Evaluation Procedure for Field Testing FPC-1®

Fuel Catalyst

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I. INTRODUCTION:

FPC-1® is a complex combustion catalyst which, when added to liquid petroleum base fuels, improves the combustion reaction. The primary result is an increase in engine efficiency and a reduction in fuel consumption. Secondary benefits include reduced engine smoking, reductions in regulated emissions, extended useable oil life, and reduced engine hard carbon. Experience with diesel power mobile and stationary equipment indicates a potential to reduce fuel consumption by 4% to 8% with catalyst fuel treatment. These findings agree closely with early research conducted in recognized independent laboratories using state-of-the-art test procedures.

This proposal outlines three areas of additive benefit verification and cost savings reduction to the end user. Since each area of benefit requires different time frames for maximum results, the proposed test is divided into three phases.

PHASE I: REDUCED FUEL CONSUMPTION VERIFICATION

Typically, testing for fuel consumption determination in the field is difficult and time consuming. Although, it is comparatively easy to monitor fuel consumption and hours of engine operation or miles traveled, it is next to impossible to determine how other factors, such as equipment load, effect the rate of fuel consumption. Changes in weather conditions, fuel properties, operators, trip cycles, idle time, etc., are just a few of the uncontrolled variables having a significant impact on fuel consumption. Laboratory test procedures were developed for this very reason, to eliminate the uncontrolled variables affecting fuel consumption.

RDI Corporation, the manufacturer of FPC-1®, has solved the problem of collecting meaningful fuel consumption data by applying a heretofore laboratory method to field testing. The method, known as the carbon mass balance calculation, is central to the EPA standardized Federal Test Procedure (FTP) and Highway Fuel Economy Test (HFET), which have been used since 1974 as the basis for fuel economy labels under the EPA voluntary fuel economy labeling program.

Carbon Mass Balance

The carbon mass balance eliminates virtually all of the variables associated with field testing for fuel consumption changes. The method requires no modifications to fuel lines or engines, and can be conducted in a short period of time with minimal expense.

Instead of measuring fuel flow into the engine (ie., the weight or volume of the fuel), measurements are made of the exhaust gases leaving the engine. More precisely, the carbon containing gases in the exhaust are measured. The method is based upon the Law of Conservation of Matter, which states that atoms can neither be created nor destroyed. Since the engines only source of carbon is the fuel it consumes, the carbon measured in the exhaust must come from the fuel. By measuring the carbon going out of the engine in the form of products of combustion, the amount of carbon entering the engine can be decided.

Carbon Balance Calculation

The carbon leaving the engine is mainly in the form of carbon dioxide ($C0_2$), carbon monoxide (CO), unburned hydrocarbons (HC), and particulate (smoke). By collecting these data while the engine is operating at a given load and speed, the fuel flow rate into the engine can be accurately determined. When engine load and speed, along with other factors influencing fuel consumption are reproduced and/or monitored to make appropriate corrections, the carbon balance can be used to confidently determine changes in fuel consumption that might result from the use of a fuel catalyst, such as FPC-1®.

With the carbon balance, engine efficiency is expressed in terms of engine performance factors. To calculate any change in engine performance, separate measurements are made with the engine running on base fuel (untreated) and FPC-1® treated fuel. Any changes are stated as percentage changes from baseline.

A copy of the carbon balance equations (Figure 1) and a sample calculation (Figure 2) are attached.

Instrumentation

Precision, state-of-the-art instrumentation is used to measure the concentrations of carbon containing gases in the exhaust stream and other factors related to fuel consumption and engine performance. The instruments and their purposes are listed below:

1)	A Sun Electric SGA-9000 non-dispersive infrared (NDIR) four gas analyzer - measures the percent of the total volume of $C0_2$, CO, and oxygen (0_2) in the exhaust, and the parts per million (ppm) of HC.

2)	EPA l/ M Calibration Gases - known gases used to internally calibrate the NDIR analyzer.
3)	A twenty (20) foot sampling train and stainless steel exhaust gas probe - inserted into the engine exhaust pipe draws a sample of exhaust gases to the analyzer.
4)	A Fluke Model 52 hand held digital thermometer and wet/dry thermocouple probe - measures exhaust, ambient, and fuel temperature.
5)	A Dwyer Magnehelic 2000 Series Pressure Gauge and pitot tube - measures exhaust air velocity and/or pressure.
6)	A Monarch Contact/Noncontact digital tachometer and magnetic tape - measures engine rpm when dash mounted tachometers are unavailable.
7)	A hydrometer and flask - determines fuel specific gravity (density).
8)	Barometric pressure is acquired from local airport or weather station.

Test Length

With the exception of engine speed, fuel density, and ambient readings, all data are collected by simply inserting probes into the exhaust stream while the engine is running at a fixed rpm and load, and the vehicle is stationary. No modifications or device installation are made to the fuel system, nor are normal equipment work cycles disrupted.

Each piece of equipment would be needed at the test site for approximately ten to twenty minutes while stabilization is verified and data is collected. The unit is then returned to its normal duty cycle. The test site (or location were the instrumentation is set up) should be easily accessed by the equipment (the test site must have access to 110 volt A/C power outlets to operate the NDIR analyzer).

After baseline testing, the test fleet will operate with FPC- 1® fuel treatment approximately 300 hours to ensure complete engine conditioning.

Field Test Procedure

The test fleet must be large enough to provide statistical confidence in the data collected and the results obtained. It is recommended that the test fleet (fleet to be treated with FPC-1®) include a minimum of ten (10) pieces of equipment. As the test will require several hundred hours of equipment operation, it is further recommended that a control fleet, consisting of at least five (5) pieces of equipment also be tested. The control will not be treated with FPC- 1®. It's function is to determine changes, if any, in the baseline rate of fuel consumption not having to do with the effect of FPC-1®.

All test and control fleet equipment must be in good mechanical working order, and not scheduled for repairs that will affect fuel consumption during the test period. Equipment having such repairs will be removed from the sample.

All test fleet equipment should be fuelled from the same location to facilitate controlled treatment with FPC-1®.

The baseline, control, and treated data will be recorded by customer's engineers with the assistance of RDI technicians. RDI will provide the instrumentation listed above at no charge to *the customer. Also, there will be no charge for RDI personnel time.

All test instruments will be calibrated by customer's engineers and readings taken in a manner prescribed by both parties (ie, pitot tube placement, number of readings, etc.). The basic procedure for testing is as follows:

1)	All instruments are calibrated according to accepted protocol.
2)	Before testing begins, a sample of fuel is drawn from the fuel tank on each piece of equipment. Using a hydrometer and wet/dry temperature probe, fuel specific gravity and temperature are recorded.
3)	Each piece of equipment to be tested is parked, brakes locked, and run out-of-gear at a specific engine speed (RPM) until engine water, oil, and exhaust temperature, and exhaust pressure have stabilized. Engine speed is controlled using either a hand held phototach or the tachometer in the cab.
4)	Engine hours (or mileage) are taken from hour meters installed on the equipment.
5)	After engine stabilization, the exhaust gas sampling probe is inserted into the exhaust stream. The Autocal button is depressed and after the LED readouts clear, test personnel take multiple readings of carbon dioxide, carbon monoxide, unburned hydrocarbons, and oxygen, along with engine speed, exhaust temperature and pressure.

6)	Periodically, ambient air temperature, atmospheric pressure, and relative humidity are recorded. Temperature readings are taken at the test site. Other ambient readings are acquired from local weather information services.
7)	All data are recorded until customer and RDI personnel are satisfied that the information is consistent and reproducible.
8)	After completing the baseline, all test fleet fuel will be treated with FPC-1®. All equipment will operate as normal for approximately 300 hours, at which time the above procedure will be reproduced without alteration, except for FPC-1® fuel treatment in the test fleet.

In addition to the above procedure, RDI recommends additional testing for the effect of FPC- 1® on engine smoke and oxides of nitrogen (NOx) emissions. Testing for reduction in smoke can be done using a smoke spot device. NOx testing can be done with a hand held device used in underground mines.

The data relative to the rate of fuel consumption would be used by customer's engineers to calculate the percent change in fuel consumption before and after FPC-1® fuel treatment.

COSTING

Sufficient FPC-1® is needed to treat fuel used by the test fleet a minimum 300 hours. One (1) gallon of the additive will treat 5,000 gallons of fuel. Projected product needs for a 300 hour test are four (4) gallons to treat a 20,000 gallon bulk storage tank, and four (4) gallons to treat fuel deliveries afterward. FPC-1® product cost during Phase I testing is $60.00 per gallon.

RDI's technicians and instrumentation are provided at no charge to your customer. The FPC-1® used during Phase I will be paid for at the conclusion of Phase I only if a net fuel savings is realized. Your company defines net fuel savings as the difference between the reduction in fuel cost and the cost of FPC-1®.

Prior testing in similar equipment indicates a potential fuel consumption reduction from FPC-1® treatment of 4% to 8%. (Your company) guarantees the use of FPC-1® will create a minimum net $0.01 per gallon fuel savings. Assuming an annual fuel consumption of ten (10) million gallons at a cost of $.75 per gallon of fuel, FPC- 1® use would result in a minimum $100,000.00 fuel savings annually. However, savings could reach a high of $400,000.00 per annum, if the maximum indicated savings were realized. Additionally, operational costs could be reduced even more as engine wear and downtime are reduced, as pointed out in Phases II and III.

PHASE II: OIL ANALYSIS

Provided the customer performs regular lube oil analysis for soot and wear metals content, further product benefit verification could be documented here. Fleets experiencing high soot and wear metals in engine lube oil find FPC- 1® fuel treatment reduces these problems.

Verification of improved lube oil life will require several months to document. RDI recommends Phase II testing begin at the time of initial fuel treatment and be extended beyond finalization of the carbon balance.

PHASE III: ENGINE HARD CARBON

Another secondary effect of FPC-1® fuel treatment is reduced hard carbon accumulation on critical engine components. Existing carbon deposits are gradually reinvolved in the combustion process and removed from the engine. The same action prevents future carbon buildup. As a result, in many applications, engine component life is improved and downtime losses reduced. RDI recommends a long term comparison of engine cleanliness and component life by qualified mechanics and engineers.

SUMMARY

Testing, in both the laboratory and the field indicate a potential for large fuel cost reductions with FPC-1® use RDI recommends carbon balance testing under field conditions to verify fuel economy benefit from FPC-1® fuel treatment. Testing is done under careful controls and in complete cooperation with your engineers.

The carbon balance method also makes possible the determination of the effect of FPC-1® upon harmful emissions such as carbon monoxide, unburned hydrocarbons, nitrogen oxides, and smoke. Reductions in any or all of these products of combustion could have a significant impact on the mine environment and upon customer's public image.

Finally, long term studies of the effect of FPC- 1® on lube oil and engine component life should be considered. The cost savings potential of FPC-1® fuel treatment could be substantial in these areas also.

Carbon Mass Balance Field Data Form

Company:	Location:	Test Date:
Test Portion: Baseline:	Treated:	Exhaust Stack Diameter: Inches
Engine Make/Model:	Miles/Hours:	LD.#:
Type of Equipment:		
Barometric Pressure:	inches of Mercury	@: (°F)
Fuel Specfic Gravity:	@: (° F)	Start Time

RPM	Exhaust Temp °F	P Inches of HZO	% CO	HC ppm	% CO_2	% O_2	NOx

		Finish Time:
Signature of Technicians:		
Names of Customer Personnel Participating in Test:		

Figure 1

Carbon Mass Balance Formula

Assumptions: C_8H_{15} and SG = 0.78
Time is Constant
Load is Constant

Data:

Mwt	= Molecular Weight
pf_1	= Calculated Performance Factor (baseline)$_{(1)}$
pf_2	= Calculated Performance Factor (treated)$_{(2)}$
PF_1	= Performance Factor (adjusted for baseline exhaust mass)$_{(1)}$
PF_2	= Performance Factor (adjusted for treated exhaust mass)$_{(2)}$
T	= Temperature (°F)
F	= Flow (exhaust CFM)
SG	= Specific Gravity
F	= Volume Fraction

$VFC0_2$	= "reading" ÷ 100
$VF0_2$	= "reading" ÷ 100
VFHC	= "reading" ÷ 1,000,000
VFCO	= "reading" ÷ 100

Equations:

$$Mwt = (VFHC)(86)+(VFCO)(28)+(VFCO_2)(44)+(VFO_2)(32) +[(1-VFHC-VFCO-VFO_2- VFCO_2)(28)]$$

$$pf_1 \text{ or } PF_1 = \frac{2952.3 \times Mwt}{89(VFHC)+13.89(VFCO)+13.89}$$

$(VFCO_2)$

$$PF_1 \text{ or } PF_2 = \frac{pf \times (T+460)}{F}$$

Fuel Economy:
Percent Increase (or Decrease) $= \frac{(PF_2 - PF_1) \times 100}{PF_1}$