Technical Bulletin
No. 102

January 1993

THE RELATIONSHIP BETWEEN EXHAUST GAS MEASUREMENTS AND ENGINE STABILITY

INTRODUCTION

Recent long-term laboratory and field tests have added to our understanding about the behavior of FPC® Catalyst. This information is critical to the successful testing of FPC® Catalyst by potential customers. It is particularly applicable to the carbon balance field tests and the length of the engine-conditioning period with FPC® Catalyst fuel treatment before maximum benefit can be documented.

A brief explanation of the critical factors relating to the carbon balance is included, and how these factors are affected by FPC® Catalyst's unique behavior.

1) CARBON DIOXIDE

Carbon dioxide (CO_2) is the heaviest weighted factor in the carbon mass balance calculation for fuel consumption change determination. Other carbon containing exhaust constituents make up a minute fraction of the exhaust gases, and have little or no bearing upon the outcome of the carbon balance test.

Carbon dioxide concentrations are affected by fuel flow to the engine. In order to insure consistent and accurate CO_2 readings, engine speed (RPM) and load must be held constant. Fuel density is measured to correct for fuel flow changes to the engine having to do with the energy content of the fuel. Exhaust temperature and pressure are recorded, along with ambient temperature (intake air) and pressure (barometric) to correct for volume changes inside the engine exhaust stack that might affect the CO_2 concentrations.

The first two calculations in the carbon mass balance relate to the weight of the combustion gases in the exhaust stream. The final calculation corrects these weights based upon changes in exhaust volume.

2) EXHAUST PRESSURE AND TEMPERATURE

Temperature and pressure are also critical to the carbon balance. Typically, if exhaust temperature increases significantly, pressure should increase also. As exhaust temperature rises, air volume and, therefore, air velocity inside the stack should rise also. This may not be so in every case, but it is typical.

In the final calculation for fuel economy determination, exhaust temperature is in the numerator and exhaust pressure (which is used to determine air velocity in cubic feet per minute {CFM} is in the denominator (pf{temp+460}/CFM). Therefore, these factors correct for each other since temperature increases usually create pressure increases and vice versa. For example:

PF = uncorrected pf(temp+460 deg)/CFM

= 150,000 (450 deg F+460)/1,000
CFM = 67,500

= 150,000 (500 deg F+460)/1,111
CFM = 67,506

Obviously, if temperature increases and pressure does not, the engine performance factor (PF) becomes larger. Likewise, if temperature decreases, but pressure increases, the final PF will be smaller. The greater the fuel economy improvements with FPC® Catalyst, the higher the final PF. Pressure and temperature, if not carefully monitored, can completely negate the effect of FPC® Catalyst.

3) THE EFFECT OF EXHAUST VOLUME UPON CO_2 READINGS

If exhaust temperature and pressure increase, CO_2 readings usually decrease. The increase dilutes the CO_2 readings. For example, if readings are:

CO_2 = 3.0%

ExT = 450 deg

ExP = 1.5″ H_2O

and pressure and temperature are increased without adding fuel to the system, then the readings might look like this:

CO_2 = 2.7%

ExT = 500 deg

ExP = 1.65″ H_2O

On the surface, because the CO_2 number is lower, it appears that the rate of fuel consumption is reduced. However, this is not the case. Rather, the increased air volume inside the exhaust stack has diluted the CO_2 concentration. The carbon balance corrects for the changes in air volume, so the fuel flow rate or engine performance factor would be identical.

4) THE IMPACT OF CARBON MONOXIDE AND UNBURNED HYDROCARBONS

Carbon monoxide (CO) and unburned hydrocarbon (HC) readings are indicators of combustion efficiency, and as stated above, have little or no effect upon fuel consumption. Most of the fuel burned by an engine becomes CO_2. CO_2 mass is approximately 100 times greater than CO mass, and can be 1,000 times greater than HC mass. Therefore, a small change in CO_2 mass is more meaningful than even large changes in CO and HC mass.

Maximum combustion efficiency is not obtained until engine pre-conditioning is complete. CO, HC, and smoke are indicators used to determine if engine conditioning is complete. CO and smoke are the more critical indicators. In 85% of the tests conducted, FPC-1® has reduced CO, unless the CO concentrations were very low to begin with (0.01%). These same tests indicate HC will be reduced in 60% to 70% of the engines tested, again depending on HC levels during baseline. Finally, engine smoking and exhaust odor are also reduced with FPC® Catalyst treatment. If CO is rising and the engine is still smoking, the engine is not yet conditioned and has not stabilized.

5) ENGINE CONDITIONING AND THE CARBON BALANCE

Exhaust reading from engines not run long enough with FPC® Catalyst treated fuel and therefore, not stabilized, are unreliable. The readings are inconsistent and usually generate results that are unreasonable.

For example, at a large mining company in Washington, FPC-1® was tested in four Cat 777 haul trucks at roughly 300-400, 700-800, and 1000-1100 hours of FPC-1® use. At the first interval, the test produced 10.2% fuel savings, however, the data was erratic. Two trucks realized 20% and 30% reductions in fuel consumed; two other trucks realized 2% and 7% increases in fuel consumption. There was no consistent pattern in the data. Additionally, CO and HC increased from baseline. The trucks were still smoking badly and exhaust odor was strong.

At the second interval, three of the trucks had small improvements (1.5%, 3%, 6%) and the fourth had a 24.2% improvement. The 24% was an obvious outlier, so the improvement was approximately 3.5%. The data was more consistent, and the CO and HC readings were improving. Engine smoking was visibly reduced.

At the final interval, three trucks improved by 4.1%, 4.7%, and 6%. The fourth experienced a 13% degradation in performance. Again, the –13% is an outlier, so the average improvements was near 5%. The exhaust data was consistent. The engine smoke was visibly reduced.

The same kind of pattern was observed in the 200-hour engine conditioning run at Southwest Research. For the first 150 hours after FPC-1® fuel treatment, data was more erratic (although under SWRI controls, the changes from data point to data point were small) than the last 50 hours when engine conditioning was complete and engine stabilization final.

CONCLUSION

We conclude from this new information that engine stabilization does not take place until exhaust smoke and CO are reduced over baseline conditions. This behavior is likely due to FPC® Catalyst's ability to re-involve engine hard carbon deposits in the combustion process. In accordance with this model, dirty engines must run FPC® Catalyst treated fuel longer to remove the hard carbon deposits, and thereby, improve the exhaust emissions and create maximum fuel consumption reductions.

Until the engine has stabilized, expect inconsistent emissions data, exhaust temperatures, and exhaust pressures.

RECOMMENDATION

In light of these new data, all future tests must take into consideration the type of fleet being test. Fleets that appear clean, which constitute the majority of our former tests, can still be repeat tested after 300 hours of FPC® Catalyst use. However, fleets in operation types that lend themselves to carbon buildup, such as mining, construction, waste disposal, and around-town delivery fleets, may need 500 to 700 hours or more.

Future testing could be done at several intervals (250 hrs., 500 hrs., etc.). Such a practice will help make engine stabilization easier to document and allow FPC® Catalyst to produce maximum results.

FPC International, Inc. · P.O. Box 705, South Point, OH 45680 · Tel: 740-377-9984 · Fax: 740-377-9913 · Web: www.fpc1.com · E-mail: rdi@netacs.net
FPC Technology, Inc. · 226 S. Cole Rd., Boise, ID 83709 · Tel: 208-378-0361 · Fax: 208-378-0364 · E-mail: fpc@fpctechnology.com
FPC Great Lakes, Inc. · 1001 W. Glen Oaks Ln., Suite 241, Mequon, WI 53092 · Tel: 262-241-3239 · Fax: 262-241-3278 · E-mail: dweltzien@wi.rr.com
International Fuel Technologies, Inc. · 3810 Summer Circle, Idaho Falls, ID 83404 · Tel: 208-528-8537 · Fax: 208-528-8537 · E-mail: bartift@sisna.com