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Exhaust Emissions and Fuel Economy from a Light-Duty Diesel Vehicle Running on Diesel Fuel and Wide Boiling Range Fuel

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Background

The U.S. Environmental Protection Agency is currently interested in the feasibility of using the Diesel engine as a powerplant for light-duty vehicles. Because Diesel-powered vehicles can be run on different grades of commercial Diesel fuels, an EPA test program was set up to measure the exhaust emissions from a light-duty Diesel vehicle when run on two common Diesel fuels.

The two fuels used in the program were #1 and #2 Diesel fuel. Both fuels meet the EPA specifications for EPA Diesel test fuel. In addition, a third fuel developed by Texaco, Inc. was tested. This fuel, referred to as 100-600 fuel, was developed by Texaco to optimize what they call the Vehicle-Fuel-Refinery System.[1] Essentially, they have attempted to maximize the miles of transportation that can be obtained from a barrel of crude oil. The 100-600 fuel is intended for use in a vehicle equipped with a Texaco controlled combustion system. However, a light-duty Diesel engine can also run on this fuel. Some specifications for each fuel are given in Table IV.

It was expected that the fuel cetane number would have the greatest effect on exhaust emissions, and that fuel consumption would be proportional to API gravity.[2] The cetane number is an indication of the ignition quality of Diesel fuel. API gravity is an inverse function of the specific gravity.

Low cetane fuels are associated with high emissions of hydrocarbons (HC) and oxides of nitrogen (NOx). Engine combustion noise may also be high. Fuels with a high cetane number should cause lower HC and NOx emissions, lower engine noise, and improved starting. However, if an engine starts and runs well on a given fuel, increasing the cetane number of the fuel may not appreciably improve starting, emissions, or engine noise levels. The magnitude of the cetane effect is influenced by engine configuration.

Fuel consumption can be expected to be proportional to API gravity because a fuel with a high API gravity contains less energy per gallon than a fuel with a low API gravity.

The conclusions from the EPA evaluation test reported here can be considered to be quantitatively valid only for the specific test car used. However, it is reasonable to extrapolate the results from this test to other vehicles in a directional or qualitative manner, i.e., to suggest that similar results are likely to be achieved on other similar vehicles.

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1 Tierney, Johnson and Crawford, "Energy Conservation, Optimization of Vehicle-Fuel-Refinery System," SAE paper 750673.

2 Broering and Holtman, "Effect of Diesel Fuel Properties on Emissions and Performance," SAE paper 740692.

Test Vehicle Description

The vehicle used in the test program was a Nissan 220C 4-door sedan powered by a four cylinder, 132.1 cu in./2165 cc Diesel engine with an output of 70 bhp/52.2 kW. The engine operates on a four-stroke cycle and has a prechamber type of combustion chamber. Engine and chassis statistics are listed on the test vehicle description sheet at the end of the report.

Test Program

Exhaust emissions and fuel economy were measured in accordance with the 1975 Federal Test Procedure ('75 FTP) for light-duty Diesel vehicles, and over the EPA Highway Cycle. Due to an equipment malfunction, hydrocarbon emissions were not measured using a heated flame ionization detector and heated sample line, although CVS measurements of hydrocarbon emissions were made. However, when Diesel exhaust is collected in sample bags (as it is in the CVS procedure), a portion of the heavier hydrocarbon molecules will condense on the walls of the sample bags. Consequently, measurement of hydrocarbon emissions based on the contents of the CVS sample bag will result in lower apparent hydrocarbon emissions than are actually emitted from the test vehicle. Thus in this report, the CVS measured hydrocarbon emissions indicate only relative changes in emission levels and not absolute emission values.

Six emission and fuel economy tests were run on the test vehicle, two tests on each of the three test fuels.

Test Results

The exhaust emissions for each of the three test fuels are summarized in the following tables:

'75 FTP Composite Mass Emissions
grams per mile
(grams per kilometer)

	CVS HC*	CO	NOx	Fuel Economy (Fuel Consumption)
#2 Diesel fuel	0.22 (0.14)	1.43 (0.89)	1.53 (0.95)	27.0 miles/gal. (8.7 liters/100 km)
#1 Diesel fuel	0.19 (0.12)	1.50 (0.93)	1.42 (0.88)	26.7 miles/gal. (8.8 liters/100 km)
100-600 fuel	0.44 (0.27)	1.94 (1.21)	1.46 (0.91)	25.3 miles/gal. (9.3 liters/100 km)

* HC data are cold FID bag data which are approximately one half the value of hot FID continuous measurements used in the standard FTP for Diesel-powered light duty vehicles.

EPA Highway Cycle
Mass Emissions in
grams per mile
(grams per kilometer)

	CVS* HC	CO	NOx	Fuel Economy (Fuel Consumption)
#2 Diesel fuel	0.07 (0.04)	0.75 (0.47)	1.27 (0.79)	33.6 miles/gal. (7.0 liters/100 km)
#1 Diesel fuel	0.10 (0.06)	0.88 (0.55)	1.28 (0.80)	33.2 miles/gal. (7.1 liters/100 km)
100-600 fuel	0.22 (0.14)	1.38 (0.86)	1.26 (0.78)	32.4 miles/gal. (7.3 liters/100 km)

* HC data are cold FID bag data which are approximately one half the value of hot FID continuous measurements used in the standard FTP for Diesel-powered light duty vehicles.

Both Diesel fuels produced about the same exhaust emissions and fuel economy. Differences were within normal test variability.

The relatively low cetane 100-600 fuel produced higher emissions of HC and CO than either Diesel fuel. HC emissions increased 36% during the '75 FTP and 84% over the Highway Cycle. NOx emissions were slightly lower for the 100-600 fuel during the '75 FTP when compared to #2 Diesel fuel.

Fuel consumption was proportional to API gravity, with #2 Diesel giving the lowest fuel consumption and the 100-600 fuel giving the highest fuel consumption.

The test vehicle started and idled well on both Diesel fuels, but the 100-600 fuel caused hard starting and poor idle quality. Engine combustion noise was high for the 100-600 fuel.

Conclusions

There was very little difference in emissions and fuel economy when running on either #1 or #2 Diesel fuel. The differences measured were within normal test variability. The 100-600 fuel caused increased emissions of HC and CO, a reduction in fuel economy, and no change in oxides of nitrogen emissions.

As expected, HC emissions increased with decreasing cetane number. However, NOx emissions did not increase with decreasing cetane number. NOx emissions from the low cetane 100-600 fuel were lower than NOx emissions from the higher cetane #2 Diesel.

It is possible that the test vehicle could be optimized to improve exhaust emissions and fuel economy when running on the 100-600 fuel. However, the data indicate that some deterioration in exhaust emissions and fuel economy can be expected if the 100-600 fuel was to be substituted for the types of Diesel fuel currently being used in light-duty Diesels.

Table I

1975 Federal Test Procedure
Mass Emissions in
grams per mile
(grams per kilometer)

Test #	HC*	CO	CO_2	NOx	mpg (liters/100 km)
#2 Diesel fuel					
16-1786	0.21 (0.13)	1.43 (0.89)	379. (236.)	1.53 (0.95)	26.7 (8.8)
16-1788	0.22 (0.14)	1.43 (0.89)	370. (230.)	1.53 (0.95)	27.3 (8.6)
Average	0.22 (0.14)	1.43 (0.89)	375. (233.)	1.53 (0.95)	27.0 (8.7)
#1 Diesel fuel					
15-1784	0.19 (0.12)	1.51 (0.94)	359. (223.)	1.40 (0.87)	26.8 (8.8)
15-1785	0.18 (0.11)	1.48 (0.92)	363. (226.)	1.44 (0.90)	26.5 (8.9)
Average	0.19 (0.12)	1.50 (0.93)	361. (224.)	1.42 (0.88)	26.7 (8.8)
100-600 fuel					
15-1815	0.42 (0.26)	1.88 (1.17)	371. (231.)	1.47 (0.91)	25.4 (9.3)
16-1787	0.45 (0.28)	2.00 (1.24)	374. (232.)	1.44 (0.90)	25.2 (9.3)
Average	0.44 (0.27)	1.94 (1.21)	373. (232.)	1.46 (0.91)	25.3 (9.3)

* HC data are cold FID bag data which are approximately one half the value of hot FID continuous measurements used in the standard FTP for Diesel-powered light duty vehicles.

Table II

EPA Highway Cycle
Mass Emissions in
grams per mile
(grams per kilometer)

Test #	HC*	CO	CO_2	NOx	mpg (liters/100 km)
#2 Diesel fuel					
16-1786	0.07 (0.04)	0.78 (0.48)	302. (188.)	1.33 (0.83)	33.6 (7.0)
16-1788	0.07 (0.04)	0.71 (0.44)		1.20 (0.75)	
Average	0.07 (0.04)	0.75 (0.47)	302. (188.)	1.27 (0.79)	33.6 (7.0)
# 1 Diesel fuel					
15-1784	0.09 (0.06)	0.86 (0.53)	289. (180.)	1.27 (0.79)	33.3 (7.1)
15-1785	0.10 (0.06)	0.89 (0.55)	292. (181.)	1.28 (0.80)	33.1 (7.1)
Average	0.10 (0.06)	0.88 (0.55)	291. (181.)	1.28 (0.80)	33.2 (7.1)
100-600 fuel					
15-1815	0.21 (0.13)	1.34 (0.83)	295. (183.)	1.30 (0.81)	32.0 (7.4)
16-1787	0.22 (0.14)	1.41 (0.88)	287. (178.)	1.22 (0.76)	32.8 (7.2)
Average	0.22 (0.14)	1.38 (0.86)	291. (181.)	1.26 (0.78)	32.4 (7.3)

* HC data are cold FID bag data which are approximately one half the value of hot FID continuous measurements used in the standard FTP for Diesel-powered light duty vehicles.

Table III

Individual Bag Emissions in Grams per Mile

Test Number	Bag 1: Cold Transient HC*	CO	CO_2	NOx	MPG	Bag 2: Stabilized HC*	CO	CO_2	NOx	MPG	Bag 3: Hot Transient HC*	CO	CO_2	NOx	MPG
#2 Diesel Fuel															
16-1786	0.20	1.42	411.	1.68	24.6	0.22	1.54	374.	1.55	27.0	0.18	1.23	364.	1.41	27.8
16-1788	0.21	1.43	392.	1.60	25.8	0.24	1.56	369.	1.56	27.3	0.19	1.20	354.	1.41	28.6
#1 Diesel Fuel															
15-1784	0.21	1.60	407.	1.51	23.6	0.18	1.57	348.	1.38	27.7	0.17	1.32	344.	1.33	28.0
15-1785	0.19	1.48	391.	1.51	24.6	0.17	1.58	367.	1.48	26.2	0.18	1.31	336.	1.31	28.7
100-600 Fuel															
15-1815	0.83	1.75	396.	1.57	23.7	0.32	2.07	370.	1.46	25.5	0.31	1.63	354.	1.41	26.6
16-1787	0.87	1.77	402.	1.54	23.4	0.35	2.21	374.	1.44	25.2	0.31	1.77	352.	1.36	26.8

* HC data are cold FID bag data which are approximately one half the value of hot FID continuous measurements used in the standard FTP for Diesel-powered duty vehicles.

Table IV

Fuel Specifications

	#1 Diesel	#2 Diesel	100-600
Gravity, API	42.5	35.0	46.1
Cetane Number	46.0 (approx.)	45.5 (approx.)	34.8
Sulfur % (wt.)	.076	0.27	
% Carbon	85.9	86.0	86.3
% Hydrogen	13.8	13.3	13.7
Distillation, °F ASTM			
IBP	325	352	121
10%	363	396	
20%	382	422	225
30%	395	442	283
40%	408	463	334
50%	421	484	379
60%	435	502	421
70%	452	522	461
80%	471	545	491
90%	501	573	532
EP	538	580	

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1973 Nissan 220C
Emission control system - None

Engine

type	4 stroke, Diesel, I-4, ohv, indirect injection
bore x stroke	3.47 x 3.90 in./88.1 x 99.1 mm
displacement	133 cu in./2170 cc
compression ratio	22:1
maximum power @ rpm	70 bhp @ 4000 rpm/52.2 kW @ 4000 rpm
fuel metering	Fuel injection, mechanical
fuel requirement	#2 Diesel fuel

Drive Train

transmission type	4 speed manual
final drive ratio	3.91:1 (approximate)

Chassis

type	Front engine, rear wheel drive
tire size	175 SR x 14
curb weight	3000 lbs/1415 kg
inertia weight	3500 lbs
passenger capacity	5
durability accumulated	6800 miles/11000 km