SAE TECHNICAL
PAPER SERIES

1999-01-2251

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The Engineering Society
For Advancing Mobility
Land Sea Air and Space®
INTERNATIONAL

Government/Industry Meeting
Washington, D.C.
April 26-28, 1999

400 Commonwealth Drive, Warrendale, PA 15096-0001 U.S.A. Tel: (724) 776-4841 Fax: (724) 776-5760

ISSN 0148-7191

Printed in USA

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ABSTRACT

Alternative compression ignition engine fuels are of interest both to reduce emissions and to reduce U.S. petroleum fuel demand. A Malaysian Fischer-Tropsch gas-to-liquid fuel was compared with California #2 diesel by characterizing emissions from over the road Class 8 tractors with Caterpillar 3176 engines, using a chassis dynamometer and full scale dilution tunnel. The 5-Mile route was employed as the test schedule, with a test weight of 42,000 lb. Levels of oxides of nitrogen (NO_x) were reduced by an average of 12% and particulate matter (PM) by 25% for the Fischer-Tropsch fuel over the California diesel fuel. Another distillate fuel produced catalytically from Fischer-Tropsch products originally derived from natural gas by Mossgas was also compared with 49-state #2 diesel by characterizing emissions from Detroit Diesel 6V-92 powered transit buses, three of them equipped with catalytic converters and rebuilt engines, and three without. The CBD cycle was employed as the test schedule, with a test weight of 33,050 lb. For those buses with catalytic converters and rebuilt engines, NO_x was reduced by 8% and PM was reduced by 31% on average, while for those buses without, NO_x was reduced by 5% and PM was reduced by 20% on average. It is concluded that advanced compression ignition fuels from non-petroleum sources can offer environmental advantages in typical line haul and city transit applications.

INTRODUCTION AND PRIOR LITERATURE

Compression ignition diesel engines offer the benefit of excellent fuel economy, but present the environmental disadvantage of emitting oxides of nitrogen (NO_x) and particulate matter (PM) at a level that raises public concern. Oxides of nitrogen contribute ultimately to the formation of smog, while PM has been implicated as a threat to human health. Spark-ignited natural gas engines are offered as an alternative to diesel engines, but they still do not enjoy the fuel economy associated with unthrottled operation, and the fuel cylinders or tanks used for on board compressed or liquefied natural gas storage are still more cumbersome than liquid fuel tanks. Diesel fuel also offers high fuel energy density and diesel engines, following years of development, enjoy high reliability. For these reasons, diesel engines dominate the heavy duty fleet and are targeted for light truck and sport utility vehicle application.

Diesel engine PM emissions can be reduced through engine modifications, such as an increase in injection pressure, improvement in injector spray pattern, and alteration of charge motion. NO_x may be reduced by retarding the injection timing, or by employing exhaust gas recirculation. Aftertreatment devices may also be employed to oxidize exhaust constituents, but “lean NO_x” catalysts are still not established for aftertreatment.

There is benefit to reducing emissions through the reformulation of compression ignition fuels, or the adoption of suitable compression ignition fuels from non-traditional sources. This is particularly desirable if these fuels can be employed successfully in existing engines with no modifications, or with modifications only to the injection timing. Research has been conducted previously to support the use of “biodiesel”, usually a methyl soy ester [1], [2]. Blends of biodiesel with diesel generally raise NO_x emissions slightly while reducing PM emissions substantially, but the widespread adoption of biodiesel is proscribed by its present market price.

It is well documented that changing the formulation of petroleum-based diesel fuel can also affect PM and NO_x emissions, and this has been the motivation in reducing sulfur content of US diesel and by the State of California in adopting a diesel that is expected to produce lower emissions than diesel in the remaining 49 states. Reducing the sulfur content will reduce PM mass by reducing the solid sulfates produced. Mann et al. [3]

reported data for a 2 liter Rover automobile diesel engine operating on seven different fuels. With the engine controls operating as received, PM was reduced when lower density fuels were used, whereas NO_x was increased. However, this work proceeded to show that results might be attributed to interactions between the combustion behavior of the fuels and the engine controls that were optimized for one fuel. For example, kerosene, representing a light fuel, suffered an ignition delay of over 0.3 degrees of crank angle relative to a dense diesel fuel merely due to its physical properties such as viscosity and density. Of course, energy densities and carbon-hydrogen ratio in the fuel can also alter the full power rating of the engine.

Ultra-low-sulfur (<0.005%) diesel fuels are being considered in Europe to reduce the PM levels from urban buses [4]. A 32% to 44% reduction in PM was obtained in buses with pre-EURO 1 engines and approximately 32% reduction in PM was obtained in buses with EURO 2 engines, while using ultra-low-sulfur European "City" diesel.

There has been recent interest in the combustion of liquid fuels produced from natural gas in compression ignition engines. Such Fischer-Tropsch fuels have been produced in Malaysia (FT-SMD) and diesel fuel has been produced from natural gas in South Africa (FT-MGCOD). Mossgas produces gasoline, diesel and other distillate fuels from natural gas, using a Fischer-Tropsch synthesis process. The natural gas feedstock (predominantly methane) is reformed using steam and oxygen into synthesis gas (carbon monoxide and hydrogen). This stream is then fed into a high temperature circulating fluidized bed reactor, employing an iron-based Fischer-Tropsch (FT) catalyst (the Synthol process) to produce a light synthetic oil, which is then further treated and refined to give the desired product slate. The high temperature FT process produces a wider product spectrum than comparable low temperature slurry-phase processes, including a fraction of relatively light olefinic hydrocarbons. In the Mossgas process, this olefinic material is then converted to a middle distillate fuel through a secondary catalytic process (Conversion of Olefins to Diesel), using a zeolite-based catalyst and employing further hydrotreating. The resulting fuel, termed COD, is slightly lower in cetane number (51.4 vs. 53.3), and lower in aromatic content (10.1% vs. 16.9%) than the straight-run FT distillate fuel that is Mossgas' main product.

A recent report by Sirman et al. [5] detailed the emissions behavior of certification diesel and six alternative compression ignition fuels in an unmodified, direct injection 2.2 liter Daimler-Benz OM 611 diesel engine operating at seven steady-state speed and load points. It was recognized that by using absolute speed-load points, a comparison of the emissions can be made based on differences in fuel consumption and chemistry, not on power variations due to fuel density variations. Data showed a reduction in PM by 37% relative to a #2 diesel, with a 6% reduction in NO_x. A 20% blend of Fischer-Tropsch fuel with diesel showed a 27% PM benefit.

Two South African Fischer-Tropsch fuels have been compared by Schaberg et al. [6] with California diesel fuel and federal diesel fuel, using a Detroit Diesel Series 60 engine under hot transient test conditions. The two novel fuels had substantially lower NO_x emissions than the federal diesel fuel, and were each over 14% lower on NO_x emissions than the California diesel fuel. The PM values for the Fischer-Tropsch fuels were each more than 20% lower than for the California diesel.

Preliminary engine studies have therefore shown that Fischer-Tropsch fuels offer an attractive alternative to conventional petroleum-based diesel fuels. However, it is also desirable to validate these fuels using field studies of in-service vehicles. Chassis dynamometer based emissions characterizations of Class 8 trucks running on California diesel and Fischer-Tropsch fuels are presented below. A further comparison using a fleet of city buses is also presented. This paper condenses and presents data discussed in three former SAE publications. [7, 8, 9]

TRANSPORTABLE LABORATORIES

The two West Virginia University Transportable Heavy Duty Vehicle Emissions Testing Laboratories are heavy duty chassis dynamometer systems that can be moved from site to site with a dedicated semi-trailer and a laboratory trailer. These laboratories were constructed with funding from the U. S. Department of Energy, Office of Transportation Technologies, and emissions data gathered by the laboratories are added to a database (http://www.afdc.nrel.gov/web_view/emishdv.html) maintained by the National Renewable Energy Laboratory (NREL), in Golden, Colorado. Using selectable flywheels and air-cooled eddy current power absorbers, both inertia and road load losses, including wind drag and rolling resistance, are simulated by the laboratories. Power is taken directly from the drivewheels of the tested vehicle via hub adapters while the vehicle runs on free-spinning rollers. Besides hub torque, vehicle speed, and engine speed, gaseous emissions data can be logged continuously during a test through use of a full scale exhaust dilution tunnel, with heated probes and sample lines and analyzers for carbon monoxide (CO), oxides of nitrogen (NO_x) and hydrocarbons (HC). Particulate matter (PM) is determined gravimetrically by collecting the PM on 70mm diameter filters

The first laboratory, described by Clark et al. [10], differs from the second, largely in the positioning of the dilution tunnel and in some aspects of the drivetrain which couples the vehicle to the power absorbers. The two laboratories have previously been correlated with one another, and both laboratories were used in this research.

The chassis test cycles adopted for use by the laboratories were in this case for the purpose of comparing the alternative and conventional fuels. Class 8 trucks and tractors, particularly those with unsynchronized manual transmissions, are generally unable to meet the acceleration requirements of the Central Business District cycle (which appears in SAE recommended practice J1376) that is commonly used for transit buses. To satisfy the need for a cycle for heavy truck testing, Clark, et al. [11] proposed a "WVU 5 peak truck cycle" which was subsequently used by the Transportable Laboratories. The cycle covers a distance of 5 miles. More recently, this 5-peak cycle was replaced by a schedule termed the 5-Mile route, in which maximum acceleration is demanded of the truck during acceleration portions of the schedule. Figure 1 shows the actual speed vs. time trace of the 5-Mile route test for one of the diesel trucks in the study. The vehicle is customarily loaded to account for wind drag and tire losses in accordance with Federal code (Code of Federal Regulations, 1996) and inertia is simulated at 70% of the gross vehicle weight (GVW) for GVW up to 60,000 lb (27,200 kg) and at 42,000 lb (19,000 kg) for vehicles with a GVW over 60,000 lb (27,200 kg) [12]. For the 80,000 lb vehicles in this study, as discussed below, the weight was therefore 42,000 lb. at time of test. A “warm up” peak is usually included prior to the start of data logging test cycle. In the present research, the 5-Mile route was used for the trucks and the CBD cycle for the buses.

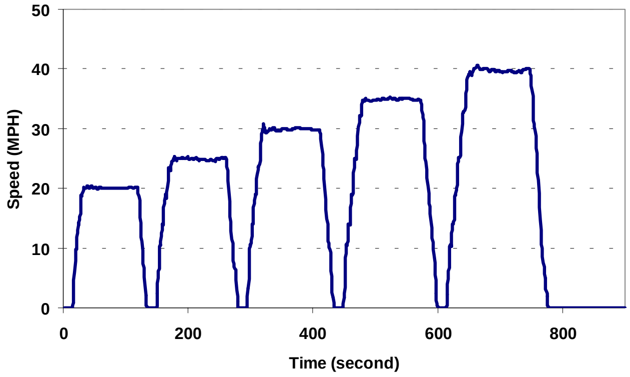

Figure 1. Actual speed vs. time for Pima Gro diesel truck on the 5-Mile route

DESCRIPTION OF SUBJECT VEHICLES

Both trucks and buses were employed in this test program. The trucks used in this study were model year 1992 to 1994 White-GMC WG64T class 8 tractors (80,000 lb gross vehicle weight) operated by Pima Gro Systems, Inc. in Southern California. The trucks were repowered with 1996 to 1997 Caterpillar 3176B diesel engines. Two of the five trucks in the study were converted by Power System Associates (PSA) for dual-fuel compressed natural gas/diesel operation. However, in this paper, no dual fuel data have been presented and the dual fuel trucks were operated in the “diesel only” mode. One of the dual-fuel trucks is show in Figure 2.

The Caterpillar 3176B is an in-line, six-cylinder, 10.3-liter electronically controlled engine. Both the diesel and dual-fuel engines tested in this program were rated at 350 horsepower. All of these trucks were tested with California #2 Diesel (CAD), four were tested with 100% Malaysia Fischer-Tropsch diesel fuel (FT-SMD), and three of them were tested with a 50/50 blend of these two fuels (FT-SMD50/CAD50).

Figure 2. Pima Gro Inc. Dual-Fuel CNG/Diesel truck

Figure 3. Pittsburgh 6V-92 Bus Mounted on the Test Bed

The six buses employed in this program were full size 40-foot transit buses in service in Pittsburgh, PA. The engines were all 6V-92 Detroit Diesel two stroke units, rated at 253 hp. Three of the buses had engines that had seen on average over 300,000 miles of service, while three of the buses were equipped with recently rebuilt engines with oxidizing catalysts. The buses had 4-speed automatic transmissions and were tested at a 32,990 lb test weight. The emissions were characterized using three fuels, a BP 49-state diesel purchased at the pump (D2), South Africa Mossgas Fischer-Tropsch derived diesel fuel (FT-MGCOD), and a 50/50 blend of these two fuels (FT-MGCOD50/D2-50).

FUEL USED

The trucks were characterized using a California #2 Diesel (CAD), Malaysia Fischer-Tropsch fuel (FT-SMD), and a 50/50 blend of the these two fuels (FT-SMD50/CAD50), while the buses were characterized using a 49 state diesel (D2), South Africa Mossgas Fischer-Tropsch derived fuel (FT-MGCOD) and a 50/50 blend of these two fuels (FT-MGCOD50/D2-50). The Malaysian FT-SMD fuel offered a high degree of saturation and vanishingly low aromatics, while the Mossgas FT-MGCOD fuel had aromatics at the 10% level, which is still considerably lower than aromatic levels in present day U. S. diesel fuels. Both the FT-SMD and FT-MGCOD were used with a lubricity additive (Paradyne, 0.02% by volume) and the 50/50 mix had one half of this additive level. Table 1 shows the properties that are known for the fuels.

Table 1. Fuel Analysis for the Fuels Used in This Study

	For Pima Gro truck tests		**For 6V-92 transit bus tests**	
Analysis	**California D2 (CAD)**	**Malaysia F-T (FT-SMD)**	**49 state Diesel (D2)**	**Mossgas F-T (FT-MGCOD)**
Distillation (% v/v)				
Initial Boiling Pt. (°C)	175		193	
5% (°C)	202		208	
50% (°C)	268		261	
90% (°C)	332		312	321.1
F.B.P (°C)	363		336	360.8
Recovery (% vol)	99.5		98.5	
Residue (% vol)	0.5		1.5	
Loss (% vol)	0		0	
Density, kg/L @ 15°C	0.8329	0.7845		0.8007
API Gravity @ 60F (API)		54	37.4	
Cetane No.	53.7	73.7	48.7	51.4
Sulfur Content (% mass)	0.01	*		<0.001
Heat of Combustion				
Gross Heat Value (BTU/gal)	136031	132716	137609	130955
Net Heat Value (BTU/gal)	127828	123615	129147	122937
Gross Heat Value (BTU/lb)	19618	20273.8	19726	19600
Net Heat Value (BTU/lb)]	18435	18883.5	18513	11400
Aromatic (% v/v)	18.1	0.1	24.7	10.1
Saturates (% v/v)		99.8	73.8	
Olefins (% v/v)		0.1	1.5	
Flash Point (°C)		72		100
Cloud Point (°C)		3		
Water & Sediment (%)		<0.02		<0.01
Carbon Residue (% mass)		0.02		
Ash (% mass)		<0.001		<0.01
Viscosity (cSt @ 40°C)		3.57		2.974
Corrosion		1A		1A
Pour Point (°C)		0		
Gums & Resins (mg/100ml)		0.2		
Lubricity SDBOCLS (grams)		1700		
Lubricity HFRR (micron)		420/540/570		
Carbon/Hydrogen (% mass)				
Carbon		84.91	86.11	85.30
Hydrogen		14.94	13.37	14.70
Nitrogen		0.57	<0.03	
Residual		-1.09		
Oxygen (by difference)		Negligible		

* Considered to be vanishingly low, but reported as <0.05%.

TEST RESULTS AND DISCUSSION

Table 2 shows an example of the repeatability from run to run of a Pima Gro tractor, exercised through the 5-Mile route. It is typical for a diesel vehicle to find that NO_x and CO_2 data are very repeatable, while CO and PM are highly sensitive to driving style. Although quality control measures for heavy duty vehicle chassis dynamometer are under examination [13], in the present research, only the total distance driven was monitored for repeatability of driver performance.

Table 3 summarizes the data for the Pima Gro trucks operated on California diesel and Malaysia Fischer-Tropsch (FT-SMD) fuel. Each line in the table represents the average of at least four runs. Figure 4 and Table 4 highlight the differences in emissions levels between the two fuels. The FT-SMD fuel showed benefits across the board in reducing regulated emissions, reducing PM by 25% and NO_x by 12%. However, it was noted that the four vehicles tested were not uniform in their NO_x and PM reduction.

Table 2. Typical test repeatability from a CAD fuel using the 5-Mile route test

Emissions results (g/mile) for CAD:						**Fuel Economy**		**Distance**
Run Seq. No.	**CO**	**NO_x**	**FIDHC**	**PM**	**CO_2**	**Mile/gal**	**BTU/ mile**	**Miles**
1167-1	3.67	12.1	0.66	0.48	1789	5.66	22952	5.01
1167-2	4.24	12.1	0.59	0.48	1736	5.83	22285	5.00
1167-3	4.06	11.7	0.62	0.46	1695	5.97	21763	5.00
1167-4	3.83	12.0	0.61	0.47	1688	6.00	21670	5.01
1167-5	4.06	12.0	0.59	0.48	1671	6.06	21457	5.00
1167 Average	3.97	12.0	0.61	0.47	1716	5.91	22025	5.00
Std. Dev.	0.22	0.1	0.03	0.01	47	0.16	601	0.00
CV%	5.6	1.2	4.6	1.4	2.7	2.7	2.7	0.1

Table 3. Average emissions (in grams/mile) and fuel economy from Pima Gro tractors operating on CAD and FT-SMD

Test ID	**Vehicle #**	**Fuel**	**CO**	**NO_x**	**FIDHC**	**PM**	**CO_2**	**MPG**	**BTU/mile**
1193	2011	CAD	2.8	14.58	0.66	0.37	1426	7.11	18300
1172	2012	CAD	5.0	13.99	0.52	0.50	1863	5.44	23926
1223	2016	CAD	4.3	12.84	0.89	0.59	1755	5.77	22541
1167	2019	CAD	4.0	11.98	0.61	0.47	1716	5.91	22025
		Average:	**4.0**	**13.35**	**0.67**	**0.48**	**1690**	**6.05**	**21698**
		Std. Dev.	**0.9**	**1.16**	**0.16**	**0.09**	**187**	**0.73**	**2403**
		CV%	**23%**	**9%**	**24%**	**19%**	**11%**	**12%**	**11%**
1191	2011	FT-SMD	2.6	11.25	0.41	0.35	1393	6.62	18701
1173	2012	FT-SMD	3.9	13.71	0.33	0.30	1709	5.38	22949
1221	2016	FT-SMD	3.2	11.24	0.50	0.48	1634	5.63	21947
1170	2019	FT-SMD	3.5	10.65	0.36	0.33	1645	5.59	22083
		Average:	**3.3**	**11.71**	**0.40**	**0.36**	**1595**	**5.81**	**21420**
		Std. Dev.	**0.6**	**1.36**	**0.07**	**0.08**	**139**	**0.55**	**1866**
		CV%	**17%**	**12%**	**19%**	**21%**	**9%**	**10%**	**9%**

Table 4. Average emissions comparison between CAD and FT-SMD for four Pima Gro tractors

Fuel	**CO**	**NO_x**	**FIDHC**	**PM**	**CO_2**
CAD	4.0	13.35	0.67	0.48	1690
FT-SMD	3.3	11.71	0.40	0.36	1595
% Reduction	18 %	12 %	40 %	25 %	6 %

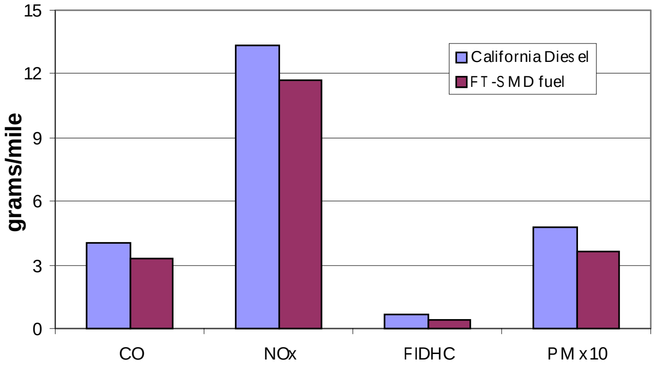

Figure 4. Average emissions comparison between CAD and FT-SMD from four Pima Gro tractors

Figure 5 and Tables 5 and 6 compare the California diesel and 50/50 blend data. Once again, the blend benefited regulated emissions across the board relative to the present day California fuel. Although the authors disfavor reaching general conclusions from a small sample of trucks, benefits were reduced by about 50% as a result of the 50% dilution, except in the case of NO_X, where the percentage improvement was similar to that for pure FT-SMD. In reviewing this data, the reader should note that California diesel fuel is already formulated to have lower emissions than 49-state fuel through reduction of aromatic content: one might expect greater advantages of the FT-SMD fuel in comparison to 49-state D2 fuel.

Table 5. Average emissions (in grams/mile) and fuel economy from Pima Gro tractors on CAD and FT-SMD50

Test ID	Vehicle #	Fuel	CO	NO_X	FIDHC	PM	CO_2	MPG	BTU/mile
1193	2011	CAD	2.8	14.58	0.66	0.37	1426	7.11	18300
1223	2016	CAD	4.3	12.84	0.89	0.59	1755	5.77	22541
1209	2017	CAD	4.8	13.28	0.69	0.61	1784	5.67	22920
		Average:	**3.9**	**13.57**	**0.75**	**0.52**	**1655**	**6.18**	**21254**
		Std. Dev.	**1.0**	**0.91**	**0.13**	**0.13**	**199**	**0.80**	**2565**
		CV%	**27%**	**7%**	**17%**	**26%**	**12%**	**13%**	**12%**
1190	2011	FT-SMD50	2.5	10.58	0.51	0.38	1438	6.65	19053
1222	2016	FT-SMD50	3.7	11.77	0.72	0.59	1717	5.57	22774
1210	2017	FT-SMD50	4.2	14.03	0.44	0.40	1621	5.89	21512
		Average:	**3.5**	**12.13**	**0.56**	**0.46**	**1592**	**6.04**	**21113**
		Std. Dev.	**0.9**	**1.75**	**0.15**	**0.11**	**142**	**0.56**	**1892**
		CV%	**25%**	**14%**	**27%**	**25%**	**9%**	**9%**	**9%**

Table 6. Average emissions comparison between CAD and FT-SMD50 for three Pima Gro tractors

Fuel	CO	NO_X	FIDHC	PM	CO_2
CAD	3.9	13.57	0.75	0.52	1655
FT-SMD50	3.5	12.13	0.56	0.46	1592
% Reduction	10 %	11 %	25 %	12 %	4 %

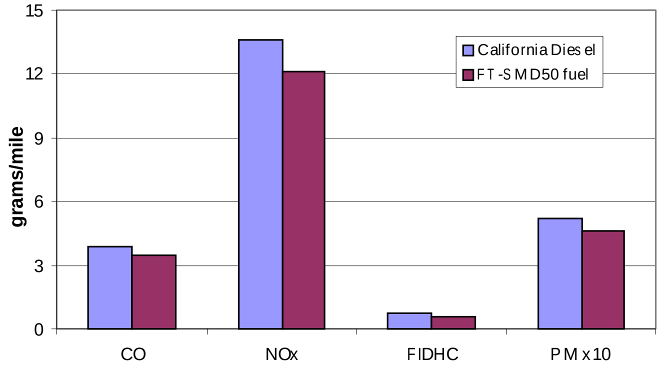

Figure 5. Average emissions comparison between CAD and FT-SMD50 from three Pima Gro tractors

Tables 7 and 8 and Figures 6 and 7 present emissions data for the Pittsburgh buses, tested using the CBD cycle, on 49-state diesel (D2), Mossgas fuel (FT-MGCOD), and 50/50 blend of these (FT-MGCOD50). The catalyst and non-catalyst buses have been separated because their emissions of CO, HC and PM differed substantially. Bus 2029 appears in both groups because the chassis was retrofitted with a rebuilt engine and fitted with a catalyst during the program. Its emissions were characterized both before and after the retrofit.

The catalyst and non-catalyst buses had similar levels of NO_X emissions. In both cases the FT-MGCOD offered a small NO_X reduction relative to the 49-state diesel, and there was also an advantage in stepping from 49-state diesel to the 50/50 blend. Although HC, CO and PM were substantially lower for the catalyst than the non-catalyst buses, all six buses showed the benefit of the FT-MGCOD and the blend in reducing HC, CO and PM. The average PM reported for the buses without aftertreatment must be carefully considered, because one of these buses was a far higher emitter than the other two. The combination of FT-MGCOD fuel, engine rebuild and catalyst addition on the city buses had the effect of reducing NO_X by 14%, CO more than 20-fold, HC by a factor of four and PM by a factor of four.

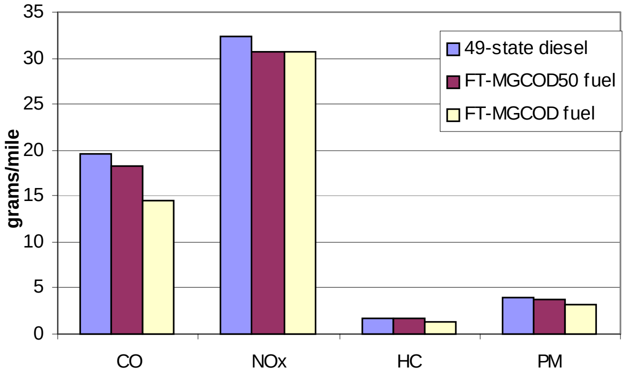

Figure 6. Average emissions comparison between D2, FT-MGCOD and their blend from three Pittsburgh transit buses without catalytic converters

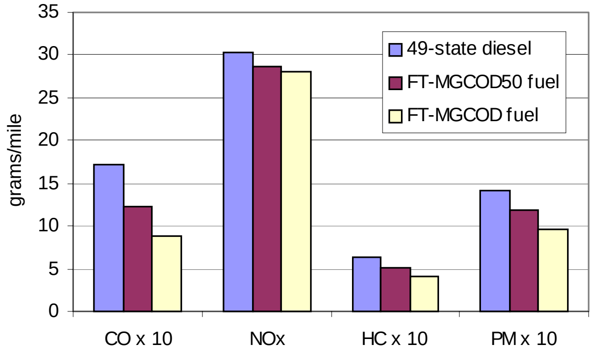

Figure 7. Average emissions comparison between D2, FT-MGCOD and their blend from three Pittsburgh transit buses with catalytic converter

Table 7. Average emissions comparison between D2, FT-MGCOD and their blend from five Pittsburgh transit buses

	Fuel	CO	NO_x	HC	PM
With Catalytic Converter	49-state Diesel	1.711	30.38	0.63	1.41
	FT-MGCOD50 Diesel	.220.	28.67	0.51	1.19
	FT-MGCOD Diesel	87	28.00	0.41	0.97
	% reduction for 50/50	**29%4**	**6%**	**19%**	**16%**
	% reduction for 100%	**9%**	**8%**	**35%**	**31%**
Without Catalytic Converter	49-state Diesel	19.60	32.33	1.75	4.00
	FT-MGCOD50 Diesel	18.16	30.72	1.63	3.75
	FT-MGCOD Diesel	14.42	30.64	1.40	3.19
	% reduction for 50/50	**7%**	**5%**	**7%**	**6%**
	% reduction for 100%	**26%**	**5%**	**20%**	**20%**

Table 8. Average emissions (in grams/mile) and fuel economy from Pittsburgh 6V-92 transit buses on D2, FT-MGCOD and their blend

	Fuel	Bus #	CO	NO_x	HC	PM	CO_2	MPG	BTU/mile
Buses **with** Catalytic Converters	**49-state Diesel**	2025	1.96	34.51	0.75	1.23	4355	2.33	55713
		2029	1.07	26.91	0.39	1.89	4458	2.28	56995
		2048	2.11	29.71	0.75	1.12	3451	2.94	44159
		Average:	**1.71**	**30.38**	**0.63**	**1.41**	**4088**	**2.52**	**52289**
	FT-MGCOD50 Diesel	2025	1.34	31.93	0.54	1.14	4360	2.20	57589
		2029	0.81	26.40	0.40	1.59	4346	2.21	57391
		2048	1.51	27.69	0.59	0.83	3381	2.84	44672
		Average:	**1.22**	**28.67**	**0.51**	**1.19**	**4029**	**2.42**	**53217**
	FT-MGCOD Diesel	2025	1.02	31.37	0.44	1.01	4206	2.19	56272
		2029	0.75	26.10	0.29	1.16	4181	2.21	55928
		2048	0.82	26.53	0.49	0.76	3338	2.77	44659
		Average:	**0.87**	**28.00**	**0.41**	**0.97**	**3908**	**2.39**	**52286**
Buses **without** Catalytic Converters	**49-state Diesel**	2029	11.73	35.85	1.82	1.79	4328	2.34	55598
		2030	6.65	34.88	2.11	1.18	4149	2.44	53221
		2034	40.42	26.26	1.31	9.03	4900	2.05	63468
		Average:	**19.60**	**32.33**	**1.75**	**4.00**	**4459**	**2.28**	**57429**
	FT-MGCOD50 Diesel	2029	10.33	32.23	1.88	1.52	4348	2.20	57601
		2030	6.26	33.93	2.03	1.13	4099	2.34	54244
		2034	37.91	26.02	0.99	8.61	4704	2.02	62887
		Average:	**18.16**	**30.72**	**1.63**	**3.75**	**4383**	**2.18**	**58244**
	FT-MGCOD Diesel	2029	11.02	33.37	1.72	1.34	4392	2.09	58963
		2030	5.73	32.92	1.75	1.16	4133	2.23	55391
		2034	26.52	25.64	0.72	7.07	4639	1.97	62596
		Average:	**14.42**	**30.64**	**1.40**	**3.19**	**4388**	**2.10**	**58984**

CONCLUSIONS

Two separate emissions studies using a chassis dynamometer have been used to evaluate novel compression ignition fuels. Fischer-Tropsch fuel offered advantages in reducing all of the regulated emissions (CO, HC, PM and NO_x) relative to California #2 diesel for Class 8 over-the-road tractors exercised through the 5-Mile route at a test weight of 42,000 lbs. Similarly, a fuel from Mossgas, containing approximately 10% aromatics, yielded lower levels of all regulated emissions than 49 state diesel when tested over the CBD cycle on transit buses, both with and without catalytic aftertreatment devices. This study has highlighted the benefits of compression ignition fuels with reformulated compositions under in-use driving conditions, and has shown that fuels derived using gas-to-liquid processing offer promise from an environmental perspective.

ACKNOWLEDGMENTS

The authors are grateful to the staff of the WVU Transportable Heavy Duty Vehicle Emissions Testing Laboratories for their work in the field and to the vehicle owners for their assistance with the testing. The study was funded by the U. S. Department of Energy, Office of Transportation Technologies.

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