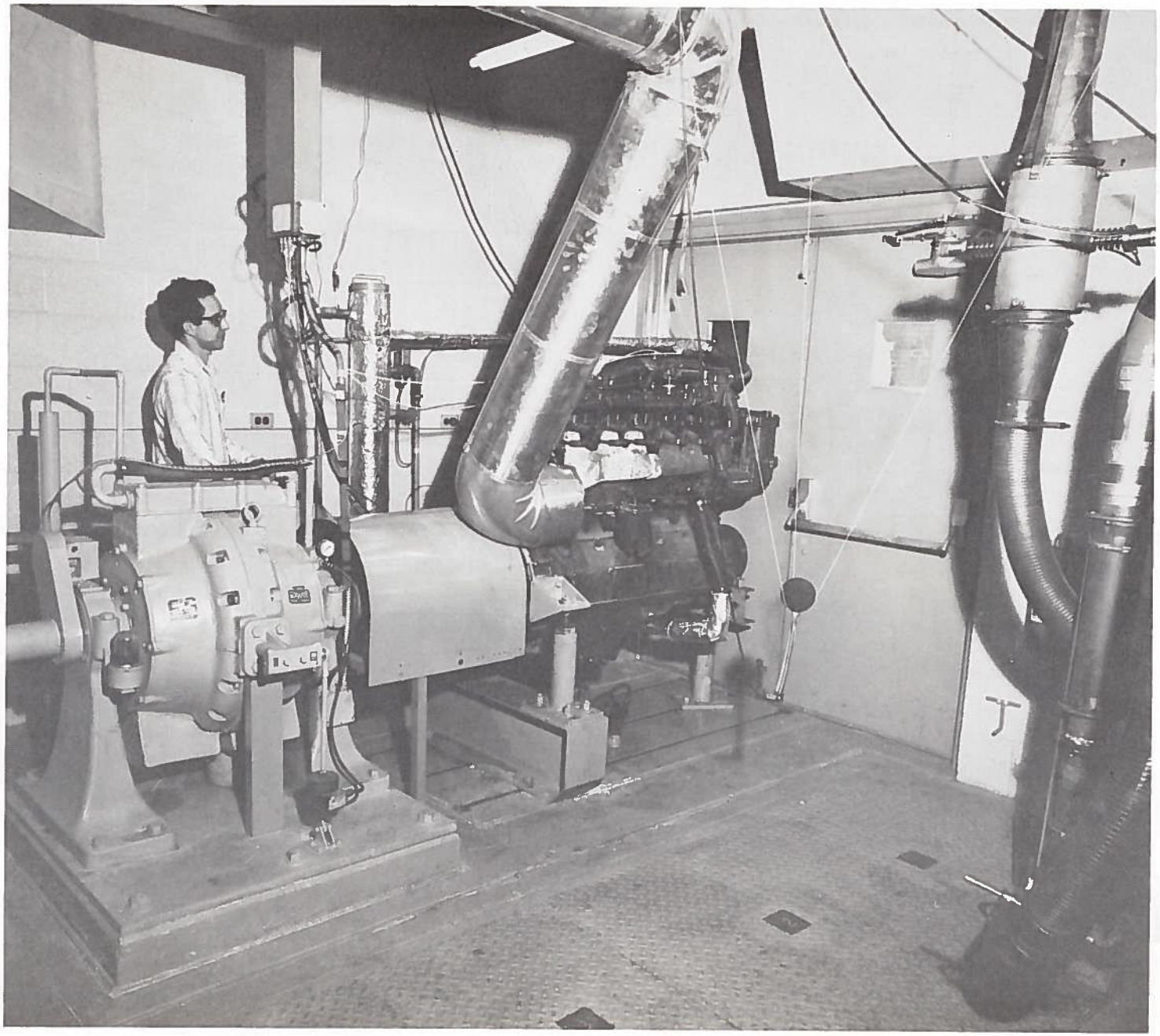

FIGURE 1. - The Test Cell and Engine Installation.

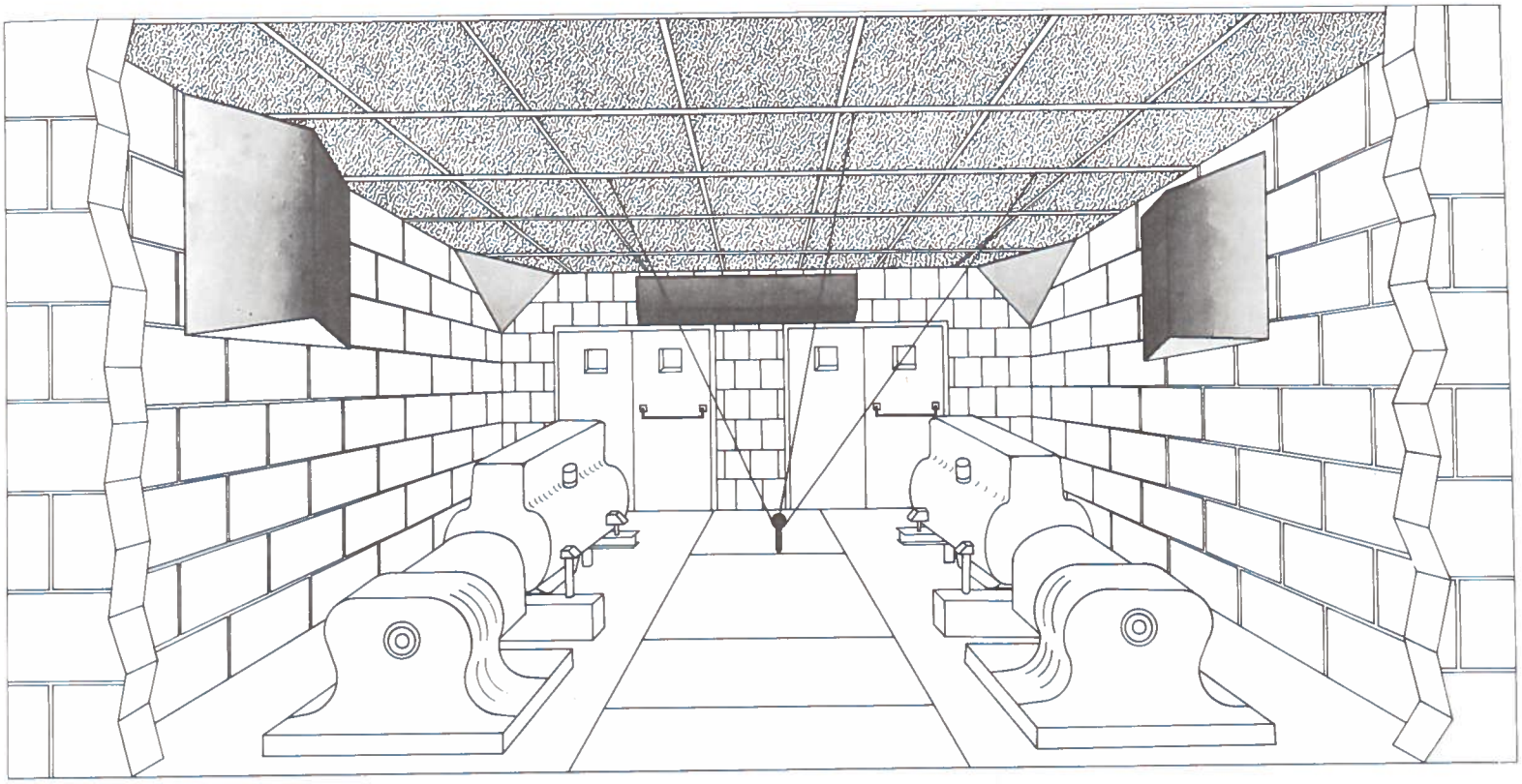

FIGURE 2. - Schematic of the Test Cell and Engine Installation.

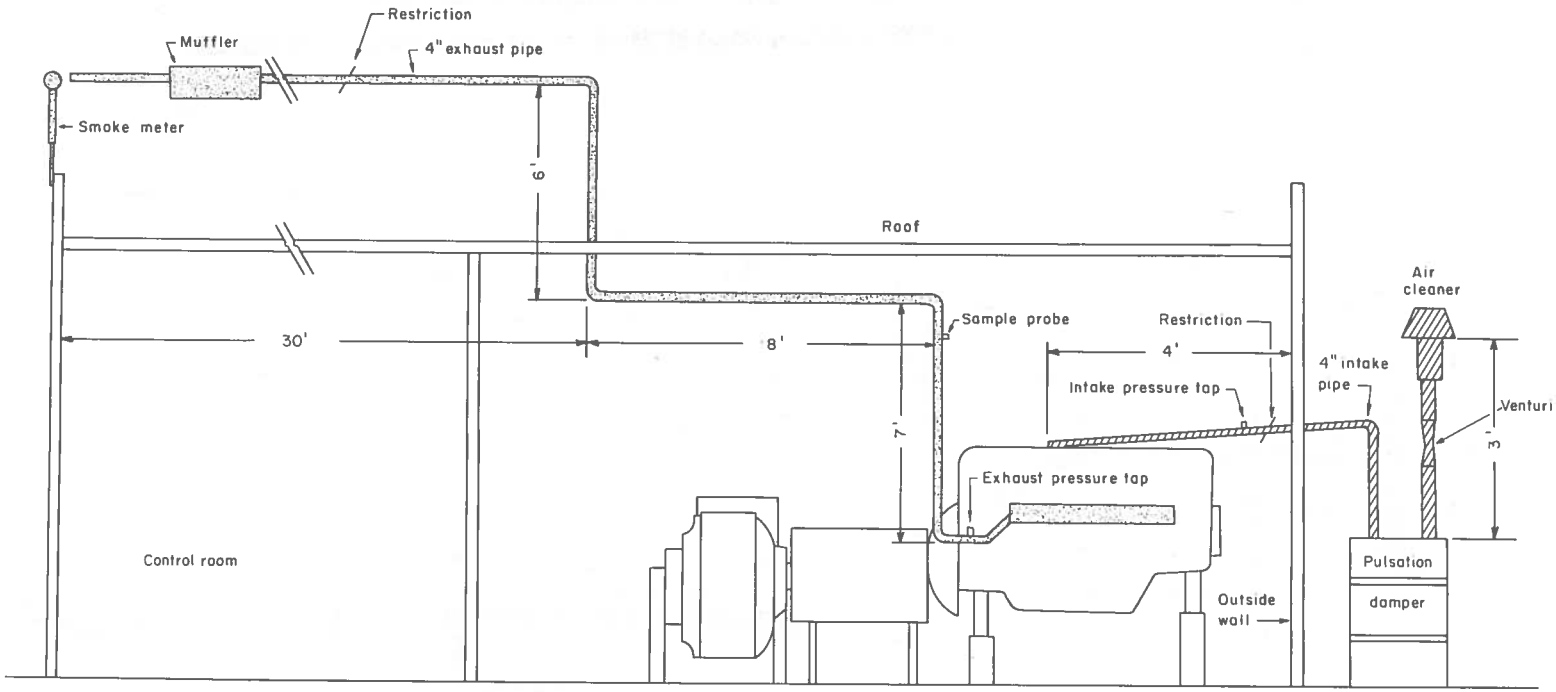

FIGURE 3. - Schematic Drawing of Intake and Exhaust Piping for the Cummins NHC-250 Tests

NOTE.--All exhaust piping within test cell was insulated with a 3-inch thickness of calcium silicate and an aluminum jacket.

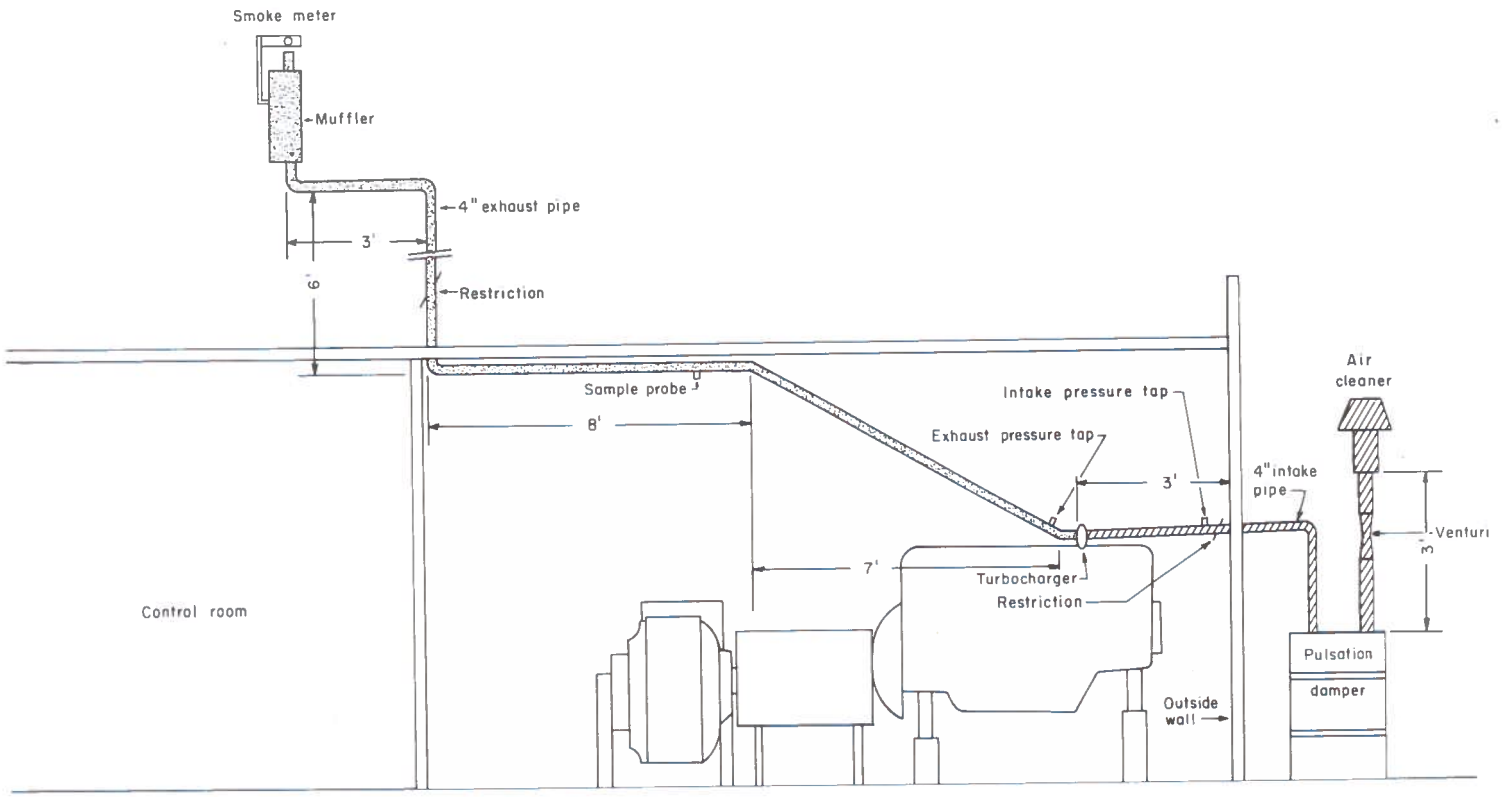

FIGURE 4. - Schematic Drawing of Intake and Exhaust Piping for Mack ENDT 675 Tests

NOTE.--All exhaust piping within test cell was insulated with a 3-inch thickness of calcium silicate and an aluminum jacket.

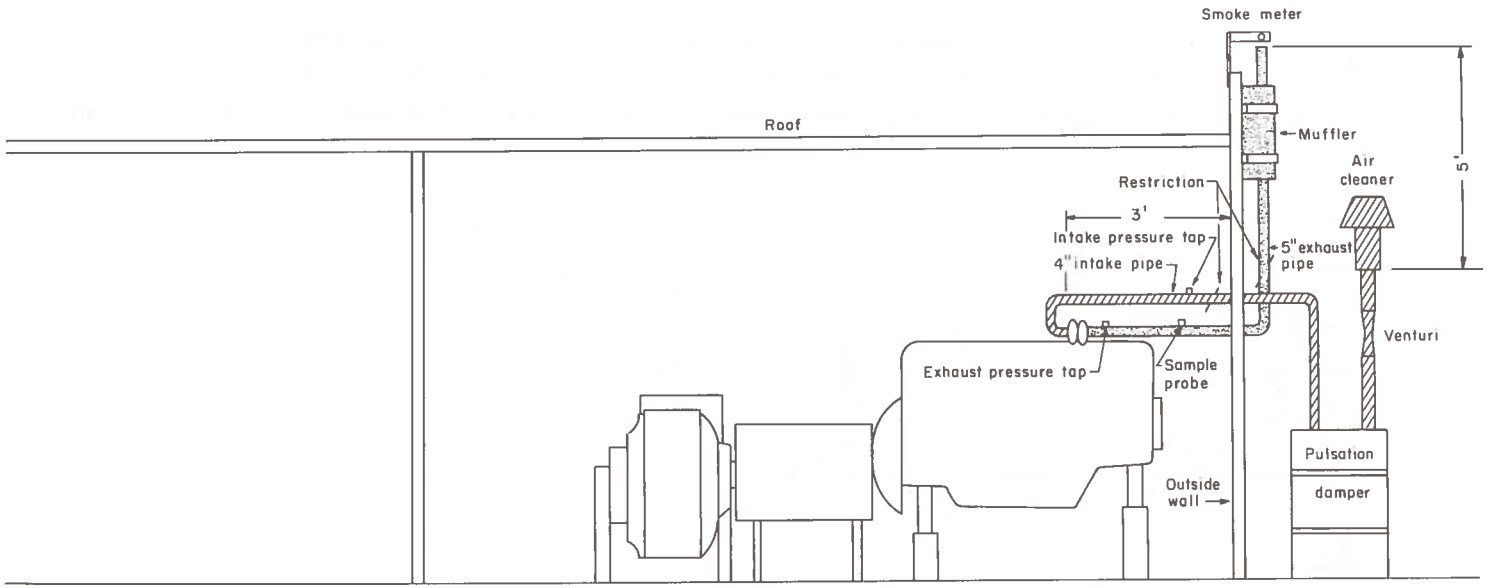

FIGURE 5. - Schematic Drawing of Intake and Exhaust Piping for the Caterpillar 1673C Tests

NOTE.--All exhaust piping within test cell was insulated with a 1-inch thickness of calcium silicate and an aluminum jacket.

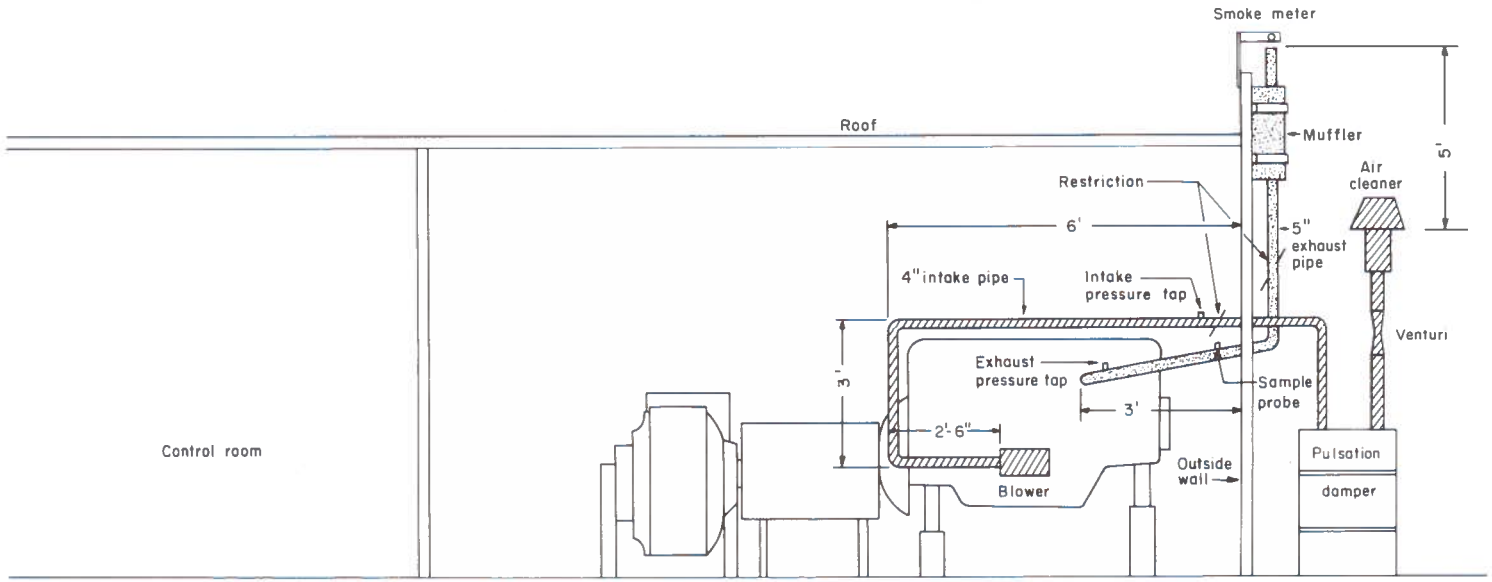

FIGURE 6. - Schematic Drawing of Intake and Exhaust Piping for the Detroit Diesel 6-71 Tests

NOTE.--All exhaust piping within test cell was insulated with a 2-inch thickness of calcium silicate and an aluminum jacket.

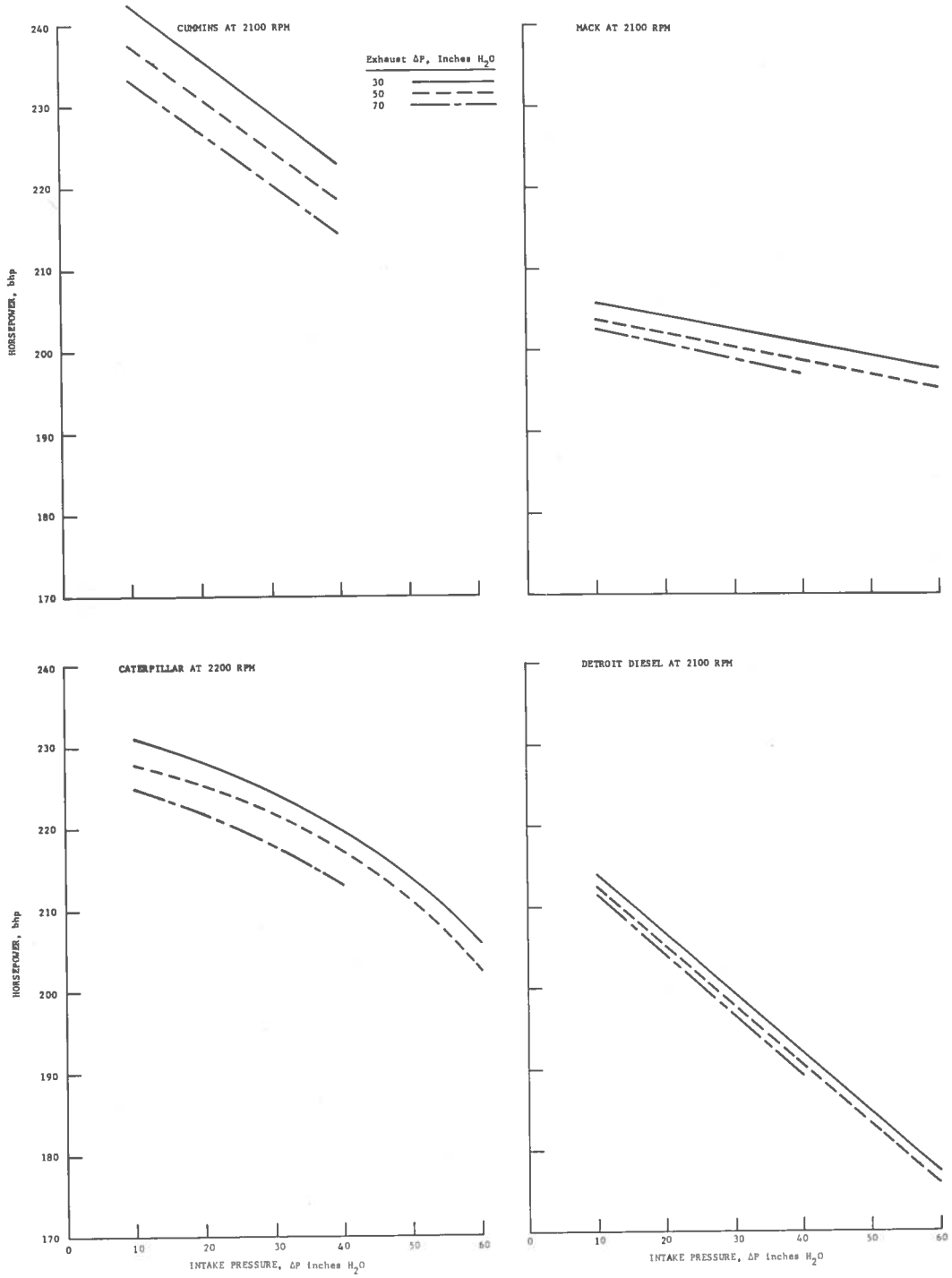

FIGURE 7. - Influence of Intake and Exhaust Restrictions on Power Output for Four Engines Operated at Full Load and Rated Speed

(Calculated from regression equations, tables 8-11)

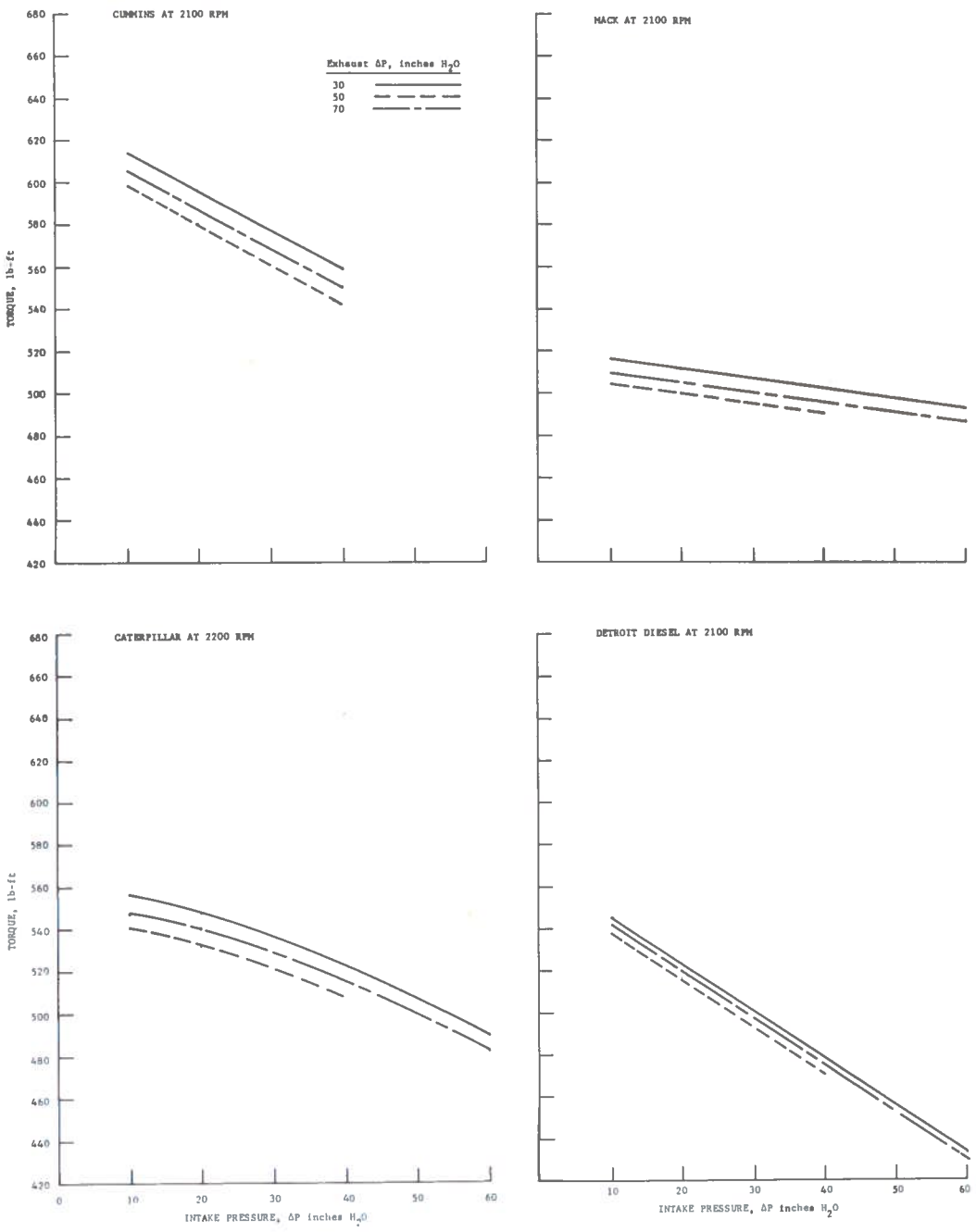

FIGURE 8. - Influence of Intake and Exhaust Restrictions on Torque for Four Engines Operated at Full Load and Rated Speed

(Calculated from regression equations, tables 8-11)

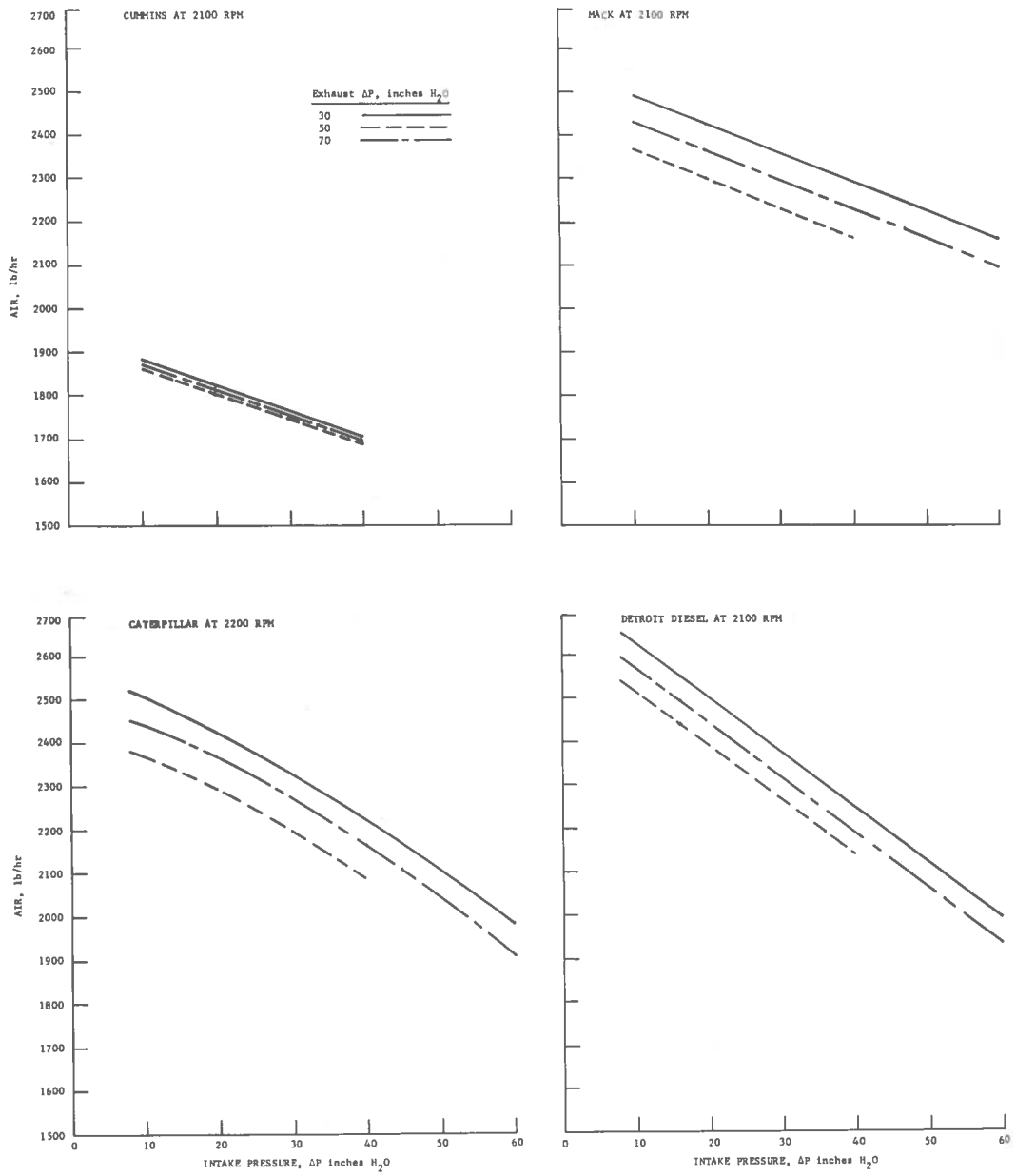

FIGURE 9. - Influence of Intake and Exhaust Restrictions on Air Consumption for Four Engines Operated at Full Load and Rated Speed

(Calculated from regression equations, tables 8-11)

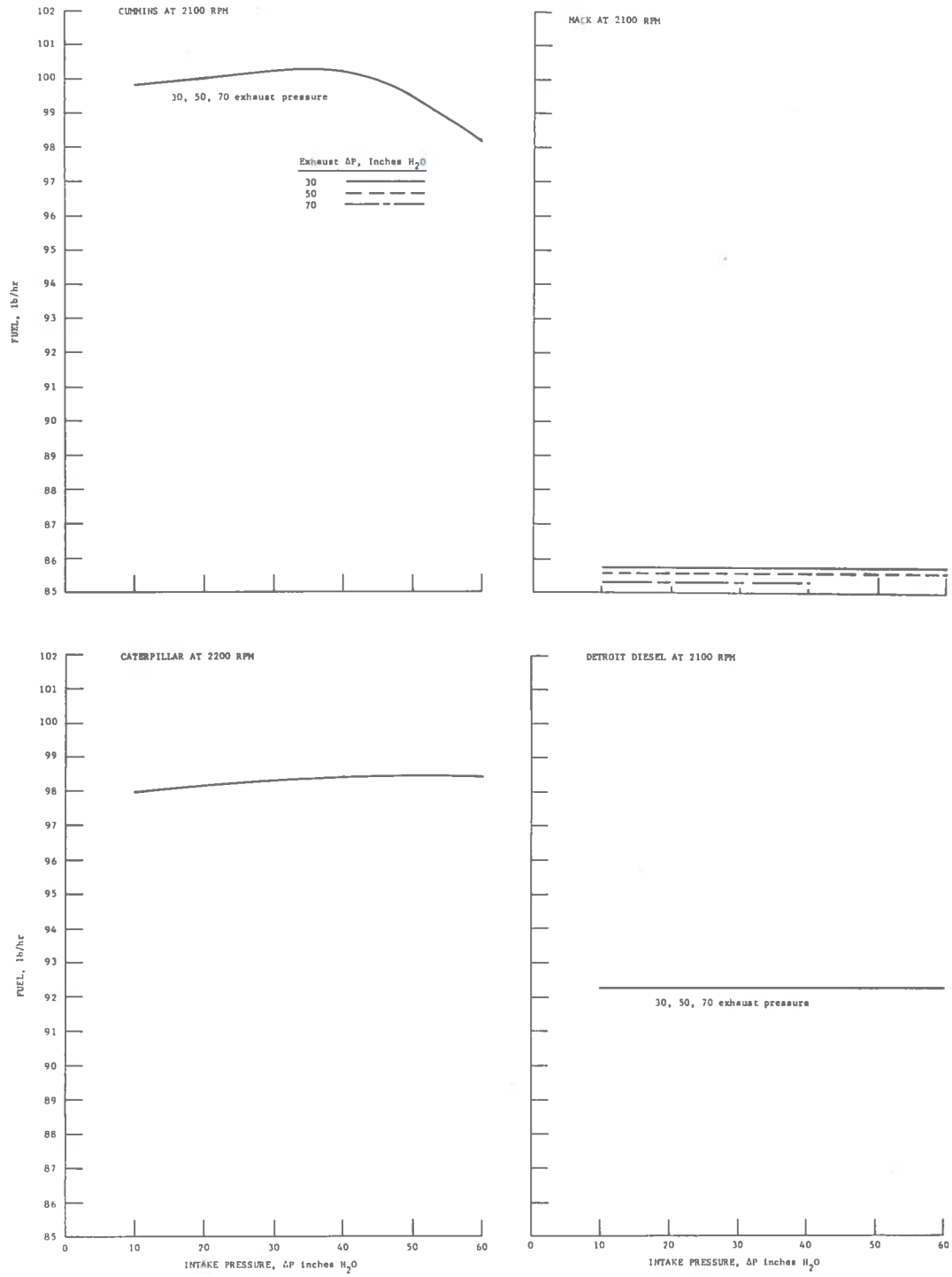

FIGURE 10. - Influence of Intake and Exhaust Restrictions on Fuel Consumption for Four Engines Operated at Full Load and Rated Speed

(Calculated from regression equations, tables 8-11)

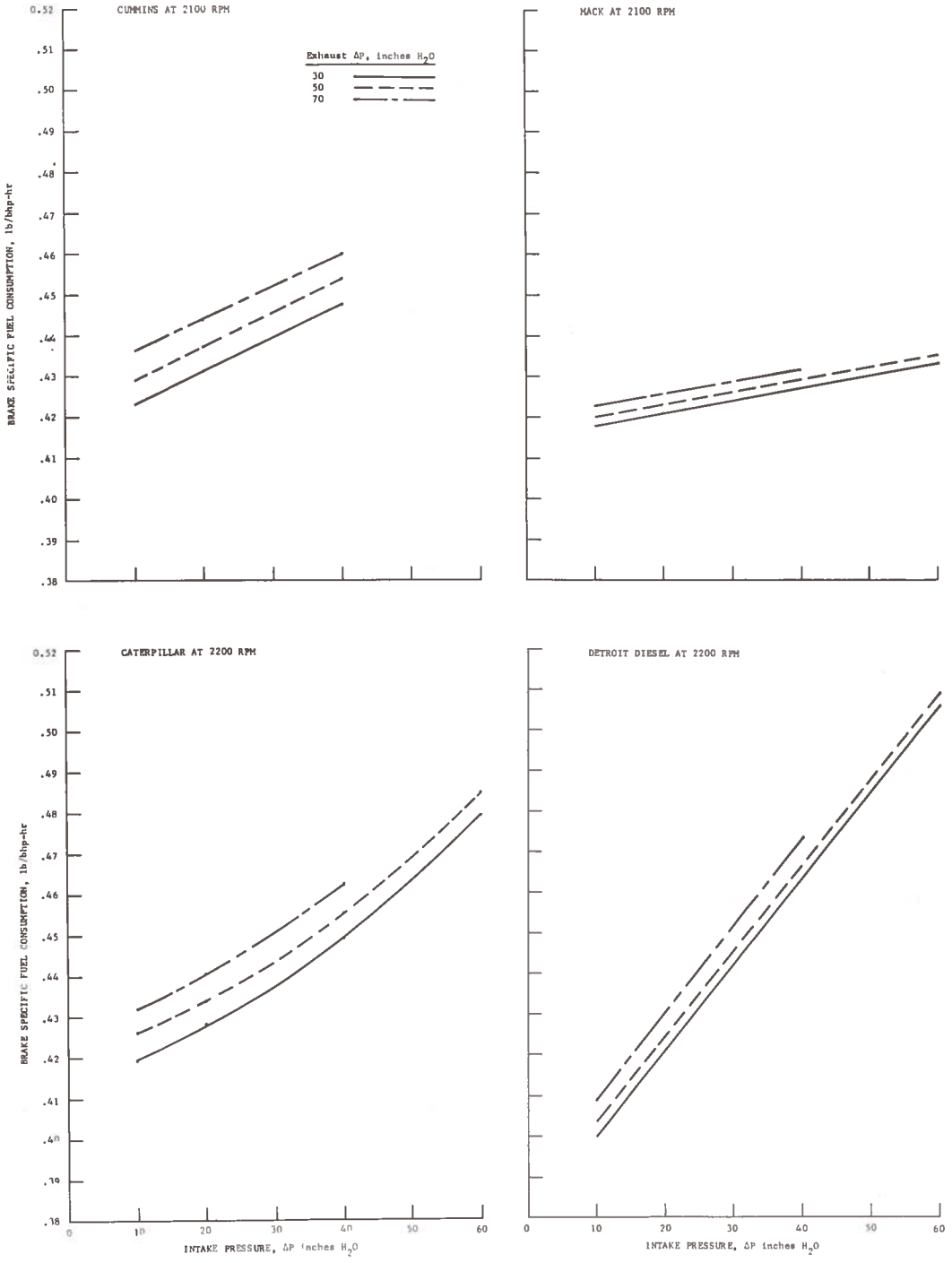

FIGURE 11. - Influence of Intake and Exhaust Restrictions on Brake Specific Fuel Consumption for Four Engines Operated at Full Load and Rated Speed (Calculated from regression equations, tables 8-11)

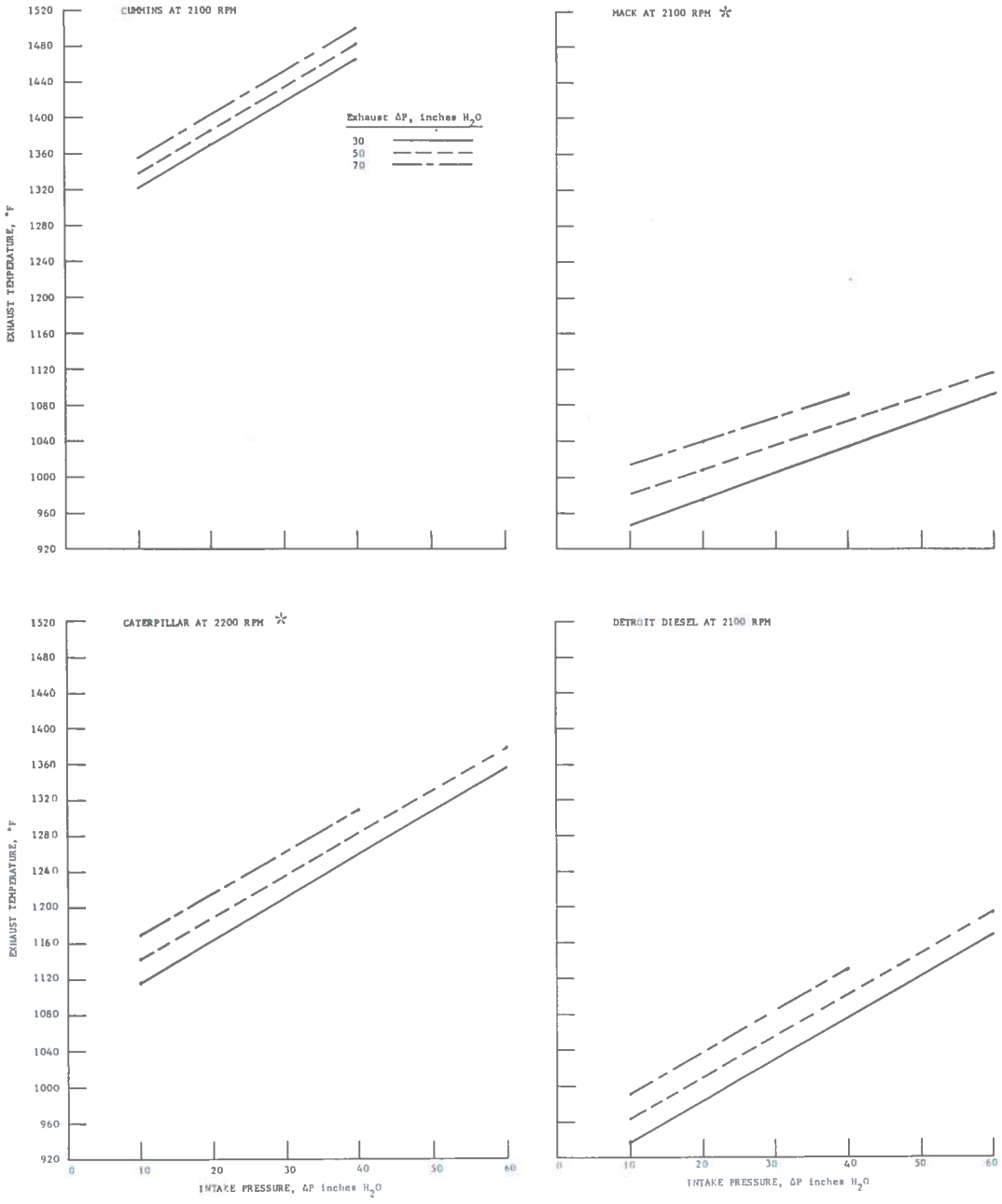

FIGURE 12. - Influence of Intake and Exhaust Restrictions on Exhaust Temperature for Four Engines Operated at Full Load and Rated Speed

*Exhaust temperature downstream of turbocharger

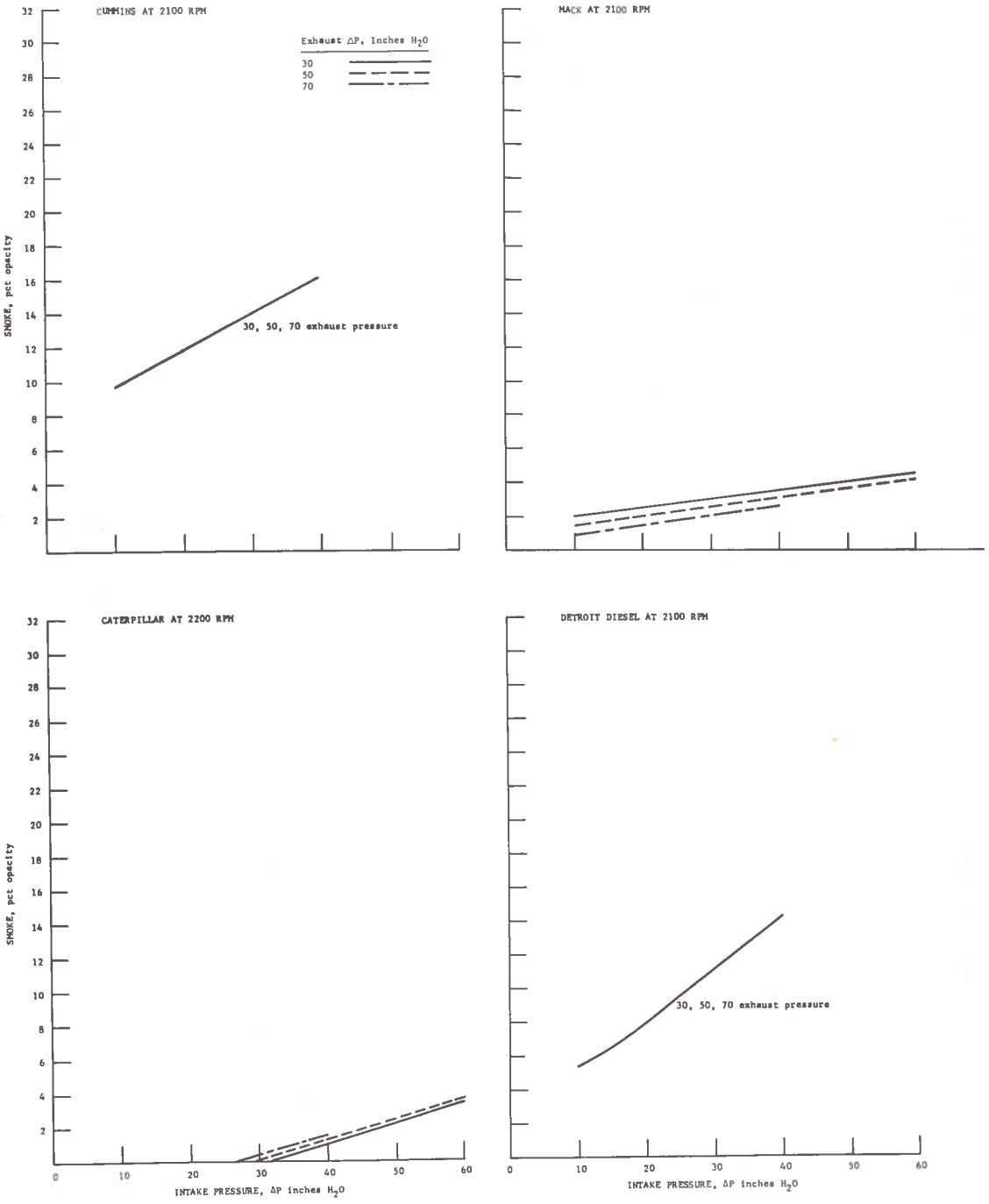

FIGURE 13. - Influence of Intake and Exhaust Restrictions on Smoke Emissions for Four Engines Operated at Full Load and Rated Speed

(Calculated from regression equations, tables 8-11)

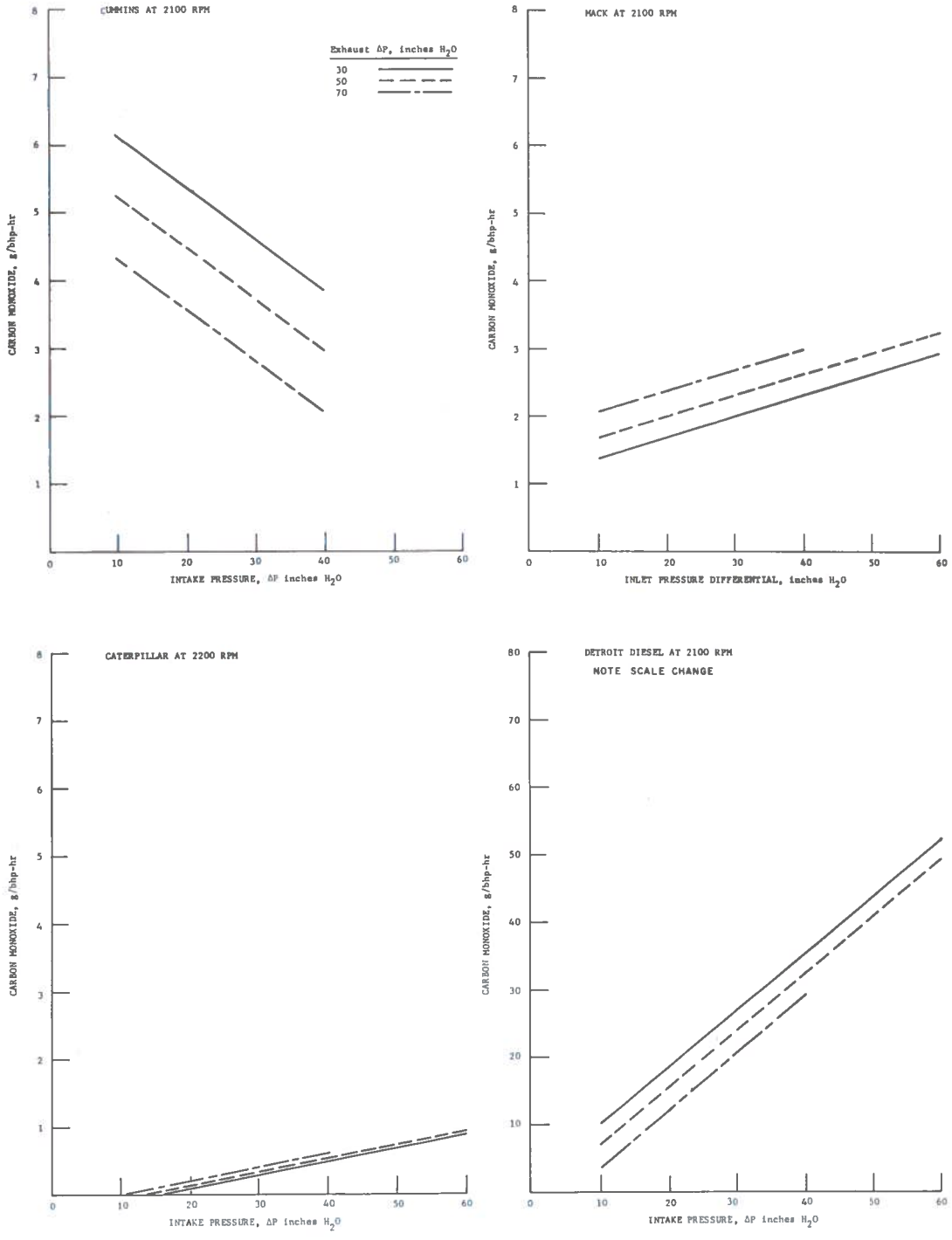

FIGURE 14. - Influence of Intake and Exhaust Restrictions on Carbon Monoxide Emissions for Four Engines Operated at Full Load and Rated Speed

(Calculated from regression equations, tables 8-11)

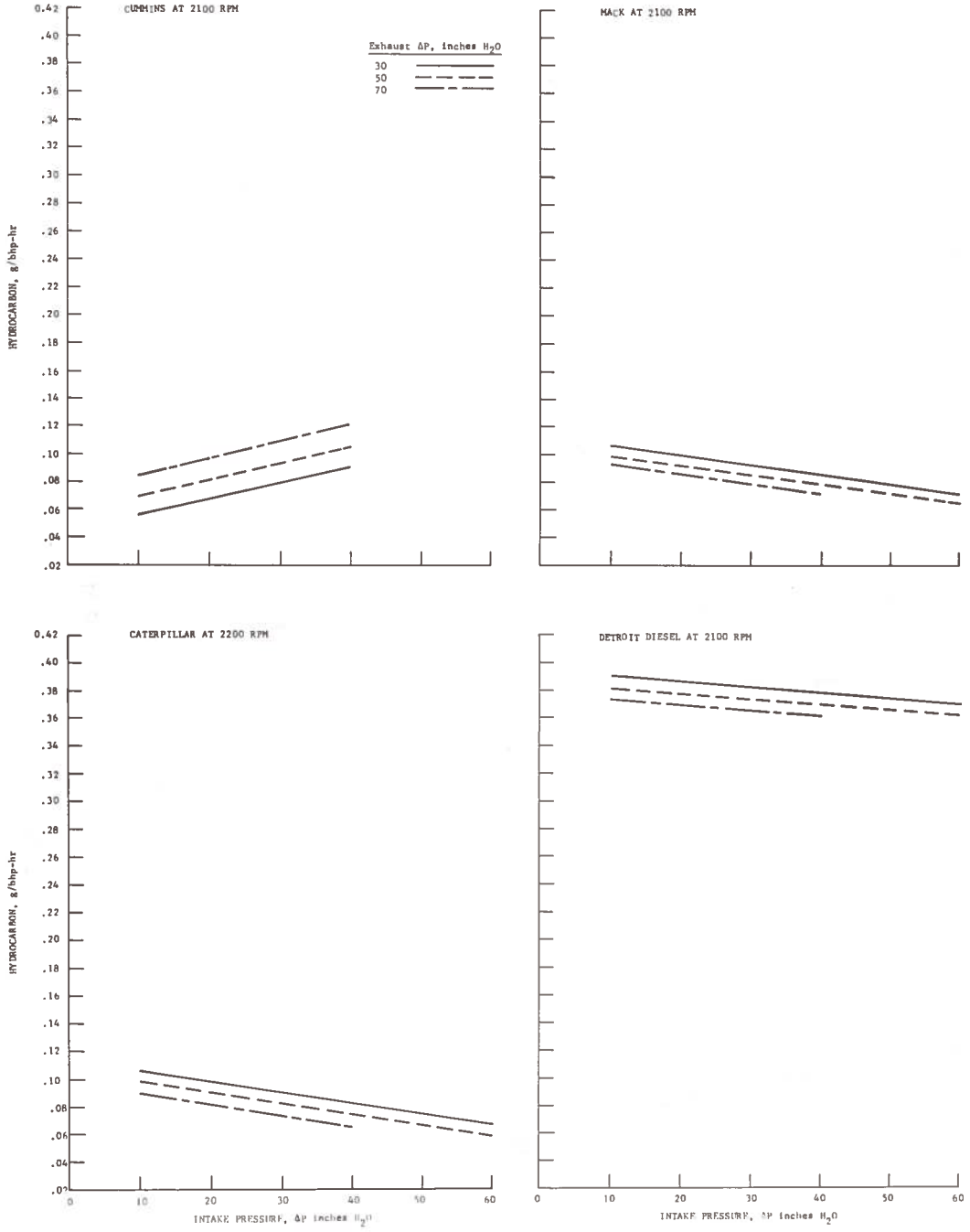

FIGURE 15. - Influence of Intake and Exhaust Restrictions on Hydrocarbon Emissions for Four Engines Operated at Full Load and Rated Speed

(Calculated from regression equations, tables 8-11)

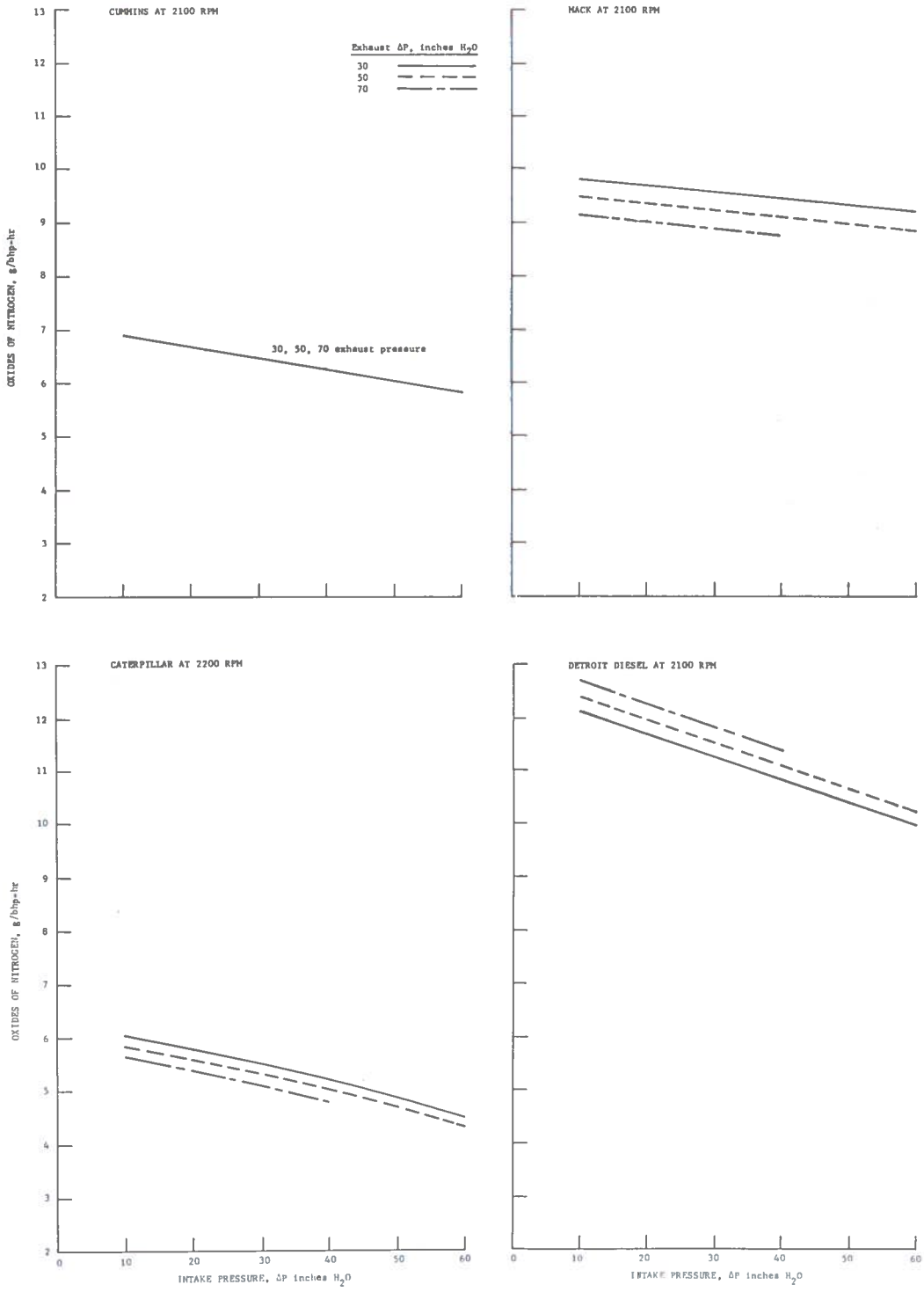

FIGURE 16. - Influence of Intake and Exhaust Restrictions on Oxides of Nitrogen Emissions for Four Engines Operated at Full Load and Rated Speed

(Calculated from regression equations, tables 8-11)

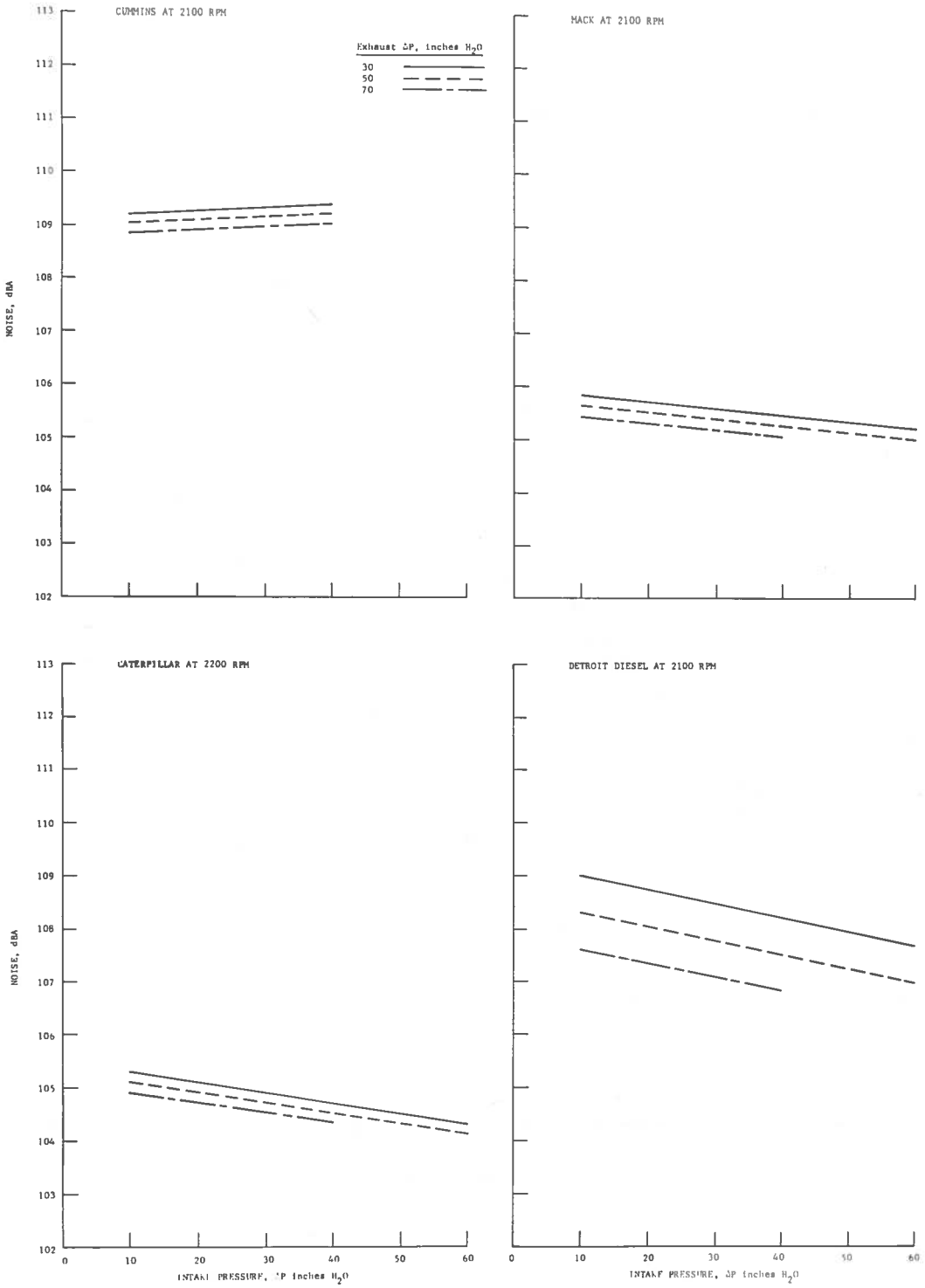

FIGURE 17. - Influence of Intake and Exhaust Restrictions on Noise for Four Engines Operated at Full Load and Rated Speed

(Calculated from regression equations, tables 8-11)

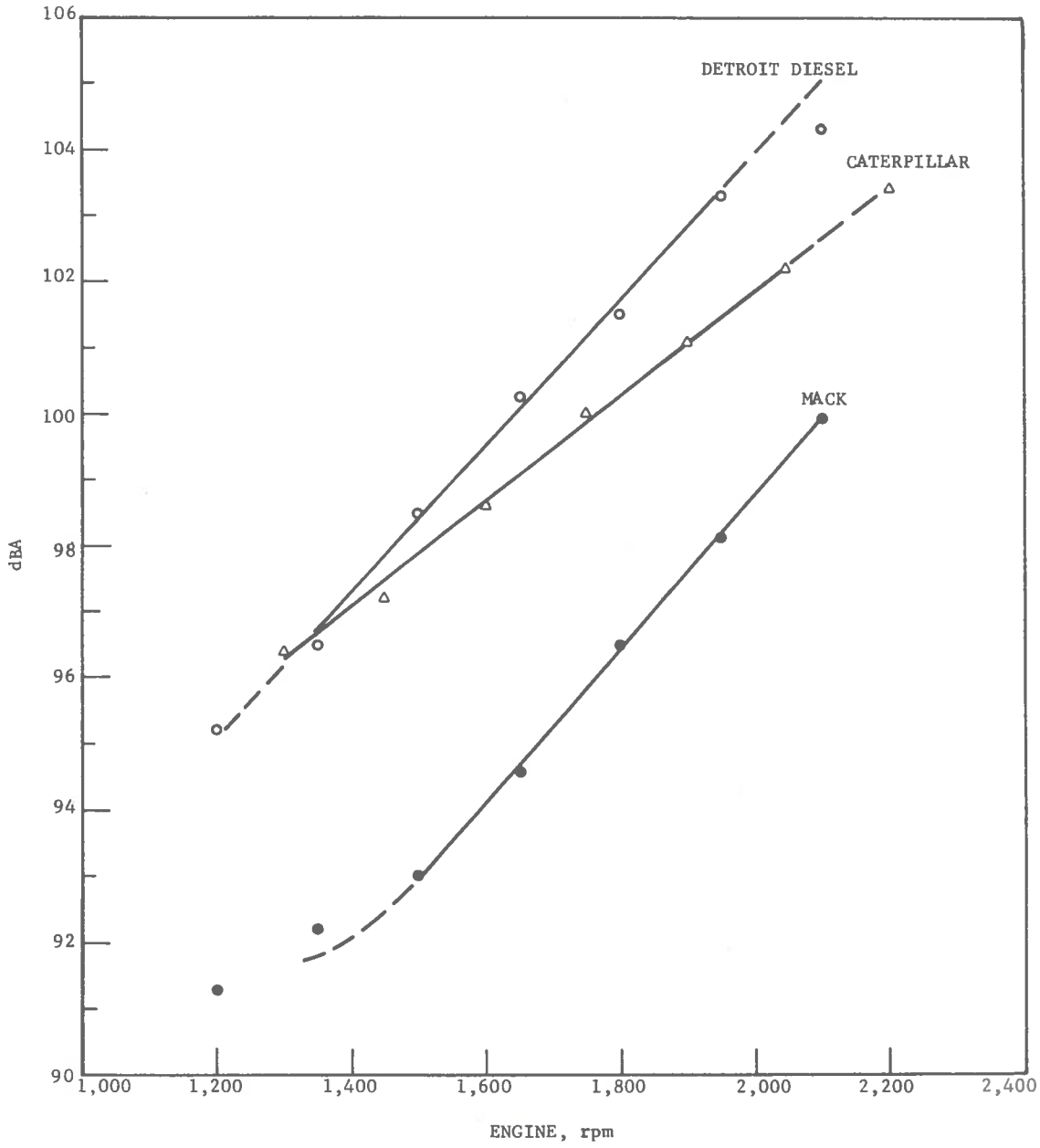

FIGURE 18. - Room Sound Pressure Levels Over Coast-down with Fuel Shut-off

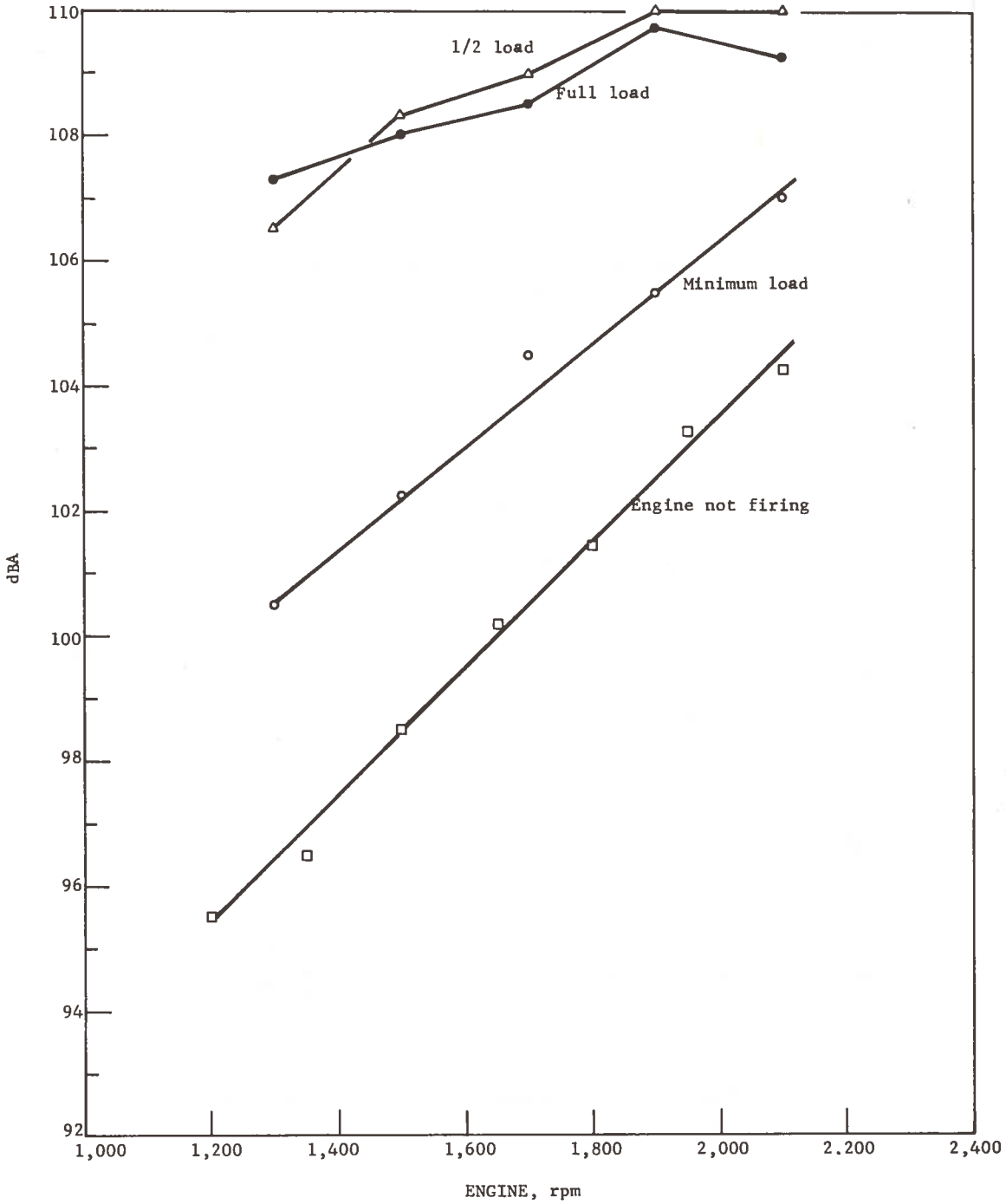

FIGURE 19. - Room Sound Pressure Levels with the Detroit Diesel 6-71 Operating at Various Loads

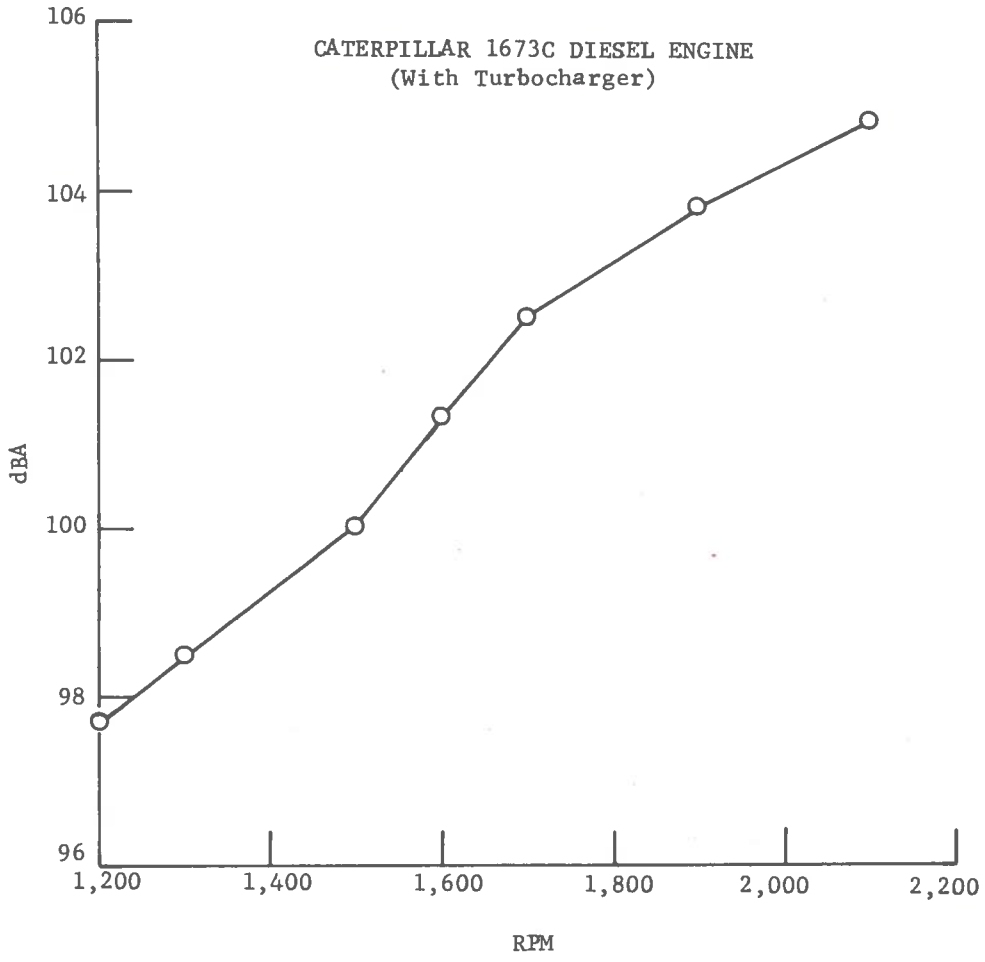

FIGURE 20. - Engine Noise Level at Full Load Condition

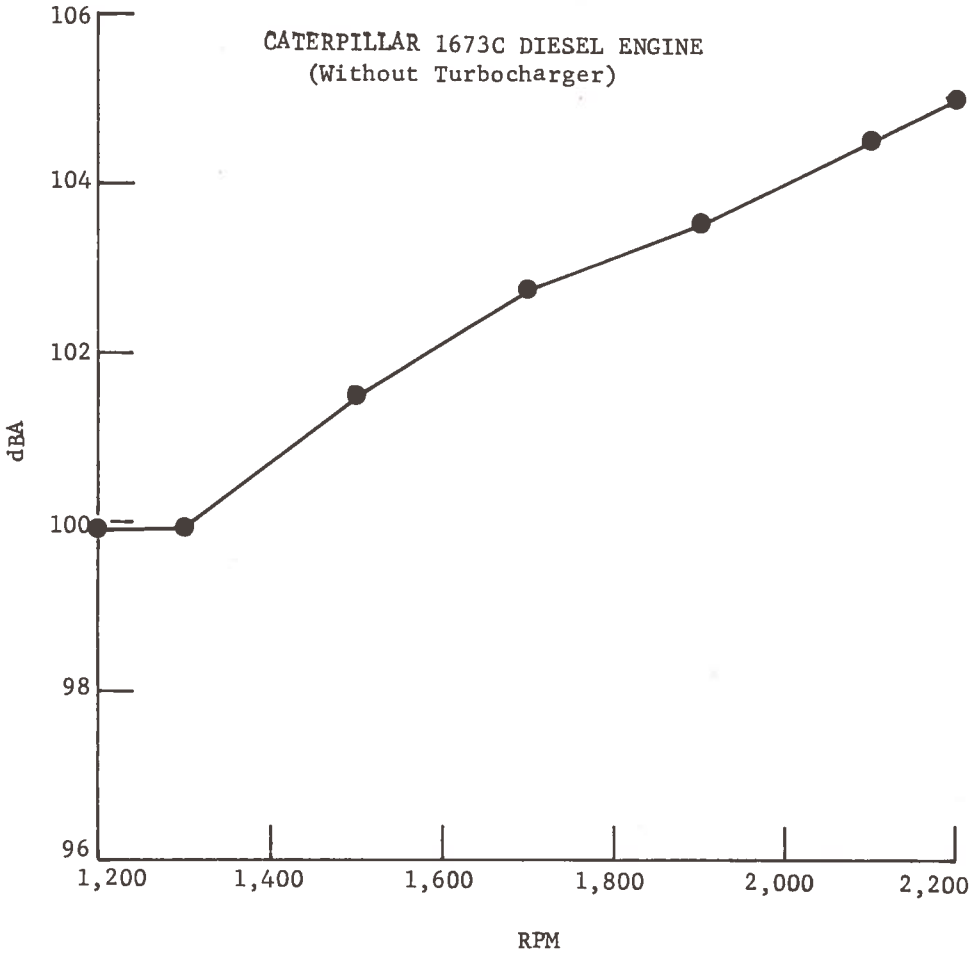

FIGURE 21. - Engine Noise Level at Part Load Condition (Approximately 1/3 of Full Load)

APPENDIX A.--CUMMINS ENGINE TEST DATA

Date	Test number	Modes	RPM	Remarks
03/16/73	4A	1-13	625-2100	
04/02/73	10	1-3	2100	Engine blanketed.
05/08/73	21	1-9	1400	
05/10/73	22	(10-18 (90-91	1750 1750	
05/16/73	23		2100	
05/18/73	24		2100	No noise levels with this test.

NOTE.--Modes marked with "**" on test data sheets used in regression analysis.

TEST 4ADATE 03/16/73 ENGINE NHC-250 FUEL2J

BY RT-DL-GG

MODE	1	2	3	4	5	6	7	8	9	10	11	12	13
BAROMETER (MMHG)	746.0	746.0	746.0	746.0	746.0	746.0	746.0	746.0	746.0	746.0	746.0	746.0	746.0
AMBIENT VP (MMHGA)	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
SPEED (RPM)	625	1300	1300	1300	1300	1300	625	2100	2100	2100	2100	2100	650
TORQUE (FT-LB)#	0	15	160	325	493	637	0	590	442	288	148	6	0
POWER (BHP)#	0.0	3.8	39.7	80.6	122.0	157.6	0.0	236.0	176.5	115.0	59.3	2.3	0.0
AIR FLOW (LB/HR)	596	1331	1289	1287	1287	1243	593	1985	2040	2094	2096	2120	629
FUEL FLOW (LB/HR)	0.2	7.0	18.0	31.6	47.7	64.9	0.3	103.0	72.5	50.5	30.0	14.8	0.3
A/F RATIO	2981.3	190.2	71.6	40.7	27.0	19.21	977.8	19.3	28.1	41.5	69.9	143.2	2097.6
BSFC (LB/BHP-HR)			0.453	0.392	0.391	0.412		0.436	0.411	0.439	0.506		
COOLANT(1000BTU/HR)													
OIL TEMP (F)	190	191	193	195	199	202	190	218	231	229	225	219	208
EXHAUST TEMP (F)	217	255	420	630	853	1122	287	1320	984	738	530	338	212
SMOKE (% OPACITY)	0.5	0.5	1.0	0.5	1.5	3.5	0.0	12.0	3.0	2.5	1.5	1.0	0.5
INTAKE REST.("H2O)*	-1.7	-0.1	-0.1	-0.1	-0.1	-0.3	-1.7	2.9	3.1	3.3	3.4	3.5	-1.7
EXHAUST REST ("H2O)	7.1	9.8	11.5	12.5	13.9	15.2	7.4	34.6	32.2	29.5	25.4	20.6	7.1
INTAKE VP(MMHGA)	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.4
INT. PRES. (MMHGA)	745.1	742.1	742.1	742.1	742.1	742.4	745.1	736.5	736.1	735.7	735.5	735.3	745.1
EXH. PRES. (MMHGA)	749.8	754.9	758.1	760.0	762.5	765.0	750.4	801.2	796.8	791.7	784.1	775.2	749.8
CO (PPM)	154	226	175	155	232	2655	159	2063	335	234	221	256	154
CO (G/HR)	40.2	132.3	100.2	89.5	135.9	1521.4	41.3	1887.6	310.3	220.0	206.3	239.7	42.4
CO (G/BHP-HR)			2.52	1.11	1.11	9.66		8.00	1.76	1.91	3.48		
HC (PPMC)	196	229	96	96	100	83	221	46	108	92	104	416	229
HC (G/HR)	25.6	67.1	27.4	27.7	29.2	23.9	28.7	20.9	50.0	43.0	48.5	194.6	31.6
HC (G/BHP-HR)			0.69	0.34	0.24	0.15		0.09	0.28	0.37	0.82		
NOX (PPM)	95	95	29	63	1215	1690	99	1109	729	424	223	81	86
NOX (G/HR)	36.9	82.8	24.7	54.1	1052.5	1435.2	38.0	1503.2	999.5	589.5	308.2	112.7	35.2
NOX (G/BHP-HR)			0.62	0.67	8.63	9.11		6.37	5.66	5.13	5.20		
SOUND (DBA)	86.0	99.0	101.0	103.0	105.0	106.5	95.0	111.0	109.0	106.5	106.0	105.0	

--13 MODE CYCLE COMPOSITE-- 1/

BSCO (G/BHP-HR)	4.98	BSFC (LB/BHP-HR)	0.4439
BSHC (G/BHP-HR)	0.61	SMOKE (% OPACITY)	2.2
BSNOX (G/BHP-HR)	6.30	POWER (BHP)	79.42

*RELATIVE TO 736.6 MMHG DRY BAROMETER

#CORRECTED TO 85 F

COMPUTED 12/19/73

1/ Exhaust restriction 34.6" at 2100 RPM full throttle. Intake restriction 2.9" at 2100 RPM full throttle.

TEST 10 DATE 0 .2/73 ENGINE NHC-250 FUEL J

(1) MODES 1&2 ENGINE NORMAL; MODE 3 BLANKETED, EXCEPT EXHAUST MANIFOLD
(2) DEW POINT ESTIMATED. (3) MODE 3 RUN ON 4-3-73. (4) MODE 1 FUEL RATE ESTIMATED.

MODE	1	2	3
BAROMETER (MMHG)	740.3	740.3	740.3
AMBIENT VP (MMHGA)	4.2	4.2	4.2
SPEED (RPM)	2100	2100	2100
TORQUE (FT-LB)#	594	583	586
POWER (BHP)#	237.6	233.1	234.3
AIR FLOW (LB/HR)	1941	1944	1967
FUEL FLOW (LB/HR)	101.0	100.0	101.0
A/F RATIO	19.2	19.4	19.5
BSFC (LB/BHP-HR)	0.425	0.429	0.431
COOLANT(1000BTU/HR)	407.8	411.7	411.6
OIL TEMP (F)	239	240	245
EXHAUST TEMP (F)	1338	1319	1320
SMOKE (% OPACITY)	12.5	9.5	11.0
INTAKE REST.("H2O)*	8.6	8.7	8.6
EXHAUST REST ("H2O)	33.2	32.5	31.2
INTAKE VP(MMHGA)	4.1	4.1	4.1
INT. PRES. (MMHGA)	724.6	724.5	724.6
EXH. PRES. (MMHGA)	798.7	797.4	794.9
CO (PPM)			
CO (G/HR)			
CO (G/BHP-HR)			
HC (PPMC)			
HC (G/HR)			
HC (G/BHP-HR)			
NOX (PPM)			
NOX (G/HR)			
NOX (G/BHP-HR)			
SOUND (DBA)	110.9	110.0	105.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

TEST 21 DATE 05/08/73 ENGINE NHC-250 FUEL J

1. M-3,6,9: RUN LAST, SMOKE LIMITED POWER, &BKMN-402 USED FOR HC,- (SEEMS LOW). 2. M-1,2,4,5,7: SMOKE METER SHIFTED 5 DIV LOW BY END OF M-7

MODE	1**	2**	3**	4**	5**	6**	7**	8**	9**
BAROMETER (MMHG)	742.1	742.1	743.4	741.6	741.6	743.4	741.5	740.4	743.4
AMBIENT VP (MMHGA)	10.7	10.7	12.8	10.7	10.7	12.8	10.7	10.7	12.8
SPEED (RPM)	1400	1400	1400	1400	1400	1400	1400	1400	1400
TORQUE (FT-LB)#	625	585	517	609	573	522	598	560	505
POWER (BHP)#	166.6	155.9	137.9	162.3	152.7	139.0	159.5	149.2	134.5
AIR FLOW (LB/HR)	1243	1153	1021	1236	1150	1001	1216	1156	991
FUEL FLOW (LB/HR)	71.0	71.3	60.7	71.2	71.5	63.4	71.3	72.0	63.3
A/F RATIO	17.5	16.2	16.8	17.4	16.1	15.8	17.1	16.1	15.7
BSFC (LB/BHP-HR)	0.426	0.457	0.440	0.439	0.468	0.456	0.447	0.482	0.470
COOLANT(1000BTU/HR)	345.8	352.8	304.9	358.1	363.4	336.7	367.2	361.2	336.3
OIL TEMP (F)	213	222	218	222	222	220	224	214	220
EXHAUST TEMP (F)	1345	1465	1284	1385	1490	1400	1418	1490	1415
SMOKE (% OPACITY)	7.0	10.5	20.0	3.0	11.0	19.0	2.5	21.0	18.0
INTAKE REST.("H2O)*	19.9	40.1	60.7	20.2	40.0	59.3	20.2	39.8	60.7
EXHAUST REST ("H2O)	26.0	24.7	25.4	55.6	55.0	55.9	85.5	84.2	85.1
INTAKE VP(MMHGA)	10.2	9.7	10.9	10.2	9.7	11.0	10.2	9.7	10.9
INT. PRES. (MMHGA)	709.6	671.2	633.9	709.0	671.4	636.6	708.9	671.7	633.9
EXH. PRES. (MMHGA)	785.3	782.7	784.0	840.7	839.4	841.2	896.4	894.1	895.8
CO (PPM)	1862	989	2771	1041	1495	1069	768		923
CO (G/HR)	1072.2	530.81	313.0	596.0	799.7	498.5	433.1		426.1
CO (G/BHP-HR)	6.43	3.41	9.52	3.67	5.24	3.59	2.72		3.17
HC (PPMC)	45	74	12	26	54	6	35	58	5
HC (G/HR)	13.0	19.8	2.7	7.4	14.4	1.3	9.9	15.6	1.0
HC (G/BHP-HR)	0.08	0.13	0.02	0.05	0.09	0.01	0.06	0.10	0.01
NOX (PPM)	1439	1336	1167	1305	1248	1135	1302	1138	1047
NOX (G/HR)	1322.9	1144.4	910.9	1193.1	1065.6	871.9	1172.0	977.8	795.8
NOX (G/BHP-HR)	7.94	7.34	6.61	7.35	6.98	6.27	7.35	6.55	5.92
SOUND (DBA)	105.9	105.9	104.9	105.0	105.8	105.2	105.2	106.1	104.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

**Used in regression analysis.

TEST 22 DATE 05/10/73 ENGINE NHC-250 FUEL J

1. SMOKE LIMITED POWER MODES 12,17,18. 2. BECKMAN 402 USED FOR M 10,11, 12, 13. HC LOW. DEW PT ESTIMATED M 17,18,90,91. 3. M 90 & 91 ARE REPLICATES OF 10 & 11.

MODE	10**	11**	12**	13**	14**	15**	16**	17**	18**	90**	91**
BAROMETER (MMHG)	743.4	743.4	743.4	743.4	753.0	752.1	751.3	742.4	742.0	742.0	742.0
AMBIENT VP (MMHGA)	12.8	12.8	12.8	12.8	11.9	11.9	11.9	11.1	11.1	11.1	11.1
SPEED (RPM)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
TORQUE (FT-LB)#	618	585	530	612	574	530	594	544	508	610	580
POWER (BHP)#	205.9	194.9	176.6	204.1	191.1	176.4	198.0	181.1	169.2	203.4	193.3
AIR FLOW (LB/HR)	1500	1384	1305	1489	1412	1303	1487	1382	1286	1501	1383
FUEL FLOW (LB/HR)	87.5	88.2	79.6	87.6	88.8	84.1	87.8	85.3	82.1	87.3	87.4
A/F RATIO	17.1	15.7	16.4	17.0	15.9	15.5	16.9	16.2	15.7	17.2	15.8
BSFC (LB/BHP-HR)	0.425	0.453	0.451	0.429	0.465	0.477	0.443	0.471	0.485	0.429	0.452
COOLANT(1000BTU/HR)	385.5	403.3	382.5	410.5	398.9	402.5	399.4	408.5	391.4	395.2	411.1
OIL TEMP (F)	230	237	234	236	225	233	227	229	234	232	233
EXHAUST TEMP (F)	1390	1500	1432	1403	1482	1520	1407	1477	1535	1389	1502
SMOKE (% OPACITY)	15.0	18.5	18.0	14.0	13.5	19.0	10.0	18.0	20.0	10.0	14.0
INTAKE REST.("H2O)*	21.3	40.9	60.0	21.4	40.3	60.3	20.7	43.2	63.3	23.5	43.3
EXHAUST REST ("H2O)	26.7	26.0	25.4	55.3	55.6	54.5	86.6	84.6	81.7	25.3	23.3
INTAKE VP(MMHGA)	12.2	11.6	10.9	12.2	10.6	10.0	11.2	9.9	9.4	10.5	9.9
INT. PRES. (MMHGA)	709.0	671.6	635.3	708.7	671.8	633.9	709.2	665.7	627.5	703.1	665.5
EXH. PRES. (MMHGA)	786.6	785.3	784.0	839.9	840.6	838.5	898.6	894.8	889.3	783.9	780.1
CO (PPM)	1336	618	929	1100	547	577	996	621	538	1336	619
CO (G/HR)	928.9	398.3	563.6	759.9	359.9	351.0	686.8	398.8	322.6	929.9	398.6
CO (G/BHP-HR)	4.51	2.04	3.19	3.72	1.88	1.99	3.47	2.20	1.91	4.57	2.06
HC (PPMC)	8	7	6	7	114	86		118	71	41	53
HC (G/HR)	2.6	2.1	1.7	2.2	37.5	26.1		37.9	21.3	14.3	17.1
HC (G/BHP-HR)	0.01	0.01	0.01	0.01	0.20	0.15		0.21	0.13	0.07	0.09
NOX (PPM)	1148	1178	1119	1147	1255	1176	1301	1118	1069	1271	1201
NOX (G/HR)	1315.1	1250.5	1118.4	1304.5	1337.4	1158.7	1455.2	1152.8	1028.1	1419.8	1242.7
NOX (G/BHP-HR)	6.39	6.42	6.33	6.39	7.00	6.57	7.35	6.36	6.08	6.98	6.43
SOUND (DBA)	107.8	108.2	107.6	107.5	107.9	107.5	106.4	107.8	107.7	107.5	107.8

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

**Used in regression analysis.

TEST 23 DATE 05/16/73 ENGINE NHC-250 FUEL J

1. NEW HC BLEND M-20. 2. SMOKE LIMITED POWER M-24, 27

MODE	19**	20**	21**	22**	23**	24**	25**	26**	27**
BAROMETER (MMHG)	742.5	742.5	742.5	742.5	742.5	742.5	742.5	742.5	743.3
AMBIENT VP (MMHGA)	11.1	11.1	11.1	16.4	16.4	16.4	16.4	16.4	8.9
SPEED (RPM)	2100	2100	2100	2100	2100	2100	2100	2100	2100
TORQUE (FT-LB)#	583	558	531	577	551	506	568	541	497
POWER (BHP)#	233.2	223.1	212.3	230.6	220.4	202.5	227.0	216.3	198.7
AIR FLOW (LB/HR)	1838	1710	1598	1824	1699	1600	1819	1690	1551
FUEL FLOW (LB/HR)	100.7	100.4	100.6	99.9	100.1	94.5	99.9	100.4	96.6
A/F RATIO	18.3	17.0	15.9	18.3	17.0	16.9	18.2	16.8	16.1
BSFC (LB/BHP-HR)	0.432	0.450	0.474	0.433	0.454	0.467	0.440	0.464	0.486
COOLANT(1000BTU/HR)	421.8	451.6	460.2	434.1	456.3	435.2	442.4	449.9	454.6
OIL TEMP (F)	243	245	248	247	247	245	245	247	244
EXHAUST TEMP (F)	1376	1466	1559	1389	1480	1474	1402	1500	1566
SMOKE (% OPACITY)	10.0	11.0	15.0	16.0	20.0	18.0	14.0	17.0	19.0
INTAKE REST.("H2O)*	20.4	40.3	59.7	20.3	40.3	59.5	20.3	40.1	60.3
EXHAUST REST ("H2O)	23.0	30.3	28.3	59.5	58.8	59.5	90.1	90.1	84.4
INTAKE VP(MMHGA)	10.6	10.0	9.5	15.7	14.9	14.1	15.7	14.9	7.5
INT. PRES. (MMHGA)	709.0	671.2	634.4	714.4	676.1	639.4	714.4	676.5	631.4
EXH. PRES. (MMHGA)	798.4	793.3	789.5	847.9	846.6	847.9	905.1	905.1	894.4
CO (PPM)	1564	789	539	1346	747	788	754	604	500
CO (G/HR)	1328.3	625.7	401.4	1134.8	589.1	585.2	634.0	473.6	360.9
CO (G/BHP-HR)	5.70	2.80	1.89	4.92	2.67	2.89	2.79	2.19	1.82
HC (PPMC)	56	47	55	39	44	55	47	50	47
HC (G/HR)	23.8	18.6	20.5	16.4	17.3	20.4	19.8	19.6	17.0
HC (G/BHP-HR)	0.10	0.08	0.10	0.07	0.08	0.10	0.09	0.09	0.09
NOX (PPM)	1135	1115	1071	1147	1103	970	1090	1003	1029
NOX (G/HR)	1548.2	1419.0	1279.3	1684.2	1514.6	1254.4	1597.5	1370.6	1154.7
NOX (G/BHP-HR)	6.64	6.36	6.03	7.30	6.87	6.20	7.04	6.34	5.81
SOUND (DBA)	109.3	109.2	110.7	108.5	109.2	109.2	108.9	108.9	109.6

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

TEST 24 DATE 05/18/73 ENGINE NHC-250 FUEL J

REPLICATE OF TEST 23, MODES 19-27

MODE	1	2	3	4	5	6	7	8	9
BAROMETER (MMHG)	738.0	738.0	738.0	738.0	738.0	738.0	738.0	738.0	738.0
AMBIENT VP (MMHGA)	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
SPEED (RPM)	2100	2100	2100	2100	2100	2100	2100	2100	2100
TORQUE (FT-LB)#	579	562	536	581	555	531	561	533	503
POWER (BHP)#	231.5	224.7	214.5	232.2	221.8	212.2	224.4	213.0	200.9
AIR FLOW (LB/HR)	1856	1716	1550	1801	1679	1562	1781	1662	1575
FUEL FLOW (LB/HR)	101.4	102.3	100.5	99.9	100.0	98.6	98.4	98.7	100.6
A/F RATIO	18.3	16.8	15.8	18.0	16.8	15.8	18.1	16.8	15.7
BSFC (LB/BHP-HR)	0.438	0.455	0.469	0.430	0.451	0.465	0.439	0.463	0.501
COOLANT(1000BTU/HR)	421.1	430.6	441.4	437.9	447.4	445.1	431.8	449.5	473.4
OIL TEMP (F)	234	236	245	246	247	243	247	247	248
EXHAUST TEMP (F)	1373	1483	1576	1415	1506	1575	1412	1510	1617
SMOKE (% OPACITY)	12.5	17.0	20.5	11.0	16.0	20.0	11.5	15.0	20.5
INTAKE REST.("H2O)*	20.2	40.2	58.2	20.3	40.1	58.2	20.2	40.1	58.9
EXHAUST REST ("H2O)	27.9	26.6	25.2	55.1	55.1	55.8	85.0	85.0	86.3
INTAKE VP(MMHGA)	9.5	9.0	8.6	9.5	9.0	8.6	9.5	9.0	8.5
INT. PRES. (MMHGA)	708.3	670.5	636.2	708.1	670.6	636.2	708.3	670.6	634.9
EXH. PRES. (MMHGA)	788.8	786.3	783.7	839.6	839.6	840.9	895.5	895.5	898.0
CO (PPM)	1674	746	559	1130	624	539	1046	584	498
CO (G/HR)	1435.2	594.5	414.2	941.3	486.0	392.2	861.5	450.7	365.6
CO (G/BHP-HR)	6.20	2.65	1.93	4.05	2.19	1.85	3.84	2.12	1.82
HC (PPMC)	39	54	60	39	51	60	42	45	58
HC (G/HR)	16.7	21.5	22.2	16.2	19.9	21.8	17.3	17.4	21.3
HC (G/BHP-HR)	0.07	0.10	0.10	0.07	0.09	0.10	0.08	0.08	0.11
NOX (PPM)	1136	1101	1070	1134	1079	1027	1090	1047	981
NOX (G/HR)	1538.5	1386.0	1252.5	1491.8	1328.6	1179.9	1417.7	1276.0	1137.9
NOX (G/BHP-HR)	6.65	6.17	5.84	6.42	5.99	5.56	6.32	5.99	5.66
SOUND (DBA)	NO DATA TAKEN								

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

APPENDIX B.--MACK ENGINE TEST DATA

Date	Test number	Modes	RPM	Remarks
06/18/73	26	1-13	650-2100	Special--"13-mode" emissions measurements.
06/20/73	27	1-9	2100	
06/27/73	28	1-9	2100	
06/28/73	29A	1-12	1500	
06/28/73	29B	13-14	2100	
07/02/73	30A	1-12	1800	
07/02/73	30B	13	2100	
07/03/73	31A	1-11	1500	
07/03/73	31B	12-13	2100	
07/05/73	32	1-12	1800	
07/09/73	33	1-2	2100	Special--Turbine and compressor of turbocharger removed.
07/16/73	34	1-12	1500	
07/17/73	35	1-12	1800	
07/18/73	36	1-11	2100	
07/18/73	37	1-13	650-2100	Special--"13-mode" emissions measurements.

NOTE.--Modes marked"**" used in regression analysis.

TEST 26 DATE 06/18/73 ENGINE ENDT675 FUEL J 13-MODE EMISSIONS

1. OIL TEMP T.C. NOT WORKING 2. SOUND NOT TAKEN 3. CCCLANT RATE NOT TAKE
4. F.I.D. INOP M-13. (HC ESTIMATED)

MODE	1	2	3	4	5	6	7	8	9	10	11	12	13
BAROMETER (MMHG)	735.5	735.3	735.1	735.3	735.3	735.3	735.3	735.3	735.3	735.5	735.5	735.5	735.5
AMBIENT VP (MMHGA)	21.5	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	21.5	21.5	21.5
SPEED (RPM)	650	1260	1260	1260	1260	1260	650	2100	2100	2100	2100	2100	610
TORQUE (FT-LB)#	0	16	210	405	617	811	0	502	375	254	126	15	0
POWER (BHP)#	0.0	3.9	50.3	97.2	148.1	194.6	0.0	200.8	149.9	101.7	50.3	6.0	0.0
AIR FLOW (LB/HR)	449	920	986	1104	1266	1493	451	2424	2288	2080	1831	1653	455
FUEL FLOW (LB/HR)	3.1	7.7	21.1	36.3	54.2	72.3	3.0	85.5	67.1	49.9	33.6	19.7	3.1
A/F RATIO	144.9	119.4	46.7	30.4	23.4	20.6	150.4	28.4	34.1	41.7	54.5	83.9	146.6
BSFC (LB/BHP-HR)			0.420	0.374	0.366	0.372		0.426	0.448	0.491	0.669		
COOLANT(1000BTU/HR)													
OIL TEMP (F)													
EXHAUST TEMP (F)	257	308	542	767	978	1116	250	1008	859	733	597	456	256
SMOKE (% OPACITY)	0.0	0.0	2.5	4.0	5.0	7.5	0.0	2.0	1.0	1.5	2.5	2.0	0.0
INTAKE REST.("H2O)*	12.6	12.7	14.1	14.6	15.4	17.0	12.3	24.5	23.2	21.2	19.6	18.1	12.6
EXHAUST REST ("H2O)	0.8	1.3	3.3	4.7	8.8	12.9	0.7	29.2	23.8	17.7	13.0	9.6	0.8
INTAKE VP(MMHGA)	21.5	20.7	20.7	20.6	20.6	20.5	20.8	20.1	20.2	20.3	21.1	21.2	21.5
INT. PRES. (MMHGA)	734.6	733.6	730.8	729.9	728.3	725.4	734.4	710.8	713.4	717.2	721.1	723.8	734.6
EXH. PRES. (MMHGA)	738.0	739.1	742.7	745.5	753.1	760.7	737.8	791.2	781.0	769.8	760.9	754.5	738.0
CO (PPM)	622	468	190	161	582	1497	638	406	228	222	268	315	654
CO (G/HR)	123.3	190.2	83.6	80.3	336.41	026.8	127.0	446.6	235.0	207.0	218.8	231.1	131.1
CO (G/BHP-HR)			1.66	0.83	2.27	5.28		2.22	1.57	2.04	4.35		
HC (PPMC)	797	722	548	592	498	293	778	355	498	566	666	822	788
HC (G/HR)	78.9	146.6	120.8	147.8	144.0	100.4	77.4	195.1	256.8	264.0	272.0	301.1	79.0
HC (G/BHP-HR)			2.40	1.52	0.97	0.52		0.97	1.71	2.60	5.41		
NOX (PPM)	247	246	670	1121	1554	1693	237	883	612	419	241	122	237
NOX (G/HR)	93.2	188.2	557.0	1055.3	1694.4	2188.4	88.8	1829.6	1189.7	736.6	375.5	170.7	90.6
NOX (G/BHP-HR)			11.08	10.86	11.44	11.25		9.11	7.93	7.24	7.47		
SOUND (DBA)													

--13 MODE CYCLE COMPOSITE--

BSCO	(G/BHP-HR)	3.36	BSFC	(LB/BHP-HR)	0.4539
BSHC	(G/BHP-HR)	2.14	SMOKE	(% OPACITY)	2.2
BSNOX	(G/BHP-HR)	10.19	POWER	(BHP)	80.21

*RELATIVE TO 736.6 MMHG DRY BAROMETER

#CORRECTED TO 85 F

COMPUTED 12/20/73

TEST 27 DATE 06/20/73 ENGINE ENDT675 FUEL J

R.T. 1. 3 EXH X 3 INTAKE REST. @ 2100 RPM

MODE	1**	2**	3**	4**	5**	6**	7**	8**	9**
BAROMETER (MMHG)	749.2	749.2	749.2	749.2	748.0	748.0	748.0	748.0	748.0
AMBIENT VP (MMHGA)	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
SPEED (RPM)	2100	2100	2100	2100	2100	2100	2100	2100	2100
TORQUE (FT-LB)#	511	507	498	505	505	497	503	499	479
POWER (BHP)#	204.4	202.8	199.2	201.7	201.9	198.7	201.1	199.4	191.6
AIR FLOW (LB/HR)	2394	2264	2125	2380	2242	2108	2356	2215	2042
FUEL FLOW (LB/HR)	87.1	85.2	86.0	85.4	86.8	86.6	85.1	85.3	83.1
A/F RATIO	27.5	26.6	24.7	27.9	25.8	24.3	27.7	26.0	24.6
BSFC (LB/BHP-HR)	0.426	0.420	0.432	0.423	0.430	0.436	0.423	0.428	0.434
COOLANT(1000BTU/HR)	404.0	401.5	412.7	401.5	411.5	406.3	400.5	397.7	396.5
OIL TEMP (F)	226	226	225	225	226	226	226	226	225
EXHAUST TEMP (F)	1016	1058	1106	1019	1069	1119	1029	1082	1121
SMOKE (% OPACITY)	1.0	2.5	3.5	2.0	2.0	4.0	3.0	4.0	4.0
INTAKE REST.("H2O)*	20.0	39.9	60.2	20.0	40.1	60.1	20.2	40.1	60.1
EXHAUST REST ("H2O)	37.3	34.6	31.2	50.9	49.6	50.2	70.6	71.3	70.6
INTAKE VP(MMHGA)	12.1	11.5	10.8	12.1	11.5	10.9	12.2	11.5	10.9
INT. PRES. (MMHGA)	711.4	673.5	634.9	711.3	673.2	635.0	711.0	673.2	635.0
EXH. PRES. (MMHGA)	806.3	801.3	794.9	831.7	829.3	830.5	868.6	869.9	868.6
CO (PPM)	410	477	590	420	514	594	437	524	609
CO (G/HR)	445.6	491.1	571.5	453.1	524.3	570.9	467.4	528.3	566.9
CO (G/BHP-HR)	2.18	2.42	2.87	2.25	2.60	2.87	2.32	2.65	2.96
HC (PPMC) @	368	307	245	313	259	198	252	215	184
HC (G/HR)	200.0	157.9	118.6	169.0	132.1	95.2	134.7	108.3	85.6
HC (G/BHP-HR)	0.98	0.78	0.60	0.84	0.65	0.48	0.67	0.54	0.45
NOX (PPM)	959	1179	1184	1091	1130	1129	1009	1015	1004
NOX (G/HR)	1698.9	1995.1	1885.1	1936.6	1896.4	1785.0	1775.3	1682.7	1537.0
NOX (G/BHP-HR)	8.31	9.84	9.46	9.60	9.39	8.98	8.83	8.44	8.02
SOUND (DBA)	105.5	105.5	105.5	105.5	105.3	105.3	105.3	105.0	105.1

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

TEST 28 DATE 06/27/73 ENGINE ENDT675 FUEL J

1.-COOLANT WATER FLOW RATE FLUCTUATED THROUGHOUT TEST

MODE	1**	2**	3**	4**	5**	6**	7**	8**	9**
BAROMETER (MMHG)	740.5	740.5	740.5	740.5	740.5	740.5	740.5	740.5	740.5
AMBIENT VP (MMHGA)	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9
SPEED (RPM)	2100	2100	2100	2100	2100	2100	2100	2100	2100
TORQUE (FT-LB)#	508	492	485	497	490	485	498	496	472
POWER (BHP)#	203.0	196.8	194.0	198.6	195.8	193.9	199.1	198.2	188.7
AIR FLOW (LB/HR)	2439	2292	2156	2387	2240	2097	2349	2197	2016
FUEL FLOW (LB/HR)	86.1	85.0	85.5	85.2	85.6	84.4	84.2	84.7	83.3
A/F RATIO	28.3	27.0	25.2	28.0	26.2	24.8	27.9	25.9	24.2
BSFC (LB/BHP-HR)	0.424	0.432	0.441	0.429	0.437	0.435	0.423	0.427	0.441
COOLANT(1000BTU/HR)	394.4	407.8	406.1	394.1	396.9	399.7	396.9	395.0	403.2
OIL TEMP (F)	225	226	226	225	225	225	225	225	226
EXHAUST TEMP (F)	1000	1033	1084	1008	1052	1100	1018	1068	1119
SMOKE (% OPACITY)	3.0	3.5	3.5	2.5	3.0	4.0	2.5	3.5	5.0
INTAKE REST.("H2O)*	20.2	40.2	60.2	20.2	40.2	60.2	20.1	40.2	60.2
EXHAUST REST ("H2O)	32.6	30.6	31.3	51.0	51.0	51.0	70.0	70.0	70.0
INTAKE VP(MMHGA)	16.4	15.5	14.6	16.4	15.5	14.6	16.4	15.5	14.6
INT. PRES. (MMHGA)	715.2	676.9	638.5	715.2	676.9	638.5	715.4	676.9	638.5
EXH. PRES. (MMHGA)	797.6	793.8	795.1	831.9	831.9	831.9	867.5	867.5	867.5
CO (PPM)	433	497	596	424	549	645	460	557	654
CO (G/HR)	479.2	517.8	585.0	459.6	558.8	616.9	490.8	557.3	601.5
CO (G/BHP-HR)	2.36	2.63	3.02	2.31	2.85	3.18	2.46	2.81	3.19
HC (PPMC)	315	258	195	233	195	157	253	210	166
HC (G/HR)	174.2	134.3	95.7	126.1	99.3	75.0	134.8	105.0	76.3
HC (G/BHP-HR)	0.86	0.68	0.49	0.63	0.51	0.39	0.68	0.53	0.40
NOX (PPM)	860	938	956	917	970	1000	952	1004	986
NOX (G/HR)	1673.9	1719.0	1651.7	1748.6	1738.5	1682.8	1784.9	1766.9	1596.0
NOX (G/BHP-HR)	8.25	8.73	8.51	8.80	8.88	8.68	8.96	8.92	8.46
SOUND (DBA)	105.5	105.5	105.5	105.5	105.5	105.0	105.5	105.0	104.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

TEST 29A DATE 06/28/73 ENGINE ENDT675 FUEL J

R.T. 1. FUEL READING FLUCTUATING.

MODE	1**	2**	3**	4	5**	6**	7	8	9**	10**	11	12
BAROMETER (MMHG)	743.0	743.0	743.0	743.0	743.0	743.0	743.0	743.0	743.0	741.5	741.5	741.5
AMBIENT VP (MMHGA)	13.3	13.3	13.3	13.3	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
SPEED (RPM)	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
TORQUE (FT-LB)#	726	705	687	539	711	692	625	465	698	687	533	438
POWER (BHP)#	207.4	201.2	196.3	154.0	203.0	197.5	178.5	132.9	199.5	196.2	152.3	125.0
AIR FLOW (LB/HR)	1800	1683	1579	1224	1718	1620	1430	1110	1654	1547	1226	1026
FUEL FLOW (LB/HR)	76.1	75.7	75.8	61.3	75.3	76.5	71.9	55.0	75.0	78.2	60.1	52.2
A/F RATIO	23.7	22.2	20.8	20.0	22.8	21.2	19.9	20.2	22.1	19.8	20.4	19.7
BSFC (LB/BHP-HR)	0.366	0.376	0.386	0.398	0.371	0.387	0.403	0.414	0.376	0.399	0.395	0.418
COOLANT(1000BTU/HR)	336.4	348.1	350.6	304.0	340.6	346.3	323.4	287.7	348.9	345.1	301.3	282.5
OIL TEMP (F)	217	219	219	215	215	219	217	213	218	218	216	212
EXHAUST TEMP (F)	1035	1090	1158	1141	1085	1142	1170	1125	1122	1188	1150	1140
SMOKE (% OPACITY)	3.5	5.0	7.0	9.5	3.5	5.5	7.5	8.5	4.0	6.0	7.5	9.5
INTAKE REST.("H2O)*	19.9	40.1	60.1	80.3	19.0	39.1	59.3	79.4	18.9	40.0	60.1	80.2
EXHAUST REST ("H2O)	30.6	30.6	30.6	30.6	50.3	50.3	51.0	50.3	71.3	70.5	70.5	70.5
INTAKE VP(MMHGA)	12.7	12.0	11.3	10.7	10.2	9.7	9.1	8.6	10.2	9.7	9.1	8.6
INT. PRES. (MMHGA)	712.1	673.6	635.4	597.1	711.2	673.0	634.9	596.7	711.4	671.3	633.4	595.2
EXH. PRES. (MMHGA)	793.8	793.8	793.8	793.8	830.6	830.6	831.9	830.6	870.0	868.5	868.5	868.5
CO (PPM)	544	737	1127	1514	671	1022	1360	1428	797	1338	1430	1665
CO (G/HR)	447.1	568.1	817.2	852.3	527.4	759.8	894.8	728.5	603.4	952.3	805.6	787.0
CO (G/BHP-HR)	2.16	2.82	4.16	5.53	2.60	3.85	5.01	5.48	3.02	4.85	5.29	6.30
HC (PPMC)	257	216	177	231	260	267	153	410	174	129	194	222
HC (G/HR)	105.6	83.2	64.1	65.0	102.1	99.2	50.3	104.6	65.9	45.9	54.6	52.4
HC (G/BHP-HR)	0.51	0.41	0.33	0.42	0.50	0.50	0.28	0.79	0.33	0.23	0.36	0.42
NOX (PPM)	1729	1741	1785	1676	1756	1755	1686	1521	1671	1685	1365	1471
NOX (G/HR)	2356.9	2225.1	2146.5	1565.7	2201.2	2081.2	1770.7	1238.0	2020.3	1915.5	1227.5	1109.9
NOX (G/BHP-HR)	11.36	11.06	10.93	10.17	10.84	10.54	9.92	9.31	10.13	9.76	8.06	8.88
SOUND (DBA)	103.0	102.5	102.5	101.5	102.5	102.5	101.5	101.5	102.5	102.5	100.5	101.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

TEST 29BDATE 06/28/73 ENGINE ENDT675 FUEL J

R.T. 1. FUEL READING FLUCTUATING.

MODE	13**	14**
BAROMETER (MMHG)	741.5	741.5
AMBIENT VP (MMHGA)	10.7	10.7
SPEED (RPM)	2100	2100
TORQUE (FT-LB)#	511	486
POWER (BHP)#	204.4	194.1
AIR FLOW (LB/HR)	2192	2029
FUEL FLOW (LB/HR)	84.6	83.1
A/F RATIO	25.9	24.4
BSFC (LB/BHP-HR)	0.414	0.428
COOLANT(1000BTU/HR)	392.0	392.5
OIL TEMP (F)	225	225
EXHAUST TEMP (F)	1083	1135
SMOKE (% OPACITY)	2.5	4.0
INTAKE REST.("H2O)*	39.8	60.1
EXHAUST REST ("H2O)	69.9	70.5
INTAKE VP(MMHGA)	9.7	9.1
INT. PRES. (MMHGA)	671.7	633.4
EXH. PRES. (MMHGA)	667.2	668.5
CO (PPM)	514	584
CO (G/HR)	512.7	540.3
CO (G/BHP-HR)	2.51	2.78
HC (PPMC)	199	169
HC (G/HR)	99.2	78.2
HC (G/BHP-HR)	0.49	0.40
NOX (PPM)	1073	1068
NOX (G/HR)	1708.6	1577.0
NOX (G/BHP-HR)	8.36	8.12
SOUND (DBA)	105.5	105.0

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

TEST 30ADATE 07/02/73 ENGINE ENDT675 FUEL J

RT. 1. MODE 10 IS REPEAT OF 9 2: MODE 9 IS VALID EXCEPT INTAKE DELTA P IS HIGH. 3:

MODE	1**	2**	3**	4**	5**	6**	7**	8	9**	10**	11**N	12**
BAROMETER (MMHG)	744.5	744.5	744.5	744.5	744.5	744.5	744.5	744.0	744.0	744.0	744.0	744.0
AMBIENT VP (MMHGA)	19.4	19.4	19.4	19.4	19.4	19.4	19.4	22.2	22.2	22.2	22.2	22.2
SPEED (RPM)	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
TORQUE (FT-LB)#	609	601	593	581	605	597	590	559	610	611	601	591
POWER (BHP)#	208.9	206.1	203.1	199.0	207.2	204.7	202.2	191.7	209.0	209.3	206.1	202.5
AIR FLOW (LB/HR)	2207	2071	1924	1804	2124	1983	1876	1686	2030	2069	1927	1796
FUEL FLOW (LB/HR)	81.0	81.2	81.1	80.7	80.6	81.1	81.2	78.3	81.3	81.1	81.3	81.3
A/F RATIO	27.3	25.5	23.7	22.4	26.4	24.5	23.1	21.5	25.0	25.5	23.7	22.1
BSFC (LB/BHP-HR)	0.388	0.394	0.399	0.405	0.389	0.396	0.402	0.408	0.389	0.387	0.394	0.401
COOLANT(1000BTU/HR)	354.6	371.4	369.2	382.2	358.6	364.8	373.7	371.6	359.8	360.3	366.5	381.5
OIL TEMP (F)	222	223	223	224	223	224	223	222	222	221	222	225
EXHAUST TEMP (F)	967	1018	1073	1140	1000	1055	1116	1169	1049	1037	1097	1156
SMOKE (% OPACITY)	1.5	3.0	3.5	5.0	2.0	3.5	5.0	7.0	2.5	2.0	3.5	5.0
INTAKE REST.("H20)*	23.0	43.0	60.5	80.4	22.9	42.4	60.5	80.0	24.6	20.1	40.0	60.0
EXHAUST REST ("H20)	31.4	30.7	30.7	31.4	50.4	50.4	50.4	50.1	70.5	70.5	71.2	70.5
INTAKE VP(MMHGA)	18.6	17.6	16.7	15.7	18.6	17.6	16.7	18.1	21.3	21.5	20.4	19.2
INT. PRES. (MMHGA)	712.1	673.8	640.2	601.8	712.3	674.9	640.2	605.1	711.8	720.6	682.1	643.5
EXH. PRES. (MMHGA)	795.3	794.0	794.0	795.3	830.9	830.9	830.9	830.4	868.5	868.5	869.7	868.5
CO (PPM)	322	490	694	814	377	569	735	1045	499	453	592	813
CO (G/HR)	322.3	462.4	609.8	672.0	364.1	514.9	630.6	807.5	461.2	426.3	521.3	668.9
CO (G/BHP-HR)	1.54	2.24	3.00	3.38	1.76	2.52	3.12	4.21	2.21	2.04	2.53	3.30
HC (PPMC)	286	232	202	145	284	240	200	153	261	265	232	178
HC (G/HR)	143.3	109.4	88.7	59.8	137.1	108.5	85.7	59.1	120.7	124.8	102.0	73.2
HC (G/BHP-HR)	0.69	0.53	0.44	0.30	0.66	0.53	0.42	0.31	0.58	0.60	0.50	0.36
NOX (PPM)	1147	1290	1317	1355	1236	1297	1314	1361	1311	1302	1328	1353
NOX (G/HR)	2106.9	2229.2	2119.4	2049.2	2187.8	2149.9	2063.7	2024.5	2335.0	2362.4	2249.4	2143.7
NOX (G/BHP-HR)	10.09	10.82	10.43	10.30	10.56	10.50	10.21	10.56	11.17	11.29	10.91	10.58
SOUND (DBA)	103.5	103.5	103.5	102.8	103.5	102.5	102.8	103.5	103.5	103.5	103.0	102.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

TEST 30 DATE 07/02/73 ENGINE ENDT675 FUEL J

MODE	13**
BAROMETER (MMHG)	744.0
AMBIENT VP (MMHGA)	22.2
SPEED (RPM)	2100
TORQUE (FT-LB)#	499
POWER (BHP)#	199.5
AIR FLOW (LB/HR)	2024
FUEL FLOW (LB/HR)	86.8
A/F RATIO	23.3
BSFC (LB/BHP-HR)	0.435
COOLANT(1000BTU/HR)	413.7
OIL TEMP (F)	228
EXHAUST TEMP (F)	1160
SMOKE (% OPACITY)	5.5
INTAKE REST.("H2O)*	80.0
EXHAUST REST ("H2O)	30.4
INTAKE VP(MMHGA)	18.1
INT. PRES. (MMHGA)	605.1
EXH. PRES. (MMHGA)	793.5
CO (PPM)	736
CO (G/HR)	680.4
CO (G/BHP-HR)	3.41
HC (PPMC)	145
HC (G/HR)	67.0
HC (G/BHP-HR)	0.34
NOX (PPM)	1120
NOX (G/HR)	1993.7
NOX (G/BHP-HR)	9.99
SOUND (DBA)	104.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

TEST 31ADATE 07/03/73 ENGINE ENDT675 FUEL J

MODE	1**	2**	3**	4	5**	6**	7	8**	9**	10	11
BAROMETER (MMHG)	746.0	746.0	746.0	746.0	746.0	746.0	746.0	746.0	746.0	746.0	746.0
AMBIENT VP (MMHGA)	18.1	18.1	18.1	18.1	18.1	18.1	18.1	18.1	18.1	18.1	18.1
SPEED (RPM)	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
TORQUE (FT-LB)#	734	711	693	530	712	694	475	700	680	545	436
POWER (BHP)#	209.6	203.0	197.8	151.4	203.2	198.3	135.6	199.9	194.2	155.5	124.6
AIR FLOW (LB/HR)	1815	1674	1557	1219	1731	1607	1110	1665	1553	1263	1031
FUEL FLOW (LB/HR)	77.3	77.2	77.3	64.2	76.4	76.4	56.3	76.3	76.4	63.4	52.9
A/F RATIO	23.5	21.7	20.2	19.0	22.7	21.0	19.7	21.8	20.3	19.9	19.5
BSFC (LB/BHP-HR)	0.369	0.380	0.391	0.424	0.376	0.385	0.415	0.381	0.393	0.408	0.424
COOLANT(1000BTU/HR)	349.0	350.1	354.1	310.7	334.5	347.2	286.4	338.1	352.2	311.2	278.8
OIL TEMP (F)	219	221	221	217	219	220	216	219	220	217	214
EXHAUST TEMP (F)	1044	1112	1176	1162	1080	1145	1133	1116	1180	1159	1135
SMOKE (% OPACITY)	3.5	5.0	8.5	10.5	4.0	6.5	10.5	5.0	7.5	9.5	10.5
INTAKE REST.("H20)*	20.3	42.7	62.5	82.2	20.3	42.7	82.2	20.3	42.7	62.5	82.2
EXHAUST REST ("H20)	30.8	30.8	30.8	30.8	50.5	51.2	51.2	70.2	70.2	70.2	70.2
INTAKE VP(MMHGA)	17.4	16.4	15.4	14.5	17.4	16.4	14.5	17.4	16.4	15.4	14.5
INT. PRES. (MMHGA)	716.1	673.0	635.1	597.3	716.1	673.0	597.3	716.1	673.0	635.1	597.3
EXH. PRES. (MMHGA)	794.3	794.3	794.3	794.3	831.1	832.4	832.4	867.9	867.9	867.9	867.9
CO (PPM)	567	880	1384	1769	697	1128	1799	812	1276	1601	1842
CO (G/HR)	470.3	674.9	990.8	994.1	551.6	832.4	918.9	619.5	910.7	930.1	874.7
CO (G/BHP-HR)	2.24	3.32	5.01	6.57	2.71	4.20	6.78	3.10	4.69	5.98	7.02
HC (PPMC)	199	190	148	203	241	138	189	175	127	168	204
HC (G/HR)	82.5	72.9	53.0	57.0	95.4	50.9	48.3	66.7	45.3	48.8	48.4
HC (G/BHP-HR)	0.39	0.36	0.27	0.38	0.47	0.26	0.36	0.33	0.23	0.31	0.39
NOX (PPM)	1601	1634	1644	1582	1596	1629	1629	1579	1600	1529	1346
NOX (G/HR)	2378.1	2246.3	2109.1	1592.7	2263.8	2152.8	1490.9	2157.9	2046.8	1591.6	1145.6
NOX (G/BHP-HR)	11.35	11.07	10.66	10.52	11.14	10.85	11.00	10.79	10.54	10.23	9.19
SOUND (DBA)	102.5	102.5	102.2	100.6	103.0	101.8	100.8	102.0	101.5	100.5	101.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

TEST 31B DATE 07/03/73 ENGINE ENDT675 FUEL J

MODE	12**	13
BAROMETER (MMHG)	746.0	746.0
AMBIENT VP (MMHGA)	18.1	18.1
SPEED (RPM)	2100	2100
TORQUE (FT-LB)#	493	475
POWER (BHP)#	197.3	189.9
AIR FLOW (LB/HR)	1988	1931
FUEL FLOW (LB/HR)	84.3	82.7
A/F RATIO	23.6	23.4
BSFC (LB/BHP-HR)	0.427	0.435
COOLANT(1000BTU/HR)	391.4	403.4
OIL TEMP (F)	227	227
EXHAUST TEMP (F)	1153	1162
SMOKE (% OPACITY)	5.0	6.0
INTAKE REST.("H2O)*	82.2	82.2
EXHAUST REST ("H2O)	30.8	51.2
INTAKE VP(MMHGA)	14.5	14.5
INT. PRES. (MMHGA)	597.3	597.3
EXH. PRES. (MMHGA)	794.3	832.4
CO (PPM)	674	683
CO (G/HR)	611.6	602.7
CO (G/BHP-HR)	3.10	3.17
HC (PPMC)	142	138
HC (G/HR)	64.5	60.9
HC (G/BHP-HR)	0.33	0.32
NOX (PPM)	1110	1029
NOX (G/HR)	1806.0	1626.3
NOX (G/BHP-HR)	9.15	8.56
SOUND (DBA)	104.5	104.0

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

TEST 32 DATE 07/05/73 ENGINE ENDT675 FUEL J

MIKE HELD SOLID

MODE	1**	2**	3**	4**	5**	6**	7**	8	9**	10**	11**	12
BAROMETER (MMHG)	741.0	741.0	741.0	741.0	741.0	742.5	742.5	742.5	742.5	741.5	741.5	741.5
AMBIENT VP (MMHGA)	18.8	18.8	18.8	18.8	18.8	15.3	15.3	15.3	15.3	16.4	16.4	16.4
SPEED (RPM)	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
TORQUE (FT-LB)#	618	605	598	591	618	606	597	554	617	613	598	491
POWER (BHP)#	211.9	207.3	204.8	202.4	211.9	207.8	204.6	189.8	211.3	210.2	204.8	168.1
AIR FLOW (LB/HR)	2247	2082	1948	1806	2144	1998	1859	1660	2063	1919	1774	1477
FUEL FLOW (LB/HR)	81.4	80.2	81.0	81.8	82.0	81.7	81.8	77.6	81.6	82.0	81.6	69.8
A/F RATIO	27.6	26.0	24.0	22.1	26.1	24.5	22.7	21.4	25.3	23.4	21.7	21.2
BSFC (LB/BHP-HR)	0.384	0.387	0.395	0.404	0.387	0.393	0.400	0.409	0.386	0.390	0.399	0.415
COOLANT(1000BTU/HR)	359.8	357.2	369.3	379.4	363.8	375.9	378.2	364.3	367.7	373.6	380.9	340.3
OIL TEMP (F)	220	221	222	222	221	221	222	221	222	221	223	220
EXHAUST TEMP (F)	951	1004	1059	1136	990	1050	1114	1161	1029	1101	1170	1170
SMOKE (% OPACITY)	1.5	2.0	3.0	4.5	1.5	3.0	4.0	5.5	2.0	3.5	5.0	8.5
INTAKE REST.("H20)*	20.1	40.3	60.1	80.3	20.1	40.3	60.3	80.3	20.2	40.3	60.0	79.9
EXHAUST REST ("H20)	30.9	30.9	30.9	30.9	50.6	50.7	50.7	50.7	71.1	70.5	70.5	70.5
INTAKE VP(MMHGA)	18.2	17.2	16.2	15.2	18.2	13.9	13.1	12.3	14.7	14.9	14.1	13.2
INT. PRES. (MMHGA)	717.2	678.3	640.4	601.6	717.2	675.1	636.8	598.6	713.5	676.2	638.4	600.3
EXH. PRES. (MMHGA)	794.3	794.3	794.3	794.3	831.2	831.4	831.4	831.4	869.5	868.5	868.5	868.5
CO (PPM)	275	399	618	836	350	517	712	849	443	714	1090	1281
CO (G/HR)	280.1	377.7	549.3	691.2	341.3	471.0	605.5	646.4	416.1	626.0	885.8	868.2
CO (G/BHP-HR)	1.32	1.82	2.68	3.41	1.61	2.27	2.96	3.41	1.97	2.98	4.33	5.16
HC (PPMC)	248	286	225	175	286	225	189	139	247	179	136	159
HC (G/HR)	126.5	135.4	100.0	72.3	139.4	102.5	80.3	52.9	116.0	78.4	55.3	53.9
HC (G/BHP-HR)	0.60	0.65	0.49	0.36	0.66	0.49	0.39	0.28	0.55	0.37	0.27	0.32
NOX (PPM)	1299	1338	1375	1421	1316	1343	1368	1337	1278	1372	1362	1212
NOX (G/HR)	2403.6	2300.4	2218.2	2133.2	2328.4	2095.1	1990.5	1741.7	2055.3	2095.5	1929.7	1430.8
NOX (G/BHP-HR)	11.35	11.10	10.83	10.54	10.99	10.08	9.73	9.18	9.73	9.97	9.42	8.51
SOUND (DBA)	103.5	103.5	103.5	103.8	104.3	104.0	103.3	102.5	103.3	103.0	102.8	102.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

Test No. 33 -- Mack ENDT 675 -- 7/9/73

	Turbine in turbocharger	Turbine removed from turbocharger
Speed, RPM.....	2100	2100
Torque.....	300	298
Exhaust, °F.....	1016	1153
Fuel, lb/hr.....	57.5	58.4
dBA[1/].....	109.0	123.5

1/ Exhaust pipe disconnected at location shown on figure 2 and microphone placed 3 feet from exhaust discharge. Bureau of Mines No. AR M71901 shows setup with microphone one foot from pipe.

TEST 34 DATE 07/16/73 ENGINE ENDT675 FUEL J

R.T. & G.G.

MODE	1**	2**	3**	4	5**	6**	7	8	9**	10**	11	12
BAROMETER (MMHG)	743.6	743.6	743.6	743.6	743.6	743.6	743.0	743.0	743.0	743.0	743.0	743.0
AMBIENT VP (MMHGA)	15.8	15.8	15.8	15.8	15.8	15.8	13.3	13.3	13.3	13.3	13.3	13.3
SPEED (RPM)	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
TORQUE (FT-LB)#	725	709	690	549	710	694	630	479	698	673	551	438
POWER (BHP)#	207.0	202.4	196.9	156.8	202.9	198.3	179.8	136.8	199.3	192.1	157.2	125.1
AIR FLOW (LB/HR)	1799	1669	1555	1245	1714	1605	1413	1124	1648	1529	1252	1048
FUEL FLOW (LB/HR)	77.1	77.1	77.6	64.3	76.5	76.7	71.5	56.6	76.4	76.4	63.8	53.5
A/F RATIO	23.3	21.6	20.0	19.4	22.4	20.9	19.8	19.9	21.6	20.0	19.6	19.6
BSFC (LB/BHP-HR)	0.372	0.381	0.394	0.410	0.377	0.387	0.398	0.414	0.383	0.398	0.406	0.428
COOLANT(1000BTU/HR)	336.5	350.2	347.9	307.5	333.9	340.9	336.7	282.8	336.5	342.7	312.4	278.6
OIL TEMP (F)	218	218	218	215	217	218	218	215	217	218	215	213
EXHAUST TEMP (F)	1044	1107	1163	1160	1074	1140	1175	1139	1118	1175	1153	1135
SMOKE (% OPACITY)	3.5	5.0	7.5	9.0	4.0	5.5	8.0	9.5	4.5	8.0	8.0	10.0
INTAKE REST.("H2O)*	20.3	40.5	60.0	79.9	20.4	40.4	59.7	79.8	20.0	40.5	59.7	80.5
EXHAUST REST ("H2O)	30.9	30.9	30.9	30.9	50.6	50.6	50.6	49.9	70.7	70.7	70.0	70.7
INTAKE VP(MMHGA)	15.2	14.3	13.6	12.8	15.2	14.4	11.3	10.7	12.7	12.0	11.3	10.6
INT. PRES. (MMHGA)	713.9	675.1	637.9	599.9	713.7	675.3	636.2	598.0	711.9	672.8	636.2	596.7
EXH. PRES. (MMHGA)	794.4	794.4	794.4	794.4	831.2	831.2	831.1	829.9	868.7	868.7	867.5	868.7
CO (PPM)	632	1025	1404	1685	707	1150	1446	1734	1024	1317	1489	1798
CO (G/HR)	519.4	783.6	1004.2	966.8	554.2	846.8	940.6	896.6	774.0	926.2	858.3	867.4
CO (G/BHP-HR)	2.51	3.87	5.10	6.17	2.73	4.27	5.23	6.56	3.88	4.82	5.46	6.93
HC (PPMC)	230	180	134	159	198	180	127	95	185	116	202	241
HC (G/HR)	94.5	68.8	47.9	45.6	77.6	66.3	41.3	24.6	69.9	40.8	58.2	58.1
HC (G/BHP-HR)	0.46	0.34	0.24	0.29	0.38	0.33	0.23	0.18	0.35	0.21	0.37	0.46
NOX (PPM)	1897	1929	1913	1816	1867	1899	1865	1888	1883	1845	1796	1594
NOX (G/HR)	2691.6	2545.6	2360.9	1798.3	2526.8	2414.7	2011.8	1619.7	2359.4	2152.5	1717.1	1275.5
NOX (G/BHP-HR)	13.00	12.58	11.99	11.47	12.45	12.18	11.19	11.84	11.84	11.21	10.92	10.20
SOUND (DBA)	102.9	102.5	102.0	101.2	102.2	102.0	101.0	99.8	102.0	101.5	98.9	100.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

TEST 35 DATE 07/17/73 ENGINE ENDT675 FUEL J

R.T.

MODE	1**	2**	3**	4**	5**	6**	7**	8	9**	10**	11**	12
BAROMETER (MMHG)	744.0	744.0	744.0	744.0	744.0	744.0	744.0	744.0	744.0	744.0	744.0	744.0
AMBIENT VP (MMHGA)	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
SPEED (RPM)	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
TORQUE (FT-LB)#	620	608	600	588	616	607	599	581	616	603	595	511
POWER (BHP)#	212.3	208.3	205.6	201.5	211.3	208.1	205.1	199.2	211.1	206.8	203.9	175.0
AIR FLOW (LB/HR)	2256	2125	1994	1846	2198	2070	1916	1767	2115	1989	1845	1594
FUEL FLOW (LB/HR)	80.2	81.4	81.8	82.4	82.5	83.1	83.0	80.9	81.8	82.0	81.4	74.0
A/F RATIO	28.1	26.1	24.4	22.4	26.6	24.9	23.1	21.8	25.9	24.3	22.7	21.5
BSFC (LB/BHP-HR)	0.378	0.391	0.398	0.409	0.391	0.399	0.405	0.406	0.388	0.397	0.399	0.423
COOLANT(1000BTU/HR)	350.4	355.4	360.7	373.6	356.7	367.6	371.0	370.0	350.9	359.6	374.3	342.4
OIL TEMP (F)	219	220	220	221	220	220	220	221	220	221	222	220
EXHAUST TEMP (F)	945	998	1052	1119	981	1032	1090	1157	1010	1066	1130	1151
SMOKE (% OPACITY)	2.0	2.5	3.0	5.0	2.0	3.0	3.5	5.0	2.0	3.0	4.5	6.5
INTAKE REST.("H20)*	20.4	39.9	60.3	80.2	20.4	39.9	60.3	80.2	20.4	39.9	60.3	80.2
EXHAUST REST ("H20)	29.8	29.8	29.8	29.8	50.1	50.1	50.1	50.1	69.8	69.8	69.8	69.8
INTAKE VP(MMHGA)	19.4	18.4	17.3	16.3	19.4	18.4	17.3	16.3	19.4	18.4	17.3	16.3
INT. PRES. (MMHGA)	717.8	680.4	641.1	602.7	717.8	680.4	641.1	602.7	717.8	680.4	641.1	602.7
EXH. PRES. (MMHGA)	792.3	792.3	792.3	792.3	830.4	830.4	830.4	830.4	867.2	867.2	867.2	867.2
CO (PPM)	279	333	517	865	400	546	682	1004	425	584	821	1067
CO (G/HR)	285.2	322.3	470.1	731.1	399.2	515.3	597.6	812.5	409.4	529.4	692.6	779.7
CO (G/BHP-HR)	1.34	1.55	2.29	3.63	1.89	2.48	2.91	4.08	1.94	2.56	3.40	4.46
HC (PPMC)	347	349	293	143	348	309	248	171	328	282	216	200
HC (G/HR)	177.5	168.7	133.2	60.4	173.8	145.7	108.6	69.2	157.8	127.9	91.1	73.1
HC (G/BHP-HR)	0.84	0.81	0.65	0.30	0.82	0.70	0.53	0.35	0.75	0.62	0.45	0.42
NOX (PPM)	1370	1454	1446	1480	1411	1426	1493	1485	1430	1411	1459	1383
NOX (G/HR)	2599.2	2606.4	2437.8	2318.3	2612.2	2493.0	2424.9	2228.8	2552.1	2373.4	2282.5	1874.5
NOX (G/BHP-HR)	12.24	12.51	11.86	11.51	12.37	11.98	11.82	11.19	12.09	11.48	11.19	10.71
SOUND (DBA)	103.9	104.0	103.5	103.0	104.0	103.6	103.5	103.5	104.0	103.5	103.7	103.0

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

TEST 36 DATE 07/18/73 ENGINE ENDT675 FUEL J

MODE	1**	2**	3	4	5**	6**	7	8	9**	10**	11
BAROMETER (MMHG)	744.5	744.5	744.5	744.5	744.5	744.5	744.5	744.5	744.5	744.5	744.5
AMBIENT VP (MMHGA)	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
SPEED (RPM)	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
TORQUE (FT-LB)#	506	495	470	389	507	499	447	348	495	485	420
POWER (BHP)#	202.5	197.9	187.8	155.5	202.7	199.4	178.8	139.1	198.0	194.0	168.0
AIR FLOW (LB/HR)	2391	2175	1956	1607	2355	2154	1891	1475	2310	2104	1778
FUEL FLOW (LB/HR)	86.1	85.9	83.3	72.7	86.2	86.7	80.3	67.0	85.1	84.3	76.5
A/F RATIO	27.8	25.3	23.5	22.1	27.3	24.8	23.5	22.0	27.1	25.0	23.2
BSFC (LB/BHP-HR)	0.425	0.434	0.444	0.467	0.425	0.435	0.449	0.482	0.430	0.435	0.455
COOLANT(1000BTU/HR)	393.3	394.1	397.2	358.2	392.4	410.8	385.4	342.0	389.0	393.3	364.6
OIL TEMP (F)	225	226	226	223	225	226	225	222	225	226	224
EXHAUST TEMP (F)	1011	1079	1143	1175	1023	1104	1146	1171	1038	1116	1158
SMOKE (% OPACITY)	2.5	3.5	5.0	7.5	3.0	3.5	5.0	7.5	2.5	3.5	5.5
INTAKE REST.("H2O)*	20.6	40.6	60.1	80.0	20.6	40.6	60.1	80.0	20.6	40.6	60.1
EXHAUST REST ("H2O)	33.4	30.7	30.7	30.7	50.4	50.4	50.4	50.4	70.1	70.8	70.8
INTAKE VP(MMHGA)	19.4	18.3	17.3	16.3	19.4	18.3	17.3	16.3	19.4	18.3	17.3
INT. PRES. (MMHGA)	717.4	679.0	641.4	603.3	717.4	679.0	641.4	603.3	717.4	679.0	641.4
EXH. PRES. (MMHGA)	799.1	794.0	794.0	794.0	830.9	830.9	830.9	830.9	867.7	869.0	869.0
CO (PPM)	419	586	736	1027	487	630	737	1047	493	636	856
CO (G/HR)	455.3	580.3	657.9	755.8	521.4	618.4	636.0	707.4	517.1	609.4	696.0
CO (G/BHP-HR)	2.25	2.93	3.50	4.86	2.57	3.10	3.56	5.09	2.61	3.14	4.14
HC (PPMC)	211	221	156	120	262	205	178	189	237	194	193
HC (G/HR)	114.5	109.4	69.7	44.1	140.1	100.6	76.8	63.8	124.3	93.0	78.4
HC (G/BHP-HR)	0.57	0.55	0.37	0.28	0.69	0.50	0.43	0.46	0.63	0.48	0.47
NOX (PPM)	1021	1059	1052	932	1019	1080	1007	864	996	989	914
NOX (G/HR)	2053.5	1944.6	1742.0	1271.7	2020.8	1966.0	1610.9	1081.2	1936.5	1757.1	1376.6
NOX (G/BHP-HR)	10.14	9.83	9.28	8.18	9.97	9.86	9.01	7.78	9.78	9.06	8.19
SOUND (DBA)	105.5	105.2	104.9	104.5	105.4	105.0	105.0	104.0	105.6	105.2	104.8

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

**Used in regression analysis.

TEST 37 DATE 07/18/73 ENGINE ENDT675 FUEL J

MODE	1	2	3	4	5	6	7	8	9	10	11	12	13
BAROMETER (MMHG)	743.0	743.0	743.0	743.9	743.9	743.9	743.9	743.9	743.4	743.4	743.4	743.4	743.4
AMBIENT VP (MMHGA)	15.8	15.8	15.8	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9
SPEED (RPM)	650	1260	1260	1260	1260	1260	640	2100	2100	2100	2100	2100	635
TORQUE (FT-LB)#	0	10	207	414	610	823	0	503	372	249	130	6	0
POWER (BHP)#	0.0	2.4	49.7	99.4	146.3	197.5	0.0	201.2	148.9	99.5	52.1	2.4	0.0
AIR FLOW (LB/HR)	449	864	967	1097	1261	1504	454	2443	2246	2007	1813	1624	452
FUEL FLOW (LB/HR)	2.9	7.6	20.6	37.1	53.2	72.9	3.1	84.7	65.8	48.3	34.2	19.9	3.0
A/F RATIO	154.7	113.7	47.0	29.6	23.7	20.6	146.5	28.8	34.1	41.5	53.0	81.6	150.7
BSFC (LB/BHP-HR)			0.414	0.373	0.364	0.369		0.421	0.442	0.485	0.656		
COOLANT(1000BTU/HR)													
OIL TEMP (F)	186	193	199	206	211	217	190	224	220	215	211	207	188
EXHAUST TEMP (F)	241	303	537	768	955	1118	260	991	849	722	605	457	244
SMOKE (% OPACITY)	0.5	0.5	2.0	1.5	3.5	8.0	0.5	3.0	2.0	1.8	2.0	1.0	0.5
INTAKE REST.("H20)*	5.4	6.5	6.7	7.2	7.7	8.8	5.5	14.2	13.3	11.8	10.6	9.6	5.8
EXHAUST REST ("H20)	4.8	6.1	8.2	11.4	14.8	18.2	5.3	33.8	25.4	19.9	17.2	13.1	5.0
INTAKE VP(MMHGA)	15.8	15.7	15.7	16.9	16.8	16.8	16.9	16.5	16.6	16.7	16.7	16.8	16.9
INT. PRES. (MMHGA)	742.3	740.2	739.8	740.1	738.9	737.0	743.2	726.5	728.2	731.2	733.4	735.4	742.7
EXH. PRES. (MMHGA)	745.5	748.1	751.9	757.9	764.2	770.6	746.4	799.8	784.0	773.9	768.8	761.2	745.9
CO (PPM)	545	424	172	131	440	1542	607	357	199	209	250	293	535
CO (G/HR)	107.8	162.9	74.6	65.3	253.5	1065.3	121.5	395.7	201.2	188.5	202.5	210.7	106.6
CO (G/BHP-HR)			1.50	0.66	1.73	5.39		1.97	1.35	1.89	3.89		
HC (PPMC)	400	465	398	473	498	240	575	346	475	519	669	721	592
HC (G/HR)	39.6	88.7	86.1	117.4	143.3	82.9	57.6	191.5	240.5	233.6	270.7	259.5	59.0
HC (G/BHP-HR)			1.73	1.18	0.98	0.42		0.95	1.62	2.35	5.19		
NOX (PPM)	271	246	742	1189	1877	1964	261	977	706	476	298	123	266
NOX (G/HR)	92.7	161.9	554.4	1037.8	1899.0	2385.8	92.0	1901.9	1257.2	753.3	424.5	155.6	93.4
NOX (G/BHP-HR)			11.14	10.44	12.98	12.08		9.45	8.44	7.57	8.15		
SOUND (DBA)													
TC BOOST PRES (PSIG)		0.5	1.7	4.3	8.1	14.0		15.0	11.7	8.1	5.1	2.6	

*RELATIVE TO 736.6 MMHG DRY BAROMETER

#CORRECTED TO 85 F

COMPUTED 12/20/73

--13 MODE CYCLE COMPOSITE--

BSCO	(G/BHP-HR)	3.10	BSFC	(LB/BHP-HR)	0.4520
BSHC	(G/BHP-HR)	1.85	SMOKE	(% OPACITY)	2.1
BSNOX	(G/BHP-HR)	10.77	POWER	(BHP)	79.96

TEST 71 DATE 10/10/73 ENGINE GM671 FUEL J SPECIAL TEST FOR DOT PROJECT OFFICER

HINMAN, ECC MODE 1 AND 2 BLOWER SHIELDED FROM MICROPHONE

MODE	1	2	3	4
BAROMETER (MMHG)	740.2	740.2	740.2	740.2
AMBIENT VP (MMHGA)	22.2	22.2	22.2	22.2
SPEED (RPM)	2100	2100	2100	2100
TORQUE (FT-LB)#	48	532	47	533
POWER (BHP)#	19.0	212.8	18.7	213.0
AIR FLOW (LB/HR)	2749	2706	2746	2686
FUEL FLOW (LB/HR)	21.0	90.5	21.5	90.0
A/F RATIO	130.9	29.9	127.7	29.8
BSFC (LB/BHP-HR)	1.103	0.425	1.151	0.423
COOLANT(1000BTU/HR)				
OIL TEMP (F)	205	225	203	226
EXHAUST TEMP (F)	327	948	325	951
SMOKE (% OPACITY)				
INTAKE REST.("H2O)*	20.1	19.9	20.0	19.8
EXHAUST REST ("H2O)	7.4	12.1	7.4	12.1
INTAKE VP(MMHGA)	21.6	21.6	21.6	21.7
INT. PRES. (MMHGA)	720.6	720.9	720.7	721.3
EXH. PRES. (MMHGA)	750.4	759.2	750.4	759.2
CO (PPM)				
CO (G/HR)				
CO (G/BHP-HR)				
HC (PPMC)				
HC (G/HR)				
HC (G/BHP-HR)				
NOX (PPM)				
NOX (G/HR)				
NOX (G/BHP-HR)				
SOUND (DBA)	107.5	110.0	108.0	109.0
AIR BOX PRES (PSIG)	3.6	3.2	3.6	3.1

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/20/73

APPENDIX E.--CUMMINS ENGINE TEST DATA (NOT USED IN REPORT)

Data not used in report but necessary for correlation with sound level tapes.

Date	Test number	Modes	RPM	Remarks
03/16/73	4B	14-18	1700	Intake ΔP 2.9" H_2O, Exhaust ΔP 35" H_2O at 2100 RPM full load.
03/20/73	7A	1-13	620-2100	Intake ΔP 4.5" H_2O, Exhaust ΔP 90" H_2O at 2100 RPM full load.
03/20/73	7B	14-18	1700	Intake ΔP 4.5" H_2O, Exhaust ΔP 90" H_2O at 2100 RPM full load.
03/20/73	8A	1-13	600-2100	Intake ΔP 42.0" H_2O, Exhaust ΔP 30" H_2O at 2100 RPM full load.
03/20/73	8B	14-18	1700	Intake ΔP 42.0" H_2O, Exhaust ΔP 30" H_2O at 2100 RPM full load.
03/21/73	9A	1-13	625-2100	Intake ΔP 46.0" H_2O, Exhaust ΔP 85" H_2O at 2100 RPM full load.
03/21/73	9B	14-18	1700	Intake ΔP 46.0" H_2O, Exhaust ΔP 85" H_2O at 2100 RPM full load.
04/05/73	11	1-6	1400-1750	Intake ΔP 5.3" H_2O and 100.4" H_2O, Exhaust ΔP 33.2" H_2O and 22.4" H_2O at 2100 RPM full load.
04/06/73	12	7-12	1400-1750	Intake ΔP 8.7" H_2O and 101.4" H_2O, Exhaust ΔP 86.8" H_2O and 86.8" H_2O at 2100 RPM full load.
04/06/73	13	13-18	1400-2100	Intake ΔP 52.4" H_2O and 53.0" H_2O, Exhaust ΔP 27.5" H_2O and 82.5" H_2O at 2100 RPM full load.
04/09/73	14	20-30	1400-2100	See restrictions in table for modes 19, 22, 25, 28.
04/11/73	15	31-36	1400-2100	Intake ΔP 27.1" H_2O and 26.7" H_2O, Exhaust ΔP 57.1" H_2O and 86.7" H_2O at 2100 RPM full load.
04/23/73	16	1-4	2100	See table for restrictions.
04/24/73	17	5-9	2100	See table for restrictions.
04/26/73	18	10-12	2100	See table for restrictions.

TEST 4BDATE 03/16/73 ENGINE NHC-250 FUEL2J

BY RT-DL-GG

MODE	14	15	16	17	18
BAROMETER (MMHG)	746.0	746.0	746.0	746.0	746.0
AMBIENT VP (MMHGA)	5.4	5.4	5.4	5.4	5.4
SPEED (RPM)	1700	1700	1700	1700	1700
TORQUE (FT-LB)#	641	489	322	159	13
POWER (BHP)#	207.6	158.2	104.2	51.3	4.4
AIR FLOW (LB/HR)	1613	1624	1690	1687	1719
FUEL FLOW (LB/HR)	86.5	62.1	41.5	24.5	10.0
A/F RATIO	18.6	26.2	40.7	68.9	171.9
BSFC (LB/BHP-HR)	0.417	0.392	0.398	0.477	
COOLANT(1000BTU/HR)					
OIL TEMP (F)	215	220	218	212	209
EXHAUST TEMP (F)	1263	1003	712	480	298
SMOKE (% OPACITY)	8.0	2.0	1.5	1.5	1.0
INTAKE REST.("H2O)*	1.1	1.3	1.5	1.5	1.5
EXHAUST REST ("H2O)	23.4	22.7	20.6	17.9	17.9
INTAKE VP(MMHGA)	5.3	5.3	5.3	5.3	5.3
INT. PRES. (MMHGA)	739.8	739.5	739.2	739.2	739.1
EXH. PRES. (MMHGA)	780.3	779.0	775.2	770.1	770.1
CO (PPM)	2669	308	188	187	217
CO (G/HR)	1987.0	227.2	142.9	140.5	164.7
CO (G/BHP-HR)	9.57	1.44	1.37	2.74	
HC (PPMC)	42	83	79	92	242
HC (G/HR)	15.5	30.8	30.0	34.3	91.5
HC (G/BHP-HR)	0.07	0.19	0.29	0.67	
NOX (PPM)	1361	970	547	252	90
NOX (G/HR)	1501.3	1061.4	614.6	280.4	101.5
NOX (G/BHP-HR)	7.23	6.71	5.90	5.46	
SOUND (DBA)	108.5		103.5		101.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

TEST 7A DATE 03/20/73 ENGINE NHC-250 FUEL J

2100 RPM FULL LD. 6" HG BACK PR. BY LAWRENCE/TATE

MODE	1	2	3	4	5	6	7	8	9	10	11	12	13
BAROMETER (MMHG)	743.7	743.7	743.7	743.7	743.7	743.7	743.7	743.7	743.7	743.7	743.7	743.7	743.7
AMBIENT VP (MMHGA)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
SPEED (RPM)	620	1300	1300	1300	1300	1300	620	2100	2100	2100	2100	2100	620
TORQUE (FT-LB)#	0	19	156	325	485	628	0	579	435	305	152	11	0
POWER (BHP)#	0.0	4.7	38.5	80.3	120.0	155.5	0.0	231.7	174.0	121.8	60.7	4.2	0.0
AIR FLOW (LB/HR)	631	1287	1287	1279	1244	1199	631	1990	2023	1999	2076	2123	631
FUEL FLOW (LB/HR)	0.1	7.5	17.6	31.0	47.6	64.5	0.1	103.2	73.9	52.9	32.6	17.5	3.0
A/F RATIO	6314.5	171.6	73.1	41.2	26.1	18.66	314.5	19.3	27.4	37.8	63.7	121.3	210.5
BSFC (LB/BHP-HR)			0.457	0.386	0.397	0.415		0.445	0.425	0.434	0.537		
COOLANT(1000BTU/HR)													
OIL TEMP (F)	196	191	194	198	200	207	201	218	228	227	223	219	199
EXHAUST TEMP (F)	238	265	425	638	860	1175	307	1345	1018	787	560	365	197
SMOKE (% OPACITY)	0.5	1.0	1.5	1.5	2.0	4.5	0.0	15.0	4.5	3.0	2.5	1.5	1.0
INTAKE REST.("H2O)*	-0.2	1.4	1.4	1.4	1.3	1.1	-0.2	4.5	4.6	4.8	4.9	4.9	-0.2
EXHAUST REST ("H2O)	7.5	19.4	22.5	26.9	31.0	32.0	9.2	90.0	83.9	75.1	62.9	53.4	7.9
INTAKE VP(MMHGA)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.8
INT. PRES. (MMHGA)	742.9	739.9	739.9	739.9	740.1	740.3	742.8	734.0	733.7	733.3	733.2	733.1	742.9
EXH. PRES. (MMHGA)	750.7	772.9	778.8	786.9	794.5	796.4	753.9	905.0	893.6	877.0	854.2	836.4	751.3
CO (PPM)	167	225	175	151	257	2899	163	1817	365	233	230	251	165
CO (G/HR)	46.2	127.8	100.1	86.8	145.21	604.6	45.11	666.2	335.5	209.4	212.1	235.2	46.0
CO (G/BHP-HR)			2.60	1.08	1.21	10.32		7.19	1.93	1.72	3.49		
HC (PPMC)	300	196	144	110	110	40	271	46	173	133	144	416	323
HC (G/HR)	41.5	55.6	41.2	31.6	31.1	11.1	37.5	21.1	79.4	59.8	66.5	195.0	44.9
HC (G/BHP-HR)			1.07	0.39	0.26	0.07		0.09	0.46	0.49	1.10		
NOX (PPM)	84	94	265	604	1085	1551	96	1008	681	412	221	87	84
NOX (G/HR)	34.6	79.4	225.4	516.7	915.01	1279.4	39.61	378.3	932.9	552.0	304.1	121.0	34.9
NOX (G/BHP-HR)			5.85	6.43	7.62	8.23		5.95	5.36	4.53	5.01		
SOUND (DBA)		99.5		103.5		105.5		110.7	108.6	106.8	106.5	106.0	96.0

--13 MODE CYCLE COMPOSITE--**

BSCO	(G/BHP-HR)	4.88	BSFC	(LB/BHP-HR)	0.4548
BSHC	(G/BHP-HR)	0.70	SMOKE	(% OPACITY)	3.1
BSNOX	(G/BHP-HR)	6.45	POWER	(BHP)	79.32

*RELATIVE TO 736.6 MMHG DRY BAROMETER

#CORRECTED TO 85 F

COMPUTED 12/19/73

**Exhaust restriction 90.0" 2100 RPM full throttle.
Intake restriction 4.5" 2100 RPM full throttle.

TEST 7BDATE 03/20/73 ENGINE NHC-250 FUEL J

2100 RPM FULL LD. 6" HG BACK PR. BY LAWRENCE/TATE

MODE	14	15	16	17	18
BAROMETER (MMHG)	743.7	743.7	743.7	743.7	743.7
AMBIENT VP (MMHGA)	5.8	5.8	5.8	5.8	5.8
SPEED (RPM)	1700	1700	1700	1700	1700
TORQUE (FT-LB)#	629	475	315	156	12
POWER (BHP)#	203.6	153.7	101.8	50.5	4.0
AIR FLOW (LB/HR)	1594	1629	1655	1696	1709
FUEL FLOW (LB/HR)	86.9	61.8	41.9	24.5	10.9
A/F RATIO	18.3	26.4	39.5	69.2	156.8
BSFC (LB/BHP-HR)	0.427	0.402	0.411	0.485	
COOLANT(1000BTU/HR)					
OIL TEMP (F)	214	217	218	213	208
EXHAUST TEMP (F)	1304	975	732	490	311
SMOKE (% OPACITY)	1.0	2.5	2.0	2.0	1.5
INTAKE REST.("H2O)*	1.7	2.7	2.8	2.9	2.9
EXHAUST REST ("H2O)	63.6	58.1	50.0	43.2	37.1
INTAKE VP(MMHGA)	5.8	5.8	5.8	5.8	5.8
INT. PRES. (MMHGA)	739.3	737.3	737.2	737.0	736.9
EXH. PRES. (MMHGA)	855.5	845.3	830.1	817.4	805.9
CO (PPM)	2390	286	192	200	239
CO (G/HR)	1760.2	212.1	142.6	150.8	180.0
CO (G/BHP-HR)	8.64	1.38	1.40	2.98	
HC (PPMC)	115	127	98	87	260
HC (G/HR)	42.3	47.0	36.4	32.8	97.9
HC (G/BHP-HR)	0.21	0.31	0.36	0.65	
NOX (PPM)	1270	878	508	238	89
NOX (G/HR)	1394.0	969.0	562.9	267.3	99.8
NOX (G/BHP-HR)	6.84	6.31	5.53	5.29	
SOUND (DBA)	108.5	105.5	104.5	103.6	103.6

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

TEST 8ADATE 03/20/73 ENGINE NHC-250 FUEL J

INLET RESTRICTED TO 48 H2O AT 2100 F.L. BY TATE/LAWRENCE

MODE	1	2	3	4	5	6	7	8	9	10	11	12	13
BAROMETER (MMHG)	745.4	745.4	745.4	745.4	745.4	745.4	745.4	745.4	745.4	745.4	745.4	745.4	745.4
AMBIENT VP (MMHGA)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
SPEED (RPM)	600	1300	1300	1300	1300	1300	650	2100	2100	2100	2100	2100	660
TORQUE (FT-LB)#	0	14	160	317	473	625	0	552	414	277	140	15	0
POWER (BHP)#	0.0	3.4	39.6	78.4	117.0	154.7	0.0	220.8	165.7	111.0	56.1	5.8	0.0
AIR FLOW (LB/HR)	625	1178	1177	1187	1177	1122	589	1715	1738	1750	1802	1812	625
FUEL FLOW (LB/HR)	0.1	8.0	17.7	31.0	46.0	66.0	0.1	103.0	71.2	50.1	30.8	16.4	0.1
A/F RATIO	6254.6	147.3	66.5	38.3	25.6	17.05891.3		16.6	24.4	34.9	58.5	110.56254.6	
BSFC (LB/BHP-HR)			0.447	0.395	0.393	0.427		0.466	0.430	0.452	0.549		
COOLANT(1000BTU/HR)													
OIL TEMP (F)	194	189	193	195	197	204	201	213	231	230	227	221	212
EXHAUST TEMP (F)	327	280	442	658	857	1210	346	1475	1111	820	630	405	235
SMOKE (% OPACITY)	0.5	0.5	1.5	2.0	2.5	8.5	0.5	21.0	6.0	3.5	2.0	1.0	0.5
INTAKE REST.("H2O)*	2.2	17.5	17.5	17.1	17.5	15.6	2.6	42.4	44.1	46.3	46.6	47.9	3.1
EXHAUST REST ("H2O)	7.4	10.8	10.8	12.2	14.2	14.2	7.4	30.5	28.5	25.8	22.4	19.0	6.7
INTAKE VP(MMHGA)	4.9	4.7	4.7	4.7	4.7	4.8	4.9	4.4	4.4	4.4	4.4	4.3	4.9
INT. PRES. (MMHGA)	737.4	708.5	708.5	709.3	708.5	712.1	736.6	661.8	658.4	654.3	653.7	651.3	735.7
EXH. PRES. (MMHGA)	750.5	756.8	756.8	759.4	763.2	763.2	750.5	793.7	789.8	784.8	778.4	772.1	749.2
CO (PPM)	146	221	171	154	260	3829	154	725	650	271	268	317	154
CO (G/HR)	40.0	114.8	89.3	82.5	139.31992.3		39.7	577.4	515.2	213.4	215.6	254.1	42.2
CO (G/BHP-HR)			2.25	1.05	1.19	12.88		2.61	3.11	1.92	3.84		
HC (PPMC)	228	265	116	111	111	64	249	79	127	127	153	503	286
HC (G/HR)	31.2	68.8	30.3	29.6	29.7	16.6	32.1	31.5	50.3	50.1	61.4	201.4	39.2
HC (G/BHP-HR)			0.77	0.38	0.25	0.11		0.14	0.30	0.45	1.09		
NOX (PPM)	98	99	291	616	1037	1456	96	968	689	429	241	103	85
NOX (G/HR)	39.6	75.5	224.4	484.4	818.61116.0		36.51135.7		804.1	498.5	285.7	121.7	34.3
NOX (G/BHP-HR)			5.66	6.18	7.00	7.21		5.14	4.85	4.49	5.09		
SOUND (DBA)	94.0	99.5	101.7	102.0	104.5	106.5	96.5	110.3	108.0	106.5	105.8	107.3	97.0

--13 MODE CYCLE COMPOSITE--**

BSCO	(G/BHP-HR)	4.51	BSFC	(LB/BHP-HR)	0.4625
BSHC	(G/BHP-HR)	0.69	SMOKE	(% OPACITY)	4.0
BSNOX	(G/BHP-HR)	5.94	POWER	(BHP)	76.19

*RELATIVE TO 736.6 MMHG DRY BAROMETER

#CORRECTED TO 85 F

COMPUTED 12/19/73

**Exhaust restriction 30.5" at 2100 RPM full throttle.
Intake restriction 42.4" at 2100 RPM full throttle.

TEST 8BDATE 03/20/73 ENGINE NHC-250 FUEL J

INLET RESTRICTED TO 48 H2O AT 2100 F.L. BY TATE/LAWRENCE

MODE	14	15	16	17	18
BAROMETER (MMHG)	745.4	745.4	745.4	745.4	745.4
AMBIENT VP (MMHGA)	5.0	5.0	5.0	5.0	5.0
SPEED (RPM)	1700	1700	1700	1700	1700
TORQUE (FT-LB)#	610	454	304	151	12
POWER (BHP)#	197.3	147.1	98.3	49.0	3.8
AIR FLOW (LB/HR)	1436	1457	1485	1506	1508
FUEL FLOW (LB/HR)	86.9	59.7	40.5	22.2	10.4
A/F RATIO	16.5	24.4	36.7	67.9	145.0
BSFC (LB/BHP-HR)	0.440	0.406	0.412	0.453	
COOLANT(1000BTU/HR)					
OIL TEMP (F)	218	226	220	218	213
EXHAUST TEMP (F)	1430	1020	765	550	340
SMOKE (% OPACITY)	13.0	3.0	2.5	1.5	0.5
INTAKE REST.("H2O)*	28.1	29.7	31.3	31.7	32.4
EXHAUST REST ("H2O)	21.7	22.4	20.3	16.9	14.9
INTAKE VP(MMHGA)	4.6	4.6	4.6	4.5	4.5
INT. PRES. (MMHGA)	688.7	685.5	682.5	681.8	680.5
EXH. PRES. (MMHGA)	777.1	778.4	774.6	768.3	764.4
CO (PPM)	909	387	212	209	265
CO (G/HR)	606.3	257.4	141.5	139.7	176.4
CO (G/BHP-HR)	3.07	1.75	1.44	2.85	
HC (PPMC)	58	95	106	127	355
HC (G/HR)	19.3	31.6	35.4	42.5	118.0
HC (G/BHP-HR)	0.10	0.21	0.36	0.87	
NOX (PPM)	1176	854	525	262	103
NOX (G/HR)	1156.0	835.8	516.6	258.5	100.5
NOX (G/BHP-HR)	5.86	5.68	5.26	5.28	
SOUND (DBA)	107.5	105.5	104.5	102.6	102.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

TEST 9ADATE 03/21/73 ENGINE NHC-250 FUEL J

INLET PRESSURE DRIFTED AND WAS RESET AT MODES 8,10,11 SMOKE METER
RE CAL. AT MODE 13 FINAL PRESS. CK. INLET=46.0 H2O, EXH=5.2 HG G
BY BHE/DL/RT/DH

MODE	1	2	3	4	5	6	7	8	9	10	11	12	13
BAROMETER (MMHG)	740.0	740.0	740.0	740.0	740.0	740.0	740.0	740.0	740.0	740.0	740.0	740.0	740.0
AMBIENT VP (MMHGA)	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
SPEED (RPM)	635	1300	1300	1300	1300	1300	625	2100	2100	2100	2100	2100	635
TORQUE (FT-LB)#	0	23	158	304	473	608	0	529	396	259	131	6	0
POWER (BHP)#	0.0	5.7	39.0	75.2	117.1	150.4	0.0	211.5	158.3	103.7	52.2	2.3	0.0
AIR FLOW (LB/HR)	589	1158	1157	1138	1297	1078	588	1671	1701	1701	1714	1750	567
FUEL FLOW (LB/HR)	0.1	7.5	18.1	30.5	48.2	66.0	0.1	105.1	71.0	49.6	30.9	16.5	0.1
A/F RATIO	5886.8	154.3	63.9	37.3	26.9	16.35	875.5	15.9	24.0	34.3	55.5	106.0	5672.6
BSFC (LB/BHP-HR)			0.464	0.406	0.412	0.439		0.497	0.449	0.478	0.592		
CCOLANT(1000BTU/HR)		49.4	88.0	136.2	204.2	309.7		379.3	293.0	207.8	158.9	122.2	
OIL TEMP (F)	200	188	193	196	200	206	204	230	224	217	220	219	208
EXHAUST TEMP (F)	262	289	456	652	908	1288	261	1550	1115	848	620	427	230
SMOKE (% OPACITY)	0.5	0.5	1.5	1.5	2.5	9.5	0.5	27.5	6.5	3.0	1.5	0.5	0.5
INTAKE REST.("H2O)*	6.5	23.0	22.6	22.2	21.1	20.0	6.6	46.2	48.6	51.4	50.3	51.0	6.3
EXHAUST REST ("H2O)	7.3	18.1	21.5	24.2	30.3	31.0	8.6	84.7	75.8	65.7	58.9	47.3	6.6
INTAKE VP(MMHGA)	6.2	6.0	6.0	6.0	6.0	6.0	6.2	5.6	5.5	5.5	5.5	5.5	6.2
INT. PRES. (MMHGA)	730.6	699.6	700.3	701.1	703.1	705.2	730.5	655.8	651.1	645.9	647.9	646.6	731.0
EXH. PRES. (MMHGA)	750.2	770.5	776.8	781.9	793.3	794.6	752.7	894.9	878.4	859.4	846.7	825.1	748.9
CO (PPM)	163	243	187	167	368	2943	167	802	643	300	281	336	146
CO (G/HR)	42.0	123.9	96.2	85.2	217.2	1475.8	43.0	623.7	499.4	230.3	214.5	259.6	36.3
CO (G/BHP-HR)			2.46	1.13	1.85	9.81		2.95	3.16	2.22	4.11		
HC (PPMC)	237	259	121	111	106	37	237	90	121	164	148	470	285
HC (G/HR)	30.6	66.1	31.1	28.4	31.2	9.3	30.5	35.0	46.9	62.9	56.6	181.8	35.4
HC (G/BHP-HR)			0.80	0.38	0.27	0.06		0.17	0.30	0.61	1.08		
NOX (PPM)	99	108	305	620	1100	1394	106	962	701	419	246	104	90
NOX (G/HR)	38.3	82.4	235.7	476.1	972.8	1048.6	40.9	1122.7	816.7	482.2	282.1	120.8	33.6
NOX (G/BHP-HR)			6.04	6.33	8.31	6.97		5.31	5.16	4.65	5.40		
SOUND (DBA)	95.5	100.0	102.5	104.0	104.8	106.5	95.5	111.7	107.0	106.5	105.3	106.0	96.5

--13 MODE CYCLE COMPOSITE--**

BSCO	(G/BHP-HR)	4.29	BSFC	(LB/BHP-HR) 0.4845
BSHC	(G/BHP-HR)	0.69	SMOKE	(% OPACITY) 4.5
BSNOX	(G/BHP-HR)	6.26	POWER	(BHP) 73.25

*RELATIVE TO 736.6 MMHG DRY BAROMETER

#CORRECTED TO 85 F
COMPUTED 12/19/73

**Exhaust restriction 84.7" at 2100 RPM full throttle.
Intake restriction 46.2" at 2100 RPM full throttle.

TEST 9BDATE 03/21/73 ENGINE NHC-250 FUEL J

INLET PRESSURE DRIFTED AND WAS RESET AT MODES 8,10,11 SMOKE METER RE CAL. AT MODE 13 FINAL PRESS. CK. INLET=46.0 H2O, EXH=5.2 HG G BY BHE/DL/RT/DH

MODE	14	15	16	17	18
BAROMETER (MMHG)	740.0	740.0	740.0	740.0	740.0
AMBIENT VP (MMHGA)	6.3	6.3	6.3	6.3	6.3
SPEED (RPM)	1700	1700	1700	1700	1700
TORQUE (FT-LB)#	591	451	294	144	6
POWER (BHP)#	191.2	146.0	95.1	46.7	1.9
AIR FLOW (LB/HR)	1404	1416	1433	1461	1475
FUEL FLOW (LB/HR)	88.0	59.4	39.5	22.3	10.7
A/F RATIO	16.0	23.8	36.3	65.5	137.9
BSFC (LB/BHP-HR)	0.460	0.407	0.415	0.478	
COOLANT(1000BTU/HR)	371.5	263.9	143.2	135.1	61.3
OIL TEMP (F)	226	225	220	216	210
EXHAUST TEMP (F)	1477	1036	775	542	341
SMOKE (% OPACITY)	16.0	3.0	1.5	1.5	0.5
INTAKE REST.("H2O)*	31.0	32.4	33.6	34.7	35.3
EXHAUST REST ("H2O)	62.9	54.8	47.3	41.2	33.1
INTAKE VP(MMHGA)	5.8	5.8	5.8	5.8	5.8
INT. PRES. (MMHGA)	684.4	681.8	679.5	677.5	676.4
EXH. PRES. (MMHGA)	854.3	839.1	825.1	813.7	798.4
CO (PPM)	520	436	203	208	274
CO (G/HR)	339.5	281.9	131.0	135.4	178.3
CO (G/BHP-HR)	1.78	1.93	1.38	2.90	
HC (PPMC)	53	90	95	106	364
HC (G/HR)	17.3	29.1	30.6	34.4	118.4
HC (G/BHP-HR)	0.09	0.20	0.32	0.74	
NOX (PPM)	1159	802	487	271	108
NOX (G/HR)	1136.6	777.7	470.9	264.7	105.9
NOX (G/BHP-HR)	5.94	5.33	4.95	5.67	
SOUND (DBA)	109.0	105.5	104.5	104.0	103.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

TEST 11 DATE 04/05/73 ENGINE NHC-250 FUEL J

DL/RT/GG ALL TESTS FULL RACK. RESTRICTIONS ARE SET AT 2100 AND NOT CHANGED FOR LOWER SPEEDS. MODES 4 & 5 - SMOKE & CC OFF SCALE (SMOKE >50% CO> 1%)

MODE	3	2	1	6	5	4
BAROMETER (MMHG)	745.4	745.4	745.4	745.4	745.4	745.4
AMBIENT VP (MMHGA)	2.9	2.9	2.9	2.9	2.9	2.9
SPEED (RPM)	1400	1750	2100	1400	1750	2100
TORQUE (FT-LB)#	646	640	599	559	516	455
POWER (BHP)#	172.3	213.1	239.3	148.9	171.8	181.8
AIR FLOW (LB/HR)	1248	1599	1936	1000	1185	1328
FUEL FLOW (LB/HR)	69.4	88.0	101.0	71.2	88.9	102.0
A/F RATIO	18.0	18.2	19.2	14.1	13.3	13.0
BSFC (LB/BHP-HR)	0.403	0.413	0.422	0.478	0.518	0.561
COOLANT(1000BTU/HR)	338.6	382.3	408.5	365.6	411.0	444.3
OIL TEMP (F)	224	233	239	227	235	241
EXHAUST TEMP (F)	1237	1311	1331	1460	1490	1560
SMOKE (% OPACITY)	4.0	5.0	8.0	24.0		
INTAKE REST.("H2O)*	0.4	2.6	5.3	51.0	76.7	100.4
EXHAUST REST ("H2O)	17.6	24.4	33.2	15.6	19.6	22.4
INTAKE VP(MMHGA)	2.9	2.9	2.9	2.5	2.3	2.2
INT. PRES. (MMHGA)	738.8	734.5	729.5	643.6	595.3	550.8
EXH. PRES. (MMHGA)	769.5	782.2	798.7	765.7	773.3	778.4
CO (PPM)	3168	2274	1950	6767		
CO (G/HR)	1828.9	1680.8	1740.5	3176.7		
CO (G/BHP-HR)	10.61	7.89	7.27	21.33		
HC (PPMC)	12	7	9	33	116	180
HC (G/HR)	3.6	2.5	4.0	7.7	32.4	56.4
HC (G/BHP-HR)	0.02	0.01	0.02	0.05	0.19	0.31
NOX (PPM)	1745	1446	1254	1295	1020	910
NOX (G/HR)	1444.8	1533.3	1605.4	872.0	816.4	817.8
NOX (G/BHP-HR)	8.39	7.20	6.71	5.86	4.75	4.50
SOUND (DBA)	107.0	109.0	110.7	109.0	111.2	113.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

TEST 12 DATE 04/06/73 ENGINE NHC-250 FUEL J

MODE 9 - NOISE DATA AND VOICE ON LEFT CHANNEL. SMOKE >50% M-10,11.
CO >1% M-10,11,12.

MODE	9	8	7	12	11	10
BAROMETER (MMHG)	741.5	741.5	741.5	741.5	741.5	741.5
AMBIENT VP (MMHGA)	5.2	5.2	5.2	5.2	5.2	5.2
SPEED (RPM)	1400	1750	2100	1400	1750	2100
TORQUE (FT-LB)#	635	617	575	535	493	430
POWER (BHP)#	169.2	205.6	230.0	142.5	164.1	172.1
AIR FLOW (LB/HR)	1238	1542	1884	1000	1184	1321
FUEL FLOW (LB/HR)	70.1	87.8	100.8	71.0	88.8	102.2
A/F RATIO	17.7	17.6	18.7	14.1	13.3	12.9
BSFC (LB/BHP-HR)	0.414	0.427	0.438	0.498	0.541	0.594
COOLANT(1000BTU/HR)	335.5	389.2	416.9	365.7	407.2	444.5
OIL TEMP (F)	220	234	243	230	237	240
EXHAUST TEMP (F)	1260	1331	1357	1452	1511	1545
SMOKE (% OPACITY)	8.5	10.5	12.5	31.0		
INTAKE REST.("H2O)*	3.6	5.9	8.7	52.1	76.4	101.4
EXHAUST REST ("H2O)	37.3	64.4	86.8	53.6	76.6	86.8
INTAKE VP(MMHGA)	5.1	5.1	5.1	4.5	4.2	3.8
INT. PRES. (MMHGA)	735.0	730.7	725.4	643.6	597.8	550.7
EXH. PRES. (MMHGA)	806.3	857.1	899.0	836.7	879.9	899.0
CO (PPM)	3067	1885	1589			
CO (G/HR)	1757.5	1346.2	1381.8			
CO (G/BHP-HR)	10.39	6.55	6.01			
HC (PPMC)	10	20	34	50	144	230
HC (G/HR)	2.9	7.1	14.8	11.8	40.1	71.7
HC (G/BHP-HR)	0.02	0.03	0.06	0.08	0.24	0.42
NOX (PPM)	1618	1341	1139	1169	967	845
NOX (G/HR)	1370.4	1415.2	1462.8	810.6	797.2	778.7
NOX (G/BHP-HR)	8.10	6.88	6.36	5.69	4.86	4.53
SOUND (DBA)	105.8	107.5	109.8	107.5	109.0	111.6

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

TEST 13 DATE 04/06/73 ENGINE NHC-250 FUEL J

MODE	15	14	13	18	17	16
BAROMETER (MMHG)	739.7	739.7	739.7	739.7	739.7	739.7
AMBIENT VP (MMHGA)	5.0	5.0	5.0	5.0	5.0	5.0
SPEED (RPM)	1400	1750	2100	1400	1750	2100
TORQUE (FT-LB)#	610	588	535	594	566	511
POWER (BHP)#	162.5	195.8	213.8	158.3	188.5	204.2
AIR FLOW (LB/HR)	1143	1398	1626	1125	1374	1586
FUEL FLOW (LB/HR)	70.2	87.8	100.8	70.5	87.7	100.5
A/F RATIO	16.3	15.9	16.1	16.0	15.7	15.8
BSFC (LB/BHP-HR)	0.432	0.448	0.472	0.445	0.465	0.492
COOLANT(1000BTU/HR)	351.8	405.9	438.1	363.8	413.0	452.9
OIL TEMP (F)	225	234	241	229	237	241
EXHAUST TEMP (F)	1355	1473	1520	1390	1516	1579
SMOKE (% OPACITY)	11.0	13.0	20.5	7.0	14.5	21.0
INTAKE REST.("H2O)*	24.2	37.3	52.4	25.1	39.2	53.0
EXHAUST REST ("H2O)	13.9	22.0	27.5	40.4	65.5	82.5
INTAKE VP(MMHGA)	4.7	4.5	4.3	4.7	4.5	4.3
INT. PRES. (MMHGA)	695.9	671.4	643.0	694.2	667.7	641.7
EXH. PRES. (MMHGA)	762.6	777.8	788.0	812.1	859.1	890.8
CO (PPM)	1736	639	682	1091	450	500
CO (G/HR)	922.7	416.0	515.6	571.0	288.2	369.6
CO (G/BHP-HR)	5.68	2.12	2.41	3.61	1.53	1.81
HC (PPMC)	14	21	36	14	30	49
HC (G/HR)	3.7	6.8	13.6	3.7	9.6	18.1
HC (G/BHP-HR)	0.02	0.03	0.06	0.02	0.05	0.09
NOX (PPM)	1557	1290	1117	1487	1221	1048
NOX (G/HR)	1220.0	1237.5	1245.7	1147.6	1152.8	1141.1
NOX (G/BHP-HR)	7.51	6.32	5.83	7.25	6.11	5.59
SOUND (DBA)	106.5	108.5	110.8	107.2	108.0	110.8

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

TEST 14 DATE 04/09/73 ENGINE NHC-250 FUEL J - EXHAUST AND INTAKE RESTRICTION VALVE SET AT 2100 RPM FULL THROTTLE AND NOT CHANGED AT THE 2 LOWER RPM MODES**

CO >1% AND SMOKE >50% M 22 & 23. F.I.D. INOP M 29 & 30
M-1 IS ROOM BACKGROUND

MODE	21	24	27	30	20	23	26	29	19	22	25	28
BAROMETER (MMHG)	744.2	744.2	744.2	744.2	744.2	744.2	744.2	744.2	744.2	744.2	744.2	744.2
AMBIENT VP (MMHGA)	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
SPEED (RPM)	1400	1400	1400	1400	1750	1750	1750	1750	2100	2100	2100	2100
TORQUE (FT-LB)#	610	548	641	632	585	503	633	618	530	439	585	567
POWER (BHP)#	162.5	146.2	170.9	168.4	194.8	167.6	210.8	206.0	211.8	175.4	233.7	226.6
AIR FLOW (LB/HR)	1179	1031	1291	1250	1454	1217	1656	1571	1687	1359	1992	1861
FUEL FLOW (LB/HR)	70.8	71.4	70.0	70.4	87.3	88.9	87.5	88.0	100.8	102.7	101.4	101.4
A/F RATIO	16.7	14.4	18.4	17.8	16.7	13.7	18.9	17.8	16.7	13.2	19.6	18.4
BSFC (LB/BHP-HR)	0.436	0.488	0.410	0.418	0.448	0.530	0.415	0.427	0.476	0.586	0.434	0.447
COOLANT(1000BTU/HR)	344.9	361.9	329.8	340.9	400.9	409.8	367.7	386.8	438.1	439.8	402.8	409.2
OIL TEMP (F)	224	226	226	226	233	234	232	236	239	238	239	240
EXHAUST TEMP (F)	1282	1446	1185	1222	1411	1511	1259	1312	1472	1567	1292	1348
SMOKE (% OPACITY)	9.0	26.5	7.0	8.0	15.0		10.0	12.0	19.5		13.5	16.5
INTAKE REST.("H2O)*	22.0	53.5	1.4	10.2	35.4	79.1	3.8	17.7	50.7	102.4	6.4	27.0
EXHAUST REST ("H2O)	29.2	36.0	55.7	18.3	46.9	50.2	43.5	26.1	57.7	57.7	57.7	35.3
INTAKE VP(MMHGA)	3.5	3.2	3.7	3.6	3.4	3.0	3.7	3.6	3.2	2.8	3.7	3.5
INT. PRES. (MMHGA)	698.9	639.8	737.7	721.1	673.7	591.5	733.3	707.0	645.0	547.7	728.3	689.6
EXH. PRES. (MMHGA)	791.2	803.9	840.7	770.9	824.2	830.6	817.9	785.3	844.5	844.5	844.5	802.6
CO (PPM)	3183	5228	2967	3540	1077		2721	2540	869		2363	2051
CO (G/HR)	1742.82	525.71	768.52	047.3	727.3		2078.71	846.1	680.8		2167.51	763.2
CO (G/BHP-HR)	10.72	17.28	10.35	12.16	3.73		9.86	8.96	3.21		9.27	7.78
HC (PPMC)	18	41	23		28	107	22		63	209	30	34
HC (G/HR)	4.9	9.9	6.9		9.5	30.6	8.4		24.7	66.9	13.8	14.6
HC (G/BHP-HR)	0.03	0.07	0.04		0.05	0.18	0.04		0.12	0.38	0.06	0.06
NOX (PPM)	1650	1378	1681	1686	1320	1097	1359	1332	1079	913	1091	1127
NOX (G/HR)	1309.9	965.61	452.41	413.81	292.2	909.81	505.91	403.41	225.1	847.11	451.31	404.9
NOX (G/BHP-HR)	8.06	6.61	8.50	8.40	6.63	5.43	7.15	6.81	5.79	4.83	6.21	6.20
SOUND (DBA)	80.5	107.5	108.3	107.0	107.0	109.8	110.8	108.9	108.8	111.0	111.9	110.2	110.8

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

**19, 20, 21 E = 50.7 I = 57.7 at 2100 RPM
22, 23, 24 E =102.4 I = 57.7 at 2100 RPM
25, 26, 27 E = 6.4 I = 57.7 at 2100 RPM
28, 29, 30 E = 27.7 I = 35.3 at 2100 RPM

TEST 15 DATE 04/11/73 ENGINE NHC-250 FUEL J - EXHAUST AND INTAKE RESTRICTION VALVE SET AT 2100 RPM AND NOT CHANGED AT THE TWO LOWER RPM MODES**

BY DL/RT/DH F.I.D. INOP M 34-36

MODE	33	36	32	35	31	34
BAROMETER (MMHG)	747.6	747.6	747.6	747.6	747.6	747.6
AMBIENT VP (MMHGA)	4.1	4.1	4.1	4.1	4.1	4.1
SPEED (RPM)	1400	1400	1750	1750	2100	2100
TORQUE (FT-LB)#	634	631	616	609	567	559
POWER (BHP)#	169.0	168.1	205.2	203.0	226.6	223.5
AIR FLOW (LB/HR)	1220	1208	1523	1501	1804	1773
FUEL FLOW (LB/HR)	70.9	70.9	87.9	87.8	101.3	100.8
A/F RATIO	17.2	17.0	17.3	17.1	17.8	17.6
BSFC (LB/BHP-HR)	0.420	0.422	0.428	0.432	0.447	0.451
COOLANT(1000BTU/HR)	342.1	345.8	388.7	400.2	426.6	436.2
OIL TEMP (F)	225	223	234	235	237	242
EXHAUST TEMP (F)	1253	1279	1346	1375	1390	1420
SMOKE (% OPACITY)	5.5	7.0	10.5	9.5	14.5	13.5
INTAKE REST.("H2O)*	9.9	9.7	17.8	17.6	27.1	26.7
EXHAUST REST ("H2O)	29.7	42.6	44.6	69.0	57.1	86.7
INTAKE VP(MMHGA)	3.9	3.9	3.8	3.8	3.7	3.8
INT. PRES. (MMHGA)	722.0	722.3	707.2	707.6	689.6	690.3
EXH. PRES. (MMHGA)	792.0	816.2	820.0	865.7	843.4	898.7
CO (PPM)	3243	3053	1793	1356	1472	1105
CO (G/HR)	1833.7	1711.2	1265.4	944.3	1228.6	907.4
CO (G/BHP-HR)	10.85	10.18	6.17	4.65	5.42	4.06
HC (PPMC)	14		19		17	
HC (G/HR)	4.0		6.7		7.1	
HC (G/BHP-HR)	0.02		0.03		0.03	
NOX (PPM)	1547	1501	1250	1236	1110	997
NOX (G/HR)	1272.8	1224.2	1284.0	1252.9	1348.3	1191.6
NOX (G/BHP-HR)	7.53	7.28	6.26	6.17	5.95	5.33
SOUND (DBA)	107.5	107.0	109.1	108.8	111.0	110.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

**31, 32, 33 E = 27.1" I = 57.1"
34, 35, 36 E = 86.7" I = 26.7"

TEST 16 DATE 04/23/73 ENGINE NHC-250 FUEL J

1. SMOKE READING QUESTIONABLE M 2,3,4. OFF SCALE M 10,11,12.
2. NO EMISSION OR SOUND DATA TAKEN. COOLANT NOT FULLY STABILIZED IN ALL MODES.

MODE	1	2	3	4
BAROMETER (MMHG)	740.0	740.0	740.0	740.0
AMBIENT VP (MMHGA)	4.2	4.2	4.2	4.2
SPEED (RPM)	2100	2100	2100	2100
TORQUE (FT-LB)#	589	580	572	567
POWER (BHP)#	235.5	231.9	228.7	226.7
AIR FLOW (LB/HR)	1880	1857	1840	1749
FUEL FLOW (LB/HR)	101.0	100.0	100.0	100.0
A/F RATIO	18.6	18.6	18.4	17.5
BSFC (LB/BHP-HR)	0.429	0.431	0.437	0.441
COOLANT(1000BTU/HR)	415.3	435.7	434.7	435.2
OIL TEMP (F)	241	245	246	247
EXHAUST TEMP (F)	1340	1360	1376	1405
SMOKE (% OPACITY)	11.0	7.0	7.0	9.0
INTAKE REST.("H2O)*	8.8	8.8	8.8	27.1
EXHAUST REST ("H2O)	33.1	58.2	86.7	35.1
INTAKE VP(MMHGA)	4.1	4.1	4.1	3.9
INT. PRES. (MMHGA)	724.3	724.3	724.2	689.9
EXH. PRES. (MMHGA)	798.4	845.4	898.7	802.2
CO (PPM)				
CO (G/HR)				
CO (G/BHP-HR)				
HC (PPMC)				
HC (G/HR)				
HC (G/BHP-HR)				
NOX (PPM)				
NOX (G/HR)				
NOX (G/BHP-HR)				
SOUND (DBA)	724.3	724.3	724.2	689.9

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

TEST 17 DATE 04/24/73 ENGINE NHC-250 FUEL J

1. SMOKE READING QUESTIONABLE M 2,3,4. OFF SCALE M 10,11,12.
2. NO EMISSION OR SOUND DATA TAKEN. COOLANT NOT FULLY STABILIZED IN ALL MODES.

MODE	5	6	7	8	9
BAROMETER (MMHG)	735.0	735.0	735.0	735.0	735.0
AMBIENT VP (MMHGA)	4.2	4.2	4.2	4.2	4.2
SPEED (RPM)	2100	2100	2100	2100	2100
TORQUE (FT-LB)#	557	556	539	529	512
POWER (BHP)#	222.9	222.2	215.7	211.3	204.7
AIR FLOW (LB/HR)	1757	1729	1621	1596	1582
FUEL FLOW (LB/HR)	101.0	101.0	101.1	101.0	101.0
A/F RATIO	17.4	17.1	16.0	15.8	15.7
BSFC (LB/BHP-HR)	0.453	0.455	0.469	0.478	0.493
COOLANT(1000BTU/HR)	444.2	410.9	436.3	452.3	440.9
OIL TEMP (F)	240	230	239	246	241
EXHAUST TEMP (F)	1404	1466	1526	1556	1556
SMOKE (% OPACITY)	13.0	16.0	21.0	17.0	21.0
INTAKE REST.("H2O)*	27.1	26.7	51.8	49.7	51.8
EXHAUST REST ("H2O)	58.2	85.4	27.0	57.6	82.7
INTAKE VP(MMHGA)	4.0	4.0	3.7	3.7	3.7
INT. PRES. (MMHGA)	689.9	690.7	643.3	647.3	643.3
EXH. PRES. (MMHGA)	845.5	896.3	787.1	844.2	891.2
CO (PPM)					
CO (G/HR)					
CO (G/BHP-HR)					
HC (PPMC)					
HC (G/HR)					
HC (G/BHP-HR)					
NOX (PPM)					
NOX (G/HR)					
NOX (G/BHP-HR)					
SOUND (DBA)	690.0	690.7	643.5	647.4	643.5

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

TEST 18 DATE 04/26/73 ENGINE NHC-250 FUEL J

1. SMOKE READING QUESTIONABLE M 2,3,4. OFF SCALE M 10,11,12.
2. NO EMISSION OR SOUND DATA TAKEN. COOLANT NOT FULLY STABILIZED IN ALL MODES.

MODE	10	11	12
BAROMETER (MMHG)	742.2	742.2	742.2
AMBIENT VP (MMHGA)	4.2	4.2	4.2
SPEED (RPM)	2100	2100	2100
TORQUE (FT-LB)#	461	442	435
POWER (BHP)#	184.3	176.9	174.0
AIR FLOW (LB/HR)	1369	1319	1318
FUEL FLOW (LB/HR)	101.4	101.9	101.7
A/F RATIO	13.5	12.9	13.0
BSFC (LB/BHP-HR)	0.550	0.576	0.584
COOLANT(1000BTU/HR)	436.6	451.1	439.1
OIL TEMP (F)	241	243	244
EXHAUST TEMP (F)	1577	1546	1559
SMOKE (% OPACITY)	0.0	0.0	0.0
INTAKE REST.("H2O)*	100.0	102.1	100.7
EXHAUST REST ("H2O)	22.0	56.0	86.5
INTAKE VP(MMHGA)	3.2	3.1	3.1
INT. PRES. (MMHGA)	552.7	548.7	551.4
EXH. PRES. (MMHGA)	777.8	841.3	898.4
CO (PPM)			
CO (G/HR)			
CO (G/BHP-HR)			
HC (PPMC)			
HC (G/HR)			
HC (G/BHP-HR)			
NOX (PPM)			
NOX (G/HR)			
NOX (G/BHP-HR)			
SOUND (DBA)	553.0	549.0	551.7

*RELATIVE TO 736.6 MMHG DRY BAROMETER
@RAW EXHAUST (DRY) BASIS
#CORRECTED TO 85 F
COMPUTED 12/19/73

APPENDIX F.--DEFINITIONS

Referring to the items in the tables of Appendices A-E, the following comments are pertinent.

The item POWER (BHP)#--the values on this line represent brake horsepower corrected only for a temperature effect with no correction applied for a pressure effect. The term

$$\text{POWER (BHP)\#} = \frac{(\text{Speed, rpm})\ (\text{Torque, lb-ft})}{5252.14} \cdot \frac{\text{Inlet air temp., °R}}{545}^{.7}.$$

It was not considered appropriate to apply a correction for a pressure effect as this was one of the parameters being evaluated.

The BSFC (lb/bhp-hr), brake specific fuel consumption (lbs. per brake horsepower hour), was calculated using the POWER (BHP)# and metered fuel rate.

INTAKE RESTRICTION ("H_2O)*--For the purpose of this study a unique correction was applied to the measured intake pressure differential. The correction is to account for the partial pressure of water in the intake air which is a part of the measured inlet system pressure differential. This correction is based on an assumption that the water behaves primarily as a diluent in the combustion process. Therefore, an inlet system pressure should be referenced to dry air for purposes of inlet restriction engine-performance comparisons. Inlet system pressures were also referenced to a standard barometric pressure defined as 736.6 mmHg (29.0 inches Hg). The corrected pressure is

$$\text{INTAKE RESTRICTION ("}H_2O\text{)*} = [\text{Reference barometric pressure - ambient barometric pressure + measured inlet pressure differential} + K \cdot (\text{vapor pressure of } H_2O \text{ in ambient air})]$$

where

$$K = 1 - \frac{\text{Uncorrected inlet pressure differential}}{\text{Barometric pressure}}$$

K is a factor to correct the partial pressure of H_2O in the ambient air to that of the inlet system following the restricting butterfly valve.

Since the raw data were taken in several differing units of pressure, care must be taken in applying tabulated values of the above corrections.

The exhaust restriction, EXHAUST RESTRICTION ("H_2O), was corrected to a reference pressure of 736.6 mmHg (29.0 inches Hg); EXHAUST RESTRICTION ("H_2O) = barometric pressure + uncorrected exhaust ΔP - reference barometric pressure. The INT. PRESS. (MMHGA) = Barometric pressure + uncorrected exhaust ΔP.

CO and NO_x concentration and mass emissions are reported on a wet exhaust gas basis using the factor: $1 - \frac{y}{x} \cdot \frac{\text{Fuel}}{\text{air}}$, where x, y are the atoms of C_xH_y and the ratio y/x assumed to be 2. The HC concentrations were measured without removal of water from the exhaust gas and, therefore, required no correction.

The 13-mode cycle composite data of the tables are calculated in accordance with the procedures of the November 15, 1972, Federal Register, Part 85, Subpart J, except that NO_x is not corrected by the humidity correction factor. The smoke and power data of the 13-mode cycle composite were included in the table but are of questionable significance.

APPENDIX G.--FUEL EFFECTS AND ENGINE NOISE

Experiments were to be conducted to measure combustion noise in a single-cylinder diesel engine and the association of combustion noise with fuel characteristics attempted. A primary assumption was that combustion noise is affected by the amount of fuel available for a detonation reaction at the moment of fuel ignition.

Diesel fuels can be modified to shorten the delay between fuel injection and ignition by small amounts of additives such as amyl nitrate. This shorter delay period can result in reduced detonation and, possibly, reduction in combustion noise. It was postulated that control of the evaporation rate of the injected fuel droplets might accomplish a change in the delay period and might thereby influence combustion noise.

It was proposed to investigate the effect of evaporation rate through the addition of small amounts of (1) a high-boiling component to a base fuel or (2) a much lower boiling component to a base fuel. In the first instance, it is possible that the small amount of high-boiling material would modify the rate of evaporation from the fuel droplet sufficiently to affect detonation resulting from the base fuel. In the second case, if the low-boiling component is very resistant to ignition, it may flash rapidly to slow evaporation of the remainder while not contributing to the vapor that, being readily ignitable, would tend to detonate upon ignition.

The planned experimental approach was to control ignition delay with fuel composition and then determine the effect of ignition delay on engine noise as indicated by direct noise measurement and by measurement of peak pressure and rate of pressure rise. A relationship of ignition delay and engine noise was desired; also, noise as a function of pressure (P), and rate of pressure rise (dP/dt) would be explored--for example, by plotting noise level as the dependent variable and P(dP/dt), or dP/dt as the independent variable. In this respect the fuel composition and fuel rate would be the independent variables; P, dP/dt, ignition delay, and noise, the dependent variables. Engine speed, injection timing, and torque would be held constant.

A series of five narrow-boiling solvents were obtained for trial use as base fuels. These boil in the ranges of 310-345° F, 349-406° F, 372-402° F, 424-460° F, and 460-495° F. For light materials the following were obtained: n-propane, n-pentane, cyclopentane, n-heptane, and benzene. For the high-boiling component, lubricating oil blending stocks (without additives) were available.

As stated in the principal body of this report, a full study as appropriate to the concept above was not made because of program limitations and changes in program priorities as determined by the DOT program managers.

APPENDIX H.--DIESEL ENGINE NOISE ANALYSIS

H.1 OVERVIEW

The method of analysis used to measure noise radiated from diesel engines in this study is discussed and a discription of the noise measurement facility, including an evaluation of the facilities acoustic characteristic for engine noise measurements is presented. Background noise sources including support equipment and other facility noise sources were measured and their levels were compared with the sound pressure level from the diesel engine itself. A comparison method was used to establish diesel engine radiated sound power from sound pressure level measurement acquired in a "reveberant facility". Finally, a description is given of the acoustic model used to predict engine sound pressure levels at 50 feet from sound power level data acquired under test.

H.2 DESCRIPTION OF FACILITY, MEASUREMENTS, SETUP

Diesel engine noise performance studies were conducted in an acoustically modified engine performance test cell at the U.S. Bureau of Mines, Energy Research Center. The test cell, approximately $75M^3$ in volume, is shown schematically in Figure H-1. During the tests, the diesel engines were positioned asymmetrically in the test cell approximately five feet from the outer wall. For quantification of diesel radiated noise, intake and exhaust gas piping systems were treated with a two inch thick performed calcium silicate double layer absorptive liner, enclosed within 24 gauge aluminum jacket outer covering. A special thermostatically controlled cooling system was designed to provide cooling water to the engine and a special surge tank was used to reduce intake air pressure fluctuations. A discussion of the cooling system arrangement is given in Section III as well as the instrumentation system which was used to monitor various engine performance parameters, (i.e., exhaust temperature, engine torque, fuel and air flow rates, intake and exhaust static pressures, smoke, hydrocarbons and etc.).

For evaluation of engine sound radiated power, a number of scattering surfaces were installed in the U.S. Bureau of Mines test cell. These scattering surfaces were positioned at various locations to minimize the influence of excessive room mode formations for frequencies in the range of 250 through 8000 H_z and to assure a diffuse sound field for sound power evaluation. Prior to engine test an initial survey was conducted to establish the spatial sound pressure field distribution in the test cell. Two acoustic sources were used, namely ILG pink noise source and the diesel engine. Sound pressure level measurement were taken at eight vertical and horizontal positions in the test cell. The diesel engine, here, was operated under full load at rated rpm. From engine sound pressure level measurements, a single microphone position was then

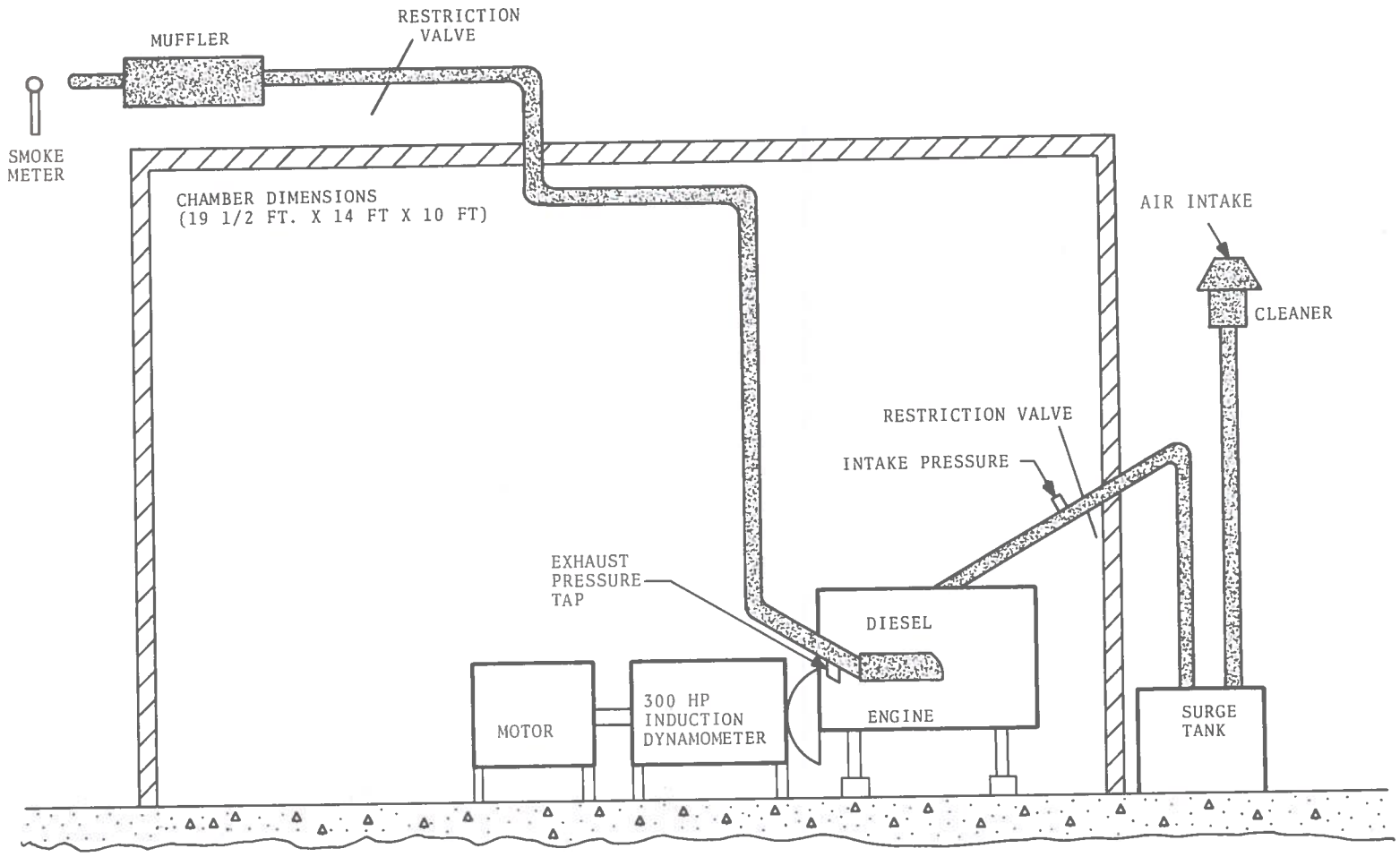

Figure H-1.- Reverberent Room Facility Typical Diesel Engine Test Set Up

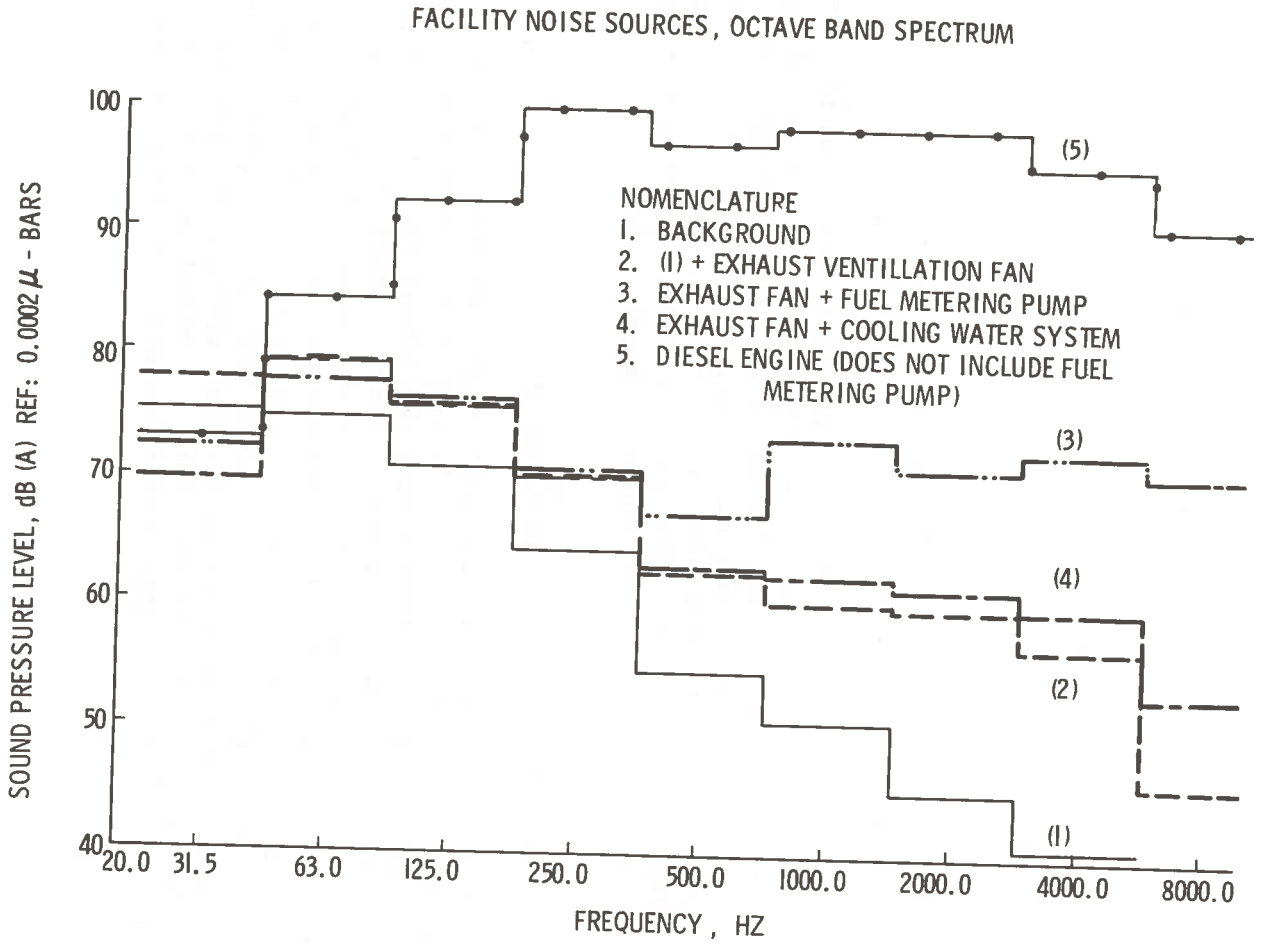

Figure H.2 -Facility Noise Sources, Octave Band Spectrum

established five feet from the floor and five feet from the engine. At this position the variance of octave band sound pressure level was found to be less than 1 dB from the average value of the mean square sound pressure level of the eight microphone positions for frequencies between 250 to 8000 H_z. Octave band room decay rates were also measured and are shown in Table H-1 below.

TABLE H-1. - OCTAVE BAND ROOM DECAY RATE

Octave Band, Hz						
125	250	500	1K	2K	4K	8K
Decay Rate (dB/Sec)						
82	76	76	61	57	54	52

The test cell qualifies, according to ANSI S1.2, as a reverberant space for octave band centered frequencies greater than 100Hz.

A number of initial base line octave band pressure levels measurements were also taken of various engine unrelated noise sources in the test facility. Results are shown in Figure H-2 of the following octave band sound pressure level spectrums (a) test chamber background noise, (b) background plus ventiliating fan system, (c) background plus ventilating fan and fuel metering pump, and (d) background plus ventilating fan and cooling water system, along with a typical octave band spectrum of engine radiated noise.

H.3 DETERMINATION OF ENGINE RADIATED SOUND POWER

The method of analysis employed to relate sound pressure level measurement of engine radiated noise to sound power is described in this section. In the determination of engine radiated sound power, the comparison technique was used. As part of this technique the acoustic source signal, in the case here, an ILG Industries, Inc. pink noise source, of known power output provided calibration data of the test cell. Room (absorption) constants were computed from acoustic source signal data and were used to relate the diesel engine sound pressure levels (SPLS) in the test cell to sound poer levels (PWLS). A-weighted sound power levels were computed based on the time average A-weight sound pressure levels for each 1/3 octave frequency band. A summation of the band average SPL or PWL provided the single number overall or A-weighted levels.

Finally, an engine noise efficiency parameter was determined which relates the overall or A-weight PWL of the diesel engine to brake horsepower (common units).

$$\eta = 10 \text{ Log}_{10} \left[\frac{W_E}{W_M} \right] : \quad W_E = \text{Overall or A-weighted Sound Power} \qquad (1)$$
$$W_M = \text{Mechanical Power (engine)}$$

The governing equation used to determine engine radiated sound power level (PWL_E) is shown below. The relationship between sound power level and sound pressure level in a diffused sound field is:

$$PWL_E = 10 \text{ Log}_{10} \left[\frac{R \langle P_E \rangle_t^2}{\rho_o c \, W_{ref}} \right] \quad \text{where:} \quad SPL_E = 20 \text{ Log}_{10} \left[\frac{\langle P_E \rangle_t}{Pref} \right]$$

$$W_{ref} = 10^{-12} \text{ Watts} \qquad (2)$$

$$P_{ref} = 0.002 \ \mu\text{-bars}$$

Here R (ft^2) denotes the room (absorption) constant, $\langle P_E \rangle_t$ the room time average sound pressure produced by the engine, ρ_o the mass density of air and c the speed of sound. Here the quality $\rho_o c$ denotes the impedence (Z) of the acoustic media.

Values of the test cell room constant, R, were obtained from measured SPL and published PWL data of the ILG source from Equation(2)(i.e. substitute $PWL_E = PWL_{ILG}$ and $\langle P_E \rangle_t = \langle P_{ILG} \rangle_t$. Third octave band spectra of the ILG source sound power levels and measured sound pressure levels in the test chamber are presented in Table H-2.
Once the test cell room (absorption) constants were determined, engine radiated sound power levels were calculated from Equation (2). A similar procedure was used to determine the A-weight engine radiated sound power. In this case, engine radiated sound pressure levels were modified by the appropriate A-weight correction for the frequency band under consideration.

Finally, diesel engine noise efficiency is defined by the following relationships.

$$\eta_o = 10 \text{ Log}_{10} \frac{W_E}{W_M} \quad \text{(OVERALL)} \quad \text{(Common Units)} \qquad (3)$$

$$\eta_A = 10 \text{ Log}_{10} \frac{W_E}{W_M} \quad \text{(A-weight)} \qquad (4)$$

where the powers W_E (OVERALL), W_E (A-weight) and W_M were obtained from:

TABLE H-2.- ILG SOURCE SOUND POWER AND TEST CELL SOUND PRESSURE LEVELS ONE-THIRD OCTAVE SPECTRUM

ONE-THIRD OCTAVE BAND CENTER FREQUENCY (H2)	SOUND POWER LEVEL (DECIBLES RE 10^{-12} WATTS)	SOUND PRESSURE LEVEL (DECIBLES RE 0.0002μ-BARS)
40	70.5	59.6
50	72.5	58.6
63	73.5	62.2
80	72.0	56.7
100	70.5	63.6
125	72.0	65.6
160	73.5	62.2
200	73.5	64.0
250	74.0	64.8
315	74.5	65.4
400	74.5	65.6
500	74.5	66.6
630	74.0	67.8
800	74.0	67.2
1000	74.5	69.5
1250	75.5	69.8
1600	75.0	72.2
2000	74.5	71.0
2500	74.0	70.7
3150	73.5	70.0
4000	73.0	68.3
5000	73.0	68.4
6300	73.0	72.3
8000	73.0	75.0

Diesel Engine Overall Sound Power Level, $PWL_E(OVERALL) = 10\ Log_{10}\left[\frac{W_E(OVERALL)}{W_{ref}}\right]$

Diesel Engine A-Weight Sound Power Level, $PWL_E\ (A\text{-weight}) = 10\ Log_{10}$

$$\left[\frac{W_E\ (A\text{-weight})}{W_{ref}}\right]$$

Mechanical Power, W_M = BRAKE HORSE POWER x 745.7 when sound power is given in watts.

H.4 FAR-FIELD SOUND PRESSURE LEVEL PREDICTIONS

The acoustic model considered for the prediction of engine radiated noise at fifty feet is presented. In modeling the far-field sound pressure, it was assumed that the source of radiation from a diesel engine is represented by an equivalent monopole point source. Band average sound power levels, paragraph H-3, were used as the power levels of this monopole source. A reflective/or rigid plane was incorporated in the model to represent the acoustic scattering from the ground. Under these assumptions, the far-field acoustic pressures can be estimated by:

$$P_{FF} = i\omega\rho_o\sqrt{\frac{W_E}{4\pi Z_o}}\left[\frac{e^{iR}}{R} + \frac{e^{iR_1}}{R_1}\right] e^{i\omega\tau}$$

where ω is the frequency, rad/sec

P_{FF}, for field Sound Pressure

Z_o, Characteristic impedence of the air media

ρ_o, air media mass density,

W_E, band average sound power

R, distance from receiver to source location

R_1, distance from receiver to image source location

τ, time

The sound pressure level is as follows:

$$SPL_{FF} = 10\ Log_{10}\left\{\left[\langle P_{FF} \rangle_f\ Conj\ \langle P_{FF}\rangle_f\right]/P^2_{ref}\right\}$$

were it is understood that $\langle P_{FF}\rangle_f$ represents an average over a frequency band, and Conj the conjugate.