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The Effects of an Iron Based Fuel Catalyst upon Diesel Fleet Operation

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ABSTRACT

This paper will discuss several aspects of fuel combustion in internal combustion engines. It will be shown that one area of significant potential cost reduction for the operator of a major diesel fleet could involve the application of a chemical fuel catalyst to improve the combustion of the diesel fuel. It will be shown that substantial reduction in engine deposits and increased fuel economy on a long term fleet basis have resulted from the use of the catalyst in several large fleets operating in Western Canada.

THE ESCALATING COST of diesel fuel, the increasing cost of engine overhauls, and the high expenses involved in mobile equipment downtime are having a major influence on diesel fleet operations. Since expenses relating to these areas are accounting for an increasingly larger share of fleet operational budgets it follows that any significant improvement can have a substantial impact upon the bottom line of the fleet operating statement.

This paper will explore the effects noted under field conditions when an iron based (ferrous picrate) fuel catalyst is introduced into diesel fuel in an effort to attain an improvement in combustion of the fuel. Since the primary interest of the fleet operator is a reduction in operating expense particular emphasis will be placed on the observed effects of the catalyst as they relate to fuel economy and engine maintenance.

As background for this study various aspects of the combustion of hydrocarbon fuel in internal combustion engines will be discussed. This will form the basis of an outline for a plausible mode of action for the catalyst. References will be drawn from a number of laboratory studies which have been carried out using vehicles under controlled conditions. Finally, the results noted using diesel fleets under actual operating conditions will be described using as primary reference the experience of three major fleets operating in Western Canada. Particular emphasis will be placed upon observed changes in engine mechanical condition as this would appear as the common factor linking the controlled laboratory situation and the field studies where precise fuel economy measurement can be substantially more difficult.

It is recognized that field studies relating to an assessment of fuel economy under actual operational conditions lack the precision of the controlled laboratory environment. This is particularly true when off-the-road mobile equipment is being considered. Measurement of engine fuel consumption under these conditions is often possible, however, an assessment of equipment work output is much more difficult. This problem of fuel economy measurement can be compounded by fleet operational conditions which may include the absence of metered fuel control into equipment, widely fluctuating workloads and operating patterns, and fluctuating weather and ground conditions. It is therefore suggested that while reductions in engine combustion residue can be desirable in itself this reduction in engine carbon can also be used as evidence of improved combustion which in turn should relate to improved fuel economy. In this manner some parallels may be drawn to link the laboratory study, the field fleet operation where some fuel economy measurement may be possible, and the off the road fleet where accurate fuel economy measurement is extremely difficult.

COMBUSTION IN ENGINES

As a background for description of a possible mode of action of the fuel additive, various aspects of combustion in engines are discussed. The combustion of hydrocarbon fuels occurs when two conditions are met: (1) an oxidant must be available in proper concentration to produce flammable mixtures with the fuel, and (2) an ignition source of sufficient strength is available to initiate the combustion reaction. The combustion reaction will proceed through the fuel-oxidant mixture only within certain limits of composition, which depend in part on mixture temperature, mixture preparation, and the strength of the ignition source. Well atomized fuel particles and good mixing also enhances combustion. The rate of propagation is dependent on several factors relating to the physical properties of the mixture. Temperature, pressure and the homogeneity of the mixture all affect flame speed. The degree of turbulence enhances propagation as the flame surface area increases due to wrinkles and distortion as hot combustion products are vigorously mixed with the reactants.

The combustion of fuel in an internal combustion engine occurs with essentially a pre-mixed flame in a conventional spark - ignition engine and possible with diffusion flames in a direct-injected compression ignition engine. Several stages comprise the process. Ignition is preceded by a delay during which pre-flame reactions occur. For a spark-ignition engine the flame propagates radially outward from the ignition source, until the flame front approaches a solid surface, which distorts and quenches the reaction process. The entire process may cover more than one-fourth of a crankshaft revolution.

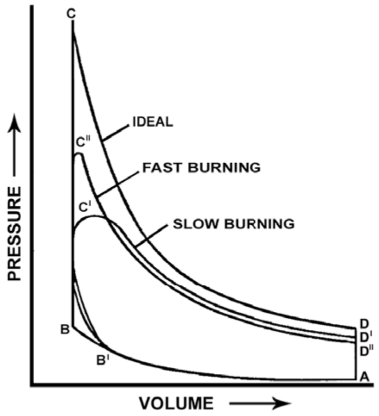

Figure 1. Ideal and actual engine cycles

The thermal efficiency of an internal combustion engine will increase if the combustion time is decreased - a greater temperature can be achieved as the heat release occurs more nearly at constant volume. Pressure is higher and more work can be accomplished for the same energy supplied. Figure 1. shows slow burning and fast burning representations of the Otto cycle compared with the ideal cycle. Cycle ABCD is the ideal cycle characterized by isentropic processes and constant volume combustion. B^1 is the point at which ignition must be accomplished in order to obtain peak pressures when the piston is at top dead center. The fuel is ignited at the same time for the slow burning and fast burning cases. The fast burning process is more complete at minimum volume and therefore better approximates the ideal cycle.

The time period required for complete combustion to occur is composed of two regimes. The induction period, or ignition delay, spans the beginning of reaction to the appearance of quiescent or cool flames. The second regime begins at the onset of cool flames and ends with the completion of vigorous combustion. The first regime is governed by chain branching reactions; the second concerns reaction in the chemically altered residual mixture. It is during the second regime that greatest rates of pressure rise occur, which usually correspond to a piston position just past top center. A temperature variation is also noted between mixture elements burned early and later in the process. In an actual engine sufficient time lapses between onset and completion of combustion that burned gas temperatures drop for the portions of

steady-state evaluations of the additive (5). The engine was operated at two different steady-state power levels during the test. Regular leaded fuel was used throughout the tests, which included the equivalent of about 1000 miles (20 hours) accumulation with the additive. Steady-state conditions were determined from engine oil the mixture which burn toward the end of the overall process. Temperature differences of up to 500 K have been calculated for early and late burning mixture elements (1).

POSSIBLE MODE OF ADDITIVE ACTION

The primary mode of action of the fuel additive is likely related to a reduction of the combustion time in an engine, though no definitive supporting information exists. Some evidence exists that the additive forms flat, crystalline particles in the air / fuel mixture in an engine. The crystalline particles in the mixture absorb radiant energy from the spark and / or flame kernel and may act as local flame initiators throughout the mixture (2). The additive may also exhibit iron catalytic effects to reduce the induction period of the fuel. Ignition throughout the mixture may also be enhanced by thermal decomposition of ferrous picrate and subsequent spontaneous oxidation of the picrate ions. Therefore, if ignition occurs more uniformly throughout the mixture more fuel combusts when the piston is near the beginning of the powerstroke, approaching the ideal cycle. Figure 1 shows an example for a spark ignition engine; the ideal combustion process in a modern high speed diesel engine may also be considered constant volume.

LABORATORY EVALUATIONS

Controlled laboratory studies have been conducted to measure the effects of the additive on fuel efficiency and regulated exhaust emissions. Steady-state automotive engine tests have been conducted in an engine dynamometer test cell, and U.S. Environmental Protection Agency (EPA) FTP and HFET evaluations have been conducted, with both gasoline and diesel vehicles. SAE J 1082 road tests have also been conducted, results of which are also described in this section.

STEADY-STATE LABORATORY TESTS - A Ford 302 CID V-8 engine in a computer controlled test cell (4) was used for temperature and ambient air temperature measurements. A series of tests each 45 seconds in duration, were run during which fuel flow and exhaust emissions were continuously monitored and recorded by the computer. The results of the evaluation tests are shown in Table 1. All results were corrected to standard conditions. A statistical analysis of the data produced 95% confidence intervals for the change in brake specific fuel consumption (BSFC). For the low power level tests, the confidence interval for an improvement in fuel efficiency (the negative of the decrease in BSFC) was 7.6% to 15.6%; for the higher power level the 95% confidence interval was -0.83% to 7.9%.

(SEE TABLE 1 - STEADY-STATE ENGINE DYNAMOMETER TEST OF COMBUSTION IMPROVER)

CHASSIS DYNAMOMETER DRIVING CYCLES - Three gasoline-powered late model vehicles and two automobiles with diesel engines were tested, with and without the additive, using duplicate hot start city and highway driving cycles specified by the EPA for light duty vehicles (6,7).

Diesel Vehicles - Table 2 shows the fuel economy and exhaust emissions results from the diesel powered vehicles (6). The Oldsmobile had never been operated with the additive, while the additive had been used in the VW since it was new. The tests conducted were the Federal Test Procedure (hot-start '74 FTP) and the Highway Fuel Economy Test (HFET). The engines were set to manufacturer's specifications prior to the evaluations. Baseline back-to-back runs with D-2 diesel control fuel were made, after which the vehicles were driven 800 miles each with treated fuel. Final back-to-back tests with the additive were then conducted. The combined fuel economy for the FTP and HFET indicates an improvement of 6.1% for the Oldsmobile and 2.4% for the VW. The average FTP fuel economy increase considering both vehicles, calculated using the harmonic average of the miles per gallon results, was 7.35%. The HFET harmonic average improvement for both vehicles was 2.11%

The improvement in fuel economy with the additive was accompanied by significant changes in some regulated exhaust emissions. The additive has virtually no effect on fuel heating value or stoichiometric air/fuel ratio, due to its extremely low concentration in treated fuel.

Oxides of nitrogen (NOx) exhaust emissions dropped in all cases, while carbon monoxide (CO) results show opposite trends for each vehicle. The unburned hydrocarbon (HC) emissions increased for all tests.

The consistent decrease in NOx emissions is likely due to lowered local temperatures in the combustion chamber. The increase in hydrocarbon emissions may be caused by several factors related to the operation of a direct injection diesel engine

Gasoline Vehicle - Three gasoline powered automobiles were tested at two different laboratories. Table 3 summarizes the results for back-to-back duplicate FTP, HFET and Hot ‘74 (FTP without the last hot-transient segment) evaluations (6) and LA-4 (first two phases of the ‘75 FTP) and HFET evaluations (4). Fuel economy increased for all vehicles and tests. Carbon monoxide emissions were also consistently reduced. The Chevrolet results were obtained after 3000 miles with the additive, and only the fuel economy improvement is reported as statistically significant at a 90% confidence level.

(SEE TABLE 3 - SUMMARY OF GASOLINE DRIVING CYCLE FUEL ECONOMY EVALUATION WITH THE FUEL ADDITIVE) (6,7) and to a phenomenon observed with the use of the additive. In diesel engines, the mass of air per cycle is almost constant. Change in load is accomplished by varying the amount of fuel injected. This, in turn, produces variations in atomization quality, Injection duration and cylinder gas pressure and temperature, and the amount of fuel deposited on the walls. As fuel economy is increased, the fuel-air ratio decreases.

The unburned hydrocarbon emissions increased with the decrease in fuel-air ratio which occurs with an improvement in fuel economy. The increased hydrocarbon emissions may also be due in part to the observed reduction in combustion chamber deposits with prolonged use of the additive. A gradual steady decline in carbon deposits which do not completely burn as they are removed could contribute to increased unburned hydrocarbon emissions.

Carbon monoxide emissions are related to the fuel-air ratio, which varies with load. The CO decreases with fuel-air ratio to a point, after which further reductions in the fuel-air ratio cause an increase in CO for a naturally aspirated diesel engine (3). The decrease in CO for the Oldsmobile, and increase for the VW, may both result from the decrease in fuel-air ratio (increased fuel economy) with the additive. A difference in the average fuel-air ratios for the Oldsmobile and VW during the FTP and HFET could explain the opposite results.

[SEE TABLE 2 - SUMMARY OF FTP AND HFET EVALUATIONS OF FUEL ADDITIVE IN DIESEL VEHICLES (5)]

<u>SAE Road Tests and Driveability</u> - Duplicate fuel economy tests on the Chevrolet were performed (7) using the SAE J1082 Suburban (SAE-2) and Interstate (SAE-I) cycles. The CRC driveability tests was performed on a road route (7). The test included a cold start and a number of driving maneuvers during the 3.6 mile test. Vehicle performance including hesitation, stumble, surging, idle quality and stalling were evaluated using a standardized system of weighting factors and demerits based on the nature and perceived severity of each undesirable characteristic. Table 5 summarizes the SAE road test and CRC driveability results. The Suburban fuel economy improvement with the additive is significant at a 99% confidence level; the Interstate fuel economy improvement is significant at a 90% level of confidence. The driveability demerits reduction of 31 is also significant at a 90% confidence level.

(SEE TABLE 4 - SUMMARY OF ROAD TESTS CONDUCTED WITH FUEL ADDITIVE FOR A SINGLE VEHICLE (7).

CATALYST EFFECTIVENESS EVALUATIONS UNDER FLEET CONDITIONS

The anticipated effect of the catalyst, as outlined by the proffered theoretical analysis and the cited laboratory studies would be an improvement in efficiency of an engine cycle using a hydrocarbon fuel. In diesel fleet operations evidence of an improved fuel burn should manifest itself in a reduction of combustion residue remaining in the engine, reductions in the total carbon content of the exhaust emissions, possible observable engine performance changes, and increased fuel economy on a pounds of fuel per horsepower hour basis. Due to the inherent difficulty of accurate measurement of several of these factors under field conditions while the fleet is carrying out its function (particularly in off the road equipment) it is suggested that engine combustion residue analysis may be an area most easily assessed by the fleet operator. The amount and the nature of this engine combustion residue is important since any improvement in the fuel burn should create less residue all other factors being unchanged. In addition the decreased level of engine deposits may in turn contribute to improved engine fuel efficiency while reduced carbon residue resulting from the better fuel burn should have a direct bearing upon engine wear and associated costs, due to the elimination of the carbon abrasive in oil and combustion gases.

From a mechanical standpoint it is generally considered that combustion residue build-up contributes to a gradual decline in diesel engine performance. In addition hard carbon, acting as a abrasive, accelerates wear in a number of engine areas including ring, liner, and bearing wear. The scrapers, graders and rubber tired loaders. The catalyst was introduced into the fuel used by the entire fleet during the second year of the project after normal engine patterns had been established. The initial engine inspected was a Caterpillar 348 engine from a 992C which was overhauled at 8000 hours including approximately 4 months of FPC® usage. An examination of the engine showed carbon deposits present at near normal levels for this type of engine service but with a marked softening of the normal hard carbon being noted in some engine areas. This was particulary noticeable around the centre of the piston crown where bare metal could be exposed by wiping the area with a rag. In addition it appeared that some carbon erosion was occurring in the upper liner area above the ring travel. Soot in the manifold exhaust area appeared finer and dryer than is normally observed.

Engines overhauled subsequently exhibited a progession of this pattern. After two years of burning the catalyst containing fuel, engines demonstrated a substantial reduction in normal engine carbon found in combustion and exhaust areas as significant engine clean up had been attained. There was almost a complete absence of hard engine carbon present as the soft residue which remained was corollary is, of course, that a reduction in the presence of hard engine carbon brought on by improved fuel combustion would have the effect of decreased wear and improved fuel performance patterns. For the purpose of this paper the effects of the fuel catalyst upon normal engine carbon residue will be considered using examples drawn from three specific diesel fleets in Western Canada. The analysis of changes in carbon based engine deposit levels under field conditions is subjective. Nevertheless, these observations and conclusions discussed herein have been made by professional equipment maintenance supervisors and experienced engine rebuild staffs. As a result there is a high degree of confidence in the accuracy of their observations.

CONSTRUCTION EQUIPMENT FLEET - The initial fleet to be considered is a large fleet of diesel powered earthmoving equipment engaged in a major construction project spanning several years. This 69 piece fleet was comprised primarily of Caterpillar equipment including off road trucks, D9 and DI0 crawler tractors, easily wiped from cylinder heads, valve ports, and piston crowns. The normal build up of hard scale on these surfaces was absent. Piston rings were exceptionally free of deposits and it was noted that cylinder compression in high hour ' engines had been maintained rather than exhibiting the reduced levels normally experienced. Valve and piston numbers were clearly visable on engine parts. Considerably less exhaust smoke was evident during idle and start up than was normally observed and the minimal deposits evident in exhaust manifolds reflected this condition. In addition engine startability showed a marked improvement. Of particular interest was the reduction in liner wear being experienced in the off road trucks. These vehicles operated under severe conditions including heavy fluctuating loads and adverse grades 60-70 times per day with intermittent idling. It was noted that cylinder liners could be reused after 8000-9000 hours of service as they, fell within Caterpillar reuseability guidelines. This is unusual for trucks in this type of service.

Fuel use for this fleet was calculated on the basis of gallons consumed per operating hour for the first year of the project before the addition of the catalyst and then for the subsequent year. To make the study meaningful only equipment carrying out repetitive functions was considered. The 12 piece group of equipment selected included crawler tractors, graders, and rubber tired loaders. The duty cycle of the other equipment was considered to be too irregular to form a meaningful data base. An analysis of the equipment being tracked indicated a reduction in fuel use of approximately 7%. The crawler tractors did not respond as their fuel use appeared as a function of the amount of ripping which they carried out when maximum power was demanded from the engine.

TRANSIT FLEET - The second fleet to be considered was a fleet of 32 public transit buses operating in an urban environment in the Vancouver Lower Mainland area. All units in the fleet were standard transit coaches powered by Detroit Diesel 6V71 transit engines. Average engine mileage was 171,000 miles. This fleet carried passengers on a scheduled run basis on established routes.

The engines in this fleet experience conditions of sustained idling and low engine temperatures common to many transit operations. As a result a greater amount of engine deposits are anticipated than in a less severe type of diesel service. The catalyst was added to the central fleet diesel fuel storage and the initial effect noted was a reduction in exhaust smoke from three of the units which had been producing abnormally high levels of visible smoke. This occurred approximately 60 days after the introduction of the catalyst and reflected 4300 miles of driving on each of the vehicles. This was noteworthy as public transit operations are sensitive to exhaust- smoke and odour for public relations reasons. A reduction of soot accumulation was noticeable in exhaust stacks at approximately a 20,000 miles of catalyst use had been accumulated on the high mileage engines. Engines inspected after this point had similar characteristics to those described in the heavy construction equipment study. Hard carbon was not in evidence on cylinder heads and piston crowns except in minor amounts around peripheral areas and the light soot which coated these combustion surfaces wiped easily to the metal base. Substantial scavenging of deposits from exhaust valve stems was evident while the carbon in exhaust ports was significantly drier and finer than was normally observed and was present in only minor volume. The carbon coating in ring land and ring groove areas was substantially reduced from normal levels. These general characteristics have been evident in all high mileage engines from this fleet which have been overhauled since mid-1981.

After operating approximately one year on the catalyst-containing fuel the fleet began burning a blend of #1 and #2 fuel rather than #1 diesel. Most public transit properties burn #1 diesel to obtain the minimum level of smoke and odour in exhaust gases. The fuel catalyst was withdrawn from the fuel and smoke and odour increased to unacceptable levels. The catalyst was then reinstated and smoke and odour abated to the prior levels. The fleet has continued to burn the blended fuel with this catalyst and engine deposits have remained as described.

Fuel usage studies were carried out using this fleet. For the purposes of this study the fleet fuel mileage reports for the 3-1/2 month period immediately prior to the introduction of the catalyst was used as a baseline. The fleet travelled 262,000 miles during this baseline period. After some instability immediately following introduction of the catalyst which lasted approximately one month (2000 miles per unit) fuel economy increased over the 5 three month point.

The first high mileage bus engine was examined at the time of overhaul approximately three months after the introduction of the catalyst. No significant change in the normal deposit pattern was observed. At this point the engine had operated approximately 250,000 miles of which approximately 7,000 was on treated fuel. Several other engines were examined over succeeding months; however, no marked decrease in engine carbon was evident until approximately

month evaluation period during which the fleet accumulated 412,000 miles. The fuel economy increase approximated 8%.

At the time of writing a transit study using the catalyst has recently been concluded in Ontario using a fleet similar to the B.C. fleet formerly described. Both results were within 1% in terms of increased fuel economy. Of particular interest in the Ontario study was the fact that the engines which initially operated below the fleet median - in terms of fuel economy - showed the largest gains after

introduction of the catalyst into the fuel. This parallels, the results noted on the Finning chassis dynamometer when two buses were tested for maximum demand horsepower. The engine which initially turned in the poorest performance showed a substantial gain in horsepower in relation to the second unit which exhibited only a minor change.

(SEE TABLE 5)

Comparison of Public Transit Bus Fuel Consumption

MINES FLEET - The third fleet considered is a mixed diesel fleet used in a large open mining operation. The fuel catalyst was originally introduced into the fuel used in the Listor engines used to power the portable light towers around the minesite. The operational conditions of a light load and constant RPM was condusive to carbon formation and these engines had traditionally exhibited a heavy carbon build-up which necessitated decarboning. The fuel catalyst was introduced into the fuel used by these engines and within 10 weeks a substantial decrease in carbon formation was attained. The fuel used by a Detroit Diesel 8V71 powered generator was also treated and the noted result was a decrease in engine exhaust smoke and a reduction of carbon in the stack area after several weeks of operation. Fuel use was not monitored in either test. At the time of writing an initial three engines from the open pit mobile equipment fleet have been overhauled after running on the catalyst containing fuel. All three engines were Caterpillar D353 models used to power the D9H crawler tractors. Each engine had operated approximately 2800 hours on the catalyst containing fuel. Total hours on the engines were 7500, 4500 and 8300 respectively.

It was noted upon disassembly that all engines were substantially cleaner internally than engines previously overhauled. With the exception of one area of one engine which had experienced a mechanical fault and which will be discussed later there was absence of hard carbon scale on pistons and cylinder heads. All of these combustion surfaces could be wiped down to bare metal. Of major interest was the absence of hard carbon encrustation on the upper ring land of pistons above the fire ring and on the lower ring land areas. This is an area of normal build up. Carbon encrustation on the upper liners was also minimal being light and soft to the point that pistons could be withdrawn from the liners without first buffing. As a result there was no carbon scuffing on the upper piston land surfaces or evidence of carbon liner scuffing. Piston rings were free of hard carbon and no evidence of carbon was present in the piston ring grooves. It was observed that valve faces were free of both hard carbon and sulphur deposits while exhaust valve stems were extraordinarily clean. Valve ports and exhaust manifolds evidenced a very marked reduction in the normal carbon and soot accumulation in the exhaust side of the engine. This is consistant with the observation of the mine mechanical staff that exhaust smoke on start up has shown a marked decrease with the catalyst in the fuel.

As aforementioned, one D353 engine experienced a mechanical failure which necessitated an early overhaul at 4500 hours. This failure related to a cracked head and broken piston ring condition which was non related to the use of the fuel catalyst. It was particularly interesting to note that under the abnormal combustion conditions which occurred in this cylinder hard engine carbon was formed on the cylinder head, piston crown, piston lands, and exhaust areas in spite of the use of the catalyst in the fuel. It is evident that there are engine conditions which can exist which can exceed the ability of the catalyst to deliver a clean fuel burn.

EXHAUST GAS ANALYSIS

As previously mentioned the inherent difficulties involved in carrying out accurate engine fuel economy measurements in mobile equipment under field conditions are well recognized. To overcome this problem area work is currently In progress to develop a carbon balance method of exhaust gas analysis which can be applied to mobile equipment in the fleet situation. At the time of writing a number of engines have been tested both with and without the catalyst yielding some promising results. Development is continuing to increase the accuracy of the technique.

CONCLUSION AND SUMMARY

A number of conclusions may be drawn from these studies:

(1) It would appear that the theoretical explainable effects of the catalyst are evident in diesel fleet operations.

(2) Under field conditions which often preclude accurate fuel use measurement the improved fuel combustion is evident when engines are mechanically inspected. The results noted in engines which have burned the catalyst for some time under normal operating conditions is a reduction of carbon residue in combustion and exhaust areas.

(3) The reduction in hard engine carbon should have a positive influence on normal diesel engine carbon related abrasive wear patterns.

(4) The reductions in hard engine carbon in combustion and exhaust areas is consistent with fleet reports of reduced exhaust soot emissions.

(5) Field fuel use studies appear to be directionally consistent with the formal studies carried out using SAE and EPA protocal. Both types of studies indicate that fleet fuel consumption can be decreased on a pounds of fuel per horsepower hour basis as a long term effect of improved fuel combustion.

(6) Work currently in progress in developing a field adaptation of the carbon balance exhaust gas analysis technique appears to be substantiating the fuel economy findings noted above. Developmental work is continuing in the area.

TABLE 1
STEADY-STATE ENGINE DYNOMOMETER TEST OF COMBUSTION IMPROVER

	Engine Condition		Percent change from Baseline			
	RPM	Torque	BSFC	HC	CO	NOx
Low Speed	1250	30	-11.68	+24.0	-17.0	-3.0
High Speed	2200	50	- 6.56	+22.0	- 9.0	+6.56

TABLE 2
SUMMARY OF FTP AND HFET EVALUATIONS OF FUEL ADDITIVE IN DIESEL VEHICLES (6)

Vehicle	Test	Percent change from Baseline MPG	HC	CO	NOx
Oldsmobile	FTP	+9.7	+18.6	- 8.3	-2.7
Oldsmobile	HFET	+1.9	+24.6	-10.3	-3.1
VW	FTP	+2.8	+14.3	+ 8.2	-8.6
VW	HFET	+2.0	+13.3	+ 4.0	-11.2

TABLE 3
SUMMARY OF GASOLINE DRIVING CYCLE FUEL ECONOMY EVALUATION WITH THE FUEL ADDITIVE (6, 7)

		Percent Change from Baseline			
Vehicle	Test	MPG	HC	CO	NOx
Plymouth TC3[a]	FTP	+5.9	+ 4.7	-8.1	-7.1
Plymouth TC3[a]	Hot ‘74	+6.6	-16.0	-47.9	-13.6
Plymouth TC3[a]	HFET	+3.3	+25.6	-27.4	-2.8
Oldsmobile[a]	FTP	+3.0	- 5.5	+2.9	-2.6
Oldsmobile[a]	Hot ‘74	+3.7	-27.1	-21.5	+7.4
Oldsmobile[a]	HFET	+2.8	-31.6	-20.8	+5.1
Chevrolet[b]	LA-4	+4.9	- 1.3	-8.1	+2.0
Chevrolet[b]	HFET	+2.6			

a Data from Reference (6)
b Data from Reference (7)

TABLE 4
SUMMARY OF ROAD TESTS CONDUCTED WITH FUEL ADDITIVE FOR A SINGLE VEHICLE (7)

		Change from Baseline	
Vehicle	Test	MPG	Demerits
Chevrolet	SAE-Surburban	+6.7	
Chevrolet	SAE-Interstate	+7.9	
Chevrolet	CRC Driveability		-31

TABLE 5
COMPARISON OF PUBLIC TRANSIT BUS FUEL CONSUMPTION

Bus Fleet	No. of Buses	Engine	Test Duration	% Change
A	32	Detroit Diesel	6 months	8.2
B	32	Detroit Diesel	6 months	7.6