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PETROLEUM TECHNOLOGY ALLIANCE CANADA

PTAC

PT BRANDS: FIELD QUALIFICATION TESTS FOR MG22D DIESEL ADDITIVE

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ACCURATA INC.
DIVERSE CONSULTING SERVICES

PT Brands MG22D Diesel Additive

Field Trials Using Three Diesel Generators on an Onshore Drilling Rig

Executive Summary

Field tests were performed on three engines driving generators on a drilling rig during December 2009 and January 2010. Valid data points were extracted for the periods of December 17 to 22 2009 and January 1 to 6 of 2010. Selected data from Caterpillar's engine control modules (ECM) were collected via an external data logging system every ten seconds. This allowed comparison of data from two engines in a common group during different time periods. The various engines are compared at the same time to consider identical ambient operating conditions. The same engine is compared over different times to consider similar engine condition data.

Fuel consumption reduction in the range of 1.7% to 2.5% is most often observed when the sample size is larger and the percent load deviation between the test and base engine is zero. Increasing the deviation of percent load up to 3% showed some data points with higher fuel consumption reduction (up to 11%) but a consistent trend is not evident. Many data points continued to show a 1.5% to 2.5% fuel consumption reduction even when the sample size was substantially increased by allowing the percent load deviation to increase up to 3%. G1 also showed a larger improvement than G3 when compared with G2 using the additive. In the case where G2 is compared G3 using the additive, the fuel consumption reduction is least. The variability is obviously very high when observing the data distribution. It is difficult to draw any conclusions with the current data set.

Data quality issues, mostly imparted the ECM, suggest that the tests could be repeated with much better results and higher accuracy. Caterpillar specifies accuracy of their power estimates at +/- 3% and fuel flow estimates at +/-5%. Clearly the reported fuel consumption reduction is less than the reported accuracy so the validity of the observations must be questioned. It is recommended that a follow-up field demonstration be performed with high accuracy direct measurement devices (i.e. flow meters, power measurement, etc.). This should increase the data accuracy and provide a more conclusive evaluation.

Introduction

Accurata Inc was retained to review the engine fuel consumption field data gathered by Encana on one of their pads for drilling Haynesville shale gas wells. Accurata was not involved in the field testing program or the data collection. Three engines were employed to qualify the affect on fuel consumption of adding MG22D to the diesel fuel. These three engines are driving generators and they are all Caterpillar 3512C DITA SCAC model diesel engines. The engines are named Generator 1, 2 and 3.

The Caterpillar engine control module (ECM) was employed to assemble an electronic data log. This module calculates fuel consumption and load. We could not determine how these parameters are estimated because Caterpillar would not reveal that information. Fuel consumption and engine load were not independently measured during the tests. Electronic log data of engine performance indicators such as cylinder head temperature were also not captured in the data logs. The log data consisted of a time stamp with fuel and load estimates as well as the drilling depth. The ECM polling frequency was at 10 second intervals which collected over 45,500 data points for each date range.

Engine conditions were not assessed before or after the tests. Plugged injectors on the engine for Generator 1 in December 2009 excluded these data points from the analysis. The tests were performed during December 2009 and January 2010. Valid data points were extracted for the periods of December 17 to 22 2009 and January 1 to 6 of 2010.

MG22D additive was applied at a 2000:1 concentration to the engines on two generators. During the January test period Generator 2 used fuel treated with MG22D. During the December test period Generator 3 used fuel treated with MG22D. The other two engines were then operated on untreated fuel. Engine "clean out" periods were employed using 500:1 ratios and these were ignored for the data comparison. The engines are not modified in any other way. In this respect the tests are a true-to-life representation of what a producer might expect to achieve by using the additive.

Data comparison is thus possible from two engines in a common group during different time periods. We can evaluate how the various engines performed at the same time to consider identical ambient operating conditions. We can also evaluate data from the same engine over different times to consider similar engine condition data.

Our objective was to determine if any changes in engine performance resulted from the use of the MG22D additive. The required scope for this report included review of the data to determine trends of reduced fuel consumption and any influence on greenhouse gas emissions. The requirement regarding impact on greenhouse gas emissions could not fulfilled since no emission measurements were recorded on site during the tests.

The ECM data was grouped in our analysis according to engines running at the same load, at the same time, with and with without the additive in the fuel. The ECM data was also was also grouped according the same engine running with and without additive in the fuel (at different times). In each case the data was further grouped into distinct load groups. The frequency distribution of the data in these groupings is examined. Caterpillar predicted fuel consumption from their engine data manuals is compared with the ECM estimated fuel consumption data both with and without the additive. This report summarizes our analysis of the data from the ECM recorded during the test periods.

Data Comparison for Different Engines Running With and Without Fuel Additive, at the Same Load and at the Same Time

In this analysis we compare the percent reduction in fuel consumption of an engine running with the fuel additive to an engine running without the fuel additive. Only two generators operated at any given time during the test periods. The advantage of this analysis is that environmental and operating conditions should be identical. Engine condition and ECM data accuracy will be the only influences that may cause issues with data quality.

Generator 3 running with the additive is compared with Generator 2 running without the additive between December 17 to 22 2009. Generator 2 running with the additive is compared with Generator 1 or 3 running without the additive between January 01 to 06 2010.

The data was grouped by the same date and the same percent load. The percent fuel reduction was listed associated with these parameters. A further sorting routine was designed to group the data according to the deviations of the percent load for the engines compared.

Presentation of this analysis is shown in Appendix A. Eight graphs are prepared with their associated data. The data pairs load and fuel consumption on each date for each standard engine versus the MG22 fuelled engine. Each graph as we go from the first to the last includes data with a wider deviation from the target power, that being the % power of generator using the additive. The first two graphs show a 0% load deviation, the next two graphs show a +/- 1% load deviation, then two graphs at +/- 2% load deviation and finally two graphs at +/- 3% load deviation. Each table is associated with the graph below it. The % load deviation is shown in the first line of each Load Range on the tables.

The best accuracy should be obtained in the first graph (0% deviation). However, it will also have the lowest population of data points to contribute to the average percent fuel consumption reduction. The data sample population increases as the differences between the loads of the engines increase. The analysis will produce erroneous results in that a zero value is plotted when the population of data points is zero.

Fuel consumption in the range of 1.7% to 2.5% is most often observed when the sample size is larger and the percent load deviation between the test and base engine is zero. The percent fuel consumption reduction value increases as the percent load deviation increases. G1 also showed a larger improvement than G3 when compared with G2 using the additive. In the case where G2 is compared G3 using the additive, the fuel consumption reduction is least. The variability is obviously very high when observing the data distribution. It is difficult to draw any conclusions under the circumstances. A discussion of the issues surrounding this data quality is presented later in the text. However, one aspect is consistent. The fuel consumption was apparently reduced in every case.

<u>Data Comparison for the Same Engines Running With and Without Fuel Additive, at the Same Load but at Different Times</u>

In this analysis we compare the fuel consumption of the same engine running with the fuel additive and without the fuel additive, but at different times. Since the engines' fuel supply was switched between fuel supplemented with the additive to that without the additive during the test period, it allowed this comparison. The advantage of this analysis is that engine condition should be similar. Changes in engine condition, ambient operating conditions and ECM estimate accuracy will be the only influences that may cause issues with data quality.

Generator 3 running with the additive during December 17 to 22 2009 is compared with Generator 3 running without the additive between January 01 to 06 2010. Generator 2 running with the additive during January 01 to 06 2010 is compared with Generator 2 running without the additive between December 17 to 22 2009. The data was grouped by percent load. The fuel consumption was listed associated with these parameters. The fuel consumption data is further compared with Caterpillar operator's manual data for fuel consumption. The average, median and mode values are presented for each load category.

Presentation of this analysis is shown in Appendix B. Two tables with associated graphs are shown, one for Generator 2 and the other for Generator 3. Caterpillar fuel consumption data is shown on each graph. Next, the sample distribution comparisons are shown on two tables. The sample size, average, median and mode is presented according to load groups for each of Generator 2 and Generator 3.

Review of the analysis shows no consistency of results. A trend of fuel savings is not consistently produced. Relationship to Caterpillar's predicated fuel consumption is shown in the middle of the power range, but that trend is also generally inconsistent. Errors can be entrenched because the power and average fuel consumption from the ECM data and the power used by Caterpillar to present their predicted values may not be the same. The percent power sample distribution parameters are fairly close in each load group. However, a percent power deviation in higher load groups is a much larger actual power deviation than at lower load groups. The consistency of this data is thus not as good as it appears.

Additional statistical and probability analysis could be employed in review of the data. The inconsistent nature of the results suggests that would not be productive. This analysis shows that data quality issues may be detracting from the relevance of the results. A discussion of data quality issues is presented next to help the reader appreciate the factors that can influence the test results.

Data Quality Discussion

The issues that affect the data quality for these tests may be grouped into two categories. The first is the mechanical and ambient operating conditions. The second is the data collection considerations.

The mechanical condition of the engines may not be the same. Furthermore, swapping the fuel supply with the additive between engines and running them at a "clean out" additive ratio most likely affected the combustion efficiency of the engine. That could change the performance of the engine over time, although in this case this cannot be confirmed. Laboratory tests on new engines showed that no change in the combustion process occurred with the addition of the MG22D. The residual effects of the additives were also found to be short-lived (<15 minutes) so the engine should readily return to its prior performance. These engines had between 4750 and 4950 hours shown on their hour meter at the beginning of the tests and finished the test with between 5175 and 5335 running hours. These run times place the engines at less one year of continuous operation. Less operating time should certainly be better for this aspect but it does not confirm the actual condition of the engine.

Ambient conditions also significantly affect the performance and efficiency of an engine. These aspects are clearly beyond the control of the testing agency. A lack of data on these aspects does not allow the opportunity to determine the contribution of these factors on the data quality. Still, the data for the engines operating at the same time and load offers the best opportunity to compare engines under the same ambient operating conditions. These data sets also contributed the most consistent results. We were advised that the time stamps of the data logs were confirmed to be accurate and consistent.

Data collection considerations offer many unknowns regarding the data quality. A concerted effort was made by both Encana and Accurata to determine how Caterpillar produced their estimates of load and fuel consumption in their ECM. Caterpillar would only provide their standard published uncertainty range for load and fuel consumption of +/-3% and +/- 5% respectively. Some common industry practices are employed to estimate the parameters but these are known to be very rough. Engine conditions and many variables affecting engine performance have a big influence on the accuracy of the results.

The dispersion of the data for the same engines with respect to Caterpillar's predicted fuel consumption demonstrates this disparity in data quality. As mentioned previously, the expression of percent load instead of power imparts nonlinear errors into the data set (even though it is normalized). The assumptions in the estimates provided by the ECM would most likely differ from the ambient conditions during the tests, the individual engine performance and the behaviour of the engine running with the additive.

Laboratory test results conducted by Colorado State University Engines and Energy Conversion Laboratory showed fuel consumption reduction with an overall average of 14%. This data shows a fuel consumption reduction of about 2%. However, the many variables that affect field testing cannot be entirely quantified to the accuracy of the analysis and therefore these test results are certainly questionable.

Conclusions

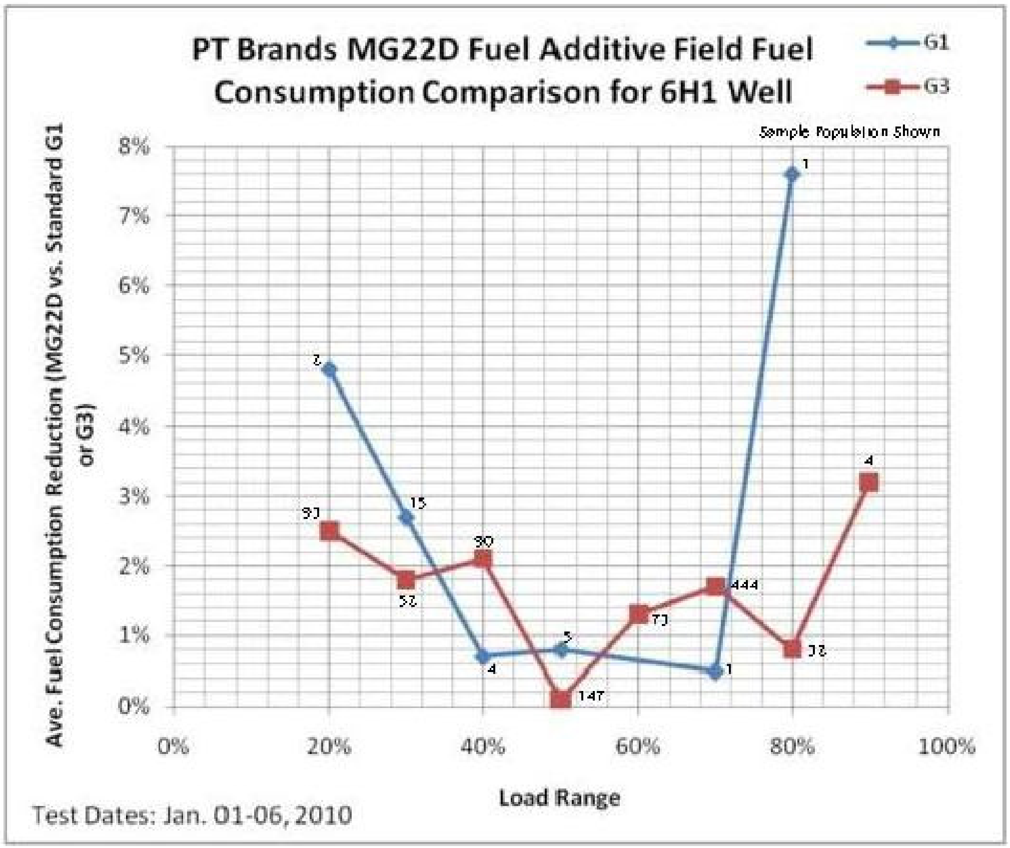
The results vary widely, probably because the engines are not in the same condition as each other at the same time or on the same engine at different times. The wide dispersion of data could also be because of a wide variety of other unquantified variables. The data exhibited reasonable consistency when the data population and the load are higher. Larger sample sizes tended to produce less average fuel savings. The typical fuel savings where the data is consistent is between 1.7% and 2.5%. This apparent fuel saving falls within the Caterpillar ECM predicted confidence limits so a trend cannot be confirmed by this analysis.

However, data quality issues mostly imparted by the ECM suggest that the tests could be repeated with much better results and higher accuracy. The load and power estimates produced by the ECM were not calibrated for the affects of the additive. The estimated data also did not exhibit close adherence to the Caterpillar predicted values. Clearly using the ECM data cannot produce reliable and repeatable results for fuel consumption data analysis. A field demonstration with direct measurement of key engine parameters is suggested to validate engine performance and hence improve the accuracy of the analysis.

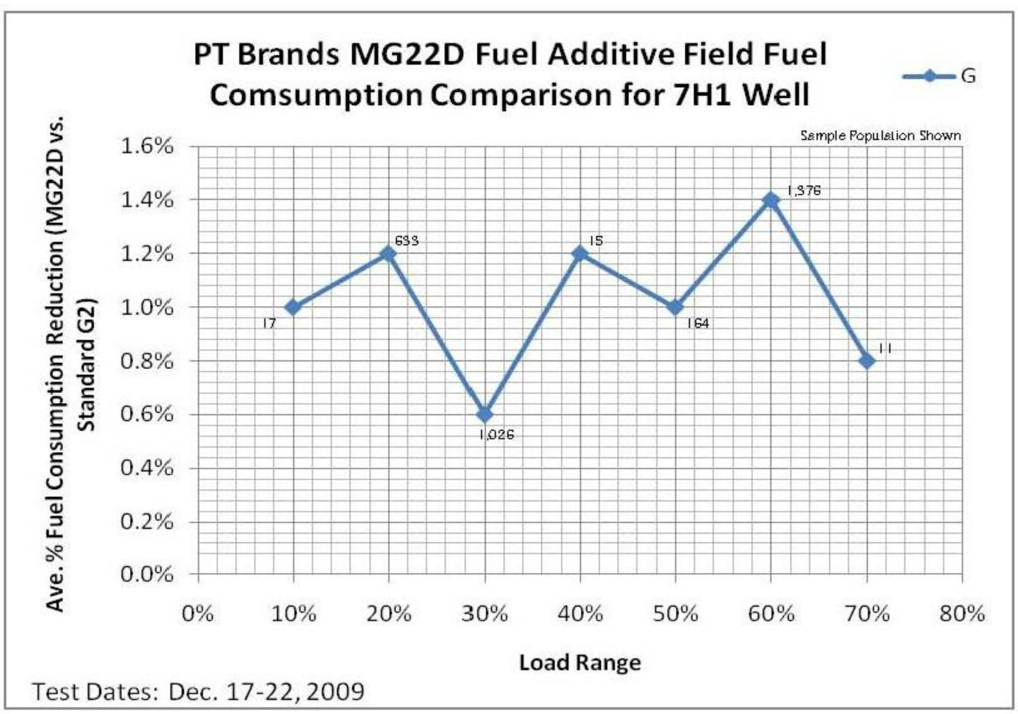
APPENDIX A

Comparison of Percent Fuel Gas Savings Between Generators With and Without the MG22D Additive at the Same Load and at the Same Time

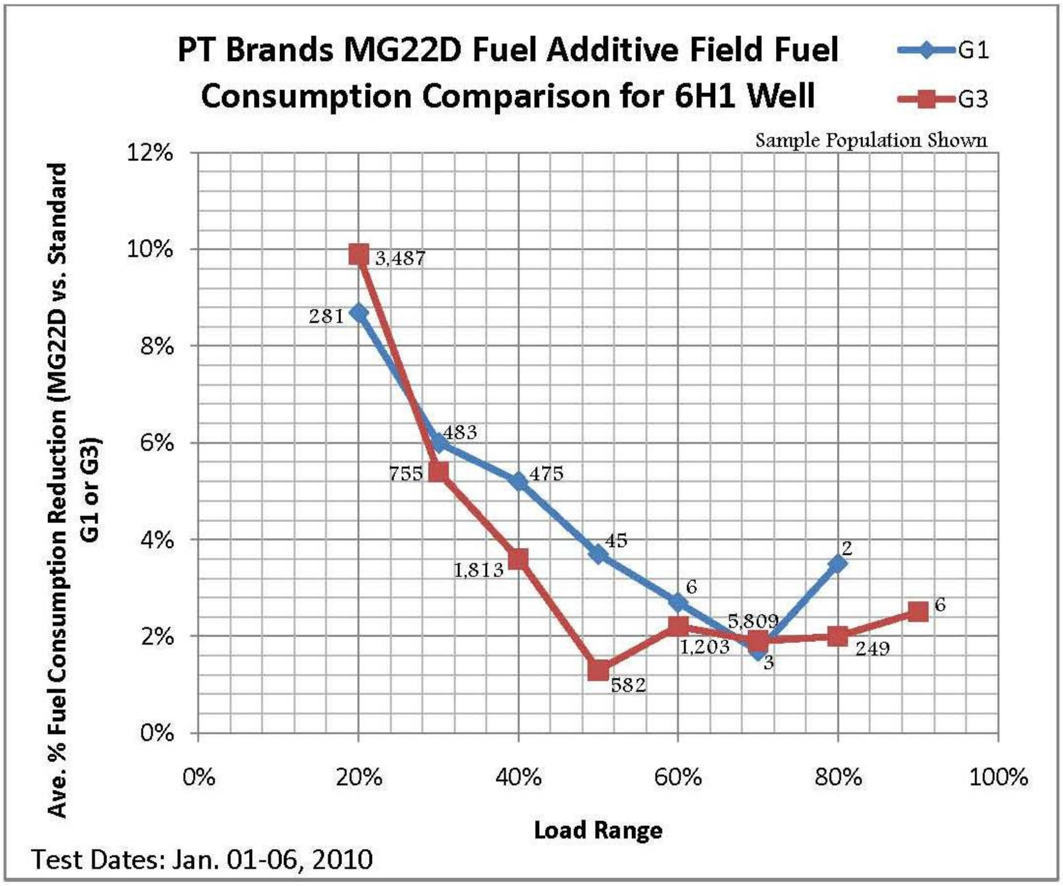
Difference of 0% between the target load for G2 with MG22D and Standard G1 or G3



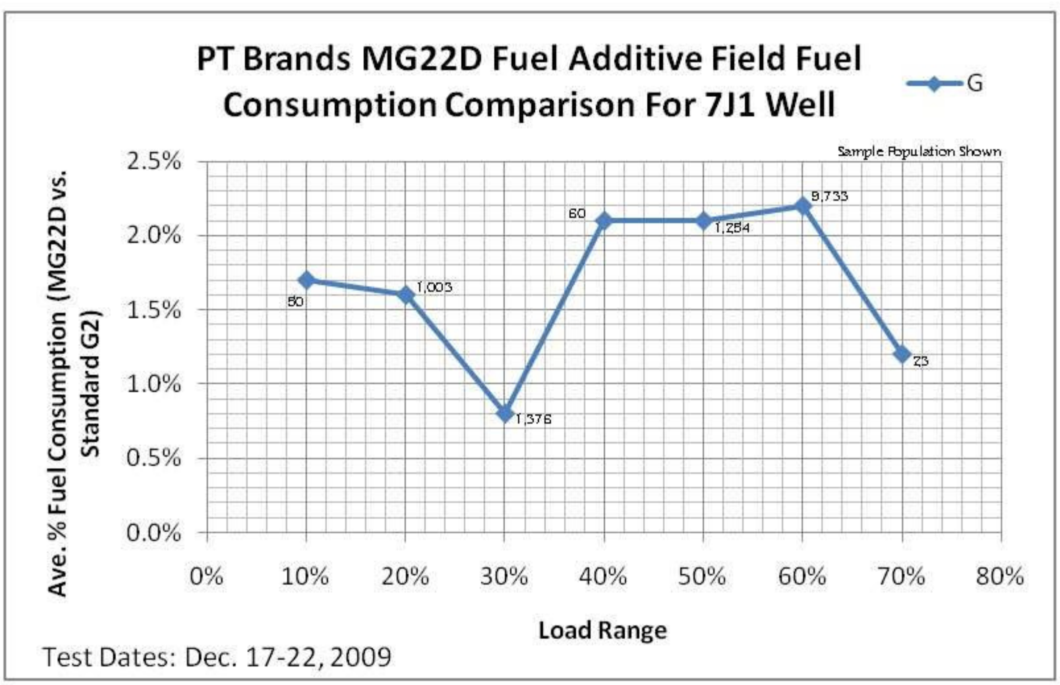
Difference of 0% between the target load for G3 with MG22D and Standard G2



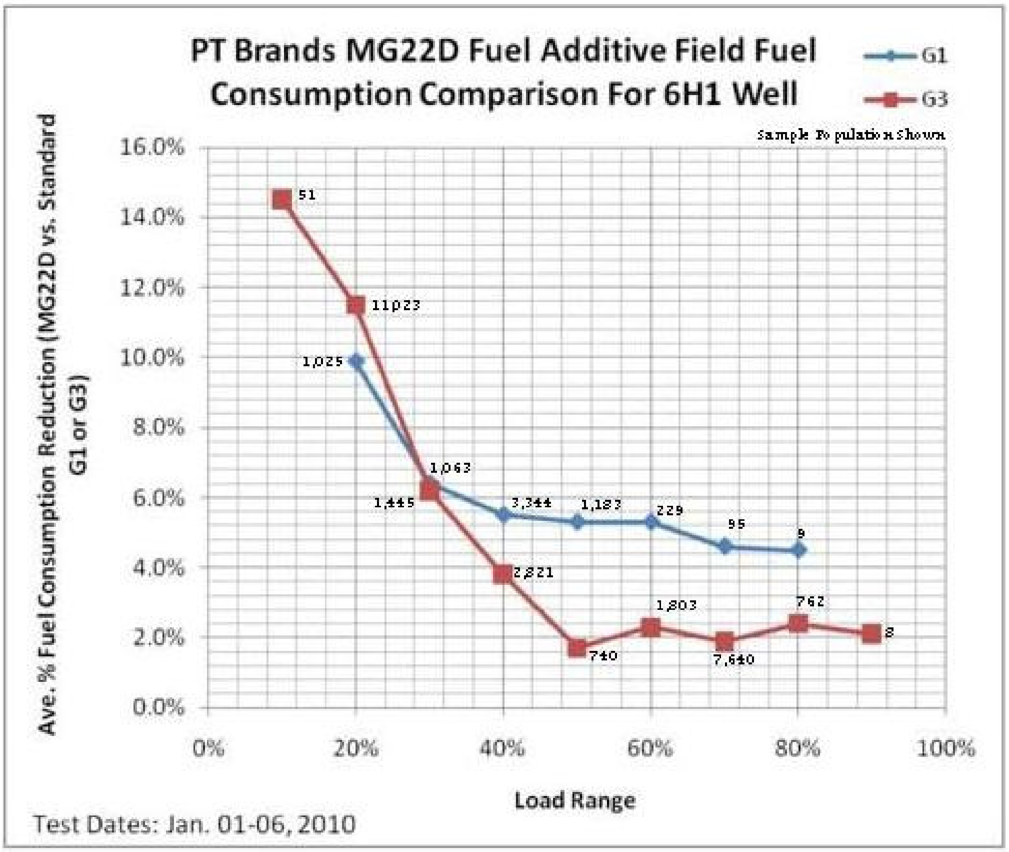
Difference of 1% between the target load for G2 with MG22D and Standard G1 or G3



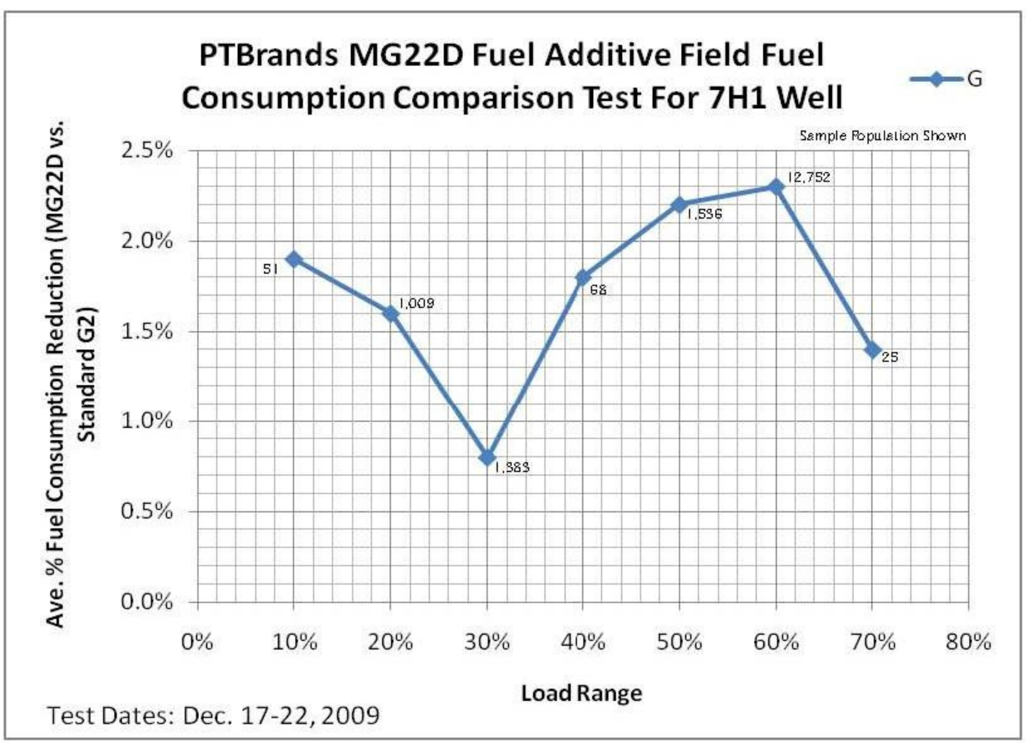
Difference of 1% between the target load for G3 with MG22D and Standard G2



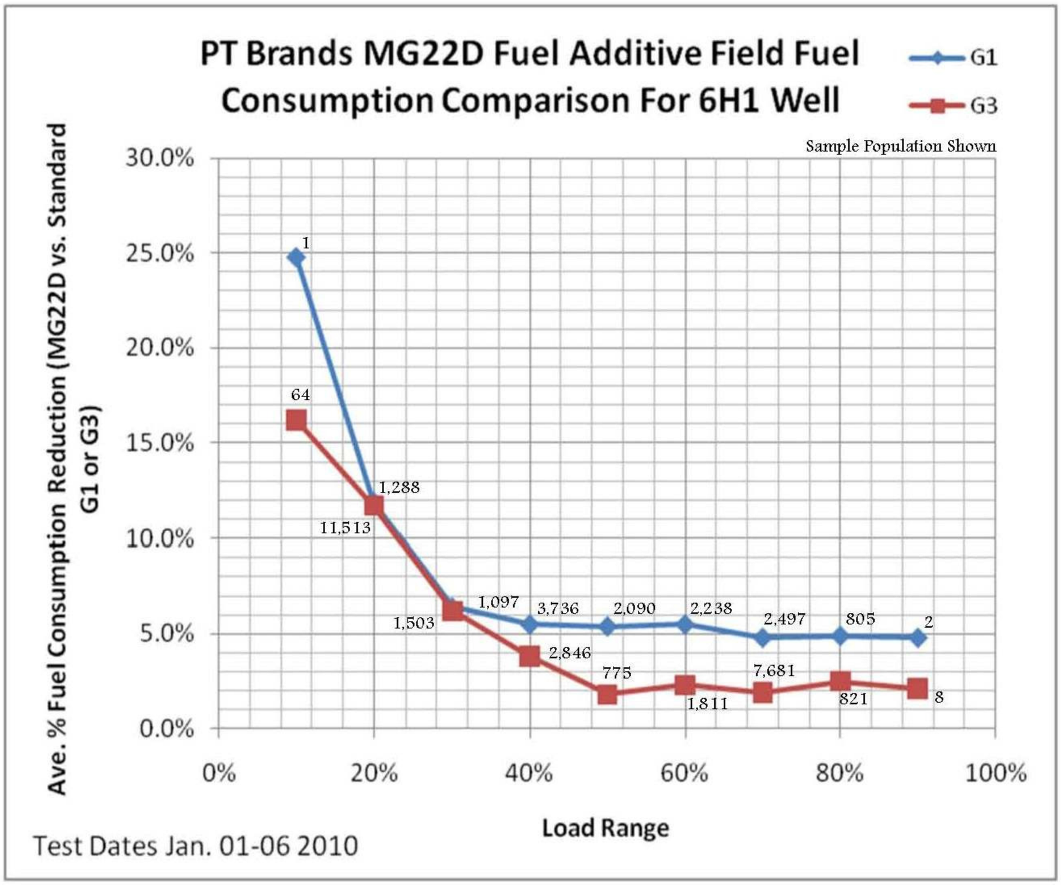
Difference of 2% between the target load for G2 with MG22D and Standard G1 or G3



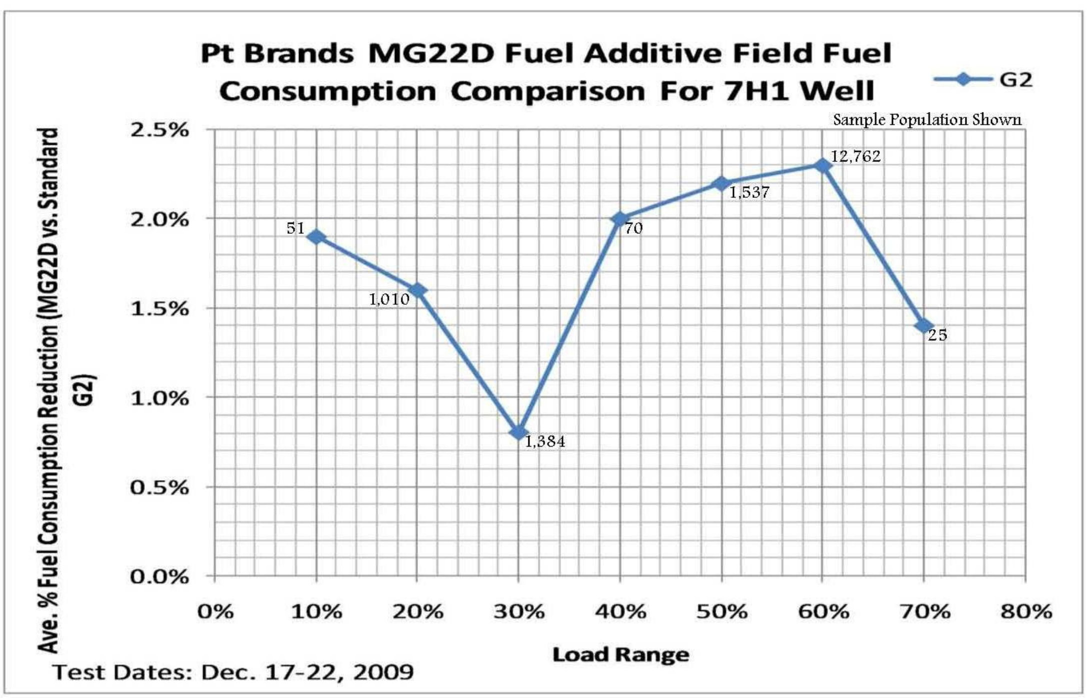
Difference of 2% between the target load for G3 with MG22D and Standard G2



Difference of 3% between the target load for G2 with MG22D and Standard G1 or G3



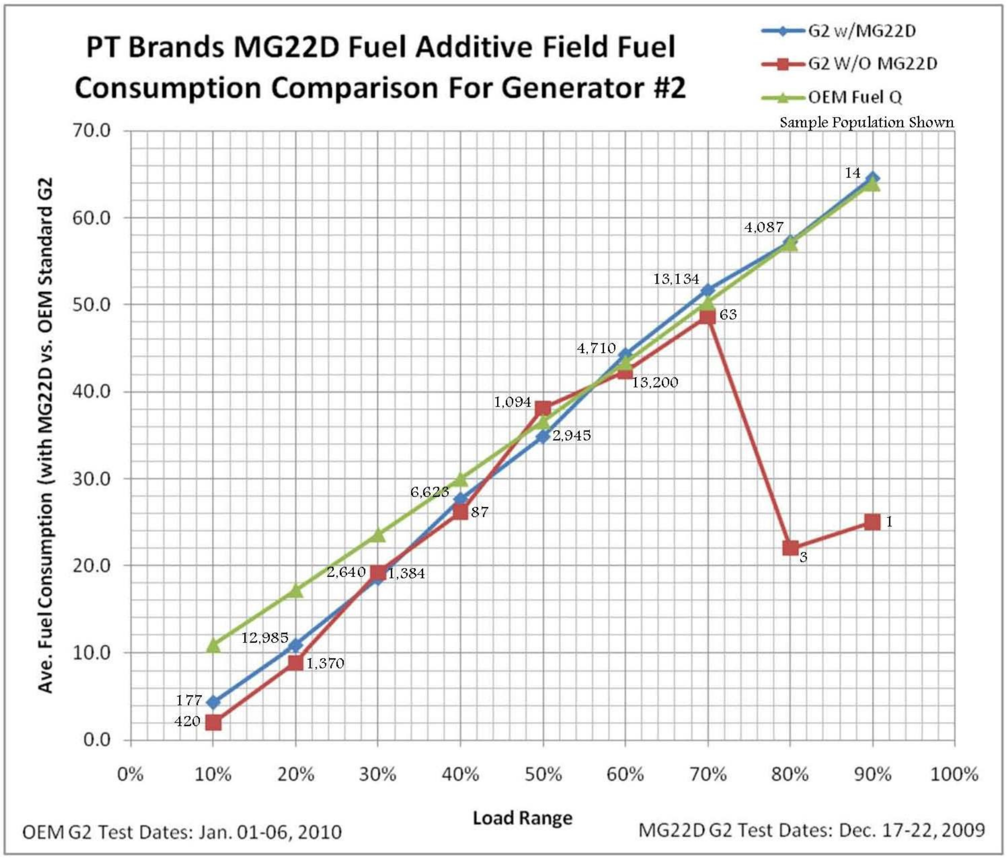
Difference of 3% between the target load for G3 with MG22D and Standard G2



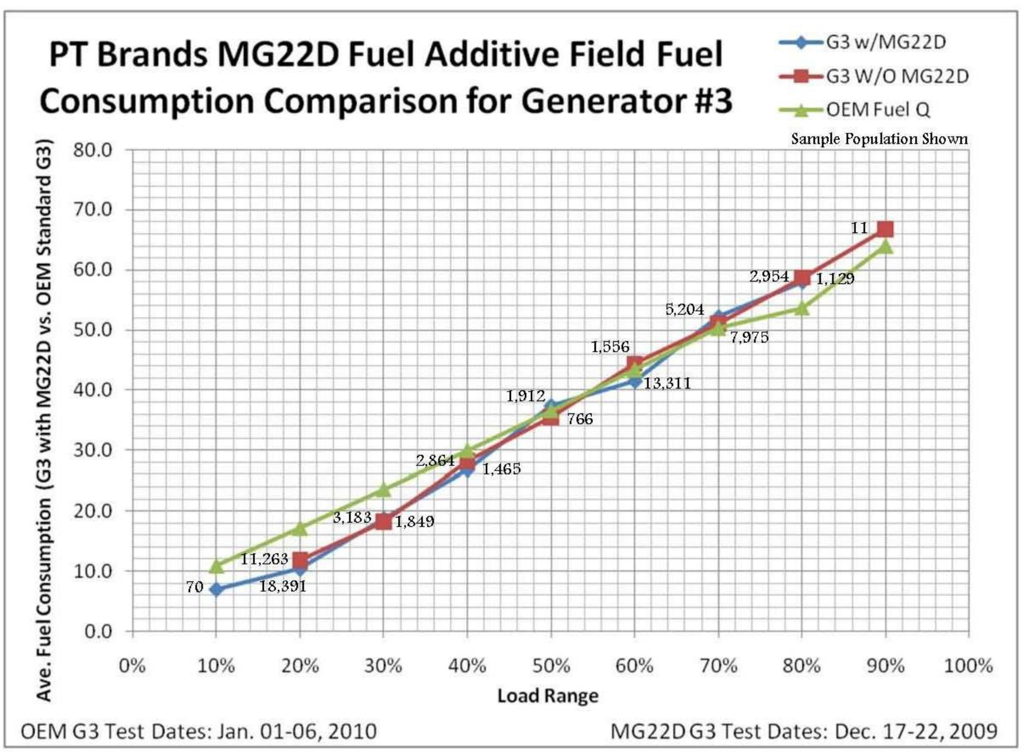
APPENDIX B

Comparison of Fuel Gas Consumption on the Same Engines With and Without the MG22D Additive at the Same Load but at Different Times

Difference of +/- 5% between the target load for G2 with MG22D and Standard Fuel G2



Difference of +/- 5% between the target load for G3 with MG22D and Standard Fuel G3



Sample Distribution Comparisons for Generator 2

PT Brands MG22D Fuel Additive Field Test Comparison For Generator #2					
Load Range	Statistic	G2 with Additive		G2 without Additive	
		%Load	Fuel Flow (GPH)	%Load	Fuel Flow (GPH)
10%	Sample	177	177	420	420
	Average	16.7	4.4	14.3	2.0
	Median	19	7	14	1.48
	Mode	19.0	1.4	14	1.23
20%	Sample	12,985	12,985	1,370	1,370
	Average	24.2	10.9	23.1	8.9
	Median	24	10.67	21	7.91
	Mode	24	10.53	20	3.45
30%	Sample	2,640	2,640	1,384	1,384
	Average	33.9	18.6	34.6	19.2
	Median	33	18.19	35	19.27
	Mode	30	15.43	35	19.22
40%	Sample	6,623	6,623	87	87
	Average	45.1	27.7	43.4	26.2
	Median	45	27.84	43	25.67
	Mode	45	27.52	40	26.68
50%	Sample	2,945	2,945	1,094	1,094
	Average	53.9	34.9	57.6	38.1
	Median	53	34.14	58	38.35
	Mode	51	32.67	59	39.19
60%	Sample	4,710	4,710	13,200	13,200
	Average	65.5	44.3	62.8	42.3
	Median	66	44.64	63	42.2
	Mode	66	44.48	63	42.23
70%	Sample	13,134	13,134	63	63
	Average	74.4	51.7	71.2	48.7
	Median	74	51.16	71	48.59
	Mode	73	50.13	70	48.93
80%	Sample	4,087	4,087	3	3
	Average	81.0	57.3	83.7	22.0
	Median	81	57.21	85	6.61
	Mode	80	56.59	N/A	N/A
90%	Sample	14	14	1	1
	Average	93.1	64.6	98.0	25.0
	Median	93	65.63	98	25.01
	Mode	93	N/A	N/A	N/A

Sample Distribution Comparisons for Generator 3

PT Brands MG22D Fuel Additive Field Test Comparison For Generator #3					
Load Range	**Statistic**	**G3 with Additive**		**G3 without Additive**	
		%Load	Fuel Flow (GPH)	%Load	Fuel Flow (GPH)
10%	Sample	70	70	0	0
	Average	19.0	7.0	N/A	N/A
	Median	19.0	7.0	N/A	N/A
	Mode	19.0	7.1	N/A	N/A
20%	Sample	18,391	18,391	11,263	11,263
	Average	23.6	10.4	25.5	11.8
	Median	24.0	10.4	26.0	11.9
	Mode	24.0	10.4	25.0	11.9
30%	Sample	3,183	3,183	1,849	1,849
	Average	34.1	18.8	33.4	18.2
	Median	34.0	19.0	33.0	17.9
	Mode	35.0	19.3	30.0	18.6
40%	Sample	1,465	1,465	2,864	2,864
	Average	44.0	26.8	45.7	28.2
	Median	43.0	26.3	46.0	28.7
	Mode	42.0	25.0	46.0	29.4
50%	Sample	1,912	1,912	776	776
	Average	56.9	37.4	54.6	35.5
	Median	58.0	37.9	55.0	35.5
	Mode	59.0	38.0	58.0	38.6
60%	Sample	13,311	13,311	1,556	1,556
	Average	62.0	41.5	65.7	44.4
	Median	62.0	41.2	67.0	45.4
	Mode	61.0	41.0	67.0	45.7
70%	Sample	5,204	5,204	7,975	7,975
	Average	74.7	52.2	73.7	51.0
	Median	75.0	52.1	74.0	50.9
	Mode	74.0	52.1	74.0	51.3
80%	Sample	2,954	2,954	1,129	1,129
	Average	81.7	58.0	82.6	58.7
	Median	82.0	58.0	83.0	58.8
	Mode	82.0	58.2	83.0	59.0
90%	Sample	0	0	11	11
	Average	N/A	N/A	93.6	66.8
	Median	N/A	N/A	94.0	67.2
	Mode	N/A	N/A	95.0	N/A