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HS-803 326

PERFORMANCE CHARACTERISTICS OF AUTOMOTIVE ENGINES
IN THE UNITED STATES
First Series - Report No. 16
1975 Volvo 121 CID (2.0 Liters), F.I.

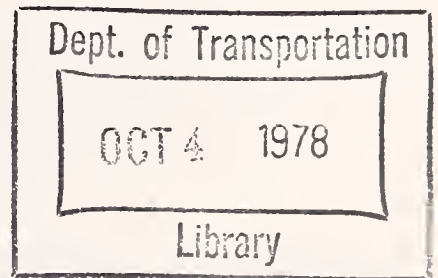
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MAY 1978

INTERIM REPORT



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VIRGINIA 22161

Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
Washington DC 20590

NOTICE

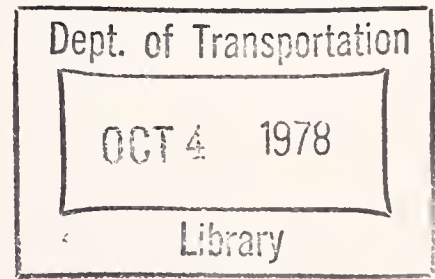
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16. Abstract Experimental data were obtained in dynamometer tests of a 1975 Volvo, 2.0 liter (121 CID) engine to determine fuel consumption and emissions (hydrocarbon, carbon monoxide, oxides of nitrogen) at steady-state engine-operating modes. The objective of the program is to obtain engine performance data for estimating emissions and fuel economy for varied engine service and duty. The intent of the work is to provide basic engine characteristic data required as input for engineering calculations involving ground transportation.					
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PREFACE

This report, prepared by the U.S. Department of Energy, Bartlesville Energy Research Center, for the U.S. Department of Transportation, Transportation Systems Center, Energy Technology Branch, Cambridge MA, presents results of experimental work to obtain information on performance characteristics of engines used in automobiles sold in the United States. The data presented in this report are from one of a series of 23 engines to be tested in the current program.

The objective of this program is to obtain fuel consumption and emissions data at steady-state conditions throughout each engine's operating range. These tests provide the basic engine characteristic data required to predict engine/emission control system performance for transient operation.

This project is funded by the National Highway Traffic Safety Administration, Office of Research and Development, Office of Passenger Vehicle Research, Technology Assessment Division.

Ralph G. Colello and James A. Kidd, Jr., U.S. Department of Transportation, Transportation Systems Center, are the technical monitors.

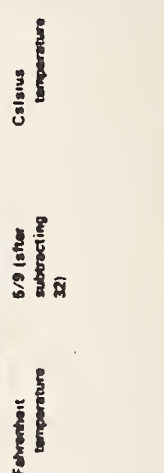
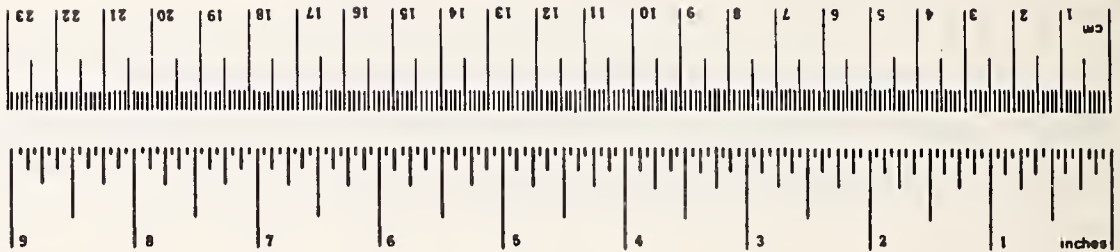
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

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

Approximate Conversions from Metric Measures

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



1. INTRODUCTION

Data acquired from steady-state tests of a 1975 Volvo, 2.0 liter (121 cubic-inch-displacement) engine are presented in this report. The test results are sufficient to establish steady-state maps for fuel consumption and emission rates of carbon monoxide, unburned hydrocarbon, and oxides of nitrogen over the operating range of the engine. These steady-state maps may be used to predict engine/emission control system performance for transient operation.

2. ENGINE TEST REPORT

The data presented in this report were obtained from steady-state tests of a Volvo 2.0 liter (121 CID) engine. A new 1975 Model 242 Volvo sedan was purchased and operated over public roads at normal driving speeds for approximately 2,000 miles. The engine was then removed from the vehicle, mounted on a test stand, and coupled to an eddy-current dynamometer. All engine accessories were transferred to the test stand except for the radiator and fan. An external cooling tower was used to maintain proper engine operating temperature, and an auxiliary battery and charging system were used in place of standard alternator. A list of manufacturer's specifications for a new mean-tolerance Volvo 2.0 liter engine may be found in table 1.

A single batch of unleaded, regular grade gasoline was used throughout the break-in and testing program. An analysis of the fuel appears in table 2.

The engine was operated at the speed and load conditions indicated in table 3. This table may be used as an index to the data tables presented in this report.

The following data were recorded at each test point:

- Test number
- Date
- Barometric pressure, mm Hg
- Dewpoint, °F
- Inlet air temperature, °F
- Speed, rpm
- Torque, lb-ft -- BLH strain gage load cell; Daytronics indicator
- Fuel rate, lb/hr -- Fluidyne positive displacement fuel flowmeter
- Ignition timing, °BTC
- Manifold vacuum, in. Hg
- Throttle angle, deg
- CO, pct -- Beckman NDIR
- CO₂, pct -- Beckman NDIR
- O₂, pct -- Beckman polarographic detector
- HC, ppmC -- Custom-built heated flame ionization detector
- NO_x, ppm -- Thermo-Electron chemiluminescent detector
- Oil temperature, °F
- Oil pressure, psig
- Coolant temperature, °F
- Exhaust temperature, °F
- Exhaust pressure, in. H₂O
- Intake manifold temperature, °F.

The following equations were used in calculating power, air/fuel ratio, absolute humidity, and mass emission rates of carbon monoxide (CO), unburned hydrocarbons (HC), and oxides of nitrogen (NO_x):

1. Partial pressure of water vapor in intake air (millimeters of mercury):

$$P = \exp \left[18.717 - \frac{7308.1}{393 + D} \right],$$

where D = dewpoint, °F.

2. Absolute humidity (grains moisture per pound dry air):

$$H = \frac{4347.8(P)}{B - P},$$

where B = barometric pressure, mm Hg.

3. Humidity correction factor (dimensionless):

$$K_H = \frac{1}{1 - 0.0047(H - 75)}.$$

Note: This factor is used to correct the NO_x mass emission rate to a standard humidity of 75 grains moisture per pound dry air.

4. Stoichiometric air/fuel ratio (dimensionless):

$$AF_s = \frac{69(2 + \frac{x}{2} - y)}{MW_{fuel}},$$

where x = hydrogen-carbon atomic ratio of fuel,
 y = oxygen-carbon atomic ratio of fuel,
 MW_{fuel} = fuel molecular weight per carbon atom,
 = 12.01115 + 1.00797x + 15.9994y.

5. Hydrogen concentration in raw exhaust (percent):

$$H_2 = \frac{x(CO)(CO + CO_2)}{2(CO + 3CO_2)},$$

where CO = carbon-monoxide concentration (percent),
 CO₂ = carbon-dioxide concentration (percent).

Note: This equation assumes a water-gas shift equilibrium constant

$$\frac{(CO)(H_2O)}{(CO_2)(H_2)} = 3.$$

6. Correction factor for emission concentrations from wet basis to dry basis (dimensionless):

$$C_w = 1 + \frac{(\frac{x}{2})(CO + CO_2) - H_2}{100},$$

Note: In these tests only HC is measured on a wet basis.
All other species are measured on a dry basis.

7. Air/fuel ratio (dimensionless):

$$AF = \frac{AF_s}{2 + \frac{x}{2} - y} \left[\frac{(1 + \frac{x}{2} - y)(CO) + (2 + \frac{x}{2} - y)(CO_2) + 2(O_2) + \frac{NO_x}{10^4} - H_2}{CO + CO_2 + C_w(\frac{HC}{10^4})} \right],$$

where O_2 = oxygen concentration (percent),
 NO_x = oxides of nitrogen (ppm),
HC = unburned hydrocarbon concentration (ppmC).

8. Exhaust flow (pounds per hour):

$$M_{EX} = M_F(1+AF),$$

where M_F = fuel flow rate (pounds per hour).

9. Carbon monoxide mass emission rate (grams per hour):

$$M_{CO} = \frac{M_{EX}(CO)}{C_w} \left(\frac{MW_{CO}}{MW_{EX}} \right) 453.59237,$$

where MW_{CO} = molecular weight of CO (=28.01115),
 MW_{EX} = molecular weight of exhaust gas (=28.967).

10. Unburned hydrocarbon mass emission rate (grams per hour):

$$M_{HC} = M_{EX} \left(\frac{HC}{10^6} \right) \left(\frac{MW_{HC}}{MW_{EX}} \right) 453.59237,$$

where MW_{HC} = molecular weight per carbon atom of HC,
= 12.01115 + 1.00797x + 15.9994y.

11. Oxides of nitrogen mass emission rate (grams per hour):

$$M_{NO_x} = \frac{M_{EX}(NO_x)}{C_w} \left(\frac{MW_{NO_x}}{MW_{EX}} \right) (K_H) 453.59237,$$

where M_{NO_x} = molecular weight of NO_2 (=46.0028).

12. Power (brake horsepower corrected to a standard barometric pressure of 736.6 mm Hg and a standard temperature of 85° F):

$$HP = \frac{N(T)}{5252.113} \left(\frac{736.6}{B - P} \right) \sqrt{\frac{t + 460}{545}},$$

where N = engine speed (revolutions per minute),
T = brake torque (foot-pounds),
t = air temperature (°F).

3. DISCUSSION OF TEST RESULTS

The maximum torque (figure 1) approximated that quoted in Table 1; the maximum brake horsepower (figure 1) exceeded the manufacturer's specifications. Air/fuel ratio decreased as brake horsepower increased (figure 2). The Volvo 2.0 liter engine exhibited emission control performance typical of modern well controlled engines. Emissions of CO, HC, and NO_x (figures 3,4, and 5) were maintained at low levels when the engine was operated at the lower speeds and power outputs typical of urban driving. Emissions tended to increase as the wide-open-throttle condition was approached. The decrease in NO_x at high-power levels (see figure 5) may be attributed to fuel-rich operation. Fuel rate increased as brake horsepower increased (figure 6).

The repeatability of emission rates, fuel consumption, and engine performance was satisfactory for the purposes of these tests.

4. CONCLUSIONS

The purpose of the experimental work that is reported here is to establish data for this engine. Those data are presented in the accompanying tables of this report.

TABLE 1. MANUFACTURERS'S ENGINE SPECIFICATIONS

Displacement, cu. in.....	121
Maximum horsepower, bhp @ 6,000 rpm.....	98
Maximum torque, lb-ft @ 3,500 rpm.....	110
Bore and stroke, inches.....	3.50 X 3.15
Configuration.....	in-line slant 4-cylinder
Compression ratio.....	8.7:1
Firing order.....	1-3-4-2
Ignition timing at idle speed, °BTDC @ 700 rpm.....	5
Block material.....	cast iron
Head material.....	cast iron
Number of crankshaft main bearings.....	5
Number of compression rings/piston.....	2
Number of oil rings/piston.....	1
Cam drive type.....	gear drive
Valve lift:	
Intake, in.....	0.420
Exhaust, in.....	0.420
Valve timing:	
Intake opens, °BTC.....	27
Intake closes, °ABC.....	70
Exhaust opens, °BBC.....	70
Exhaust closes, °ATC.....	27
Spark plug gap, in.....	0.028 to 0.032
Engine weight, lb....	341
Crankcase emission control:	
Control method.....	positive crankcase ventilation
Point of discharge.....	intake manifold
Fuel system.....	fuel injection
Distributor specifications:	
Distributor number.....	0237 002 002
Centrifugal advance, begins, ° @ 430-600 rpm... 0	
Centrifugal advance, intermediate,	
° @ 830-1,010 rpm.....	5
° @ 1,230-1,400 rpm.....	10
Centrifugal advance, full, ° @ 1,600 rpm.....	14.5 ± 1
Vacuum retard, begins, ° @ 1.2-4.4 in. Hg.....	0
Vacuum retard, intermediate, °@ 1.8-4.6 in. Hg. 1	
Vacuum retard, ends, ° @ 4.8 in. Hg.....	2.5 ± 1
Air injection system:	
Pump type.....	rotary vane
Point of discharge.....	exhaust manifold

TABLE 2. FUEL SPECIFICATIONS

Fuel No.....	7619
Research octane No.....	91.5
Motor octane No.....	83.5
Specific gravity.....	0.7160
Reid vapor pressure, psig.....	9.5
Distillation, °F:	
10 pct evaporated.....	128
50 pct ".....	218
95 pct ".....	404
100 pct ".....	417
API gravity, deg.....	66.1
FIA analysis, pct:	
Aromatics.....	6
Olefins.....	17
Paraffins.....	77
Sulfur, pct.....	0.024
Lead, g/gal.....	Trace
Hydrogen/carbon atomic ratio.....	2.040
Oxygen/carbon atomic ratio.....	0.000

TABLE 3. TEST-NUMBER CROSS-REFERENCE INDEX

Pct Full Load	Engine Speed, rpm										
	800	900	1,000	1,500	2,000	2,500	3,000	3,500	4,000	5,000	6,000
0	1 79	4	14	22	30	38	46			70	78
10		5 82 83	13	21	29	37	45			69	77
25		6 84 127	12	20	28	36	44	52	60	68	76
40	2 80		11	19	27	35	43	51	59	67	75
60			10	18	26	34	42	50	58	66	74
75			9	17	25	33	41	49	57	65	73
90			8	16	24		40		56	64	72
100	3 81			15	23	31	39	47		63	71
Motored			115 118	116 119	117						

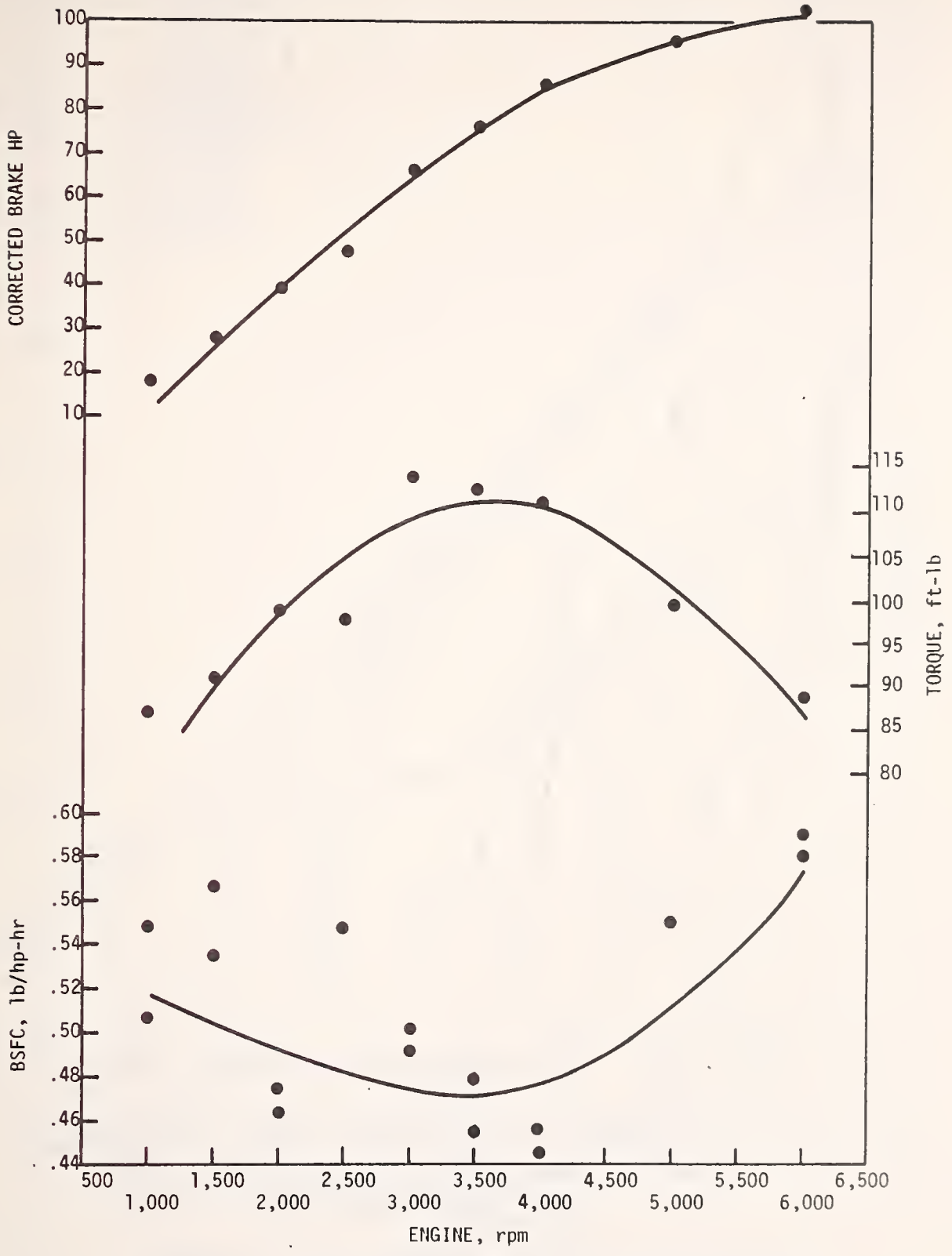


FIGURE 1. Brake Specific Fuel Consumption, Torque, and Brake Horsepower versus Engine rpm at Wide-Open-Throttle--121-CID Volvo Engine.

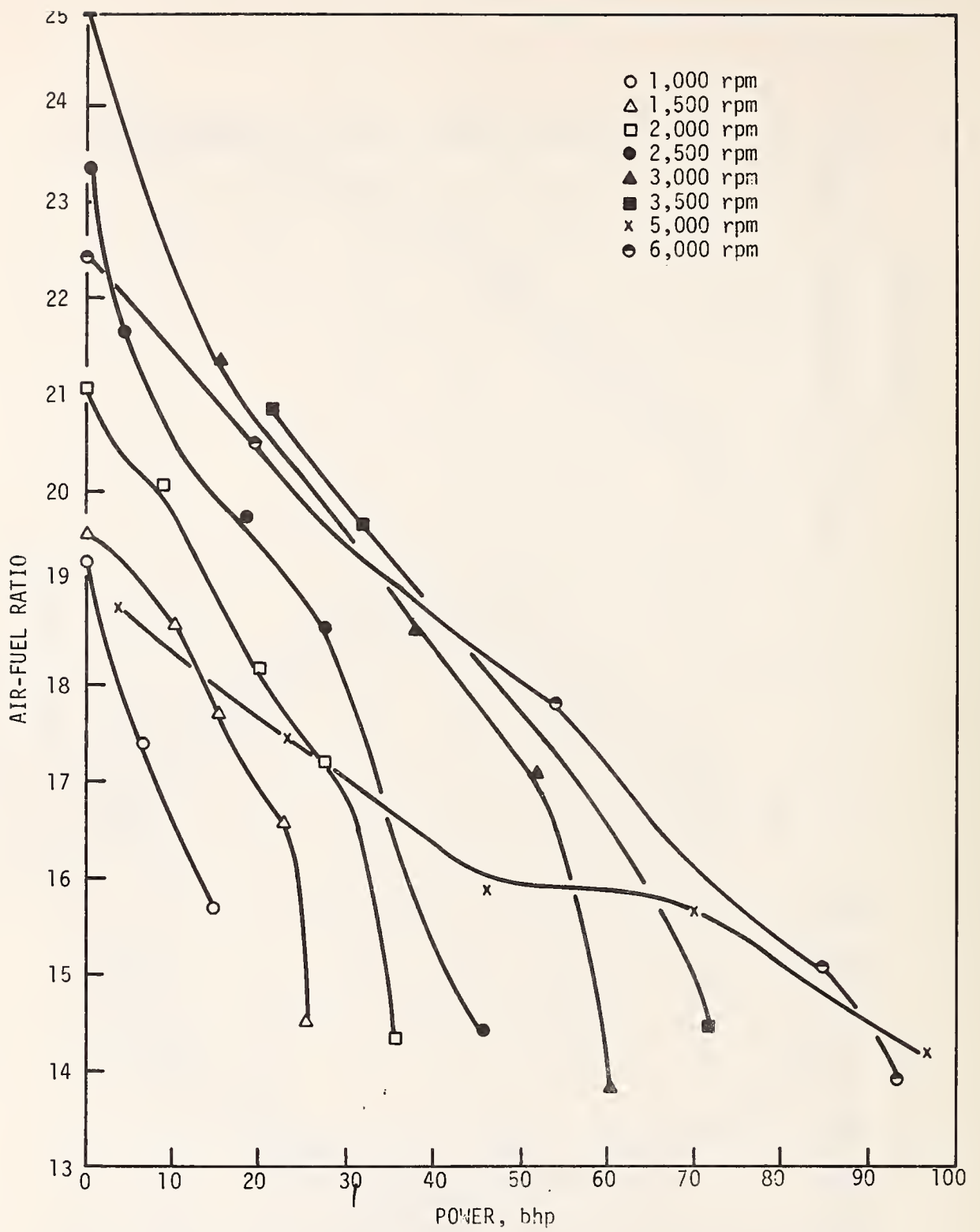


FIGURE 2. Air/Fuel Ratio versus Power at Various Speed and Load Conditions--121-CID Volvo Engine.

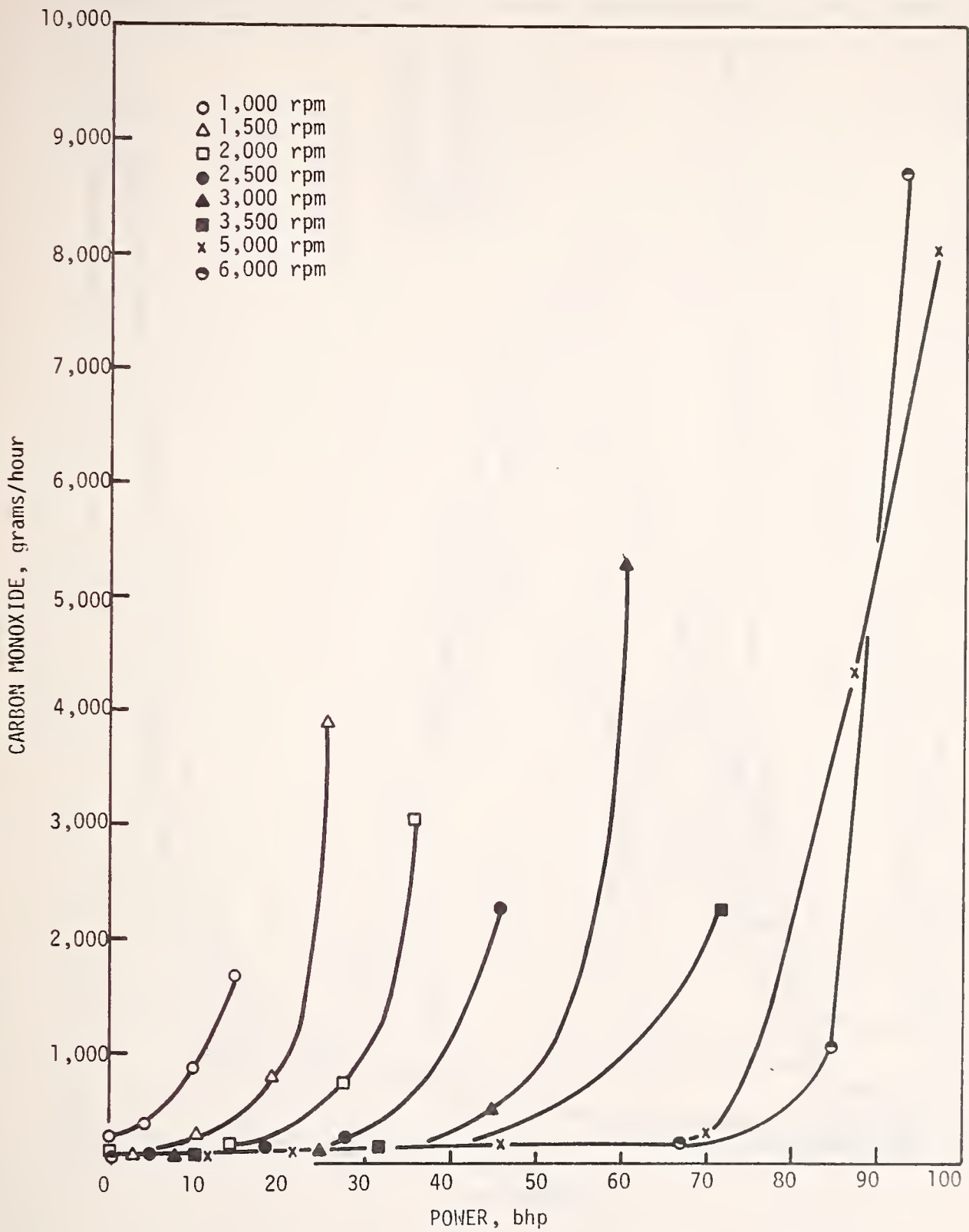


FIGURE 3. Carbon Monoxide Emissions versus Power at Various Speed and Load Conditions-- 121-CID Volvo Engine.

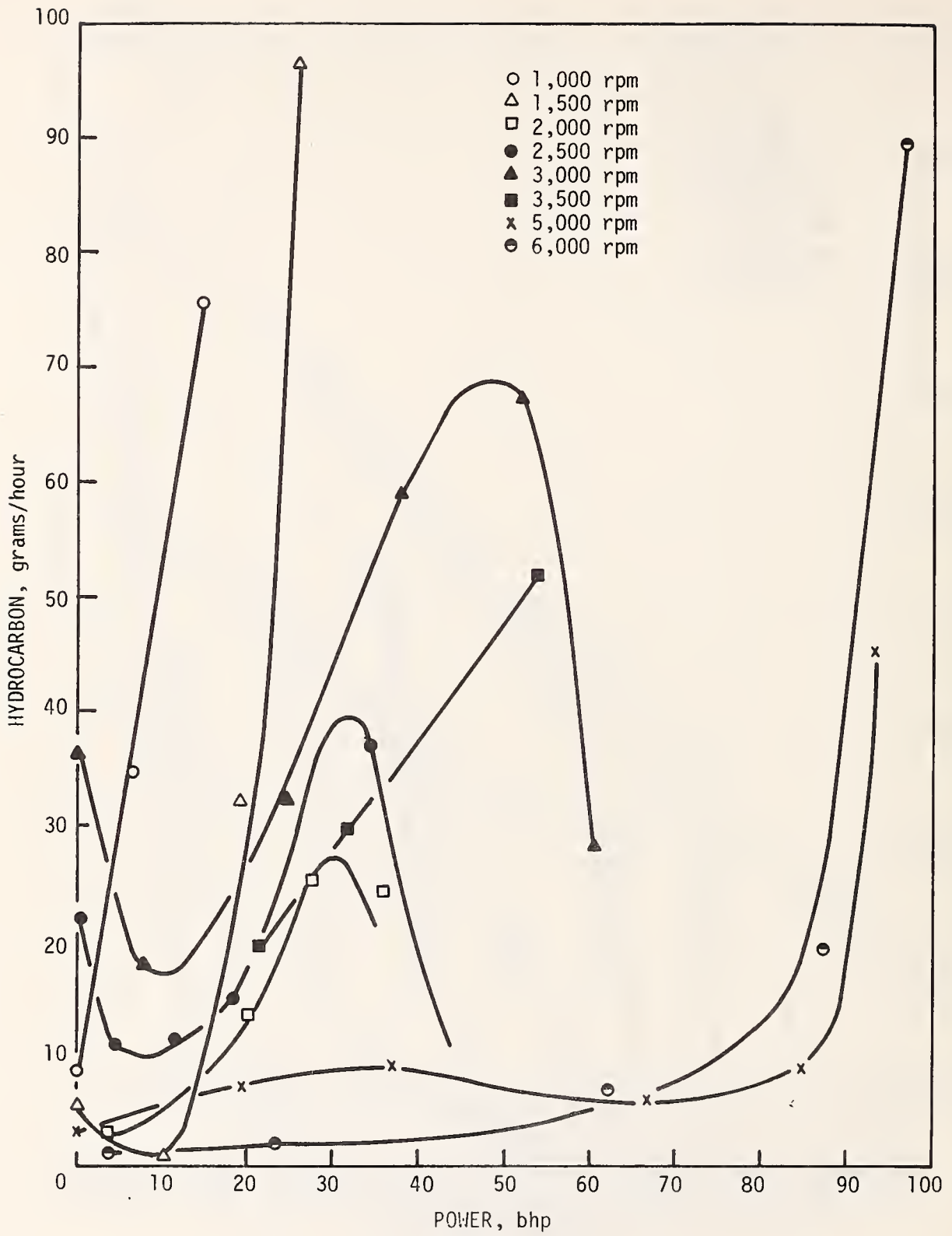


FIGURE 4. Hydrocarbon Emissions versus Power at Various Speed and Load Conditions-- 121-CID Volvo Engine.

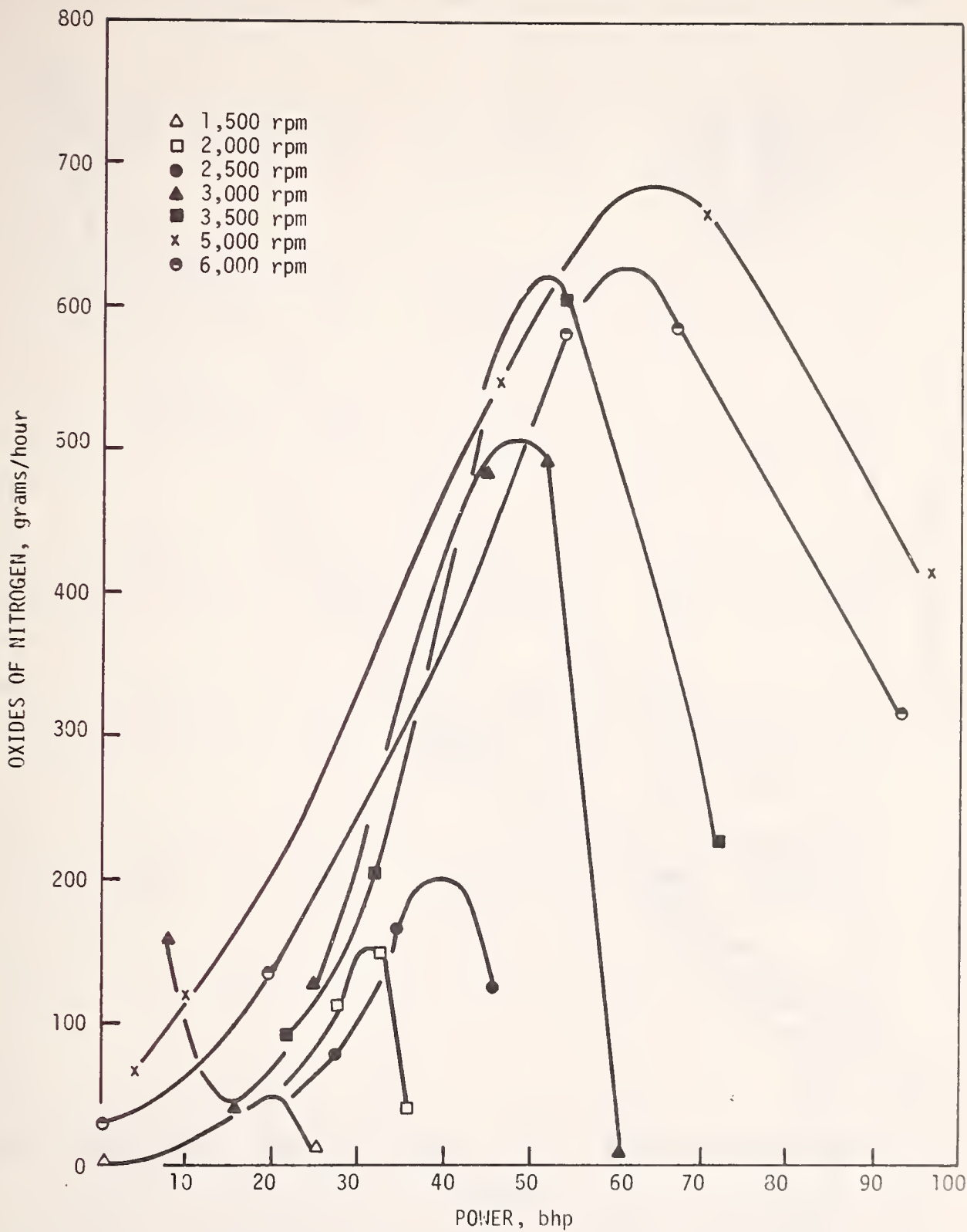


FIGURE 5. Oxides of Nitrogen Emissions versus Power at Various Speed and Load Conditions-- 121-CID Volvo Engine.

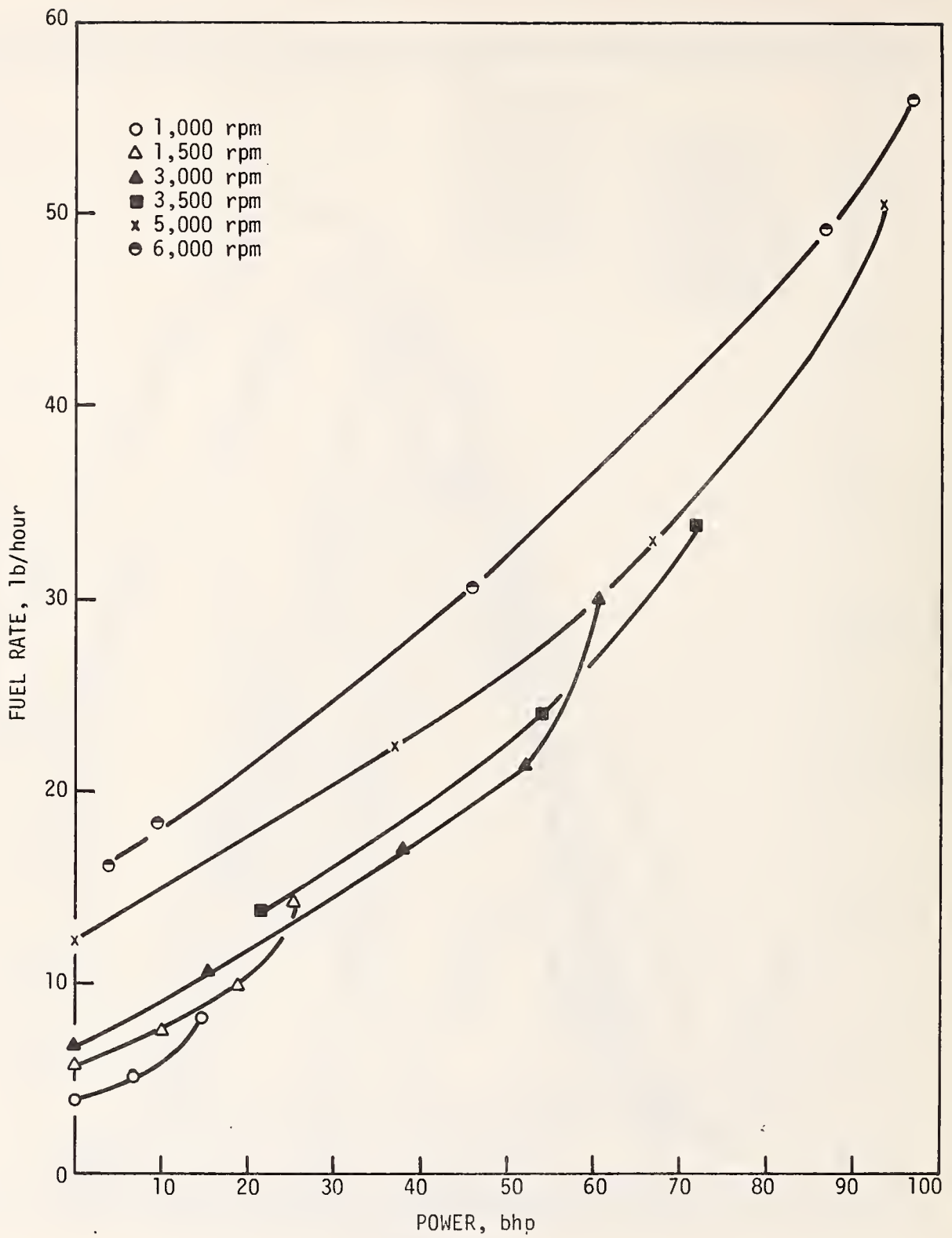


FIGURE 6. Fuel Rate versus Power at Various Speed and Load Conditions--121-CID Volvo Engine.

ENGINE CODE VOL121

TEST NUMBER	1.1	2.1	3.1	4.1	5.1	6.1
TEST DATE	4/ 7/76	4/ 7/76	4/ 7/76	4/ 7/76	4/ 7/76	4/ 7/76
FUEL CODE	7602	7602	7602	7602	7602	7602
BAROMETER, MMHG	740.7	740.7	740.7	740.7	740.7	740.7
HUMIDITY, GRAINS/LB	68	68	68	68	68	68
TEMPERATURE, F	82	81	81	82	82	81
ENGINE SPEED, RPM	800	800	800	900	900	900
TORQUE, FT-LB	.0	10.0	20.0	.0	10.0	20.0
POWER, BHP*	.0	1.5	3.1	.0	1.7	3.4
FUEL RATE, LB/HR	3.1	3.4	3.9	3.4	3.7	4.0
IGNITION TIMING, DEG BTDC	.0	.0	.0	.0	.0	.0
MANIFOLD VACUUM, IN HG	10.4	9.3	7.0	13.2	10.0	8.5
THROTTLE ANGLE, DEG	.0	1.0	3.5	.0	1.0	2.0
INTAKE MAN. TEMP., F	122	124	130	134	125	122

CONCENTRATIONS, DRY BASIS

CO, %	.7760	.6816	.9092	.9692	1.1000	1.3700
CO2, %	9.99	10.29	10.50	9.99	10.29	10.09
O2, %	6.00	5.75	4.45	5.75	5.50	5.00
HC, PPMC	1601	1166	2006	1406	1062	1456
NOX, PPM	32	38	74	37	43	54

AIR/FUEL RATIO

AIR/FUEL RATIO	19.56	19.39	17.85	19.17	18.78	18.11
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EMISSION RATES, G/HR

CO	195.6	185.1	262.9	265.4	321.0	417.3
HC	20.3	16.0	29.2	19.4	15.6	22.4
NOX+	1.3	1.6	3.4	1.6	2.0	2.6

OIL TEMPERATURE, F	180	178	177	184	185	188
OIL PRESSURE, PSI	54	53	47	52	53	51
COOLANT TEMPERATURE, F	182	180	192	185	186	192
EXHAUST PRESSURE, IN. H2O	.0	.0	.0	.0	.0	.0
EXHAUST TEMPERATURE, F	411	406	440	454	443	491

* CORRECTED SAE J8168
 + CORRECTED FOR HUMIDITY

ENGINE CODE VOL121

TEST NUMBER	8.1	9.1	10.1	11.1	12.1	13.1
TEST DATE	4/ 7/76	4/ 7/76	4/ 7/76	4/ 7/76	4/ 7/76	4/ 7/76
FUEL CODE	7602	7602	7602	7602	7602	7602
BAROMETER, MMHG	740.7	740.7	740.7	740.7	740.7	740.7
HUMIDITY, GRAINS/LB	68	68	68	68	68	68
TEMPERATURE, F	81	81	81	81	81	81
ENGINE SPEED, RPM	1000	1000	1000	1000	1000	1000
TORQUE, FT-LB	76.5	63.7	51.0	34.0	21.2	8.5
POWER, BHP*	14.7	12.2	9.8	6.5	4.1	1.6
FUEL RATE, LB/HR	8.0	7.4	5.5	5.0	5.2	4.0
IGNITION TIMING, DEG BTDC	6.0	5.0	5.0	4.0	2.7	3.0
MANIFOLD VACUUM, IN HG	1.5	2.5	3.0	5.0	6.0	10.5
THROTTLE ANGLE, DEG	15.0	11.0	7.9	5.0	4.9	1.8
INTAKE MAN. TEMP., F	106	118	151	168	172	147
CONCENTRATIONS, DRY BASIS						
CO, %	3.2200	2.6500	2.2900	1.7200	1.0500	.9810
CO2, %	9.89	10.09	10.09	10.29	10.90	10.39
O2, %	3.75	3.90	4.25	4.55	4.55	5.25
HC, PPMC	2867	2458	2421	1893	1232	710
NOX, PPM	355	130	80	48	43	53
AIR/FUEL RATIO	15.65	16.14	16.65	17.34	17.83	18.70
EMISSION RATES, G/HR						
CO	1683.6	1320.5	869.0	619.4	399.4	303.1
HC	75.5	61.7	46.3	34.4	23.6	11.1
NOX+	29.6	10.3	4.8	2.8	2.6	2.6
OIL TEMPERATURE, F	195	196	195	195	194	195
OIL PRESSURE, PSI	54	55	49	53	55	55
COOLANT TEMPERATURE, °F	178	194	189	189	182	180
EXHAUST PRESSURE, IN. H2O	2.0	2.0	1.0	1.0	1.0	.0
EXHAUST TEMPERATURE, F	640	573	557	535	580	524

* CORRECTED SAE J816B

+ CORRECTED FOR HUMIDITY

ENGINE CODE VOL121

TEST NUMBER	14.1	15.1	16.1	17.1	18.1	19.1
TEST DATE	4/ 7/76	4/ 7/76	4/ 7/76	4/ 7/76	4/ 7/76	4/ 7/76
FUEL CODE	7602	7602	7602	7602	7602	7602
BAROMETER, MMHG	740.7	740.7	740.7	740.7	740.7	740.7
HUMIDITY, GRAINS/LB	68	68	68	68	68	68
TEMPERATURE, F	81	81	81	81	81	80
ENGINE SPEED, RPM	1000	1500	1500	1500	1500	1500
TORQUE, FT-LB	.0	88.4	79.6	66.3	53.0	35.3
POWER, BHP*	.0	25.4	22.9	19.1	15.2	10.1
FUEL RATE, LB/HR	3.8	14.3	11.4	9.9	9.0	7.5
IGNITION TIMING, DEG BTDC	1.0	11.0	13.5	13.0	13.0	13.0
MANIFOLD VACUUM, IN HG	11.5	.5	2.0	2.5	4.5	7.0
THROTTLE ANGLE, DEG	1.1	90.9	19.0	14.0	10.2	7.0
INTAKE MAN. TEMP., F	108	97	97	120	133	154
CONCENTRATIONS, DRY BASIS						
CO, %	.9465	4.5700	1.6500	1.1600	.7025	.5285
CO2, %	10.29	9.79	11.55	11.55	11.55	11.11
O2, %	5.75	3.00	3.50	3.70	4.00	4.75
HC, PPMC	548	2240	870	919	560	39
NOX, PPM	38	82	75	440	290	116
AIR/FUEL RATIO	19.23	14.46	16.52	17.01	17.62	18.57
EMISSION RATES, G/HR						
CO	287.7	3918.5	1276.9	804.6	460.0	305.0
HC	8.4	96.8	33.9	32.1	18.5	1.1
NOX+	1.8	11.1	9.3	48.6	30.3	10.7
OIL TEMPERATURE, F	155	169	198	208	209	212
OIL PRESSURE, PSI	60	64	61	60	60	60
COOLANT TEMPERATURE, F	182	185	188	185	195	185
EXHAUST PRESSURE, IN. H2O	.0	7.0	7.0	6.0	6.0	5.0
EXHAUST TEMPERATURE, F	388	698	793	766	738	689

* CORRECTED SAE J8168

+ CORRECTED FOR HUMIDITY

ENGINE CODE VOL121

TEST NUMBER	20.1	21.1	22.1	23.1	24.1	25.1
TEST DATE	4/ 7/76	4/ 7/76	4/ 7/76	4/ 8/76	4/ 8/76	4/ 8/76
FUEL CODE	7602	7602	7602	7602	7602	7602
BAROMETER, MMHG	740.7	740.7	740.7	746.5	746.5	746.5
HUMIDITY, GRAINS/LB	66	68	68	71	71	71
TEMPERATURE, F	80	80	80	82	82	81
ENGINE SPEED, RPM	1500	1500	1500	2000	2000	2000
TORQUE, FT-LB	22.1	10.0	.0	93.8	84.4	72.0
POWER, BHP*	6.3	2.9	.0	35.7	32.2	27.4
FUEL RATE, LB/HR	6.5	6.0	5.8	16.8	14.8	13.0
IGNITION TIMING, DEG BTDC	13.0	13.0	13.0	19.0	18.0	19.0
MANIFOLD VACUUM, IN HG	9.0	9.5	10.5	.5	2.0	3.5
THROTTLE ANGLE, DEG	5.5	4.9	4.1	91.0	25.2	19.0
INTAKE MAN. TEMP., F	167	177	180	97	98	116
CONCENTRATIONS, DRY BASIS						
CO, %	.4235	.2584	.2278	3.0700	1.3100	.7905
CO2, %	10.90	10.90	11.00	11.78	12.01	11.89
O2, %	5.25	5.25	5.50	1.25	2.80	3.50
HC, PPMC	295	162	238	483	411	548
NOX, PPM	70	53	46	240	925	750
AIR/FUEL RATIO	19.12	19.30	19.50	14.25	16.26	17.12
EMISSION RATES, G/HR						
CO	216.0	124.1	106.9	3027.1	1294.1	721.5
HC	7.6	3.9	5.6	24.0	20.5	25.2
NOX+	5.6	4.1	3.4	38.2	147.3	110.4
OIL TEMPERATURE, F	211	209	209	221	244	214
OIL PRESSURE, PSI	60	61	61	64	62	64
COOLANT TEMPERATURE, F	185	194	184	190	191	196
EXHAUST PRESSURE, IN. H2O	4.0	3.0	3.0	16.0	12.0	10.0
EXHAUST TEMPERATURE, F	664	669	668	1164	945	854

* CORRECTED SAE J8168
 + CORRECTED FOR HUMIDITY

ENGINE CODE VOL121

TEST NUMBER	26.1	27.1	28.1	29.1	30.1	31.1
TEST DATE	4/ 8/76	4/ 8/76	4/ 9/76	4/ 9/76	4/ 9/76	4/13/76
FUEL CODE	7602	7602	7602	7602	7602	7602
BAROMETER, MMHG	746.5	746.5	748.2	748.2	748.2	748.2
HUMIDITY, GRAINS/LB	71	71	43	43	43	43
TEMPERATURE, F	82	81	79	80	81	82
ENGINE SPEED, RPM	2000	2000	2000	2000	2000	2500
TORQUE, FT-LB	52.6	37.5	23.2	9.3	.0	97.0
POWER, SHP*	20.0	14.3	8.7	3.5	.0	45.8
FUEL RATE, LB/HR	10.7	9.0	7.6	6.8	6.1	24.9
IGNITION TIMING, DEG BTDC	19.0	18.0	18.0	13.0	15.0	27.0
MANIFOLD VACUUM, IN HG	6.0	8.5	11.5	13.0	15.0	.5
THROTTLE ANGLE, DEG	13.0	10.0	7.9	7.0	5.9	90.0
INTAKE MAN. TEMP., F	133	147	156	170	176	93

CONCENTRATIONS, DRY BASIS

CO, %	3619	2738	2380	1325	1650	1.5600
CO2, %	11.66	11.21	10.69	10.50	9.99	13.53
O2, %	4.20	4.95	5.90	6.05	6.50	.10
HC, PPMC	335	225	149	95	201	73
NOX, PPM	400	175	93	64	47	600

AIR/FUEL RATIO

AIR/FUEL RATIO	18.06	18.91	19.99	20.35	20.99	14.27
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EMISSION RATES, G/HR

CO	286.6	191.3	149.8	76.4	88.3	2257.6
HC	13.4	7.9	4.7	2.7	5.4	5.3
NOX+	51.1	19.7	8.3	5.3	3.6	124.0

OIL TEMPERATURE, F	225	225	190	218	216	257
OIL PRESSURE, PSI	63	63	65	64	64	65
COOLANT TEMPERATURE, F	193	190	191	190	192	191
EXHAUST PRESSURE, IN. H2O	7.0	5.0	4.0	3.0	2.0	28.0
EXHAUST TEMPERATURE, F	819	780	717	712	668	1388

* CORRECTED SAE J8168

+ CORRECTED FOR HUMIDITY

ENGINE CODE VOL121

	33.1	34.1	35.1	36.1	37.1	38.1
TEST NUMBER	4/13/76	4/13/76	4/13/76	4/13/76	4/13/76	4/13/76
TEST DATE	7602	7602	7602	7602	7602	7602
FUEL CODE	748.2	748.2	748.2	748.2	748.2	748.2
BAROMETER, MMHG	43	43	43	43	43	43
HUMIDITY, GRAINS/LB	81	81	81	81	81	82
TEMPERATURE, F	2500	2500	2500	2500	2500	2500
ENGINE SPEED, RPM	72.7	58.2	38.8	24.3	9.7	.8
TORQUE, FT-LB	34.3	27.4	18.3	11.5	4.6	.4
POWER, BHP*	15.7	12.9	11.0	9.5	7.4	6.1
FUEL RATE, LB/HR	25.0	24.0	25.0	24.0	22.0	21.0
IGNITION TIMING, DEG BTDC	4.5	6.5	9.5	11.5	13.0	14.5
MANIFOLD VACUUM, IN HG	21.0	16.0	13.0	11.5	9.5	8.0
THROTTLE ANGLE, DEG	111	125	133	143	157	167
INTAKE MAN. TEMP., F						
CONCENTRATIONS, DRY BASIS						
CO, %	5080	2180	1769	1420	1373	1465
CO2, %	12.01	11.55	10.90	10.59	9.79	8.92
O2, %	2.70	4.50	5.50	6.00	6.90	8.00
HC, PPMC	684	420	334	287	318	730
NOX, PPM	1075	560	280	155	80	55
AIR/FUEL RATIO	16.67	18.45	19.58	20.21	21.52	23.22
EMISSION RATES, G/HR						
CO	546.0	213.6	157.3	113.0	91.5	87.2
HC	37.1	20.8	15.0	11.5	10.7	21.9
NOX+	165.0	78.4	35.5	17.6	7.6	4.7
OIL TEMPERATURE, F	238	246	236	242	231	227
OIL PRESSURE, PSI	65	64	65	66	65	65
COOLANT TEMPERATURE, F	192	187	194	188	186	185
EXHAUST PRESSURE, IN. H2O	18.0	14.0	11.0	8.0	4.0	4.0
EXHAUST TEMPERATURE, F	890	844	772	749	693	668

* CORRECTED SAE J816B
 + CORRECTED FOR HUMIDITY

ENGINE CODE VOL121

TEST NUMBER	39.1	40.1	41.1	42.1	43.1	44.1
TEST DATE	4/13/76	4/13/76	4/13/76	4/13/76	4/13/76	4/13/76
FUEL CODE	7602	7602	7602	7602	7602	7602
BAROMETER, MMHG	748.2	748.2	741.8	741.8	741.8	741.8
HUMIDITY, GRAINS/LB	43	43	68	68	68	68
TEMPERATURE, F	83	83	83	82	82	81
ENGINE SPEED, RPM	3000	3000	3000	3000	3000	3000
TORQUE, FT-LB	106.6	91.4	78.0	66.0	43.0	27.0
POWER, BHP*	60.4	51.8	44.9	37.9	24.7	15.5
FUEL RATE, LB/HR	30.1	21.2	18.8	17.0	12.3	10.6
IGNITION TIMING, DEG BTDC	30.0	29.0	31.0	31.0	30.5	29.0
MANIFOLD VACUUM, IN HG	.8	2.5	4.7	6.0	10.0	12.0
THROTTLE ANGLE, DEG	90.0	32.0	24.5	20.5	16.0	12.0
INTAKE MAN. TEMP., F	94	103	112	116	127	134
CONCENTRATIONS, DRY BASIS						
CO, %	3.1500	.7190	.3468	.2116	.1229	.1229
CO2, %	12.62	12.01	11.78	11.43	10.59	10.09
O2, %	.25	3.18	3.80	4.38	5.85	6.75
HC, PPMC	337	909	938	912	627	488
NOX, PPM	40	2350	2225	1875	780	280
AIR/FUEL RATIO	13.64	16.92	17.71	18.37	20.06	21.18
EMISSION RATES, G/HR						
CO	5280.0	1060.8	474.8	272.9	126.0	114.5
HC	28.5	67.6	64.7	59.3	32.4	22.9
NOX+	9.6	495.1	486.4	386.2	127.7	41.7
OIL TEMPERATURE, F	258	262	264	250	256	242
OIL PRESSURE, PSI	66	66	66	66	68	69
COOLANT TEMPERATURE, F	188	189	189	192	194	189
EXHAUST PRESSURE, IN. H2O	39.0	26.0	21.0	17.0	12.0	10.0
EXHAUST TEMPERATURE, F	1305	990	934	900	808	745

* CORRECTED SAE J816B
+ CORRECTED FOR HUMIDITY

ENGINE CODE VOL121

TEST NUMBER	45.1	46.1	47.1	49.1	50.1	51.1
TEST DATE	4/13/76	4/13/76	4/13/76	4/14/76	4/14/76	4/14/76
FUEL CODE	7602	7602	7602	7602	7602	7602
BAROMETER, MMHG	741.8	741.8	741.8	740.6	740.6	740.6
HUMIDITY, GRAINS/LB	68	68	68	68	66	68
TEMPERATURE, F	82	81	82	80	82	82
ENGINE SPEED, RPM	3000	3000	3500	3500	3500	3500
TORQUE, FT-LB	13.6	.0	107.0	80.3	64.2	47.2
POWER, BHP*	7.8	.0	71.7	53.8	43.1	31.7
FUEL RATE, LB/HR	8.6	6.8	34.1	24.0	19.4	16.6
IGNITION TIMING, DEG BTDC	32.0	31.0	30.0	30.0	30.0	33.0
MANIFOLD VACUUM, IN HG	15.0	18.0	.5	4.5	7.0	10.0
THRUSTLE ANGLE, DEG	11.0	8.5	90.0	24.0	18.0	13.0
INTAKE MAN. TEMP., F	145	157	93	103	115	121
CONCENTRATIONS, DRY BASIS						
CO, %	1180	1277	11200	4740	1534	1127
CO2, %	9.30	8.36	14.21	11.78	10.90	10.59
O2, %	7.75	9.00	.10	3.10	4.75	5.10
HC, PPMC	437	1031	2404	607	650	438
NOX, PPM	1225	58	720	2250	2000	963
AIR/FUEL RATIO	22.80	24.85	14.26	17.10	18.97	19.43
EMISSION RATES, G/HR						
CO	96.3	89.8	2209.3	802.9	233.7	150.7
HC	18.0	36.5	239.0	51.9	49.9	29.5
NOX+	159.7	6.5	226.8	607.6	481.6	205.2
OIL TEMPERATURE, F	242	240	249	228	266	267
OIL PRESSURE, PSI	68	69	70	72	68	68
COOLANT TEMPERATURE, F	188	186	187	192	188	188
EXHAUST PRESSURE, IN. H2O	6.0	3.0	50.0	31.0	23.0	17.0
EXHAUST TEMPERATURE, F	711	680	1358	1025	936	900

* CORRECTED SAE J816B

+ CORRECTED FOR HUMIDITY

ENGINE CODE VOL121

TEST NUMBER	52.1	56.1	57.1	58.1	59.1	60.1
TEST DATE	4/14/76	4/14/76	4/14/76	4/14/76	4/14/76	4/15/76
FUEL CODE	7602	7602	7602	7602	7602	7602
BAROMETER, MMHG	740.6	740.6	740.6	740.6	740.6	736.1
HUMIDITY, GRAINS/LB	68	68	68	68	68	69
TEMPERATURE, F	82	83	82	82	83	81
ENGINE SPEED, RPM	3500	4000	4000	4000	4000	4000
TORQUE, FT-LB	31.8	93.2	79.4	61.0	40.7	35.2
POWER, BHP*	21.4	71.6	60.9	46.8	31.3	27.2
FUEL RATE, LB/HR	13.9	32.3	28.1	23.4	18.2	18.0
IGNITION TIMING, DEG BTDC	34.0	33.0	33.0	33.0	33.0	33.0
MANIFOLD VACUUM, IN HG	12.0	2.0	5.0	7.0	10.0	11.0
THROTTLE ANGLE, DEG	10.2	47.0	32.0	23.0	15.0	13.5
INTAKE MAN. TEMP., F	128	96	104	114	120	118

CONCENTRATIONS, DRY BASIS

CO, %	.0561	.1373	.2328	.2337	.1325	.1443
CO2, %	9.99	13.13	12.75	11.78	10.79	10.79
O2, %	6.00	1.40	2.30	3.50	5.10	5.10
HC, PPMC	320	57	93	112	164	296
NOX, PPM	490	1837	1912	1700	800	880

AIR/FUEL RATIO

AIR/FUEL RATIO	20.64	15.91	16.56	17.65	19.37	19.34
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EMISSION RATES, G/HR

CO	66.8	288.6	444.0	397.5	193.3	208.0
HC	19.2	6.0	8.9	9.6	12.0	21.5
NOX+	93.0	615.5	581.3	460.9	186.0	203.0

OIL TEMPERATURE, F	262	288	198	263	271	272
OIL PRESSURE, PSI	69	68	79	70	70	70
COOLANT TEMPERATURE, F	189	190	160	189	188	190
EXHAUST PRESSURE, IN. H2O	13.0	52.0	40.0	30.0	20.0	19.0
EXHAUST TEMPERATURE, F	845	1299	1026	1055	951	950

* CORRECTED SAE J816B

+ CORRECTED FOR HUMIDITY

ENGINE CODE Y0L121

TEST NUMBER	63.1	64.1	65.1	66.1	67.1	68.1
TEST DATE	4/15/76	4/15/76	4/15/76	4/15/76	4/15/76	4/15/76
FUEL CODE	7602	7602	7602	7602	7602	7602
BAROMETER, MMHG	736.1	736.1	736.1	736.1	736.1	736.1
HUMIDITY, GRAINS/LB	69	69	69	69	69	69
TEMPERATURE, F	86	81	83	83	82	82
ENGINE SPEED, RPM	5000	5000	5000	5000	5000	5000
TORQUE, FT-LB	96.2	87.8	69.2	55.8	38.4	20.0
POWER, BHP*	93.2	84.7	66.9	53.9	37.1	19.3
FUEL RATE, LB/HR	50.9	42.7	33.4	27.9	22.7	18.0
IGNITION TIMING, DEG BTDC	30.0	32.0	32.0	31.2	32.0	32.0
MANIFOLD VACUUM, IN HG	1.0	2.5	5.5	8.0	11.0	14.0
THROTTLE ANGLE, DEG	90.0	54.0	35.0	26.0	17.0	15.3
INTAKE MAN. TEMP., F	98	103	111	114	117	121
CONCENTRATIONS, DRY BASIS						
CO, %	3.0700	.3914	.0772	.1465	.1180	.0940
CO2, %	12.75	14.91	13.80	12.50	11.55	10.69
O2, %	.20	.20	1.80	3.50	4.60	6.00
HC, PPMC	316	67	52	58	101	93
NOX, PPM	700	1000	1675	1825	1200	570
AIR/FUEL RATIO	13.67	14.87	16.17	17.57	18.70	20.27
EMISSION RATES, G/HR						
CO	8716.7	1004.7	169.7	294.0	206.1	141.7
HC	45.3	8.7	5.8	5.8	8.9	7.0
NOX+	318.2	410.9	589.2	586.2	335.6	137.6
OIL TEMPERATURE, F	313	291	308	308	303	297
OIL PRESSURE, PSI	67	70	68	69	70	71
COOLANT TEMPERATURE, F	191	191	189	188	188	187
EXHAUST PRESSURE, IN. H2O	93.0	82.0	55.0	41.0	29.0	20.0
EXHAUST TEMPERATURE, F	1445	1468	1294	1156	1056	987

* CORRECTED SAE J8168
 + CORRECTED FOR HUMIDITY

ENGINE CODE VOL121

TEST NUMBER	70.1	71.1	72.1	73.1	74.1
TEST DATE	4/15/76	4/27/76	4/27/76	4/27/76	4/27/76
FUEL CODE	7602	7602	7602	7602	7602
BAROMETER, MMHG	736.1	746.4	746.4	746.4	746.4
HUMIDITY, GRAINS/LB	69	43	43	43	43
TEMPERATURE, F	81	85	86	85	86
ENGINE SPEED, RPM	5000	6000	6000	6000	6000
TORQUE, FT-LB	11.2	85.0	76.5	61.6	54.4
POWER, BHP*	10.8	96.8	87.2	70.1	62.0
FUEL RATE, LB/HR	15.4	56.8	49.9	45.0	39.5
IGNITION TIMING, DEG BTDC	32.0	30.0	29.0	28.5	28.0
MANIFOLD VACUUM, IN HG	16.0	.9	1.9	4.1	6.4
THROTTLE ANGLE, DEG	12.2	90.0	63.0	43.0	31.0
INTAKE MAN. TEMP., F	128	95	106	112	116

CONCENTRATIONS, DRY BASIS

CO, %	.0844	2.4800	1.4800	.0940	.0700
CO2, %	10.50	12.75	13.14	13.67	13.53
O2, %	6.90	.30	.15	.73	1.20
HC, PPMC	79	551	130	52	52
NOX, PPM	330	900	1100	1650	1500

AIR/FUEL RATIO

AIR/FUEL RATIO	21.20	13.95	14.33	15.41	15.76
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EMISSION RATES, G/HR

CO	113.9	8036.0	4323.6	266.0	177.9
HC	5.4	89.9	19.2	7.5	6.7
NOX+	71.3	417.2	459.7	668.0	545.5

OIL TEMPERATURE, F	296	318	331	326	334
OIL PRESSURE, PSI	72	60	62	64	62
COOLANT TEMPERATURE, F	188	191	190	189	191
EXHAUST PRESSURE, IN. H2O	14.0	125.0	110.0	101.0	78.0
EXHAUST TEMPERATURE, F	932	1510	1530	1528	1433

* CORRECTED SAE J816B

+ CORRECTED FOR HUMIDITY

ENGINE CODE VOL121

TEST NUMBER	75.1	76.1	77.1	78.1	79.1	80.1
TEST DATE	4/27/76	4/27/76	4/27/76	4/27/76	4/15/76	4/15/76
FUEL CODE	7602	7602	7602	7602	7602	7602
BAROMETER, MMHG	746.4	746.4	746.4	746.4	736.1	736.1
HUMIDITY, GRAINS/LB	43	43	43	43	69	69
TEMPERATURE, F	82	83	83	83	81	81
ENGINE SPEED, RPM	6000	6000	6000	6000	800	800
TORQUE, FT-LB	40.6	20.4	8.5	3.4	.0	10.0
POWER, BHP*	46.1	23.2	9.7	3.9	.0	1.5
FUEL RATE, LB/HR	31.0	22.9	18.7	16.5	2.8	3.5
IGNITION TIMING, DEG BTDC	30.0	30.0	30.0	30.5	1.0	1.0
MANIFOLD VACUUM, IN HG	10.0	13.7	15.5	16.8	11.0	8.5
THROTTLE ANGLE, DEG	19.0	16.5	14.0	13.0	.0	.5
INTAKE MAN. TEMP., F	107	121	128	132	134	125
CONCENTRATIONS, DRY BASIS						
CO, %	.0844	.0561	.0607	.0607	.1420	.1229
CO2, %	13.40	12.25	11.66	11.32	9.69	10.59
O2, %	1.00	2.90	3.85	4.30	6.50	5.20
HC, PPMC	26	25	25	19	2315	556
NOX, PPM	1950	1100	620	385	28	45
AIR/FUEL RATIO	15.63	17.20	18.08	18.55	20.76	19.45
EMISSION RATES, G/HR						
CO	167.2	90.8	84.4	76.9	34.2	34.9
HC	2.6	2.1	1.8	1.2	28.1	8.0
NOX+	552.8	254.8	123.4	69.7	1.1	2.0
OIL TEMPERATURE, F	250	305	304	313	182	194
OIL PRESSURE, PSI	76	69	69	70	47	50
COOLANT TEMPERATURE, F	189	190	186	188	188	182
EXHAUST PRESSURE, IN. H2O	45.0	28.0	19.0	16.0	1.0	1.0
EXHAUST TEMPERATURE, F	1140	1080	1006	988	366	378

* CORRECTED SAE J8168

+ CORRECTED FOR HUMIDITY

ENGINE CODE VOL121

TEST NUMBER	81.1	82.1	83.1	84.1	115.1	116.1
TEST DATE	4/16/76	4/16/76	4/16/76	4/16/76	4/28/76	4/28/76
FUEL CODE	7602	7602	7602	7602	7602	7602
BAROMETER, MMHG	744.0	744.0	744.0	744.0	749.6	749.6
HUMIDITY, GRAINS/LB	68	68	68	68	43	43
TEMPERATURE, F	81	81	80	81	88	80
ENGINE SPEED, RPM	800	900	900	900	1000	1500
TORQUE, FT-LB	20.6	6.4	10.0	20.0	-6.8	-15.0
POWER, BHP*	3.1	1.1	1.7	3.4	1.3	4.2
FUEL RATE, LB/HR	3.7	3.5	3.8	4.6	2.9	3.1
IGNITION TIMING, DEG BTDC	1.0	1.0	1.0	2.0	.5	6.0
MANIFOLD VACUUM, IN HG	7.0	10.0	9.0	5.0	12.9	17.7
THRUSTLE ANGLE, DEG	20.0	.7	3.0	4.0	.0	.0
INTAKE MAN. TEMP., F	122	128	128	154	132	131
CONCENTRATIONS, DRY BASIS						
CO, %	.3910	.1229	.1682	.2380	.2890	.2335
CO2, %	10.79	10.50	10.69	11.00	11.33	9.50
O2, %	5.00	5.75	5.50	4.95	5.20	7.65
HC, PPMC	750	652	458	1002	7842	30285
NOX, PPM	65	43	53	53	29	12
A/F/FUEL RATIO	18.90	19.98	19.65	18.88	17.89	17.09
EMISSION RATES, G/HR						
CO	114.2	35.9	52.0	85.5	61.3	52.6
HC	11.0	9.6	7.1	18.1	83.8	344.0
NOX*	3.0	2.0	2.6	3.0	.9	.4
OIL TEMPERATURE, F	183	190	189	189	182	189
OIL PFEASURE, PSI	47	49	50	51	55	60
COOLANT TEMPERATURE, F	194	181	181	182	187	181
EXHAUST PRESSURE, IN. H2O	1.0	1.0	1.0	1.0	.0	.0
EXHAUST TEMPERATURE, F	424	444	422	449	354	378

* CORRECTED SAE J8168

+ CORRECTED FOR HUMIDITY

ENGINE CODE VOL121

TEST NUMBER	117.1	118.1	119.1
TEST DATE	4/28/76	4/28/76	4/28/76
FUEL CODE	7602	7602	7602
BAROMETER, MMHG	749.6	749.6	749.6
HUMIDITY, GRAINS/LB	43	43	43
TEMPERATURE, F	79	80	80
ENGINE SPEED, RPM	2000	1000	1500
TORQUE, FT-LB	-16.7	-6.8	-15.1
POWER, BHP*	6.3	1.3	4.3
FUEL RATE, LB/HR	3.6	2.9	3.1
IGNITION TIMING, DEG BTDC	12.0	1.0	6.0
MANIFOLD VACUUM, IN HG	19.7	12.7	17.7
THROTTLE ANGLE, DEG	.0	.0	.0
INTAKE MAN. TEMP., F	122	123	118

CONCENTRATIONS, DRY BASIS

CO, %	.2116	.2990	.2116
CO2, %	9.11	11.22	9.50
O2, %	8.50	5.35	7.75
HC, PPMC	28852	15340	29066
NOX, PPM	11	25	11

AIR/FUEL RATIO

AIR/FUEL RATIO	18.06	16.99	17.35
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EMISSION RATES, G/HR

CO	57.7	61.8	47.8
HC	396.4	159.8	331.0
NOX+	.4	.7	.4

OIL TEMPERATURE, F	198	194	193
OIL PRESSURE, PSI	63	52	60
COOLANT TEMPERATURE, F	190	187	186
EXHAUST PRESSURE, IN. H2O	1.0	6.0	.0
EXHAUST TEMPERATURE, F	412	361	390

* CORRECTED SAE J8168

+ CORRECTED FOR HUMIDITY

HE 18.5 .A34
no. DOT-TSC-
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