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November 2004

Technical Bulletin – Effects of Fitch Fuel Catalyst
Heavy - Duty Diesel Engine Combustion Test

Topic: Engine Tested DT 466

APSI commissioned fuel economy and emission tests on an in use heavy-duty diesel fueled vehicle. The purpose of the test was to quantify the emissions and fuel economy benefit of employing the Fitch Fuel Catalyst on this specific equipment.

This test was conducted by Ocean Air Environmental LLC of Somis, California, a test company unrelated to APSI, the manufacturer of the fuel, or the manufacturer of the engine. The Dynamometer employed was a Superflow chassis dynamometer located at Holt Equipment Center in Sacramento. The vehicle was an in use vehicle owned by the City of Sacramento.

Test procedure: The vehicle was brought to the facility 11/1/2004 for Baseline data capture. A Fitch Model F 500 was fitted to the vehicle and 250 miles were accumulated. The vehicle was re tested using the identical procedure 11/12/2004.

The test procedure consisted of 5 (five) separate constant speed modes or steady-state load points. This makes for ease of data capture and reproducibility. Vehicle operation surveys conducted by EPA and others have shown that true steady-state operation rarely occurs in customer use. Fitch users are likely to experience fuel economy improvement greater than that reflected in this evaluation when engines are operated in a transient mode or a blend of transient and steady-state modes.

In addition to the 5 (five) separate steady state modes a single Max HP mode test was also conducted at Baseline and Retrofit and the results are reported separately.

EMISSIONS TEST AND FUEL ECONOMY REPORT DT466

FITCH FUEL CATALYST

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Background: Ocean Air Environmental LLC (OAE) was retained to evaluate the impact of the Fitch Fuel Catalyst on an in service vehicle operated on transportation diesel fuel purchased in the State of California at the time of the eva luation, November 2004.

Advanced Power Systems International, Inc. (APSI) the manufacturer of the product describes the product in product literature as follows:

"The Fitch Fuel Catalyst is a polymetalic alloy housed in a canister and connected into an engines fuel system between the fuel tank and the engine prior to the fuel filter and before the fuel pump. Its purpose is to reformulate fuel on board the vehicle prior to combustion. It performs its function at the temperatures experienced by vehicles in normal service.

The Fitch Fuel Catalyst is not a fuel additive. It is a special alloy that does not dissolve in fuel. The fuel is reformulated by the alloy catalyst to a state where it is capable of a more complete combustion. As a result, an engine converts the chemical energy in the fuel to mechanical energy in a more efficient manner. The engine power is increased as a result and the toxic exhaust emissions are decreased."

Units used for the test were supplied by APSI.

Purpose of the Program: To evaluate the effect of Fitch Fuel Catalyst on emission of NOx, CO, HC, PM, Smoke Opacity and fuel economy.

Test Set Up: A dump truck operated by the City of Sacramento was used for evaluation. The truck was baseline tested using the procedures outlined in Appendix A. The results are presented in Appendix B. After the baseline test, the truck was equipped with a Fitch Fuel Catalyst installed in the fuel supply line to the engine. The test was repeated after 250 miles of service. The operator had changed air filter prior to the test. OAE measured the effects of fuel filter change and found no increase in air flow to the engine.

Testing Location: Testing was done at Holt Equipment Company in Sacramento, California, using their Superflow chassis dyno.

Test Results Discussions: The test data represents controlled environment testing where the same baseline operating parameter can be duplicated for post-Fitch vehicle evaluation. Fuel economy testing on the road can introduce many more variables, like road conditions, driver input, and traffic pattern. The results of testing are as follows:

Baseline Data

Five mode weighted results:

H.P. 103.8
Fuel Consumption: 8.87 gal/hr
Bsfc: 0.0854 gal/bhp-hr
NOx: 3.99 gms/bhp-hr
THC: 0.06 gms/bhp-hr
CO: 5.09 gms/bhp-hr
PM10: 1.1 mg/filter (based on 10 lit/min exahsut flow to PM collection system for five minutes on the filter at each mode)

Snap Idle Opacity: 17.5
Single point (max power) fuel economy = 0.053 gal/bhp-hr

Retrofit – with Fitch Data

Five mode weighted results:

H.P. 103.8 (horsepower was maintained in order to be able to compare the two results) Fuel Consumption: 8.36 gal/hr
Bsfc: 0.0805 gal/bhp-hr
NOx: 3.77 gms/bhp-hr
THC: 0.10 gms/bhp-hr
CO: 0.2 gms/bhp-hr
PM10: 1.03 mg/filter (based on 10 lit/min exhaust flow to PM collection system for five minutes on the filter at each mode)

Snap Idle Opacity: 13.5
Single point (max power) fuel economy = 0.052 gal/bhp-hr

Discussion of Results

Effect of Fitch Catalyst

All emissions were reduced and fuel economy improved as a result of the installation of the Fitch Fuel Catalyst on board the test vehicle.

NOx + THC (ozone precursors) = 4.51% reduction
PM10 = 6.36% reduction
CO = 96.04% reduction
Five mode weighted fuel economy = 5.75% improvement

Single point (max power) fuel economy = 1.94%
improvement Snap Idle Opacity = 22.86% reduction

References:

Ocean Air Environmental LLC 805-386-1882 http://www.oceanairllc.com/
Test Location Holt Equipment Company Sacramento California
Chassis Dynamometer - Superflow SF-601602 http://www.superflow.com/
Engine International DT 466
http://www.internationaldelivers.com/site_layout/engine/dt466detail.asp

Appendix A

Heavy-Duty Diesel, Gasoline, and Alternative Fuel Vehicle Engines Emissions Testing

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Heavy-Duty Vehicle Emissions Testing Program

OceanAir Environmental has over ten years experience in emissions testing of heavy-duty diesel, gasoline, and alternative fuel vehicle engines.

Emissions Test Cycle Description

Engines used in heavy-duty vehicles are certified by the engine manufacturers using the EPA transient test procedures.

OceanAir's testing program is a cost effective method for measuring emissions and fuel economy without the time and expense of conducting the transient test cycle on a full chassis dyno. Prior to EPA's heavy-duty transient test procedures for engine certification, engines were certified using the 13-mode steady state test procedure below.

: EPA 13-Mode Test Cycle For Heavy-Duty Vehicles

Mode #	RPM	Load	Weighting Factor
1	**Idle**	**Idle**	**0.067**
2	**Intermediate**	**2%**	**0.08**
3	**Intermediate**	**25%**	**0.08**
4	**Intermediate**	**50%**	**0.08**
5	**Intermediate**	**75%**	**0.08**
6	**Intermediate**	**100%**	**0.08**
7	**Idle**	**Idle**	**0.067**
8	**Rated**	**100%**	**0.08**
9	**Rated**	**75%**	**0.08**
10	**Rated**	**50%**	**0.08**
11	**Rated**	**25%**	**0.08**
12	**Rated**	**2%**	**0.08**
13	**Idle**	**Idle**	**0.067**

The 13-mode test procedure is still widely used to certify heavy-duty engines. The Euro 2 standard (for Europe) requires certification on the 13- mode cycle.

OceanAir Environmental (OAE) used the 13-mode steady state test cycle as the basis for a shorter, more cost effective test, after determining the five mode test cycle compared favorably with the standard 13-mode test procedure. OAE's five mode test cycle is as follows:

OAE's Five Mode Test Cycle

Mode	RPM	Load	Weighting Factor
1	Rated	100%	0.15
2	Rated	75%	0.25
3	Rated	50%	0.25
4	Rated	25%	0.2
5	Rated	Idle	0.15

A comparison of OAE's five mode test cycle with the 13-mode test cycle has provided statistically insignificant deviation. OAE's five mode test procedure provides a reliable estimate of the effect of a technology change on in-use vehicle emissions and fuel economy. Moreover, the shorter test method is ideally suited to operator testing at or close to the operator's area of operation where cost and down time are at a premium. The calculation procedures employed here include the adjustment factors via data reduction software developed by OAE.

The smoke opacity measurements are taken using the snap acceleration test and a smoke opacity meter. The smoke measurements are taken by consecutive smoke reading during snap acceleration and the peak smoke recorded. When the difference between the two readings is less than 10%, that reading is recorded as the final smoke opacity number. The above procedure complies with California Sections 2190-2194, Title 13, California Code of Regulations, "Heavy-duty Diesel Powered Vehicle Periodic Smoke Inspection."

Emissions Test Instruments

The following instruments are used by OAE for emissions testing and performance verification:

Dynamometer: Superflow SF-601/602 water brake chassis dynamometer. The dyno is capable of measuring roll power (power applied/absorbed by the rear wheel). Testing of tandem axle rear wheel is possible with this dyno. The dyno sensors provide information on vehicle speed, fuel flow, and engine rpm. For the purpose of test, vehicle speed is generally kept at 50-60 mph with radiator fan continuously on for maximum horsepower absorption.

Fuel Meter: Available as part of chassis dynamometer. Fuel measurement is done using the gravimetric method where engine fuel tank is by passed and the engine fuel system is connected to a small fuel canister that is weighted continuously for the duration of the test.

Smoke Meter: An Bosch RTP 100 Infra red opacity meter is used for this purpose. The smoke meter complies with SAE J1243. Five snap idle opacity readings are taken, the first two are to clear the system, the last three readings are then averaged for the results. The smoke meter is calibrated at zero and 100% opacity.

Emissions Analyzer: Enerac 3000E emissions analyzer was employed for these tests. The emissions analyzer is capable of measuring NO, NO_2, NOx (calculated), CO, SOx, oxygen, exhaust temperature, percent combustibles, excess air (calculated), and CO_2 (calculated). The sample conditioning system includes a permeation drier (silica gel) which is capable of drying samples up to 20% moisture content to a 50 deg F dew point level. The dry exhaust gas is then introduced to electrochemical sensors to measure concentration. NO and NO_2 are each measured independently without the use of an NO_2 to NO converter. The standard emissions measurement equipment at engine manufacturer's test cells are based on chemi-luminescent analyzers which measure only NO; the NO_2 in exhaust gases is converted to NO in the converter and is read as NO. The sample rate in the Enerac 3000 is approximately 800 cc/min. A filter housing at the probe tip filters out particulate matter. The Enerac 3000 is an approved analyzer under EPA Conditional Test Method CTM - 022. OAE follows the same calibration and span check procedures as specified in the CTM.

HC Analyzer: HC measurements are taken via bag samples. The sampling procedure is in accordance with EPA Method 18. The exhaust sample is drawn via an evacuated canister through a stainless steel/teflon probe into a Tedlar bag.

The samples are stored out of sunlight, packaged, and sent to an analytical laboratory for analysis of C_1 to C_6 + species by gas chromatograph. Lab analysis is done according to EPA Method 25C

PM Analyzer: Total particulate matter sampling is done by the filter weighing method. A pre-weighed dry filter is inserted into the holder close to the exhaust stack to collect the particulate sample. Exhaust gases are sent to the filter through a vacuum pump connected to a gas flow meter. The sampled filter is then baked in the oven at 105 deg C to exclude the moisture from the analysis. USEPA approved factors are applied to the analyzed total particulate matter to derive PM10 fraction or PM2.5 fractions.

Horsepower: Roll power (power at wheel) is measured through the chassis dynamometer. The maximum roll power is then compared with the engine rated horsepower to derive losses between the engine output and power at wheels.

Engine RPM: Chassis dynamometer speed sensor is used for the RPM measurement.

Ambient Temperature, Pressure, and Humidity: A hand-held digital meter is used for this purpose.

Instrument Calibration

Emissions Analyzer: Enerac 3000 is calibrated prior to the in-field test assignment using the procedures outlined in the CTM-22. For diesel engine testing, the NOx sensor is calibrated at 1,011 ppmv and 200 ppmv using calibration gas. Mid range PCM sensor is utilized for NO (1000-3500 ppm). NO_2 sensor can read up to 500 ppmv. NO_2 calibration is done at 200 ppmv calibration gas. SO_2 sensor is set at low-range (500 ppm-2000 ppm). CO sensor is set at low range (500 ppm-2000 ppm). CO sensor is calibrated at 500 ppm. SO_2 sensor is calibrated at 200 ppm. The analyzer is auto zeroed prior to each test. After the completion of in-field testing, the analyzer is checked for drift by introducing the calibration gases and comparing the Enerac readings. The sensors are calibrated in accordance with the procedures specified in the CTM.

Smoke Meter: Opacity meter is calibrated at 100%, 0%, and mid range opacity.

Dynamometer: Dynamometer is calibrated by the dealership in accordance with their calibration schedule.

Test Procedures (Emissions Test)

Baseline Test

- Calibrate the emissions test instruments
- Secure the vehicle to a chassis dynamometer, hook up fuel flow meter (supply and return), engine RPM sensor.
- Hook up emissions test instruments
- Allow the vehicle to warm up as determined by the engine coolant temperature and oil temperature
- For Mode 1 of the test, run the engine at wide open throttle, keep the vehicle speed to around 50 mph in lower gear, set the RPM to rated engine RPM, determine the maximum stable roll power. Record the emission, fuel consumption, RPM, roll power, and vehicle speed
- For Mode 2, keep all of the parameters same as above, except the roll power is now reduced to 75%
- For Mode 3, the roll power is reduced to 50%
- For Mode 4, the roll power is reduced to 25%
- For Mode 5, the roll is locked, readings are taken at idle
- Record snap idle opacity

Controlled Test

- Same procedures as above except the test is now done with the control or retrofit technology installed.

Test Results Calculations

The exhaust gas flow rate is calculated based on EPA Method 19 calculation which defines the procedure for calculating stoichiometric exhaust gas flow rate (0% oxygen in the exhaust) based on fuel flow rate. The stoichiometric flow rate calculated from Method 19 is then increased based on oxygen concentration measured in the exhaust (excess air) to provide actual SCFH of exhaust flow rate. The pollutant concentration is then multiplied by this calculated exhaust gas flow rate to come up with mass flow rate (lbs/hr) of pollutants in the exhaust. This calculation is repeated for each mode. A mode weighted horsepower is then calculated. The sum of total mass flow rate of pollutants for the five modes is then divided by the weighted horsepower to derive total weighted gms/bhp-hr. Similarly lbs of pollutants/1,000 gallons of fuel burned is calculated by dividing total pollutant mass by the weighted average fuel flow.

The NOx results are adjusted for humidity according to the following equation: Humidity correction factor = 1/(1-0.0182(H-10.71))

Where H = Absolute humidity of engine intake air in grams of water per kg of dry air.

Single Point / Max Power Fuel Economy Test Procedures

The max power fuel economy test is done at 400-500 rpm below the engines maximum rpm, at maximum achievable engine power. This is to simulate engine operation at or near peak torque condition. The five mode test provides mode weighted fuel economy that is indicative of actual road conditions. The maximum torque fuel economy is listed as single point fuel economy on the output table.

Appendix B Baseline Data

ENGINE EXHAUST EMISSIONS TEST

On-Road Five Mode Test Cycle

Purpose of Test: Evaluate Fitch Fuel Catalyst
Test Date: 11/1/2004 Test Number: 1 Engine Tech: Bob
Fuel Type: D2 Test Cycle: On Road Five Mode Emissions Tech: MT
Engine Type: DT466 Project Leader: MT
Aspiration: Turbo Owner City of Sacramento Test Location Holt, Sacramento, CA
Engine Rating: H.P. 195 @ RPM 2,600
Comments:
File Name dt466fitch.xls

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
A. ENGINE PERFORMANCE DATA					
Roll Power	111	84	61	36	0
Engine Power (bhp)	161	134	111	86	8
Engine power (kw)	120	100	83	64	6
Fuel Flow (kg/hr)	42.38	39.19	28.36	23.58	1.91
Intake Air (dry kg/hr)	1099	1072	830	732	141
Exhaust flow (dry kg/hr)	1141	1111	858	756	143
Engine RPM	2599	2633	2667	2701	531
Engine RPM % of Rated	1.00	1.01	1.03	1.04	0.20
Engine Load % of Rated	0.83	0.69	0.57	0.44	0.04
Fuel Flow (gal/hr)	13.30	12.30	8.90	7.40	0.60
B. GASEOUS EMISSIONS					
THC	6.6	6.3	18	23	15
NOx (dry ppmv)	365	325	280	230	218
CO (dry ppmv)	692	704	573	545	401
O2 (%)	10.9	11.4	12	12.5	17.3
PM10 mg/filter	0.2	1.1	1.6	1.9	0.1
C. EXHAUST EMISSIONS ANALYSIS					
Mode Weighting Factors	0.15	0.25	0.25	0.2	0.15
Weighted Specific THC (gms/kw-hr)	0.01	0.01	0.03	0.02	0.00
Weighted Specific NOx (gms/kw-hr)	1.33	1.92	1.27	0.74	0.10
Weighted Specific PM10, mg/filter	0.030	0.275	0.400	0.380	0.015
Weighted Specific CO (gms/kw-hr)	1.53	2.53	1.59	1.06	0.11

D. RESULTS

Total Mode Weighted NOx	**5.35 gms/kw-hr**	**3.99 gms/bhp-hr**
Total Mode Weighted THC	**0.08 gms/kw-hr**	**0.06 gms/bhp-hr**
Total Mode Weighted PM10	**1.10 mg/filter for**	**five minute sample @10lit/min**
Total Mode Weighted CO	**6.82 gms/kw-hr**	**5.09 gms/bhp-hr**

Mode Weighted h.p. **103.8 h.p.**
Mode weighted fuel consumption **8.865 gal/hr**
Mode weighted bsfc **0.08540462 gal/hp-hr**

Single Point Fuel Economy Test

Roll Power 135
H.P. 195
Fuel 10.3 gal/hr
bsfc 0.053 gal/bhp-hr
Snap Opacity Test (average of last three readings from Bosch partial flow meter) 17.5

Appendix B - Retrofit Data

ENGINE EXHAUST EMISSIONS TEST

On-Road Five Mode Test Cycle

Retrofit Data - with Fitch

Purpose of Test:	Evaluate Fitch Fuel Catalyst				
Test Date: 11/12/2004	Test Number:	2		Engine Tech:	Bob
Fuel Type: D2	Test Cycle: On Road Five Mode			Emissions Tech:	MT
Engine Type:	DT466			Project Leader:	MT
Aspiration: Turbo	Owner	City of Sacramento		Test Location	Holt, Sacramento, CA
Engine Rating:	H.P.	195 @ RPM	2,600		
Comments:	Owner changed air filter prior to test				
File Name	dt466fitch.xls Fitch installed				

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
A. ENGINE PERFORMANCE DATA					
Roll Power	111	84	61	36	0
Engine Power (bhp)	161	134	111	86	8
Engine power (kw)	120	100	83	64	6
Fuel Flow (kg/hr)	38.87	33.78	29.63	24.22	0.64
Intake Air (dry kg/hr)	1008	924	857	743	50
Exhaust flow (dry kg/hr)	1047	957	887	767	50
Engine RPM	2590	2628	2661	2705	531
Engine RPM % of Rated	1.00	1.01	1.03	1.04	0.20
Engine Load % of Rated	0.83	0.69	0.57	0.44	0.04
Fuel Flow (gal/hr)	12.20	10.60	9.30	7.60	0.20
B. GASEOUS EMISSIONS					
THC	25	32	6.5	30	57
NOx (dry ppmv)	395	330	267	237	218
CO (dry ppmv)	26	32	22	27	16
O2 (%)	10.9	11.4	11.9	12.4	17.5
PM10 mg/filter	0.1	2.8	0.8	0.5	0.1
C. EXHAUST EMISSIONS ANALYSIS					
Mode Weighting Factors	0.15	0.25	0.25	0.2	0.15
Weighted Specific THC (gms/kw-hr)	0.03	0.05	0.01	0.03	0.00
Weighted Specific NOx (gms/kw-hr)	1.32	1.68	1.26	0.77	0.04
Weighted Specific PM10 mg/filter	0.015	0.700	0.200	0.100	0.015
Weighted Specific CO (gms/kw-hr)	0.05	0.10	0.06	0.05	0.00

D. RESULTS

Total Mode Weighted NOx	**5.05 gms/kw-hr**	**3.77 gms/bhp-hr**
Total Mode Weighted THC	**0.13 gms/kw-hr**	**0.10 gms/bhp-hr**
Total Mode Weighted PM10	**1.03 mg/filter for five minute sample @10lit/min**	
Total Mode Weighted CO	**0.27 gms/kw-hr**	**0.20 gms/bhp-hr**

Mode Weighted h.p.	**103.8 h.p.**
Mode weighted fuel consumption	**8.355 gal/hr**
Mode weighted bsfc	**0.080491329 gal/bhp-hr**

Single Point Fuel Economy Test

Roll Power	135
H.P.	195
Fuel	10.1 gal/hr
bsfc	0.052 gal/bhp-hr
Snap Opacity Test	13.5 (average of last three readings from Bosch partial flow meter)

Discussion of Results

NOx+THC Reduction	4.51%
PM10 Reduction	6.36%
CO Reduction	96.04%
Five Mode Fuel Consumption Reduction	5.75%
Single Point Fuel Consumption Reduction	1.94%
Opacity Reduction	22.86%