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DOT-HS-804 016

## PERFORMANCE CHARACTERISTICS OF AUTOMOTIVE ENGINES IN THE UNITED STATES

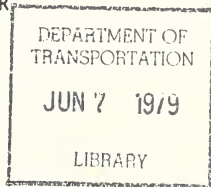
Third Series - Report No. 11  
1978 Oldsmobile Diesel, 350 CID (5.7 Liters), F.I.

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W.F. Marshall

U.S. DEPARTMENT OF ENERGY  
BARTLESVILLE ENERGY TECHNOLOGY CENTER  
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APRIL 1979  
INTERIM REPORT



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U.S. DEPARTMENT OF TRANSPORTATION  
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Office of Research and Development  
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NOTICE

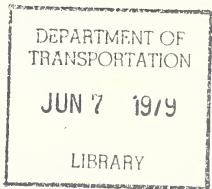
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No. DOT-TSC-NHTSA-79-22 L.V

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16. Abstract Experimental data were obtained in dynamometer tests of a 1978 Oldsmobile 350 CID diesel 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 Technology 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 an engine used in automobiles sold in the United States. The Oldsmobile 350 CID diesel engine used in this work is one of a series of 15 engines to be tested in the current program. This is the eleventh of the reports to be published covering work with those engines. This project is funded by the National Highway Traffic Safety Administration, Office of Research and Development, Office of Passenger Vehicle Research, Technology Assessment Division.

James A. Kidd, Jr. of the U.S. Department of Transportation, Transportation Systems Center, is the technical monitor.

# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	<b>LENGTH</b>			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	<b>AREA</b>			
sq ft	square inches	6.5	square centimeters	cm <sup>2</sup>
sq ft	square feet	0.09	square meters	m <sup>2</sup>
sq yd	square yards	0.8	square meters	m <sup>2</sup>
sq mi	square miles	2.6	square kilometers	km <sup>2</sup>
acres	acres	0.4	hectares	ha

### MASS (weight)

oz	ounces	28	grams	g
lb	pounds	4.5	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t

### VOLUME

tblsp	tablespoons	5	milliliters	ml
fl oz	fluid ounces	15	milliliters	ml
cup	cups	240	milliliters	ml
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
cu ft	cubic feet	0.03	cubic meters	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.76	cubic meters	m <sup>3</sup>

### TEMPERATURE (exact)

F	Fahrenheit temperature	$(F - 32) \times \frac{5}{9}$ (after subtracting 32)	C	Celsius temperature
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## Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	<b>LENGTH</b>			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
km	kilometers	1.1	miles	mi
	kilometers	0.6	miles	mi
	<b>AREA</b>			
sq cm	square centimeters	0.16	square inches	sq in
sq m	square meters	1.1	square yards	sq yd
km <sup>2</sup>	square kilometers	0.4	square miles	sq mi
ha	hectares (10,000 m <sup>2</sup> )	2.5	acres	acres

### MASS (weight)

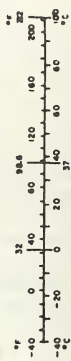
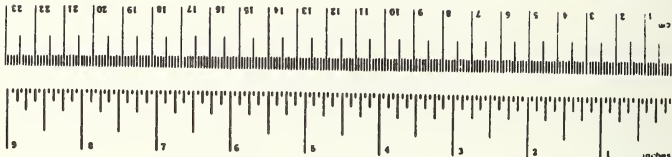
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	short tons

### VOLUME

ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m <sup>3</sup>	cubic meters	35	cubic feet	cu ft
m <sup>3</sup>	cubic meters	1.3	cubic yards	yd <sup>3</sup>

### TEMPERATURE (exact)

C	Celsius temperature	$(C \times \frac{9}{5}) + 32$ (then add 32)	F	Fahrenheit temperature
---	---------------------	---	---	------------------------



## 1. INTRODUCTION

The objective of this program is to obtain engine performance data for estimating fuel economy and emissions for varied engine service and duty. The intent of the work done at the Bartlesville Energy Technology Center is to provide basic engine characteristic data required as input for engineering calculations of fuel consumption and emissions involving ground transportation.

The data acquired from tests of a 1978 Oldsmobile 350 CID diesel engine are presented in this report. Oldsmobile uses the 350 CID diesel engine in the Delta 88 and in the Custom Cruiser wagon with inertia weights of 4,500 lb and 5,000 lb, respectively. The engine as equipped is intended for use in a forty-nine state (Federal) vehicle with automatic transmission. The test results are sufficient to establish steady-state maps for fuel consumption and emissions (carbon monoxide, hydrocarbons, and oxides of nitrogen) over the entire operating range of the engine.

## 2. ENGINE TEST REPORT

The engine test setup included a complete mean-tolerance engine (SAE definition) coupled to an eddy current dynamometer. A cooling tower was used in place of the fan and radiator. The alternator was included but was not wired into the engine's electrical system. The emission control systems included positive crankcase ventilation. The manufacturer's engine specifications are listed in Table 1.

Prior to testing, engine break-in consisted of 40 hours of operation at various speed/load modes representative of normal engine operation. Table 2 contains details of the break-in schedule. A single batch of No. 2 diesel fuel was used throughout the break-in and test; a detailed fuel analysis is given in Table 3. Engine testing began on August 11, 1978, and ended on September 26, 1978.

During steady-state tests the engine was operated at the following speed/load modes:

Speeds: 1,000; 1,300; 1,600; 2,000; 2,500; 3,000; 3,600 rpm

Loads: 0, 10, 25, 40, 60, 75, 90, 100 pct of full load  
(0, 10, 25 and 40 pct points were repeated at  
all engine speeds)

Idle speed/load modes: 750 rpm -- 0 lb-ft  
600 rpm -- 0 lb-ft

Over speed mode: 3,850 rpm -- 161 lb-ft (full rack)

Total number of test modes..... 59  
Total number of repeats..... 97  
Total number of tests..... 156

The following data were recorded for each test point:

Test number  
Date  
Data source code  
Barometric pressure, mm Hg  
Wet bulb temperature, °F  
Dry bulb temperature, °F  
Speed, rpm  
Torque, lb-ft -- BLH strain gauge; Daytronic indicator  
Fuel rate, lb/hr -- Fluidyne positive displacement fuel flow meter  
Rack position (throttle angle), degrees  
CO, pct -- Beckman NDIR



CO<sub>2</sub>, pct -- Beckman NDIR  
 O<sub>2</sub>, pct -- Beckman polarographic detector  
 HC, ppmC -- Custom built heated flame ionization detector  
 NO<sub>x</sub>, ppm -- Thermo-Electron chemiluminescent detector  
 Oil temperature, °F  
 Oil pressure, psi  
 Coolant temperature, °F  
 Exhaust temperature, °F  
 Exhaust pressure, in. H<sub>2</sub>O  
 Smoke, pct opacity -- Celesco smoke meter  
 Particulate, mg/m<sup>3</sup> -- Ikor air quality monitor, Model 206

The computed data include absolute humidity, power, and emission rates of carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NO<sub>x</sub>) in grams per hour. The following equations were applied in the computations:

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

$$P_v = \exp \left[ 18.717 - \frac{7308.1}{393 + T_w} \right] + \frac{P_b}{2784.2} \left[ 1 + \frac{T_w}{1533.2} \right] \left[ T_w - T_D \right]$$

T<sub>w</sub> = Wet bulb temperature, °F

T<sub>D</sub> = Dry bulb temperature, °F

P<sub>b</sub> = Barometric pressure, mm Hg

2. Humidity (grains moisture per pound dry air):

$$H = \frac{(4347.3) (P_v)}{P_b - P_v}$$

3. Corrected brake horsepower:

0.7

$$HP_c = \left[ \frac{T N}{5252.11} \right] \left[ \frac{T_D + 460}{545} \right] \left[ \frac{P_b - P_v}{736.6} \right]$$

T = Brake torque (lb-ft)

N = Engine speed (rpm)

4. Fuel mass flow rate (lb/hr):

$$\dot{m}_f = \dot{V}_f P_f \left( \frac{3600}{453.59} \right) [1 + 0.0007(60 - T_F)]$$

$\dot{V}_f$  = Volume flow rate (cc/sec)

$P_f$  = Fuel specific gravity

$T_F$  = Fuel temperature ( $^{\circ}$ F)

5. Convert hydrocarbon concentration measurements from wet basis to dry basis:

$$HC_D = HC_W \left[ 1 + \frac{X}{200} \left( \frac{3CO_2[CO + CO_2]}{CO + 3CO_2} \right) \right]$$

$HC_W$  = Hydrocarbon concentration on wet basis (pct)

$X^W$  = Fuel hydrogen/carbon atomic ratio

$CO_2$  = Carbon dioxide concentration on dry basis (pct)

$CO$  = Carbon monoxide concentration on dry basis (pct)

6. Carbon monoxide mass emission rate (grams/hour):

$$\dot{m}_{CO} = \frac{(453.59) (m_F)}{(M_F) (CO + CO_2 + HC_D)} (CO) (M_{CO})$$

$M_{CO}$  = Molecular weight of CO

$M_F^{CO}$  = Fuel molecular weight per carbon atom

7. Hydrocarbon mass emission rate (grams/hour):

$$\dot{m}_{HC} = \frac{(453.59) (m_F)}{(M_F) (CO + CO_2 + HC_D)} (HC_D) (M_{HC})$$

$M_{HC}$  = Molecular weight of HC per carbon atom (assumed equal to  $M_F$ )

8. Oxides of nitrogen mass emission rate (grams/hour) (corrected for humidity):

$$\dot{m}_{NO_X} = \frac{(453.59) (m_F)}{(M_F) (CO + CO_2 + HC_D)} (NO_X) (M_{NO_2}) \left[ \frac{1}{1 - 0.0025 (H - 75)} \right]$$

$M_{NO_2}$  = Molecular weight of  $NO_2$

$NO_X$  = Oxides of nitrogen concentration on dry basis (pct)

### 3. DISCUSSION OF TEST RESULTS

Maximum corrected brake horsepower, maximum corrected torque, and brake specific fuel consumption (bsfc) are plotted as functions of engine speed at full rack position in Figure 1. The maximum power output and torque of the engine were produced at the specified speeds and were similar to the values quoted in Table 1. The minimum bsfc was produced at 1,000 rpm for the speeds tested. The fuel rates were found to be nearly a linear function of power for all engine speeds and were repeatable for all speeds duplicated (Figure 2).

Emissions of CO, HC, and NO<sub>x</sub> are plotted as functions of power for all engine speeds (Figures 3 thru 5). Emissions of CO remained at fairly constant levels during moderate load operation for each speed. At the light load and heavy load conditions, emissions of CO tended to increase significantly for most engine speeds. Emissions of HC tended to decrease with increasing power for most engine speeds. At particular speed/load modes, some scatter in the data was observed. Additional testing at these particular speed/load modes was conducted to verify the data. Emissions of NO<sub>x</sub> tended to increase with increasing power up to 60 to 90 percent of full load for each engine speed.

Emissions of smoke from the engine remained below 8 percent opacity for all light and moderate load operations (Figure 6). During operation at and near full rack position, the emissions of smoke increased up to 30 percent opacity. Emissions of particulate from the engine remained at low levels (below 180 mg/m<sup>3</sup>) up to 75 percent of full load where significant increases were observed near full rack position (Figure 7). Particulate measurements were not conducted at all operating modes. This is indicated by a zero entered where the particulate measurement would be.

#### 4. CONCLUSIONS

The experimental work to obtain performance data for the Oldsmobile 350 CID diesel engine has been completed; these data are presented in the tables accompanying this report.

TABLE 1. MANUFACTURER'S ENGINE SPECIFICATIONS

Displacement, cubic inches.....	350
Maximum horsepower, bhp @ 3,600 rpm.....	120
Maximum torque, lb-ft @ 1,600 rpm.....	220
Bore and stroke, inches.....	4.057 x 3.385
Configuration.....	V-8
Compression ratio.....	22.5 to 1
Firing order.....	1-8-4-3-6-5-7-2
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.....	Chain
Valve lift:	
Intake, inches.....	0.375
Exhaust, inches.....	0.376
Valve timing:	
Intake opens, °BTC.....	16
Intake closes, °ABC.....	38
Exhaust opens, °BBC.....	64
Exhaust closes, °ATC.....	17
Engine weight, pounds.....	670
Crankcase emissions control:	
Control method.....	Positive crankcase ventilation
Point of discharge.....	Intake manifold
Carburetor type.....	Fuel injection
Injection pump type.....	Roosa Master
Combustion chamber type.....	Pre-chamber
Governor type.....	Mechanical
Injection timing:	
°BTDC @ 600 rpm.....	4.5
°BTDC @ 3,600 rpm.....	16

TABLE 2. ENGINE BREAK-IN SCHEDULE

Simulated vehicle speed, mph	Engine speed, rpm	Torque, lb-ft	Fraction of time in mode
Idle	575	0	1/10
20	650	43	"
30	900	49	"
40	1,250	56	"
50	1,550	67	"
60	1,850	81	"
25	800	45	"
35	1,100	51	"
45	1,400	61	"
55	1,700	74	"

Mileage per cycle = 90 miles.

Total mileage accumulated over 40 hours break-in period = 1,440 miles.

TABLE 3. FUEL SPECIFICATIONS

---

Fuel No. (No. 2 diesel).....	7828
Distillation, °F:	
10 pct.....	429
50 pct.....	510
95 pct.....	618
End point.....	638
API gravity.....	33.2
Specific gravity.....	0.859
FIA analysis, pct:	
Aromatics.....	35
Olefins.....	3
Paraffins.....	62
Sulfur, pct.....	0.27
Hydrogen to carbon ratio.....	1.9

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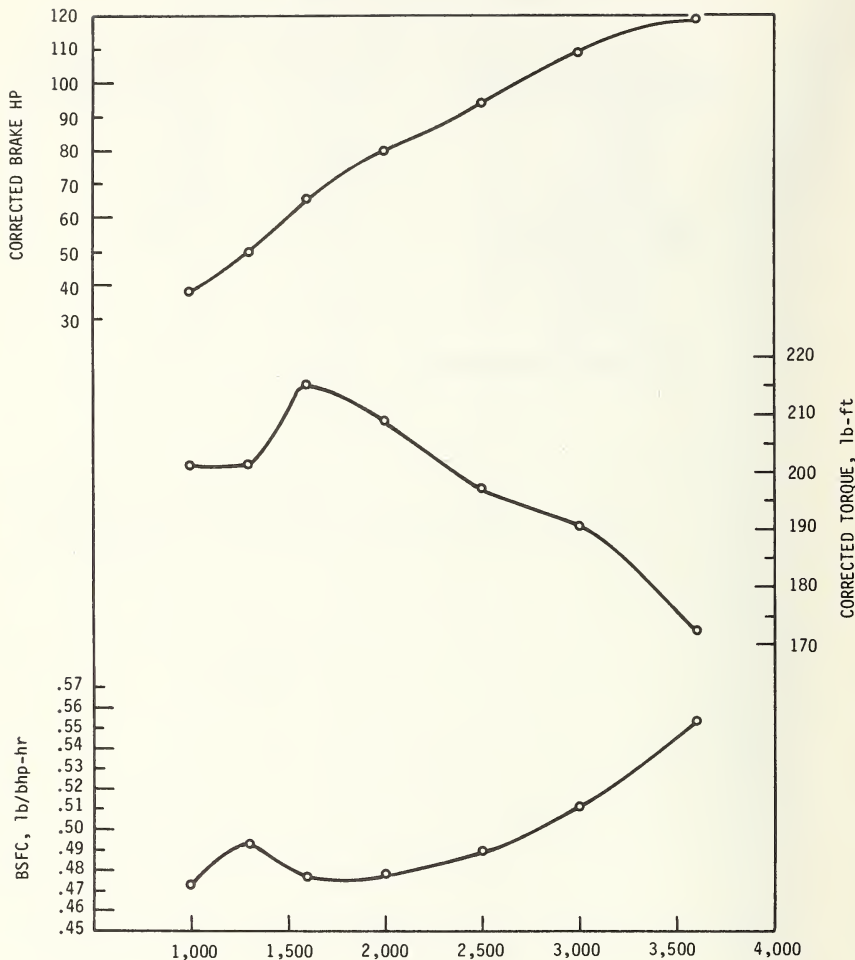


FIGURE 1. Brake Specific Fuel Consumption, Torque and Brake Horsepower versus Engine rpm at Full Rack Position--Oldsmobile 350 CID (Diesel) Engine.



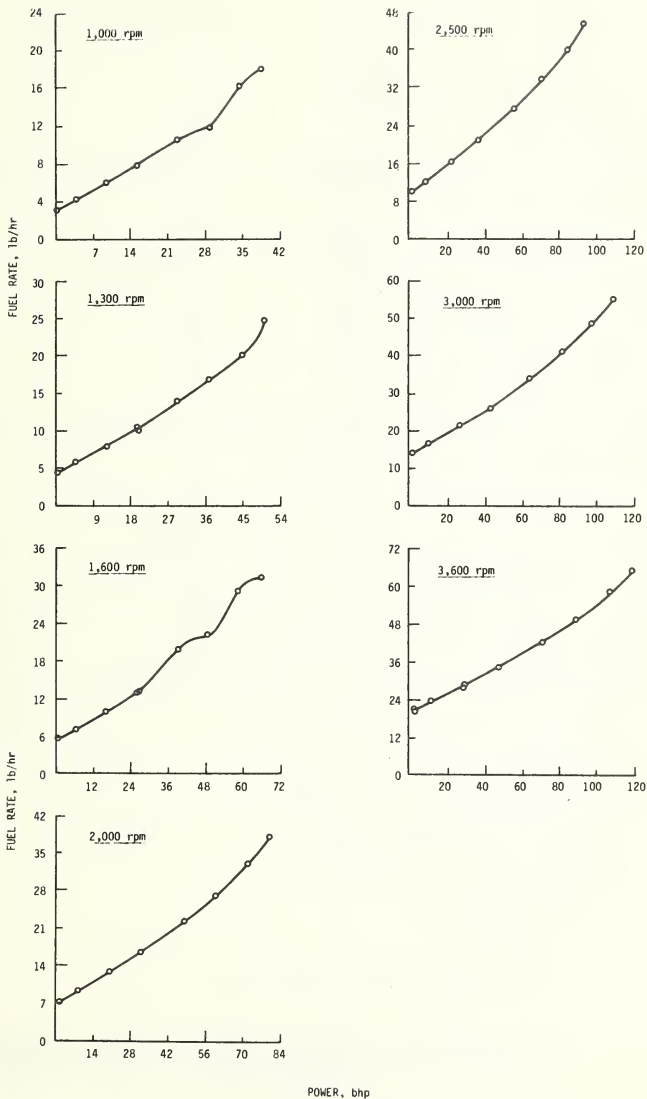


FIGURE 2. Fuel Rate versus Power at Various Speed and Load Conditions--Oldsmobile 350 CID (Diesel) Engine.

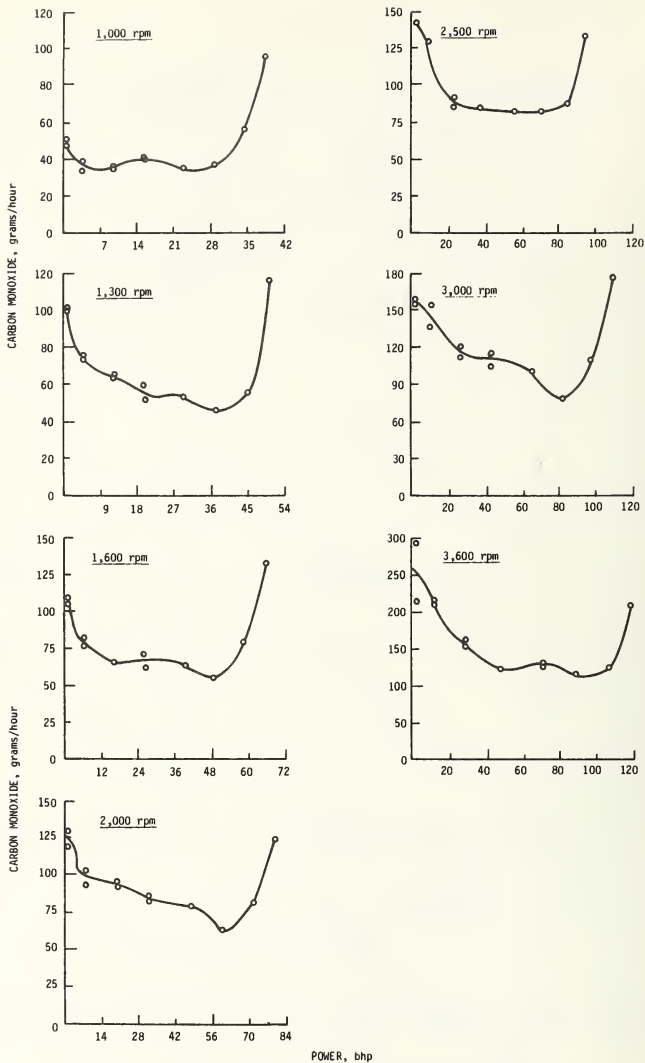


FIGURE 3. Carbon Monoxide Emissions versus Power at Various Speed and Load Conditions--Oldsmobile 350 CID (Diesel) Engine.

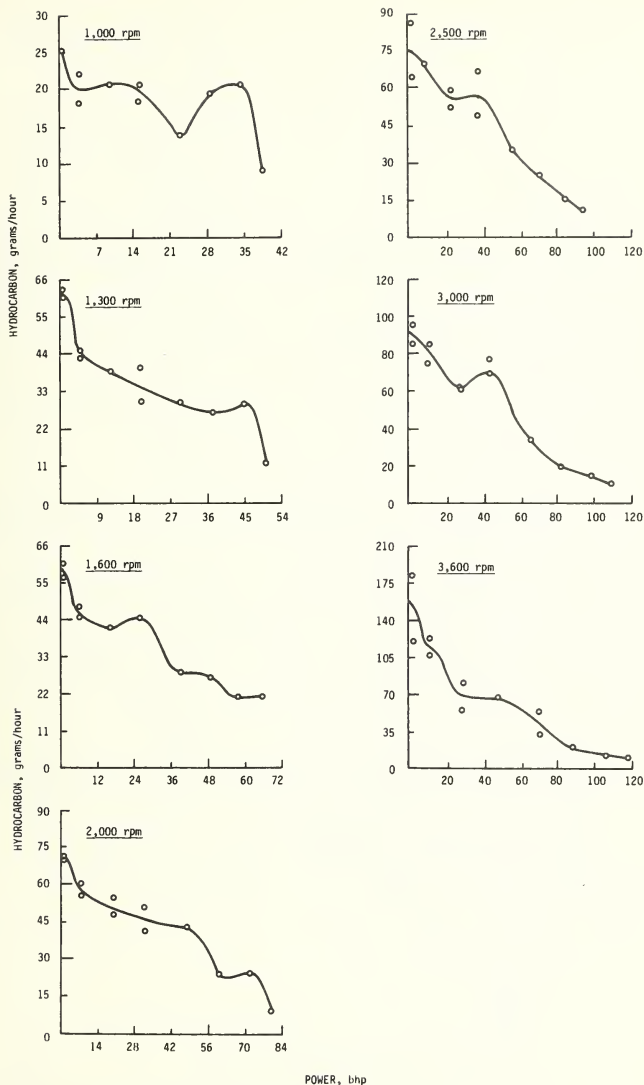


FIGURE 4. Hydrocarbon Emissions versus Power at Various Speed and Load Conditions-- Oldsmobile 350 CID (Diesel) Engine.

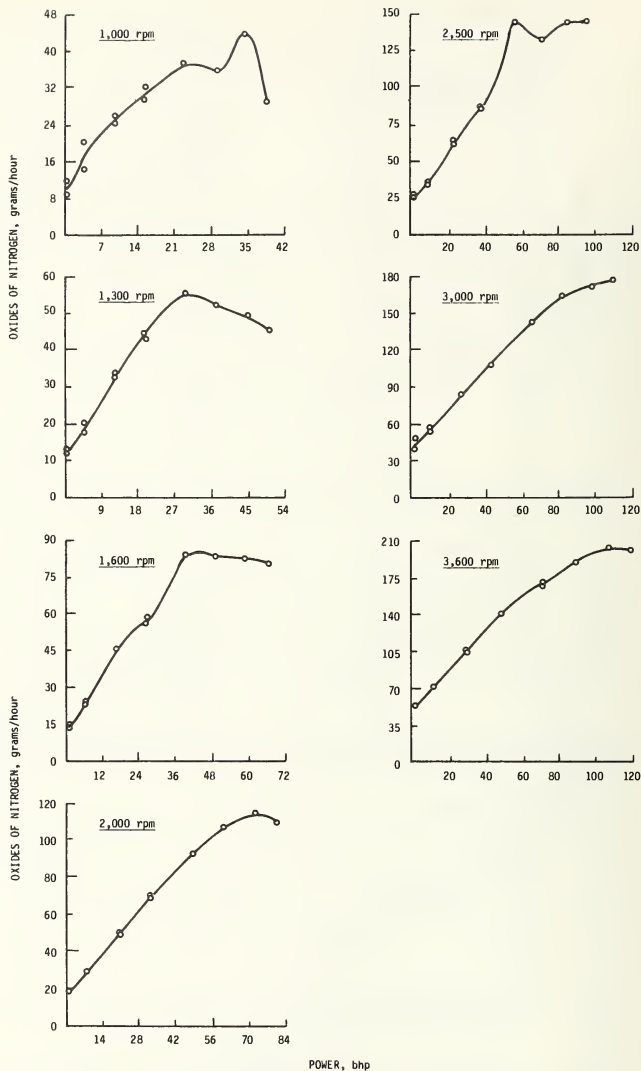


FIGURE 5. Oxides of Nitrogen Emissions versus Power at Various Speed and Load Conditions--Oldsmobile 350 CID (Diesel) Engine.

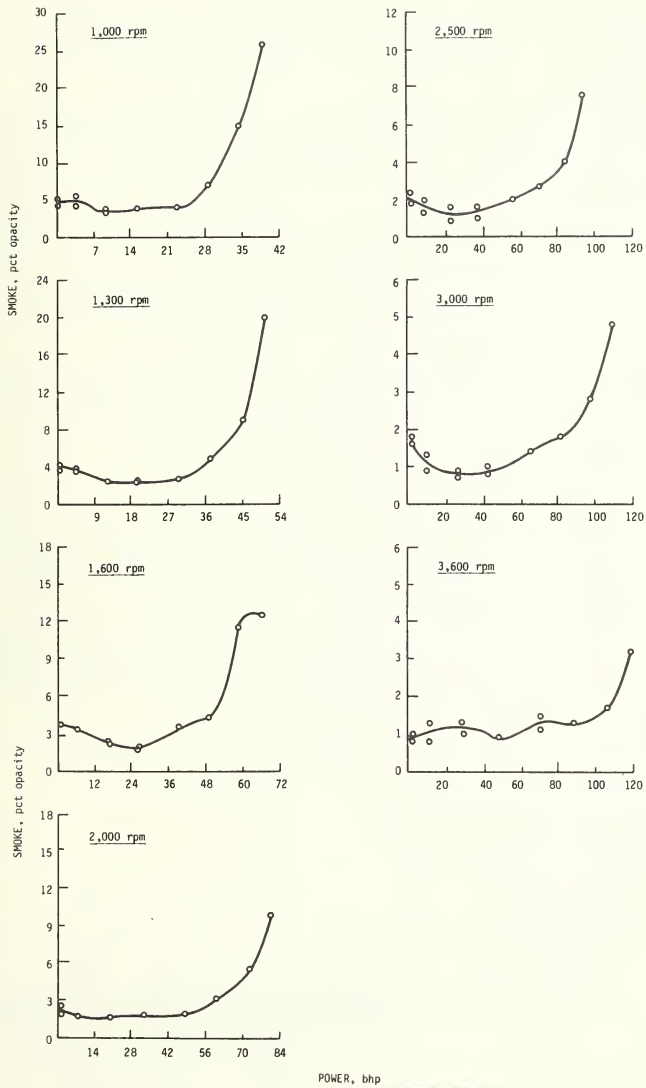


FIGURE 6. Smoke versus Power at Various Speed and Load Conditions-- Oldsmobile 350 CID (Diesel) Engine.

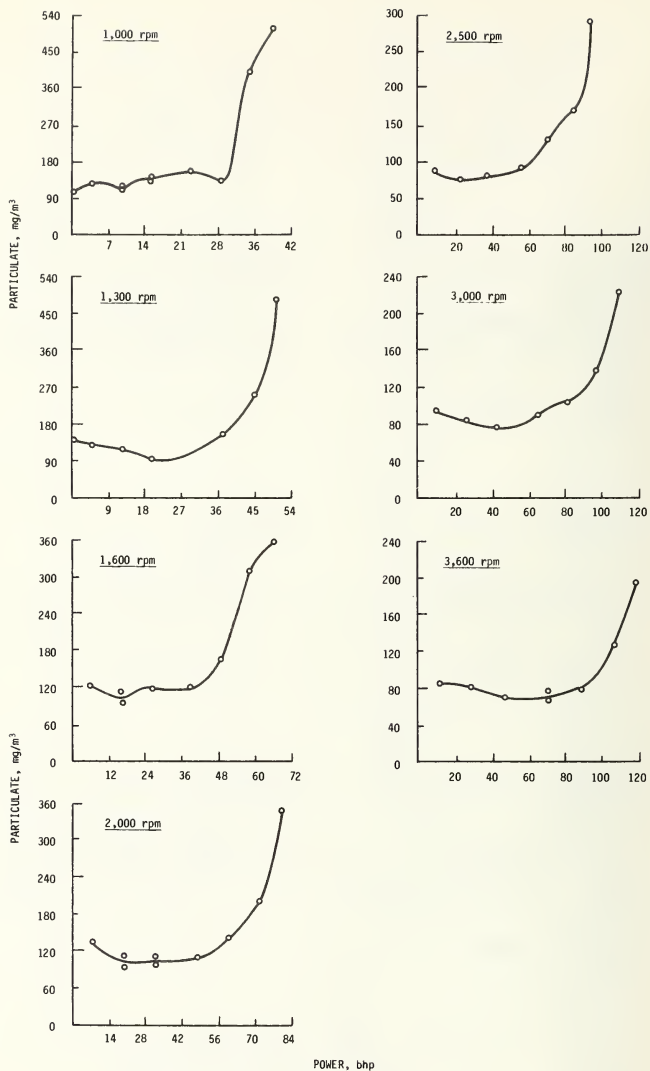


FIGURE 7. Particulate versus Power at Various Speed and Load Conditions--Oldsmobile 350 CID (Diesel) Engine.







## ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE: 7828

TEST NUMBER: 1

DATA SOURCE CODE: 1

TEST DATE: 8/29/78

BAROMETER, MMHG: 745.0

HUMIDITY, GRAINS/LB: 66

TEMPERATURE, F: 90

ENGINE SPEED, RPM: 1600

TORQUE, FT-LB: 193.0

POWER, BHP\*: 58.1

FUEL RATE, LB/HR: 29.3

THROTTLE ANGLE, DEG: 16.0

	20.01	21.01	22.01	24.01	25.01	27.01
	1	1	1	1	1	1
	8/29/78	8/29/78	8/29/78	8/29/78	8/29/78	8/28/78
BAROMETER, MMHG	745.0	744.0	744.5	744.5	745.0	743.0
HUMIDITY, GRAINS/LB	66	66	66	66	66	72
TEMPERATURE, F	90	87	86	83	83	92
ENGINE SPEED, RPM	1600	1600	1600	1600	1600	2000
TORQUE, FT-LB	193.0	161.0	129.0	53.9	21.5	210.0
POWER, BHP*	58.1	48.5	38.9	16.2	6.5	79.6
FUEL RATE, LB/HR	29.3	22.2	19.7	10.1	7.1	38.1
THROTTLE ANGLE, DEG	16.0	8.9	6.8	2.6	.7	53.0
CONCENTRATIONS, DRY BASIS						
CO, %	.0353	.0230	.0236	.0266	.0306	.0443
CO <sub>2</sub> , %	11.61	8.32	6.70	3.58	2.48	12.19
O <sub>2</sub> , %	4.60	9.03	10.91	15.51	16.54	4.74
HC, PPMC	189	221	213	331	379	67
NOX, PPM	228	217	198	113	58	240
EMISSION RATES, G/HR						
CO	80.8	55.7	63.1	67.0	78.1	125.9
HC	21.5	26.6	28.2	41.5	48.1	9.5
NOX*	83.8	84.5	84.8	45.8	23.7	111.3
OIL TEMPERATURE, F						
OIL PRESSURE, PSI	242	232	230	216	214	256
COOLANT TEMPERATURE, F	25	23	23	26	34	26
EXHAUST PRESSURE, IN. H <sub>2</sub> O	190	189	189	188	183	192
EXHAUST TEMPERATURE, F	41.0	33.0	30.0	24.0	22.0	57.0
SMOKE, % OPACITY	934	748	625	388	313	1077
PARTICULATE (MG/M <sup>3</sup> )	11.6	4.4	3.5	2.4	3.3	10.0
	309.0	165.0	120.0	112.0	124.0	348.0

\* CORRECTED SAE J816B  
+ CORRECTED FOR HUMIDITY

ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE:	7828								
TEST NUMBER	1	28.01	29.01	30.01	31.01	32.01	33.01		
DATA SOURCE CODE	1								
TEST DATE	8/28/78	8/28/78	8/28/78	8/28/78	8/29/78	8/29/78	8/29/78		
BAROMETER, MMHG	743.5	743.5	743.5	742.5	744.5	744.5	745.0		
HUMIDITY, GRAINS/LB	72	72	72	72	70	70	70		
TEMPERATURE, F	92	89	89	90	81	83	83		
ENGINE SPEED, RPM	2000	2000	2000	2000	2000	2000	2000		
TORQUE, FT-LB	189.0	157.5	157.5	126.0	84.0	52.5	21.0		
POWER, BHP*	71.6	59.6	59.6	47.8	31.7	19.8	7.9		
FUEL RATE, LB/HR	33.1	27.1	27.1	22.3	16.5	12.7	9.1		
THROTTLE ANGLE, DEG	13.5	10.0	10.0	8.0	5.0	3.2	1.4		
CONCENTRATIONS, DRY BASIS									
CO, %	.0282	.0216	.0216	.0266	.0271	.0295	.0334		
CO2, %	10.18	8.25	8.25	6.72	4.82	3.61	2.57		
O2, %	6.83	9.72	9.72	11.85	14.49	15.87	16.83		
HC, PPMC	165	162	162	287	335	352	359		
NOX, PPM	241	223	223	192	143	101	59		
EMISSION RATES, G/HR									
CO	83.2	64.5	64.5	79.8	83.5	93.2	104.6		
HC	24.2	24.0	24.0	42.9	51.2	55.2	55.9		
NOX+	116.4	108.6	108.6	93.9	71.7	52.0	30.1		
OIL TEMPERATURE, F									
OIL TEMPERATURE, F	251	244	244	242	228	226	225		
OIL PRESSURE, PSI	28	28	28	31	25	28	27		
COOLANT TEMPERATURE, F	189	190	190	186	186	186	185		
EXHAUST PRESSURE, IN. H2O	53.0	48.0	48.0	45.0	42.0	38.0	34.0		
EXHAUST TEMPERATURE, F	955	774	774	600	497	420	352		
SMOKE, % OPACITY	5.5	3.2	3.2	2.0	1.8	1.6	1.8		
PARTICULATE (MG/M3)	202.0	142.0	142.0	109.0	112.0	114.0	134.0		

\* CORRECTED SAE J8168  
+ CORRECTED FOR HUMIDITY

## ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE:	7828								
TEST NUMBER:	1	35.01	36.01	37.01	38.01	39.01	40.01		
DATA SOURCE CODE:	1								
TEST DATE:	8/30/78	8/30/78	8/30/78	8/30/78	8/30/78	8/30/78	8/30/78		
BAROMETER, MMHG:	747.5	747.5	747.5	747.5	747.5	747.5	747.5		
HUMIDITY, GRAINS/LB:	65	65	65	65	65	67	65		
TEMPERATURE, F:	83	90	90	90	87	87	86		
ENGINE SPEED, RPM:	2500	2500	2500	2500	2500	2500	2500		
TORQUE, FT-LB:	200.0	180.0	150.0	150.0	120.0	80.0	50.0		
POWER, BHP*:	93.8	84.4	70.3	70.3	56.3	37.5	23.4		
FUEL RATE, LB/HR:	45.9	40.2	33.5	33.5	27.7	21.0	16.5		
THROTTLE ANGLE, DEG:	52.6	15.0	11.9	11.9	9.2	1.1	4.2		
CONCENTRATIONS, DRY BASIS									
CO, %:	.0372	.0240	.0225	.0221	.0221	.0224	.0218		
CO <sub>2</sub> , %:	11.52	9.88	8.18	8.18	6.62	4.95	3.77		
O <sub>2</sub> , %:	5.24	7.30	9.70	9.70	11.76	13.72	14.84		
HC, PPMC:	61	82	135	135	186	257	269		
NOX, PPM:	252	246	224	224	190	145	105		
EMISSION RATES, G/HR									
CO:	134.8	89.0	83.7	83.7	83.8	85.9	85.8		
HC:	11.0	15.1	24.9	24.9	35.1	48.9	52.6		
NOX*:	146.6	146.5	134.0	134.0	115.7	89.3	66.1		
OIL TEMPERATURE, F									
OIL PRESSURE, PSI:	242	259	255	255	249	247	239		
COOLANT TEMPERATURE, F:	27	27	27	27	29	30	32		
EXHAUST PRESSURE, IN. H <sub>2</sub> O:	189	192	190	190	189	189	187		
EXHAUST TEMPERATURE, F:	96.0	91.0	83.0	83.0	74.0	65.0	59.0		
SMOKE, % OPACITY:	1050	1000	856	856	724	589	481		
PARTICULATE (MG/H <sub>3</sub> ):	7.6	4.0	2.7	2.7	2.0	1.6	1.6		
	291.0	170.0	130.0	130.0	93.0	81.0	78.0		

\* CORRECTED SAE J8168

+ CORRECTED FOR HUMIDITY

## ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE: 7828	43.01	44.01	45.01	46.01	47.01	48.01
TEST NUMBER	1	1	1	1	1	1
DATA SOURCE CODE	8/30/78	8/30/78	8/30/78	8/30/78	8/30/78	8/30/78
TEST DATE	747.0	746.5	746.5	746.5	748.5	748.5
BAROMETER, MMHG	67	58	65	61	64	64
HUMIDITY, GRAINS/LB	94	87	93	90	85	86
TEMPERATURE, F	3000	3000	3000	3000	3000	3000
ENGINE SPEED, RPM	193.0	174.0	145.0	116.0	77.0	48.0
TORQUE, FT-LB	109.0	97.7	81.7	65.3	43.3	27.0
POWER, BHP*	55.7	49.0	41.2	34.1	27.1	21.6
FUEL RATE, LB/HR	52.0	.1	12.8	9.8	7.3	5.3
THROTTLE ANGLE, DEG						
CONCENTRATIONS, DRY BASIS						
CO, %	.0425	.0256	.0183	.0228	.0229	.0266
CO2, %	11.94	10.34	8.57	6.96	5.23	4.27
O2, %	4.00	6.50	8.68	10.54	13.36	14.49
HC, PPMC	45	66	87	149	325	276
NOX, PPM	263	256	236	203	145	116
EMISSION RATES, G/HR						
CO	180.3	110.4	80.2	101.3	106.9	121.0
HC	9.4	14.1	18.8	33.0	75.6	62.4
NOX+	179.7	174.1	165.8	143.0	108.3	84.3
OIL TEMPERATURE, F						
	277	249	267	261	248	252
OIL PRESSURE, PSI						
	28	30	28	30	29	28
COOLANT TEMPERATURE, F						
	135.0	125.0	114.0	104.0	94.0	89.0
EXHAUST PRESSURE, IN. H2O						
	1233	1057	940	804	654	572
EXHAUST TEMPERATURE, F						
	4.8	2.8	1.8	1.4	.8	.9
SMOKE, % OPACITY						
	223.0	137.0	103.0	89.0	76.0	84.0
PARTICULATE (MG/M3)						

\* CORRECTED SAE J816B

+ CORRECTED FOR HUMIDITY

## ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE: 7828

TEST NUMBER	49.01	51.01	52.01	53.01	54.01	56.01
DATA SOURCE CODE	1	1	1	1	1	1
TEST DATE	8/31/78	9/ 6/78	9/ 6/78	9/ 6/78	9/ 6/78	9/ 6/78
BAROMETER, MMHG	746.5	743.9	743.4	743.9	743.9	743.9
HUMIDITY, GRAINS/LB	67	64	64	64	64	64
TEMPERATURE, F	89	99	105	102	93	95
ENGINE SPEED, RPM	3000	3600	3600	3600	3600	3600
TORQUE, FT-LB	19.0	174.0	156.8	130.4	104.3	42.8
POWER, BHP*	10.7	118.2	106.5	88.6	70.8	29.0
FUEL RATE, LB/HR	16.7	65.3	58.6	49.6	42.0	27.6
THROTTLE ANGLE, DEG	3.6	52.0	20.7	15.4	12.1	5.6
CONCENTRATIONS, DRY BASIS						
CO, %	.0345	.0448	.0261	.0234	.0263	.0290
CO2, %	3.28	12.59	10.98	9.12	7.50	4.66
O2, %	16.26	4.26	6.18	8.66	10.88	14.08
HC, PPMC	328	43	49	78	125	202
NOX, PPM	79	270	264	242	208	127
EMISSION RATES, G/HR						
CO	156.7	211.2	126.6	115.6	133.4	155.2
HC	74.1	10.2	11.8	19.2	31.5	53.6
NOX+	58.0	203.5	205.2	191.3	169.5	108.2
OIL TEMPERATURE, F	248	287	285	280	232	258
OIL PRESSURE, PSI	27	26	26	28	26	27
COOLANT TEMPERATURE, F	189	195	194	194	193	192
EXHAUST PRESSURE, IN. H2O	82.0	184.0	169.0	154.0	141.0	117.0
EXHAUST TEMPERATURE, F	483	1303	1192	1030	880	663
SMOKE, % OPACITY	1.3	3.2	1.7	1.3	1.5	1.3
PARTICULATE (MG/M3)	94.0	195.0	127.0	78.0	67.0	81.0

\* CORRECTED SAE J816B

+ CORRECTED FOR HUMIDITY

## ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE: 7828	57.01	59.01	60.01	61.01	63.01	64.01
TEST NUMBER	1	1	1	1	1	1
DATA SOURCE CODE	9/ 6/78	9/ 7/78	9/ 7/78	9/ 7/78	9/ 7/78	9/ 7/78
TEST DATE	741.9	744.4	744.4	744.4	743.9	742.9
BAROMETER, MMHG	64	79	79	75	75	79
HUMIDITY, GRAINS/LB	97	82	84	85	85	87
TEMPERATURE, F	3600	750	575	1000	1000	1000
ENGINE SPEED, RPM	17.6	2.0	2.0	80.0	20.0	2.0
TORQUE, FT-LB	12.0	.3	.2	15.2	3.8	.4
POWER, BHP*	23.1	2.6	2.3	7.8	4.1	3.2
FUEL RATE, LB/HR	4.6	1.0	1.0	2.2	.0	.0
THROTTLE ANGLE, DEG						
CONCENTRATIONS, DRY BASIS						
CO, %	.0407	.0338	.0371	.0272	.0247	.0313
CO2, %	3.82	2.03	2.35	4.59	2.29	1.68
O2, %	15.36	18.45	17.39	14.31	18.01	18.93
HC, PPMC	395	199	274	244	228	307
NOX, PPM	83	29	32	119	55	32
EMISSION RATES, G/HR						
CO	220.4	38.2	31.8	41.7	39.6	52.3
HC	106.4	11.2	11.7	18.6	18.2	25.5
NOX+	72.0	5.5	4.5	30.0	14.5	8.8
OIL TEMPERATURE, F						
	255	180	176	191	189	187
OIL PRESSURE, PSI						
	32	17	11	23	23	24
COOLANT TEMPERATURE, F						
	189	179	178	186	181	181
EXHAUST PRESSURE, IN. H2O						
	112.0	4.0	2.0	9.0	7.0	7.0
EXHAUST TEMPERATURE, F						
	598	223	229	402	285	226
SMOKE, % OPACITY						
	1.3	7.3	7.1	3.8	5.5	4.8
PARTICULATE (MG/H3)						
	85.0	177.0	192.0	136.0	127.0	106.0

\* CORRECTED SAE J8168  
+ CORRECTED FOR HUMIDITY

## ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE: 7828

TEST NUMBER	73.01	74.01	75.01	76.01	77.01	78.01
DATA SOURCE CODE	1	1	1	1	1	1
TEST DATE	9/ 8/78	9/ 8/78	9/11/78	9/11/78	9/11/78	9/11/78
BAROMETER, MMHG	741.9	742.4	738.9	738.9	738.9	738.9
HUMIDITY, GRAINS/LB	72	75	71	71	71	71
TEMPERATURE, F	89	88	81	82	85	86
ENGINE SPEED, RPM	2000	2000	2000	2000	2500	2500
TORQUE, FT-LB	84.0	53.0	21.0	3.0	80.0	50.0
POWER, BHP*	32.0	20.2	8.0	1.1	38.0	23.7
FUEL RATE, LB/HR	16.2	12.5	9.1	7.3	20.9	16.3
THROTTLE ANGLE, DEG	5.0	3.3	1.5	.0	6.2	4.4
CONCENTRATIONS, DRY BASIS						
CO, %	.0290	.0319	.0304	.0374	.0230	.0246
CO <sub>2</sub> , %	4.80	3.64	2.60	1.99	5.03	3.86
O <sub>2</sub> , %	14.22	15.59	17.72	18.40	14.24	15.76
HC, PPMC	274	313	394	445	359	314
NOX, PPM	141	99	58	35	141	100
EMISSION RATES, G/HR						
CO	88.1	98.1	94.5	119.8	86.3	93.3
HC	41.4	48.0	60.9	70.9	67.0	59.3
NOX*	69.9	50.3	29.2	18.2	86.5	61.6
OIL TEMPERATURE, F						
OIL TEMPERATURE, F	222	219	211	212	232	232
OIL PRESSURE, PSI	31	32	32	32	32	32
COOLANT TEMPERATURE, F	188	187	187	188	189	188
EXHAUST PRESSURE, IN. H <sub>2</sub> O	41.0	37.0	34.0	31.0	65.0	59.0
EXHAUST TEMPERATURE, F	523	433	344	309	586	496
SMOKE, % OPACITY	1.8	1.7	1.7	1.9	1.0	.9
PARTICULATE (MG/M <sup>3</sup> )	99.0	93.0	.0	.0	.0	.0

\* CORRECTED SAE J816B

+ CORRECTED FOR HUMIDITY

## ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE: 7828	79.01	80.01	82.01	83.01	85.01	86.01
TEST NUMBER	1	1	1	1	1	1
DATA SOURCE CODE	9/11/78	9/11/78	9/11/78	9/11/78	9/11/78	9/12/78
TEST DATE	738.9	738.4	737.9	737.9	736.9	736.4
BAROMETER, MMHG	71	71	76	76	80	71
HUMIDITY, GRAINS/LB	84	84	87	87	93	90
TEMPERATURE, F	2500	2500	3000	3000	3600	3600
ENGINE SPEED, RPM	20.0	4.4	48.0	19.0	70.0	43.4
TORQUE, FT-LB	9.5	2.1	27.4	10.9	48.1	29.9
POWER, BHP*	12.2	10.2	21.4	16.7	34.3	28.3
FUEL RATE, LB/HR	2.4	1.5	5.5	3.5	8.5	6.2
THROTTLE ANGLE, DEG						
CONCENTRATIONS, DRY BASIS						
CO, %	0.343	0.374	.0255	.0307	.0243	.0328
CO2, %	2.82	2.34	4.34	3.31	6.08	5.04
O2, %	17.15	18.04	15.06	16.36	12.62	14.26
HC, PPMC	369	341	275	378	262	319
NOX, PPM	60	42	114	73	168	130
EMISSION RATES, G/HR						
CO	131.4	144.0	112.9	138.1	123.9	165.5
HC	70.3	65.2	60.7	84.6	66.6	80.3
NOX+	37.4	26.2	83.6	54.2	142.6	106.6
OIL TEMPERATURE, F						
OIL TEMPERATURE, F	225	220	241	237	260	252
OIL PRESSURE, PSI	32	33	33	31	31	31
COOLANT TEMPERATURE, F	188	188	189	189	192	190
EXHAUST PRESSURE, IN. H2O	54.0	51.0	87.0	81.0	134.0	119.0
EXHAUST TEMPERATURE, F	405	361	574	490	787	685
SMOKE, % OPACITY	1.4	1.8	.7	.9	.9	1.0
PARTICULATE (MG/M3)	.0	.0	.0	.0	.0	.0

\* CORRECTED SAE J816B  
+ CORRECTED FOR HUMIDITY



## ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE: 7828

TEST NUMBER	87.01	88.01	92.01	94.01	99.01	100.01
DATA SOURCE CODE	1	1	1	1	1	1
TEST DATE	9/12/78	9/12/78	9/14/78	9/14/78	9/15/78	9/15/78
BAROMETER, MMHG	736.4	736.4	741.0	741.0	743.0	743.5
HUMIDITY, GRAINS/LB	71	71	83	83	82	107
TEMPERATURE, F	98	91	87	90	83	88
ENGINE SPEED, RPM	3600	3600	1300	2500	1000	1300
TORQUE, FT-LB	17.1	3.9	80.0	20.0	2.0	2.0
POWER, BHP*	11.8	2.7	19.9	9.6	.4	.5
FUEL RATE, LB/HR	23.4	20.7	10.1	12.1	3.3	4.5
THROTTLE ANGLE, DEG	4.5	3.6	3.2	2.3	.0	.0
CONCENTRATIONS, DRY BASIS						
CO, %	.0414	.0574	.0257	.0335	.0293	.0489
CO <sub>2</sub> , %	4.05	3.53	4.47	2.77	1.76	1.82
O <sub>2</sub> , %	15.43	16.03	14.64	16.88	18.39	17.56
HC, PPMC	478	706	296	361	309	580
NOX, PPM	86	64	127	53	45	35
EMISSION RATES, G/HR						
CO	213.8	297.0	52.1	130.3	48.0	103.2
HC	122.6	181.6	29.9	69.9	25.2	60.9
NOX*	72.6	53.7	43.2	34.5	12.4	13.3
OIL TEMPERATURE, F						
OIL PRESSURE, PSI	252	249	206	224	183	218
COOLANT TEMPERATURE, F	31	31	24	29	24	26
EXHAUST PRESSURE, IN. H <sub>2</sub> O	189	189	185	188	182	182
EXHAUST TEMPERATURE, F	115.0	112.0	16.0	48.0	7.0	12.0
SMOKE, % OPACITY	615	569	439	403	226	273
PARTICULATE (MG/M <sup>3</sup> )	.8	.8	2.5	2.0	4.2	4.2
	.0	.0	94.0	88.0	.0	.0

\* CORRECTED SAE J816B

+ CORRECTED FOR HUMIDITY

## ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE: 7828	101.01	102.01	103.01	104.01	105.01	106.01
TEST NUMBER	1	1	1	1	1	1
DATA SOURCE CODE	9/15/78	9/15/78	9/15/78	9/15/78	9/15/78	9/18/78
TEST DATE	743.5	742.5	742.5	741.5	741.0	739.0
BAROMETER, MMHG	80	81	81	86	86	79
HUMIDITY, GRAINS/LB	84	84	87	92	95	86
TEMPERATURE, F	1600	2000	2500	3000	3600	1000
ENGINE SPEED, RPM	2.8	3.5	4.0	4.5	5.0	80.0
TORQUE, FT-LB	.9	1.3	1.9	2.6	3.4	15.4
POWER, BHP*	5.4	7.0	10.0	14.1	20.4	7.9
FUEL RATE, LB/HR	.0	.0	.0	.0	.0	2.6
THROTTLE ANGLE, DEG						
CONCENTRATIONS, DRY BASIS						
CO, %	.0413	.0408	.0360	.0353	.0465	.0272
CO2, %	1.80	1.90	2.19	2.74	3.40	4.79
O2, %	18.02	17.82	17.39	16.65	15.59	14.55
HC, PPMC	440	453	433	422	671	280
NOX, PPM	32	36	42	60	66	132
EMISSION RATES, G/HR						
CO	106.9	131.4	145.0	161.3	246.9	40.2
HC	56.7	72.6	86.6	95.9	177.0	20.6
NOX*	14.0	19.3	28.3	46.4	59.0	32.5
OIL TEMPERATURE, F						
OIL TEMPERATURE, F	197	207	213	233	239	192
OIL PRESSURE, PSI	26	28	30	33	31	23
COOLANT TEMPERATURE, F	183	185	187	189	189	186
EXHAUST PRESSURE, IN. H2O	18.0	28.0	45.0	69.0	99.0	9.0
EXHAUST TEMPERATURE, F	266	295	349	439	529	405
SMOKE, % OPACITY	3.6	2.5	2.4	1.6	1.1	4.0
PARTICULATE (MG/M3)	.0	.0	.0	.0	.0	149.0

\* CORRECTED SAE J816B

+ CORRECTED FOR HUMIDITY

## ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE: 7828

TEST NUMBER	107.01	108.01	109.01	110.01	111.01	112.01
DATA SOURCE CODE	9/18/78	9/18/78	9/18/78	9/18/78	9/15/78	9/15/78
BAROMETER, MMHG	738.5	738.5	738.5	738.5	738.0	738.5
HUMIDITY, GRAINS/LB	80	83	76	81	81	78
TEMPERATURE, F	86	87	86	87	88	87
ENGINE SPEED, RPM	1000	1300	1300	1600	1600	1600
TORQUE, FT-LB	50.0	50.0	20.0	86.0	53.9	21.5
POWER, BHP*	9.6	12.5	5.0	26.5	16.6	6.6
FUEL RATE, LB/HR	6.0	7.8	5.7	13.0	9.8	6.9
THROTTLE ANGLE, DEG	.5	1.7	.2	4.0	2.7	.8
CONCENTRATIONS, DRY BASIS						
CO, %	.0243	.0323	.0355	.0256	.0270	.0331
CO2, %	3.54	3.42	2.40	4.76	3.52	2.42
O2, %	16.17	16.23	17.51	14.30	15.97	17.41
HC, PPMC	275	385	429	366	339	357
NOX, PPM	104	99	58	145	110	59
EMISSION RATES, G/HR						
CO	36.9	66.2	74.6	63.0	67.3	83.8
HC	20.8	39.2	44.8	44.8	42.0	45.0
NOX+	26.3	34.2	20.2	59.6	46.0	24.9
OIL TEMPERATURE, F						
OIL PRESSURE, PSI	191	198	198	182	208	204
COOLANT TEMPERATURE, F	24	30	30	31	24	25
EXHAUST TEMPERATURE, IN. H2O	184	186	184	177	187	185
EXHAUST TEMPERATURE, F	8.0	14.0	12.0	23.0	21.0	20.0
SMOKE, % OPACITY	334	360	293	447	391	313
PARTICULATE (MG/M3)	3.8	2.3	3.4	2.0	2.2	3.4
	114.0	119.0	129.0	116.0	94.0	122.0

\* CORRECTED SAE J816B

+ CORRECTED FOR HUMIDITY

## ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE: 7828	114.01	115.01	116.01	117.01	118.01	119.01
TEST NUMBER	1	1	1	1	1	1
DATA SOURCE CODE	9/19/78	9/19/78	9/21/78	9/26/78	9/26/78	9/26/78
TEST DATE	745.0	744.5	750.5	746.0	745.5	745.5
BAROMETER, MMHG	80	80	62	66	66	66
HUMIDITY, GRAINS/LB	96	96	89	82	82	83
TEMPERATURE, F	3600	3600	1600	1300	1300	1300
ENGINE SPEED, RPM	104.0	69.6	220.0	80.0	50.0	120.0
TORQUE, FT-LB	71.0	47.5	65.6	29.3	12.2	29.3
POWER, BHP*	42.4	33.7	31.1	10.4	8.0	13.8
FUEL RATE, LB/HR	12.0	8.5	54.0	3.3	1.7	5.6
THROTTLE ANGLE, DEG						
CONCENTRATIONS, DRY BASIS						
CO, %	.0165	.0187	.0581	.0299	.0322	.0273
CO2, %	7.41	5.91	12.20	4.66	3.56	6.36
O2, %	10.80	13.00	4.51	14.76	16.16	12.51
HC, PPMC	218	283	181	402	392	306
NOX, PPM	209	165	222	141	101	177
EMISSION RATES, G/HR						
CO	85.4	96.3	134.4	59.8	64.3	53.3
HC	56.2	72.5	20.8	39.9	39.0	29.7
NOX*	180.8	142.1	81.7	45.2	32.5	55.5
OIL TEMPERATURE, F						
OIL TEMPERATURE, F	265	261	225	189	195	194
OIL PRESSURE, PSI	27	29	28	23	25	24
COOLANT TEMPERATURE, F	192	191	191	186	184	186
EXHAUST PRESSURE, IN. H2O	138.0	122.0	35.0	13.0	13.0	16.0
EXHAUST TEMPERATURE, F	904	760	1018	424	364	526
SMOKE, % OPACITY	1.0	.8	12.7	2.3	2.4	2.6
PARTICULATE (MG/M3)	76.0	70.0	356.0	.0	.0	.0

\* CORRECTED SAE J816B

+ CORRECTED FOR HUMIDITY

ENGINE: 1978 OLDSMOBILE 350-CID DIESEL  
 FUEL CODE: 7828

TEST NUMBER	120.01	121.01	122.01	123.01	124.01	125.01
DATA SOURCE CODE	1	1	1	1	1	1
TEST DATE	9/26/78	9/26/78	9/26/78	9/26/78	9/26/78	9/26/78
BAROMETER, MMHG	745.5	745.5	745.5	745.5	745.5	745.5
HUMIDITY, GRAINS/LB	66	66	70	66	64	64
TEMPERATURE, F	82	82	83	84	86	88
ENGINE SPEED, RPM	1300	1600	1600	1600	3000	3000
TORQUE, FT-LB	20.0	3.2	86.0	54.0	4.9	77.0
POWER, BHP*	4.9	1.0	25.9	16.2	2.8	43.5
FUEL RATE, LB/HR	5.8	5.7	12.8	9.9	14.2	26.6
THROTTLE ANGLE, DEG	.2	.0	4.1	2.6	2.6	7.4
CONCENTRATIONS, DRY BASIS						
CO, %	.0380	.0446	.0300	.0325	.0359	.0264
CO2, %	2.52	2.01	4.79	3.62	2.87	5.50
O2, %	17.43	18.07	14.44	15.88	16.93	13.46
HC, PPMC	420	495	371	417	391	320
NOX, PPM	53	32	145	107	56	157
EMISSION RATES, G/HR						
CO	77.3	111.1	72.4	79.4	157.4	115.1
HC	42.5	61.3	44.5	50.6	85.2	69.5
NOX+	17.5	12.7	56.9	42.0	39.3	109.4
OIL TEMPERATURE, F						
OIL PRESSURE, PSI	192	192	200	203	228	238
COOLANT TEMPERATURE, F	26	31	28	28	30	30
EXHAUST PRESSURE, IN. H2O	182	182	186	185	188	189
EXHAUST TEMPERATURE, F	11.0	22.0	22.0	20.0	71.0	84.0
SMOKE, % OPACITY	292	277	457	391	436	645
PARTICULATE (MG/M3)	3.7	3.7	1.8	1.8	1.8	1.0
	.0	.0	.0	.0	.0	.0

\* CORRECTED SAE J816B  
 + CORRECTED FOR HUMIDITY

## ENGINE: 1978 OLDSMOBILE 350-CID DIESEL

FUEL CODE: 782B

TEST NUMBER	1	126.01	127.01	128.01
DATA SOURCE CODE	1			
TEST DATE	9/26/78	9/26/78	9/26/78	10/16/78
BAROMETER, MMHG	745.5	745.5	745.5	751.5
HUMIDITY, GRAINS/LB	64	64	64	44
TEMPERATURE, F	88	93	93	99
ENGINE SPEED, RPM	3600	3600	3600	3850
TORQUE, FT-LB	5.0	104.0	104.0	161.0
POWER, BHP*	3.4	70.5	70.5	115.4
FUEL RATE, LB/HR	20.2	42.1	42.1	68.8
THROTTLE ANGLE, DEG	4.0	12.0	12.0	.0

## CONCENTRATIONS, DRY BASIS

CO, %	.0422	.0254	.0316
CO <sub>2</sub> , %	3.49	7.58	11.84
O <sub>2</sub> , %	16.02	10.64	4.88
HC, PPMC	469	216	138
NOX, PPM	67	216	289

## EMISSION RATES, G/HR

CO	217.3	127.9	166.6
HC	120.0	54.1	36.1
NOX*	55.0	173.7	233.0

OIL TEMPERATURE, F	243	261	285
OIL PRESSURE, PSI	28	25	28
COOLANT TEMPERATURE, F	189	192	194
EXHAUST PRESSURE, IN. H <sub>2</sub> O	103.0	137.0	193.0
EXHAUST TEMPERATURE, F	543	886	1302
SMOKE, % OPACITY	1.0	1.1	1.5
PARTICULATE (MG/M <sup>3</sup> )	.0	.0	.0

\* CORRECTED SAE J8168

+ CORRECTED FOR HUMIDITY

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