Dynamometer Test of Caterpillar 3412 Mechanical Engine

Rebuilt Caterpillar 3412-12-cylinder (~800 horsepower) mechanical diesel engine. Fitch Fuel Catalyst model F150HDG shown installed on engine frame in photo (to right of blue-colored dynamometer absorber). This model engine uses an in-line pump for fuel supply and nearly 100% of all fuel supplied to engine is consumed. This is in contrast to many other mechanical engines and all electronic engines in that there is virtually no unburned fuel returned to the supply tank. In order to attain full treatment of the fuel with the Fitch Fuel Catalyst, fuel was pre-circulated in one of the 55-gallon drums through the device for several hours prior to the engine test using a small transfer pump.

Test Facilities
Hawthorne Power Systems (Division of Hawthorne CAT) Dynamometer Facility, San Diego, CA

Test Equipment
A digital scale was used for measuring weight to nearest tenth of a pound and timer for measuring elapsed time to nearest second. e-Instruments™ Gas Analyzer was used for measurements of exhaust gases (O_2, CO and CO_2) and EGT temperatures inside the exhaust stack. A Super Flow 3100 water-brake engine dynamometer and WinDyn data monitoring and recording system provided engine performance parameters.

Purpose
Measure fuel consumption, engine stack temperatures, exhaust emissions, horsepower and torque with and without a Fitch Fuel Catalyst (FFC) in-line unit retrofitted to a diesel engine under comparable loads.

Description of Test Procedure
Fuel consumption was measured by change in weight of the fuel container for Baseline and Retrofit cycles. Fuel was supplied from 55-gallon drums filled with 6-month aged marine grade diesel fuel. The line to the suction side of the fuel pump and return line from the fuel rail were placed in 55-gallon drum placed on a weigh scale.

The Baseline test was conducted from one drum without Fitch treatment. The Retrofit test was conducted using fuel from the second 55-gallon drum that had been pre-circulated through the FFC

Test Protocol

The plan called for continuous ramp from zero to maximum load, transition mode testing and maximum load testing at 100%.

Baseline Test

The engine was started and brought up to operating temperature. Recordings of time and fuel weight were taken at approximately 5 pound intervals.


Retrofit Test

The drum of untreated fuel was removed from the scale platform and replaced with the drum of fuel that had been pre-circulated through the FFC for about 3 hours. The FFC was then connected into the engines fuel system. The engine was re-started and brought up to operating temperature before measurements commenced.

Fuel Measurements

Fuel measurement results are presented in graphical and tabular form below.

The dyno operator observed that the engine operated at a higher RPM with the FFC treated fuel and responded more easily to load changes than with the untreated fuel. This is borne out by the horsepower and torque data captured verses elapsed time shown below. The continuous ramp runs (baseline and retrofit) show substantial reduction in fuel consumption along with increased horsepower and torque.

Fuel consumption results are presented in relation to the horsepower and torque produced by the engine under various loads, the fuel weight consumption data was cross-referenced to the engine dyno data provided in the WinDyn data files. The Super Flow dyno monitors and displays continuous readings of all measured parameters; however, the WinDyn system samples and stores a digital record every 30 seconds of elapsed time.

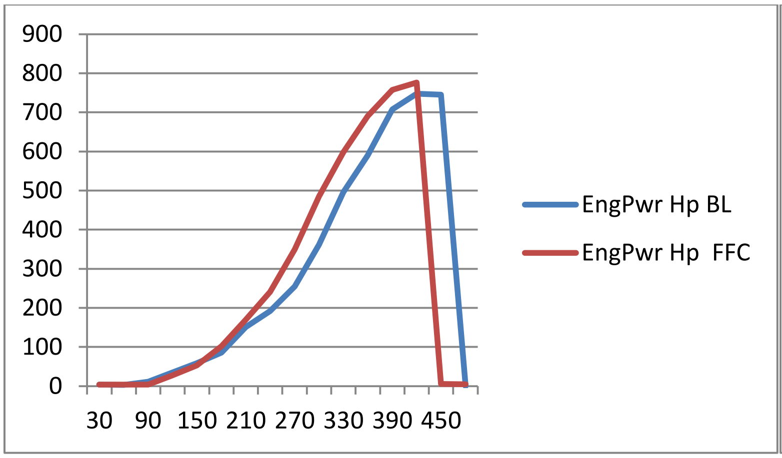
Maximum Load Test

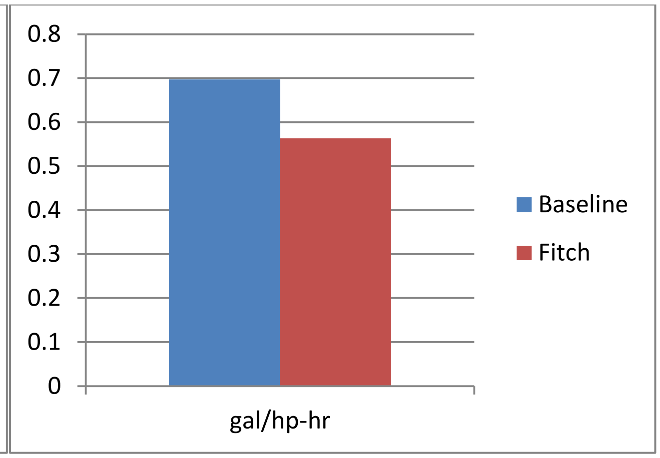
The 100% load run with the FFC fuel showed a 2.49gph reduction in average gross fuel consumption. Relative to horsepower, a 0.77% reduction in gal/hp-hr was calculated with a corresponding 2% increase in hp. Relative to torque, a 2.48% reduction in gal/ftlb-hr was calculated with a corresponding 3.9% increase in torque. Below are two screen shots of the WynDyn display at the highest values seen (778hp and 2,013.3ftlbs) during this 100% run verses baseline maximums

(753.5hp and 1,870.4ft-lbs). This represents an improvement of 3.25% in horsepower and 7.64% in torque as a result of pre-treating the fuel with the Fitch Fuel Catalyst.

Continuous Ramp Protocols

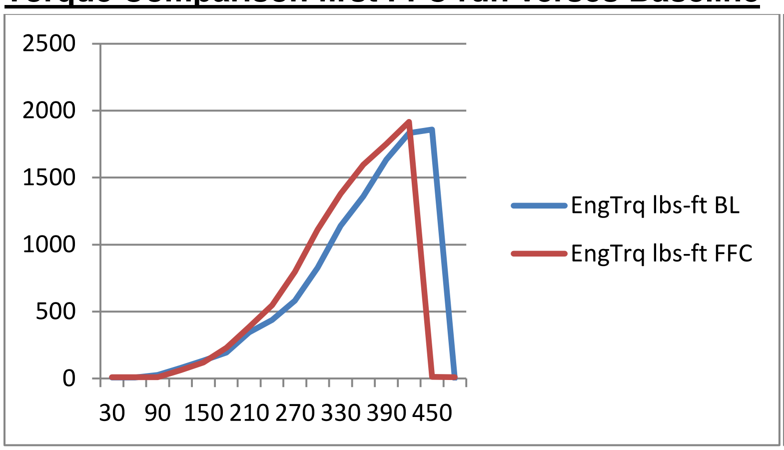
Horsepower Comparison first FFC run verses Baseline





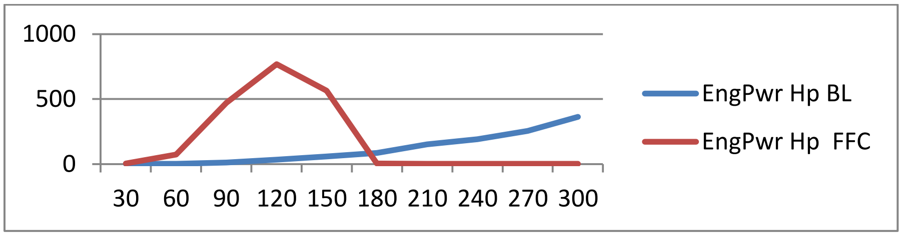
There was a reduction in fuel consumed of 0.1338gal/hp-hr which equates to 19.21%.

Torque Comparison first FFC run verses Baseline

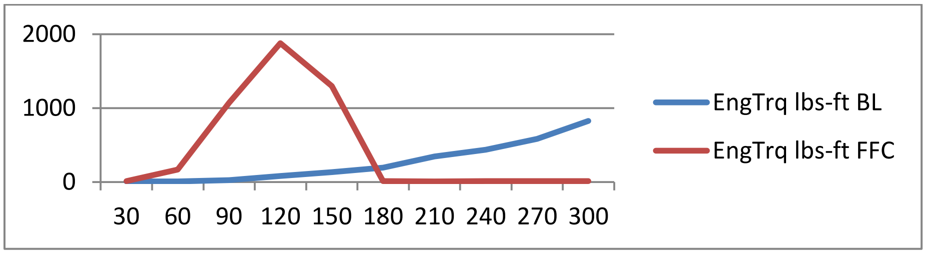


There was a reduction in fuel consumed of 0.054gal/ftlb-hr which equates to 18.25%.

Horsepower Comparison second FFC run verses Baseline



Torque Comparison second FFC run verses Baseline



Exhaust Gas Temperature and Emissions Analysis

Temperatures inside the stack were recorded at most data points with a probe. Percent oxygen (O_2) and carbon dioxide (CO_2) in the exhaust stack were measured as well as concentrations of carbon monoxide (CO) in parts per million (ppm). CO_2 and CO were reduced with FFC in later runs (50, 75, 100 and 100(2)). Average flue temps were consistently higher with FFC than without although the difference decreased the longer the engine ran. The higher flue temps indicate excess BTU's, related to better fuel combustion with FFC treated fuel are being vented out the stack.

Load Bank Test on Caterpillar 3406 powered 300Kw generator

The final phase of the evaluation program of the FFC also occurred at Hawthorne Power Systems dyno facility in San Diego. In this case, fuel consumption of a generator powered by a 400hp Caterpillar 3406 engine was measured with a laboratory quality fuel flow meter manufactured by AIC Systems in Switzerland.

The AIC fuel meters use a piston displacement method to measure the suction of the fuel drawn from the tank to replenish fuel consumed by the engine. The return fuel is diverted back to the engine intact after passing through a heat exchanger to dissipate heat in the closed loop fuel supply. The accuracy and repeatability of the measurements obtained during tests with the AIC meter was better than 99%. Although the differences in fuel consumption observed at each of the five load points measured in the baseline and retrofit tests were small, they could be relied upon because of the extreme accuracy of the meter. Twenty readings were taken for each load point (0, 25, 50, 75 and 100%) and within each set there was never more than one-tenth of a gallon per hour (gph) variance in the readings.

In addition to the power data provided by a programmable resistive/reactive load bank, exhaust temperature (EGT) and other exhaust data were obtained with the e-Instruments Gas Analyzer used previously.

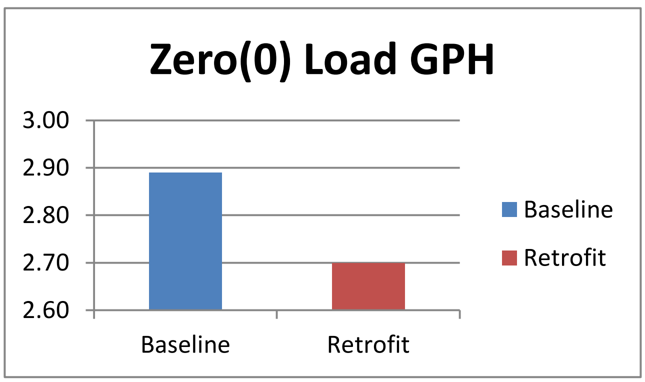
Caterpillar 3406 engine **End view of engine with AIC meter and FFC**

Some of the key elements of the load bank test are shown on this page. The load bank itself was a permanent unit located on top of the roof of the test bays. The operator pre-programmed the agreed upon test protocol into the computer control module. The test sequence was 20 minutes at each load point (0, 75, 150, 225 and 300 kilowatts) representing 0, 25, 50, 75 and 100 percent of maximum power.

The 200-gallon capacity day tank shown below was filled with ULSD#2 drawn from the facility's 4,000 gallon underground storage tank. Prior to starting the retrofit tests with the FFC, the remaining fuel in the day tank was circulated through a second F150HDG unit (on corner of cart in front of tank) using a small transfer pump.

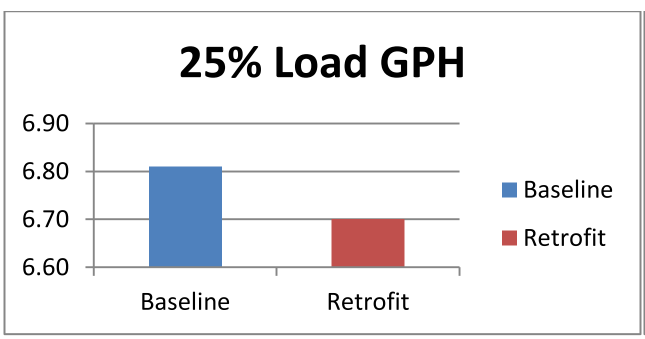
200 gallon day-tank used to supply ULSD#2 for test. **Close-up of AIC-6008 fuel flow meter**

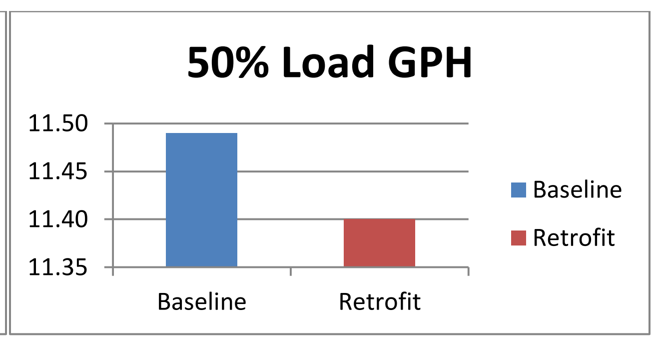
Fuel Measurement Results

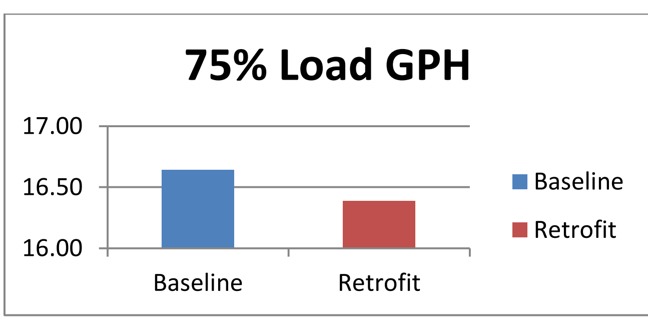


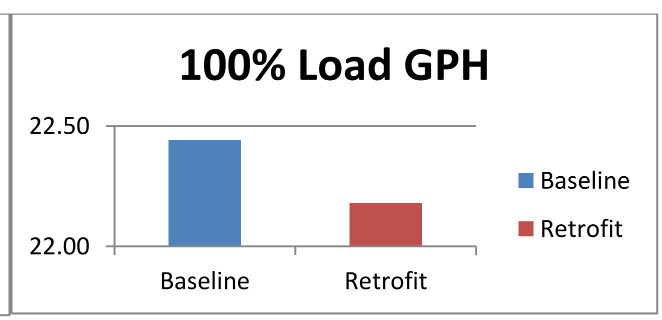
The engine was started and brought up to normal operating temperature prior to commencing the test for baseline and retrofit data collection. Upon starting of the pre-programmed script which controlled the load applied to the gen-set, data collection began.

A fuel consumption reading was taken each minute for each 20-minute segment. EGT and emission readings were taken with the portable Gas Analyzer every third reading.









The above charts illustrate a comparison of the average of the 20 readings taken at each load point. There was never more than one-tenth (0.10) gph range in any set of data. At least 18 of the 20 readings were exactly the same demonstrating the accuracy of the fuel meters used.

In all cases, the fuel consumption with the FFC was measurably less under identical load and operating conditions. On average, the improvement was ¼ gph. Another positive measurement was that the engine ran slightly cooler with the FFC as shown in the comparison of EGT temperature in the following table. It also appears the benefits of reduced fuel consumption, lower EGT and lower emission increased over time. The longer the engine ran with the FFC the greater the improvement observed.

Load %	**Zero**	**25**	**50**	**75**	**100.0**
FFC- °F	416.4	659.0	796.3	885.3	973.6
BL- °F	416.1	660.2	804.3	895.6	986.0
Diff- °F	0.3	-1.2	-8.0	-10.3	-12.4

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