F E R O X

Date: 19 February 1990
Subject: Commercial Boiler Applications
Reference: Field Request

SALES BULLETIN	NO. 3

FEROX FACTS

Commercial Boiler Applications

Introduction

The combustion of heavy fuel oils and residual fuels in commercial steam boilers and power generation plants frequently results in serious corrosion, fouling, and emission problems. Most fuel problems can be traced to the presence of mineral impurities such as sodium, vanadium, nitrogen, and sulfur. Combustion products of sodium and vanadium are major contributors to energy robbing mineral deposits and slag. Vanadium containing deposits also promote the formation of sulfuric acid which is responsible for serious acid corrosion problems. Major combustion products of sulfur and nitrogen are regulated emissions which are harmful to the environment and are significant contributors to acid rain.

The FEROX Formula

Ferox products are iron based combustion managers which have been scientifically formulated and engineered to eliminate heavy fuel combustion problems. Ferox products contain catalysts which promote more complete fuel combustion. Ferox products also contain combustion surface modifiers which remove harmful deposits and prevent the formation of harmful emissions.

The FEROX Solution

Regular fuel treatment with Ferox 230, at the rate of one gallon to every 2,500-10,000 gallons of fuel, will resolve even the most difficult heavy fuel combustion problems. Ferox 230 treatment is more effective than the best MAG-OXIDE treatments currently available in reducing acid corrosion, and harmful emissions. Ferox 230 treatment will also prevent the formation of vanadium pentoxide deposits and will eliminate soot and slag.

The FEROX Effect

The combustion catalysts in Ferox 230 will promote a cleaner more rapid fuel burn which allows reduced oxygen levels in the flame envelope and lowers the excess air requirement. The combustion surface modifiers in Ferox 230 will prevent combustion particles from sticking to each other and from sticking to combustion equipment surfaces. Increased particle surface area results in more complete combustion, reduces particle mass and lowers carbon content in the ash. Active ingredients in Ferox also inactivate catalytic particle sites responsible for acid build up and other harmful emissions.

The FEROX Benefit

The regular use of FErox treated fuel will minimize or eliminate heavy fuel combustion problems. Ferox treatment will:

1) improve combustion efficiency by up to 5 percent and overall boiler efficiency by up to 10 percent. Ferox treatment will reduce fuel consumption and fuel expense.

2) Ferox treatment will reduce emissions. There will be less smoke, less carbon monoxide, less sulfur oxide, less nitrogen oxides, and reduced plume opacity. The of less expensive fuel may be possible while still meeting emission and efficiency requirements.

3) Ferox treatment will eliminate vanadium pentoxide formation in the firebox and will remove slag and soot deposits in the entire system. Stack gas temperatures will be up to 100 degrees F lower. Ferox treatment will reduce maintenance cost and simplify annual maintenance procedures.

4) Ferox treatment will prolong boiler life and improve or maintain high boiler efficiency during the entire operational life of the system.

The FEROX Promise

Ferox treated fuel will not harm fuel handling or combustion equipment and is as safe to store and handle as untreated fuel. NOne of the commonly measured fuel properties used in setting fuel specifications is effected by Ferox fuel treatments. If fuel meets specifications before Ferox treatment, it will still meet specifications after Ferox treatment.

Each boiler system presents its own unique set of problems which result from a combination of maintenance history, combustion history, mechanical configuration, fuel characteristics, and control settings. The surface modification aspects of Ferox products may require several months of continuous operation with Ferox treated fuel. Periodic monitoring of boiler operation parameters with appropriate adjustments to boiler controls may be required to achieve optimum results. When careful attention is paid to these requirements, operation will be cleaner and more efficient.

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TEST DATA BULLETIN 28 SEPTEMBER 1993

Statistical Analysis Summary

of

Ferox 230
Fuel Economy Test

conducted at

Savage Industries, American Fork, UT terminal

1 October 1989 through 30 April 1990

Analysis made by

Shanee Von Strahl
Statistical Analyst

6 July 1990

at

DATA WORKS

145 North Geneva Road Vineyard Utah 84058 Tel 801 226 8610 Fax 801 226 8496

CODE: 2.3.2.-1

TITLE: Savage Industries/AF

DATE: 1 October 1989 through 30 April 1990

TASK: To discover whether or not treating diesel fuel with ferox 230 will significantly improve fuel and maintenance economy of over-the-road tractor and trailer vehicles.

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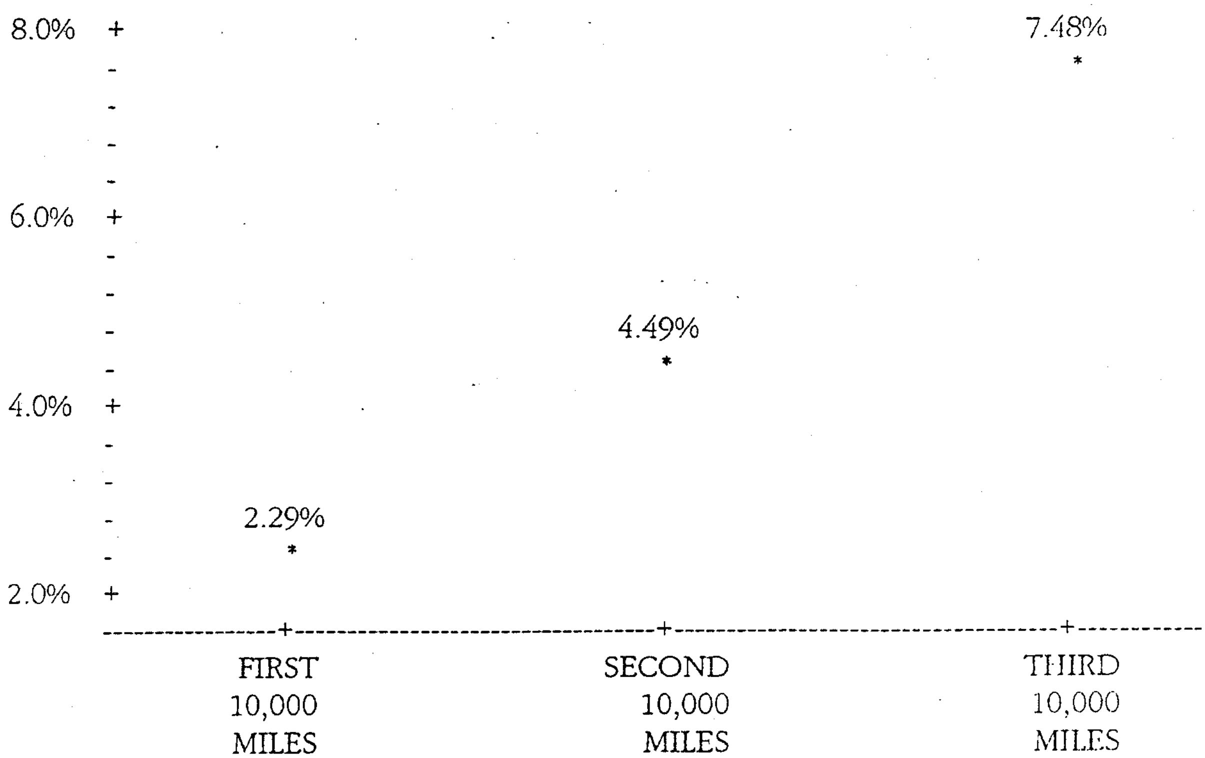
TEST DATA BULLETIN 28 SEPTEMBER 1993 (CONT)

STATISTICAL ANALYSIS SUMMARY

This summary describes and displays the most important data from an exhaustive statistical analysis of test data supplied, over a seven month period of time, 9 Oct. 89 through 30 Apr. 90, by Savage Industries, American Fork, Utah bulk hauling terminal. The test compared the fuel economy of matched truck and trailer vehicles. The test vehicles (S246, S251) burned diesel fuel treated with Ferox 230 and traveled a combined total of 241,079 miles; the control vehicles (S245, S248) burned untreated diesel fuel and traveled a combined total of 246,836 miles. The fuel was treated by the drivers of the vehicles. The data analyzed was collected by terminal personal and supplied to Data Works for analysis via Parish Chemical.

Over the first 10,000 miles driven, the average mpg of vehicles burning treated fuel was 2.29% better than that of vehicles burning untreated fuel; 4.49% better over the second 10,000 miles; and 7.48% better over the third 10,000 miles (see Figure 1).

Figure 1: The graph below shows the actual percentage of improvement (in mpg) that took place over the first 30,000 miles driven by the vehicles from the Savage Trucking terminal in American Fork.



Using actual results in a linear regression analysis, it can be predicted with 90% confidence that the improvements in mpg will be between -0.56% and 4.97% over the first 10,000 miles; between 2.35% and 7.16% over the second 10,000 miles; and between 4.53% and 10.16% over the third 10,000 miles. Figure 2 shows the actual predicted values based on the test results.

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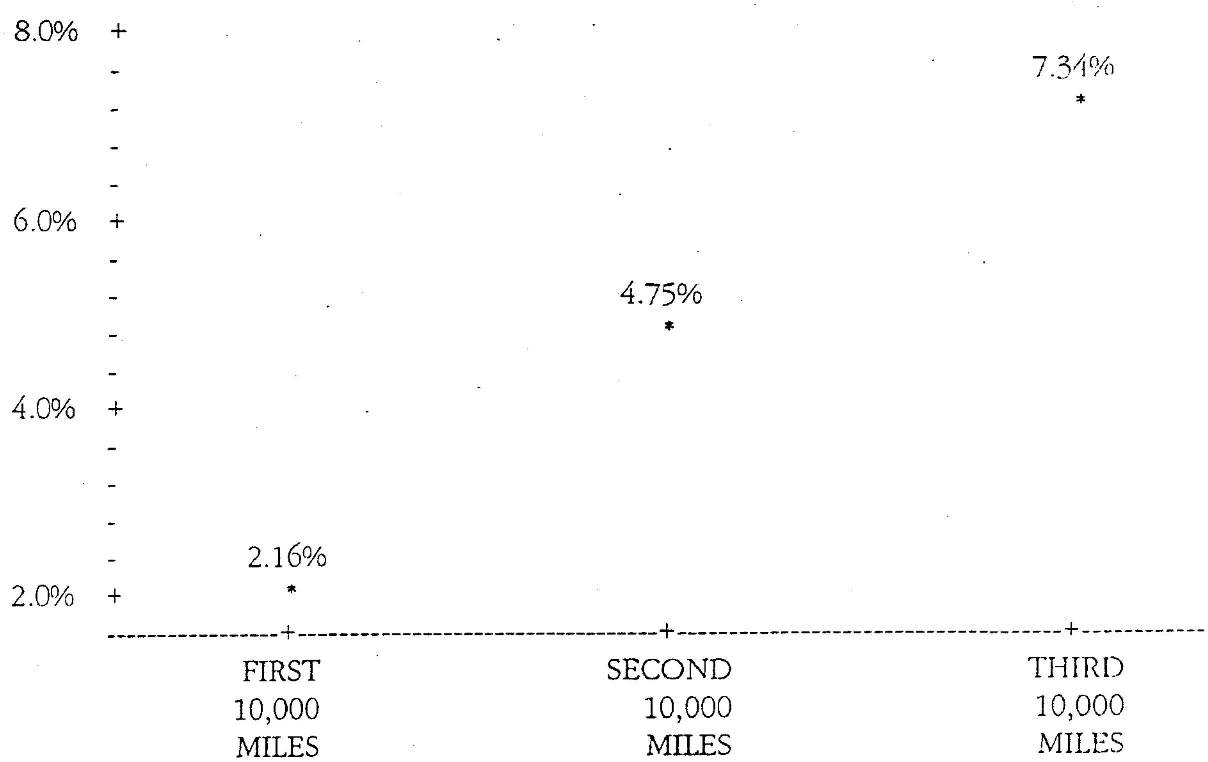
TEST DATA BULLETIN — 28 SEPTEMBER 1993 (CONT)

Figure 2: The graph below shows the statistically expected percentage of improvement (in mpg) for the first 30,000 miles the vehicles are driven burning Ferox treated fuel.



After 30,000 miles have been driven burning Ferox 230 treated fuel, the rate of improvement stabilizes and does not continue to increase. One set of data showed a decrease after 30,000 miles. Test results show that, at a 99% confidence level, the percent improvement in mpg is between 4.54% and 5.75%.

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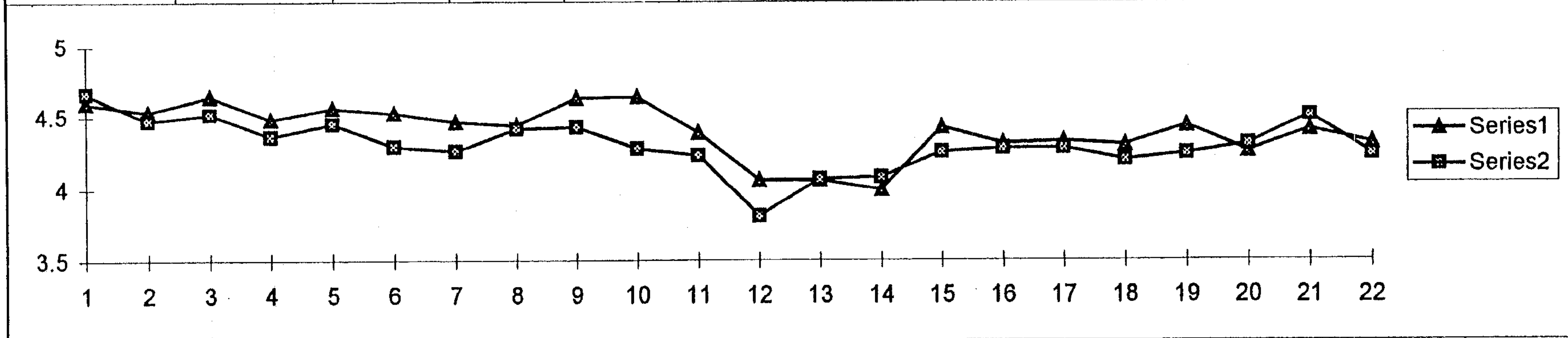
The oil test results are based on ten samples taken May 3, 1990 and May 23, 1990, from six vehicles. Vehicles S244, S246, and S251 burned fuel treated with Ferox 230, while vehicles S245, S248, and S252 burned untreated fuel. Statistical analysis of the data from these samples confirms a significant difference between the oil of vehicles which burned treated fuel and the oil of those which burned untreated fuel. Due to the small sample size, these results are preliminary; further testing must be done to improve confidence levels. At this point, it can be concluded with 90% confidence that the rate at which soot, silicon, chrome, and copper build up in the oil of vehicles burning Ferox 230 treated fuel is significantly less than the rate of substance build up in the oil of vehicles which burned untreated fuel.

MPG DATA		TREATED (Series 1)				CONTROL (Series 2)		
VEHICLE ID		S-246	S-251	AVG.	MONTH NUMBER	S-245	S-248	AVG.
BASELINE	SEPTEMBER	4.515	4.676	4.5955	1	4.497	4.829	4.663
TEST BEGINS	OCTOBER	4.342	4.727	4.5345	2	4.456	4.486	4.471
	NOVEMBER	4.606	4.681	4.6435	3	4.566	4.465	4.5155
	DECEMBER	4.423	4.541	4.482	4	4.376	4.349	4.3625
	JANUARY	4.488	4.637	4.5625	5	4.436	4.459	4.4475
	FEBRUARY	4.507	4.545	4.526	6	4.324	4.265	4.2945
	MARCH	4.396	4.527	4.4615	7	4.218	4.307	4.2625
	APRIL	4.29	4.584	4.437	8	4.406	4.421	4.4135
TEST ENDS	MAY	4.473	4.794	4.6335	9	4.425	4.425	4.425
ALL TREATED	JUNE	4.422	4.859	4.6405	10	4.275	4.281	4.278
	JULY	4.375	4.396	4.3855	11	4.311	4.149	4.23
	AUGUST	4.251	3.867	4.059	12	3.772	3.84	3.806
	SEPTEMBER	4.036	4.081	4.0585	13	4.103	4.028	4.0655
	OCTOBER	3.739	4.24	3.9895	14	4.063	4.093	4.078
	NOVEMBER	4.509	4.333	4.421	15	4.154	4.357	4.2555
	DECEMBER	4.429	4.191	4.31	16	4.24	4.313	4.2765
	JANUARY	4.363	4.285	4.324	17	4.243	4.324	4.2835
	FEBRUARY	4.366	4.239	4.3025	18	4.2	4.2	4.2
	MARCH	4.623	4.246	4.4345	19	4.298	4.184	4.241
	APRIL	4.282	4.235	4.2585	20	4.346	4.269	4.3075
	MAY	4.398	4.414	4.406	21	4.582	4.429	4.5055
	JUNE	4.362	4.266	4.314	22	4.205	4.268	4.2365



FEROX

Combustion Managers

TEST DATA BULLETIN

29 SEPTEMBER 1993

Effect of Ferox on Fuel Economy

Statistical Analysis

by Russell D. Henry

August 26, 1992

Report for Parish Chemical

Orem, Utah

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FEROX

Combustion Managers

TEST DATA BULLETIN

29 SEPTEMBER 1993 (CONT)

Effect of Ferox on Fuel Economy

Introduction

Four matched vehicles were tested to determine the effect of adding FEROX on the fuel economy of matched tractor/trailer vehicles. The vehicles were 1990 International tractors powered by 400 hp 3406B Caterpillar diesel engines. Beall bottom-dump trailers were used. Each vehicle traveled a similar route and carried a similar load (24 hours a day, five days a week). The vehicles were given identical maintenance routines.

From 9 October 1989 to 31 May 1990 two of the vehicles used FEROX and two of the vehicles used a placebo. The drivers were responsible for adding the FEROX or Placebo in a double-blind test.

This report shows that the trucks that used FEROX had a significant increase in MPG, with increases up to five percent.

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TEST DATA BULLETIN

29 SEPTEMBER 1993 (CONT)

Results

The improvement in MPG is calculated by comparing the average MPG each month for the FEROX trucks and the control group. The results are shown below:

Month	Improvement
September	-1.4%
October	1.4%
November	2.8%
December	2.7%
January	2.6%
February	5.4%
March	4.7%
April	0.5%
May	4.7%

The percentage shown is the percent improvement in MPG of the FEROX trucks. For example, in November the trucks that were using FEROX had an average MPG 2.8 percent higher then the trucks that used a placebo.

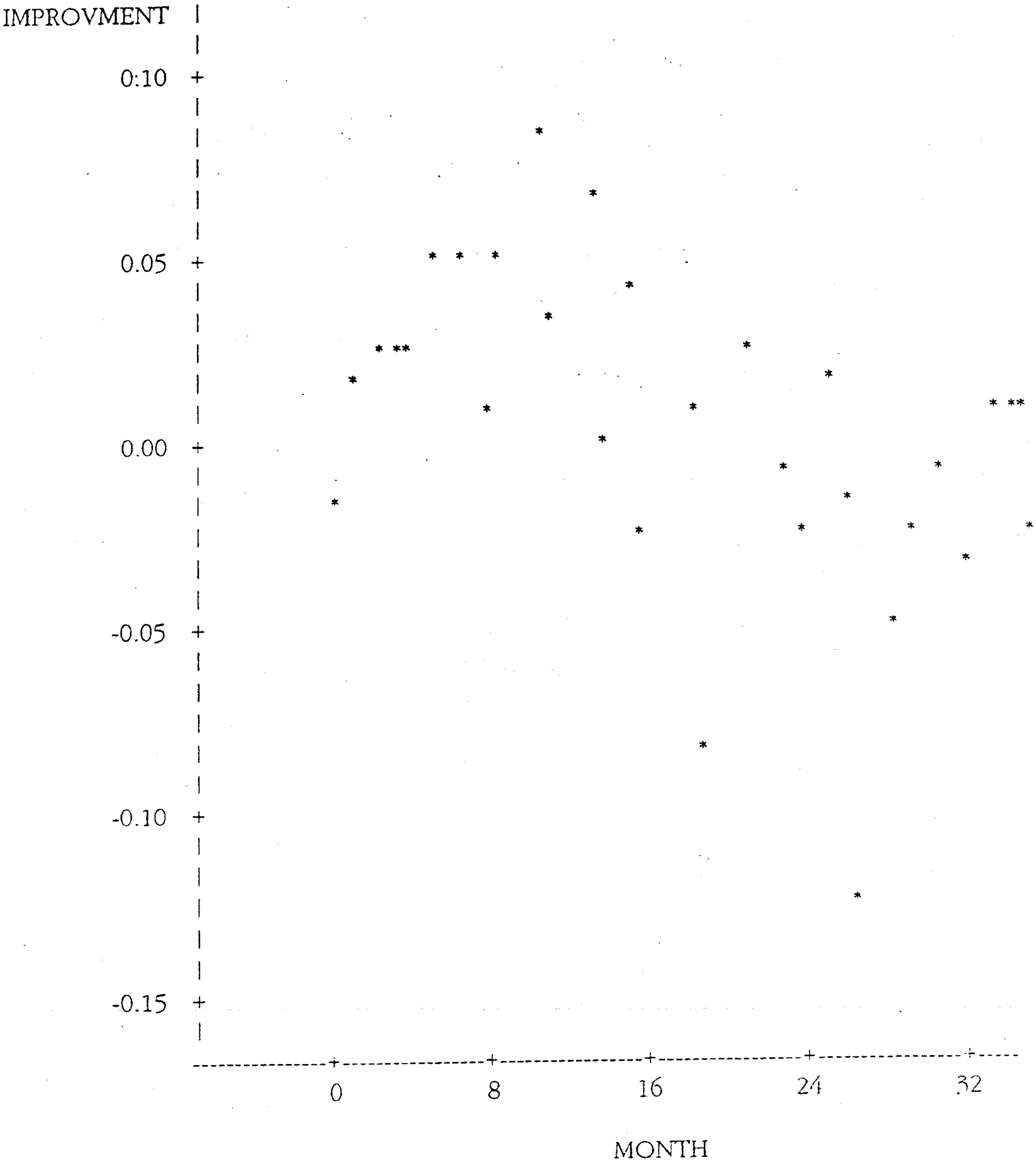
September is included to show the status of the trucks at the beginning of the experiment. As shown, the trucks that later got FEROX were averaging 1.4 percent less MPG before the experiment.

APPENDIX

In June 1990 all trucks in the study began using FEROX, and the next page shows a plot of the results. The x-axis is the Month and the y-axis is Improvement. As before, the average MPG for each group is compared, and the "improvement" score is how much better the treatment group did than the control group. Of course, after month 8, both groups used FEROX. A negative percentage means that the control group did better.

The experiment covers the time span from month zero to month eight. Notice the upward trend, as the FEROX trucks did better and better.

After month eight, we compare the results of the two groups as both received FEROX. There is a clear downward trend from that point. This means that the control group caught up with the treatment group once it began using FEROX.



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FEROX

Combustion Managers

TECHNICAL BULLETIN

5 NOVEMBER 1993

How Ferox Works on Deposits

Deposits are mostly carbon and aromatic compounds in a highly combustion resistant state. Deposits are the source for many engine and combustion associated problems. Eliminating deposits solves many of the problems that are of a major concern to society. This bulletin generally explains how Ferox combustion surface modifiers and deposit surface modifiers cause the removal of, and inhibit the formation of deposits. How deposits are formed and the basic surface chemistry will be explained first.

Deposit formation begins with spherical molecules called primary particles and branched aromatic chains both of which are produced in the early stages of combustion. The chain branches consist of alkyl, alcohol, carbonyl and carboxyl compounds. The alkyls tend to oxidized to alcohols which tend to oxidize to carbonyls which tend to oxidize to carboxyls. The oxidation process stops with the carboxyl compounds which are acidic and highly combustion resistant with a high energy of activation. The various branch compounds are somewhat attracted to the primary particles which spin at an extremely high rates of speed. When a branch becomes attached to a primary particle the entire chain structure is quickly wrapped around the primary particle forming a secondary particle. When several of these secondary particles agglomerate they form a tertiary particle. This can happen when several primary particles become attached to the same chain on different branches and simultaneously become secondary particles and a tertiary particle as they wrap up the chain. When tertiary particles agglomerate on a surface they become further coated forming what is called a quaternary particle. Coated quaternary particles are what make up deposits. The chain structures coating the surface of deposits leave branches exposed. These branches are where the Ferox catalyst begins destroying the deposit.

The carboxyl branches being acidic, attract the Ferox catalyst oxide which is basic. When the two combine a process called dehydration occurs and a water molecule is produced. What remains is a compound with a low energy of activation which readily breaks down at high temperatures releasing a CO_2 molecule and the catalyst oxide. Upon releasing the CO_2 and the catalyst oxide, the end of the chain re-oxidizes to an alkyl, alcohol or carbonyl compound and finally to a carboxyl compound. When the end of the chain reaches this state the catalyst oxide once again combines with the carboxyl and starts the break down cycle again. With time the deposit is removed by being converted to CO_2 and water.

Ferox inhibits the formation of new deposit material in much the same way it destroys existing deposits. The Ferox catalyst interacts with the ends of the aromatic chains and the attachment sites on the primary particles. This interaction keeps the primary particles from wrapping up full chains by blocking or destroying the attachment sites and/or breaking the chains. This interference stops the deposit agglomeration process at the primary or secondary particle agglomeration state thus resulting in lighter smaller particles that don't stick together. The result of this interference is a lower mass of particulate emissions and the production of CO_2 and water which are the desirable products of combustion.

By the methods explained above we begin to understand how Ferox inhibits the formation of deposits and destroys existing ones. With the deposits eliminated, the major source of hydrocarbon emissions is also eliminated. Less soot and smoke is produced and particulate size and mass drop. The Ferox catalyst promotes the production of CO_2 and water during the entire combustion process thus giving rise to cleaner emissions.

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TECHNICAL BULLETIN

FEROX

Combustion Managers

26 JANUARY 1995

The Ferox Combustion Catalyst

Ferox technology is based on the catalytic effects of organo metalics. The main active ingredients are synergistic, multifuctional combustion catalysts, that include combustion surface modifiers and deposit surface modifiers. Ferox can be used with any liquid hydrocarbon fuel ranging from gasoline to diesel to residual fuel. Ferox also shows promise for use with solid carbon fuels such as coal.

In a Ferox treated environment the surfaces of the fuel particles and deposits are modified such that the catalyst lowers the energy of activation of the modified surfaces. The modified surfaces can then burn up at a much lower temperature.

A typical engine develops a temperature gradient ranging from 200°C at the combustion chamber wall, to 1200°C at the center of the combustion process. Many of the fuel components require a temperature greater than 600°C to combust. The heavy fuel components that are exposed only to the 200 - 600°C range never fully burn and are what contribute to deposit formation, particulates, emissions and other undesirable combustion side effects.

The Ferox modified surfaces and fuel particles begin to combust at temperatures as low as 200°C. This is often below the surface temperature of exposed deposits and fuel particles even at the combustion chamber wall. This allows Ferox treated fuel and modified deposit surfaces to burn over the entire temperature range to which they will be exposed. The result is more complete combustion and eventually complete removal of all engine deposits as well as the inhibition of new deposit buildup. This ultimately leads to lower emissions of CO, SO_x, NO_x, HC's and PM-10, lower fuel consumption, and over all better performance and maintenance.

The process of deposit removal by Ferox begins immediately but can take up to 5 months, 600 hours or 4,000 miles for the full benefits to be realized. The actual time required for the full benefits of Ferox to be achieved and the degree of change noticed depends on the operation, history and age of the engine in question.

In a new, clean engine the difference made by the immediate catalytic effect of Ferox on the fuel itself is often not noticeable although the combustion process is more complete than would otherwise be attainable. What will be noticed however, is that engine performance will not degrade as quickly and maintenance will remain at a minimum due to the fact that deposits will not form. Also a gasoline engine will not experience octane requirement increase. The biggest difference resulting from the use of a Ferox combustion catalyst becomes apparent upon complete removal of the deposits from the fuel injectors, intake and exhaust valves, and other parts exposed to the combustion chamber of a dirty engine. This difference can show up as a 5% - 90% drop in total emissions and a 3% - 10% increase in fuel economy.

A Ferox combustion catalyst will keep a new engine clean and can clean up a dirty engine while allowing the fuel used to burn cleaner. Ferox offers a cost effective way to conserve energy and protect the environment yet not sacrifice performance.

Ferox is sold in 55 gallon drums or by various sizes of tank trucks and rail cars. In some instances cases containing four 1 gallon containers are sold for smaller applications. Ferox has treatment ratios of 1:5,000, 1:10,000 and 1:20,000 depending on the formulation.

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FEROX

Combustion Managers

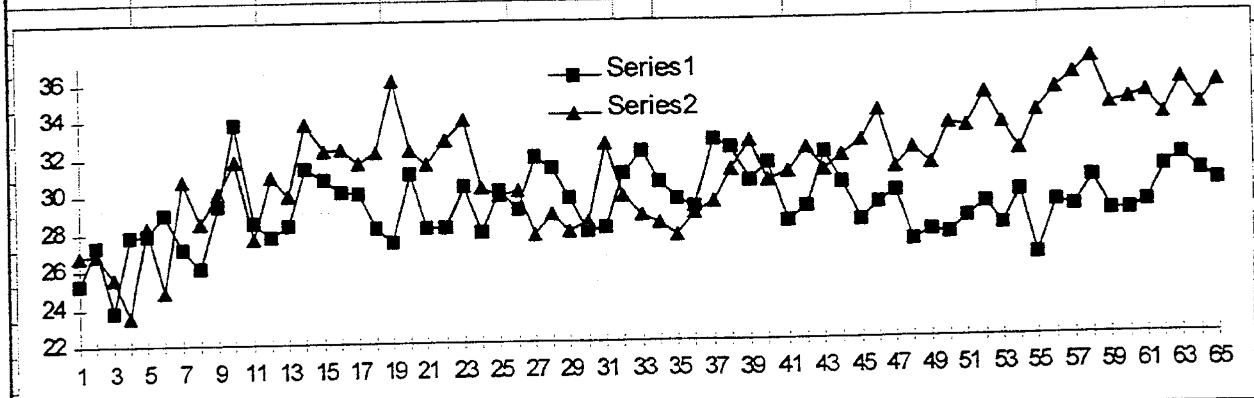
25 NOVEMBER 1996

FEROX GASOLINE FLEET TEST SUMMARY

In late 1989 Ferox, Inc. began a fuel economy evaluation with Ferox on a fleet of over 40 vehicles owned by Parish Chemical Company employees. In January of 1990 the fleet was split into two matched groups of twenty (20) vehicles each and monitored for a year on non-treated fuel in order to obtain baseline data and confirm the stability of the two groups. Each group fueled from its own fueling station. In January of 1991 one group was picked to begin using Ferox treated fuel. The two groups were then monitored for ten (10) months. The test was concluded on the last week of October 1991. The result was an average 9.5% improvement in fuel economy with a statistical confidence level of 95% for the treated group over the non-treated group.

The following spreadsheet shows a summary of the data. Averages were calculated every ten (10) days for each fleet. From periods 1 through 36 the two groups follow each other very closely. The up and down variations follow the same basic trends for both groups indicating that outside variables affected both groups in the same way. At period number 37 the treatment began. Two months later (period number 43) the groups began to diverge and by three months (period number 46) the treated group clearly split from the control group. Even after the split the two groups still followed the same up and down trends indicating that outside variables were still affecting both groups. This indicates that the margin of difference in the performance was due solely to the effects of Ferox. The fact that the two groups do not cross each other, and the minimum overlap by the standard deviations, leads to a 95% confidence level that the difference is real.

	BASELINE					TREATMENT PERIOD			
	Group 1		Group 2			Control		Treated	
1	25.28	mpg	26.75	mpg					
2	27.28	mpg	26.84	mpg		Group 1		Group 2	
3	23.77	mpg	25.60	mpg	37	32.73	mpg	29.44	mpg
4	27.82	mpg	23.57	mpg	38	32.29	mpg	31.08	mpg
5	27.87	mpg	28.33	mpg	39	30.50	mpg	32.66	mpg
6	28.95	mpg	24.77	mpg	40	31.47	mpg	30.56	mpg
7	27.15	mpg	30.76	mpg	41	28.30	mpg	30.95	mpg
8	26.12	mpg	28.46	mpg	42	29.10	mpg	32.23	mpg
9	29.43	mpg	30.10	mpg	43	31.95	mpg	31.04	mpg
10	33.72	mpg	31.78	mpg	44	30.33	mpg	31.78	mpg
11	28.45	mpg	27.62	mpg	45	28.30	mpg	32.55	mpg
12	27.71	mpg	30.94	mpg	46	29.27	mpg	34.20	mpg
13	28.32	mpg	29.89	mpg	47	29.85	mpg	31.16	mpg
14	31.41	mpg	33.79	mpg	48	27.20	mpg	32.11	mpg
15	30.76	mpg	32.32	mpg	49	27.69	mpg	31.30	mpg
16	30.10	mpg	32.40	mpg	50	27.58	mpg	33.42	mpg
17	30.03	mpg	31.60	mpg	51	28.35	mpg	33.28	mpg
18	28.13	mpg	32.20	mpg	52	29.19	mpg	35.01	mpg
19	27.34	mpg	36.10	mpg	53	27.99	mpg	33.39	mpg
20	31.02	mpg	32.35	mpg	54	29.72	mpg	31.94	mpg
21	28.14	mpg	31.57	mpg	55	26.34	mpg	34.05	mpg
22	28.10	mpg	32.85	mpg	56	29.15	mpg	35.25	mpg
23	30.32	mpg	33.97	mpg	57	28.91	mpg	35.94	mpg
24	27.86	mpg	30.28	mpg	58	30.44	mpg	36.85	mpg
25	30.12	mpg	29.84	mpg	59	28.67	mpg	34.39	mpg
26	29.08	mpg	30.10	mpg	60	28.62	mpg	34.58	mpg
27	31.88	mpg	27.71	mpg	61	29.11	mpg	34.97	mpg
28	31.25	mpg	28.80	mpg	62	30.91	mpg	33.74	mpg
29	29.64	mpg	27.85	mpg	63	31.55	mpg	35.65	mpg
30	27.87	mpg	28.40	mpg	64	30.72	mpg	34.25	mpg
31	28.02	mpg	32.61	mpg	65	30.20	mpg	35.43	mpg
32	30.98	mpg	29.78	mpg					
33	32.14	mpg	28.71	mpg		Series 1		Series 2	
34	30.55	mpg	28.30	mpg		Group 1		Group 2	
35	29.58	mpg	27.66	mpg					
36	29.18	mpg	28.83	mpg					



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29 January 1997

Evaluation of Ferox - Fuel Catalyst for Reducing Exhaust Emissions and Increasing Fuel Economy

One of the solutions for reducing the exhaust emissions from heavy duty diesel engines is the modification or reformulation of existing diesel fuels. A recent example of the latter was the introduction of low sulfur diesel fuels. For the modification of fuels, a technique that is employed is to add small volume percentages of chemicals to the existing fuel. In general, these additives/catalysts have been designed to modify the combustion process with the targeted benefits of reduced fuel consumption and exhaust emissions. The following information concerns a testing program that was conducted on such a product. Ferox, a fuel catalyst developed by Parrish Chemical in the US and distributed in Canada by MEA Technologies of Hamilton was the focus of a collaborative government/industry urban bus exhaust emissions and fuel consumption evaluation program.

The Mobile Sources Emissions Division, Environment Canada, agreed to support a testing program to evaluate Ferox under laboratory controlled conditions to determine its effectiveness for reducing exhaust emissions and fuel consumption. Three DDC 6V92 engine powered urban buses of the same vintage and configuration, one as a control and the other two using diesel fuel treated with Ferox, were laboratory chassis dynamometer tested for exhaust emissions after 0, 400 and 1000 hours of regular inservice operation. At each of these points, all three buses were tested over simulated driving cycles designed to generally represent a city/suburban operation. The exhaust emissions that were determined included total hydrocarbons(THC), carbon monoxide(CO), oxides of nitrogen(NOx), particulate mass(PM), carbon dioxide(CO2), volatile organic compounds(VOC), carbonyls and polycyclic aromatic hydrocarbons(PAH). The first three compounds are referred to as the criteria emissions as they are regulated by both the Canadian and United States federal governments. The remaining emissions except for CO2 are unregulated constituents of the exhaust stream. Fuel economy was determined by the carbon balance method which involved a calculation based on the measurements of the carbon compounds in the fuel.

As Ferox was developed to improve the combustion characteristics of an inuse engine over a period of time, it was expected that the maximum benefits accruing from the use of the catalyst would occur by 1000 hours of engine operation. Thus, the differences determined in the exhaust emissions and fuel economy between the zero hours(baseline) and 1000 hours represents the expected improvements with the use of the product. For purposes of taking into consideration normal engine/vehicle variability over time, the control bus results served as the average that would be expected over this length of time. Any changes outside of this range would then be attributable to the Ferox.

The test design consisted of the three buses to be tested over two cycles ie. the Central Business District(CBD) and the New York Bus Composite(NYBC). The test plan required that each bus undergo a total of four 'hot start' repeats of each cycle, on both the diesel control fuel and the diesel fuel treated with Ferox. While the buses were in normal inservice accumulation, the fuel used was the same as supplied to the local transit authority plus the recommended quantity of Ferox added by an MSED technician.

The results from this evaluation indicate that fuel economy consistently improved with the continual use of the Ferox treated diesel fuel. The average increases for the treated buses at 1000 hrs were 7.0% for the CBD and 4.6% for the NYBC. With the control bus being factored in, the results indicated increases of up to 6.1% for the CBD and up to 5.5% for the NYBC. The variability in these increases could be attributable to maintenance conducted on one of the Ferox treated buses (#8919) and the control bus which could have resulted in the smaller percentage gains. For bus #8919, a number of maintenance problems including the replacement of a fuel injector on two separate occasions, were experienced. The bus specific results are found in the following table

Table Percentage Increases in Fuel Economy

BUS	CBD	NYBC	AVERAGE
8919	1.6	0.8	1.2
8939	**12.3**	**8.4**	10.4
8915 (control)	**6.2**	**2.9**	4.6

Note. Bold values are statistically significant

With respect to the exhaust emissions, the data indicated a consistent reduction in CO_2 corresponding to the increases in fuel economy. For NO_x, though the average results increased over time, these values were less than the increases as measured from the control bus. The particulate mass measurements resulted in a decrease in this criteria emission for three of the four test sequences. The control bus indicated the same trend but with larger percentage decreases. The CO results were more variable, with decreases for the CBD and increases for the NYBC. THC data from one of the buses indicated an average statistically significant reduction of 8.8%. The following table summarizes the results for the criteria exhaust emissions and CO_2.

Exhaust Emissions at 1000 hr (gm/mi) and % change compared to Zero hr.

Bus	Cycle	THC	CO	NOx	PM	CO2
8919	**NYBC**	2.89	13.7	20.1	3.06	2652
	% chg	[+10]*	[+22]	[-4.7]	[+35]	[-1]
	CBD	2.16	7.1	15.9	2.11	2578
	% chg	[+5]	[-12]	[+8]	[-1]	[-2]
8939	**NYBC**	3.0	13.2	18.65	2.60	2608
	% chg	[-8]	[+3]	[+17]	[-6]	[-8]
	CBD	2.39	6.88	15.2	1.98	2493
	% chg	[-9]	[-4]	[+2]	[-14]	[-18]

*Note. [+] refers to an increase

The other known compounds in the exhaust stream are not regulated at this time although a number of these are on Canada's Priority Substance List. The carbonyls, VOC and PAH discussed above were included in this study as they are known to exist in diesel engine exhaust streams and contain specific compounds known to be hazardous to human health. The carbonyls, consisting primarily of formaldehyde and acetaldehyde were measured and analyzed using pre-prepared cartridges and liquid chromatography. The results indicated that for the total carbonyl analysis, the Ferox treated buses had slightly greater reductions than the control bus. For acetaldehyde, the average reductions of 41% were twice that indicated by the control bus. Formaldehyde, which is normally 50 to 90% of the total carbonyls in the exhaust stream followed the same trend but the reductions were only approximately 5% larger than the control bus.

The second important category of unregulated exhaust emissions from these vehicles is PAH, of which 15% is in the gaseous form and the remaining 85% adheres to the particulate. During the baseline testing an average of 14 compounds were identified. This decreased to 10 at the 1000 hr point with 4 being at the non-detectable level for the analysis instrumentation The 1000 hr testing also indicated that all of the identified PAH compounds were decreased when the Ferox treated fuel. This was the case for both buses with reductions in the range of +50% for three of these compounds.

In summary, based on the methodology and vehicles used in this program, the Ferox treated fuel was effective in increasing fuel economy and reducing some of the compounds in the tailpipe exhaust stream including THC, NOx, CO2, formaldehyde, acetaldehyde and PAH.

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FEROX

Combustion Managers

TECHNICAL MEMO

12 FEBRUARY 1997

COMBUSTION CHEMISTRY

Ferox works on the chemical level of the combustion process and therefore works in exactly the same way regardless of the type of liquid or solid fuel in which it is used. Ferox interacts with the carbon-carbon and carbon-hydrogen bonds of fuel particles. It makes no difference whether the particle is a short carbon chain (gasoline), a medium length carbon chain (kerosene), or a long carbon chain (diesel). The Ferox combustion catalysts interact with one carbon bond at a time. When the temperature of the combustion environment reaches a minimum of about 200 °C the Ferox catalysts are activated and the chemical reaction begins to occur. The catalysts can't tell what kind of fuel they are in, or what type of engine they are in, or what type of combustion environment they are in. All they see are carbon-carbon and carbon-hydrogen bonds in an environment of 200 °C or more. For a visual illustration of this process please refer to the color bulletin titled "The Combustion Process". This process is the same for all hydrocarbon fuels regardless of whether it is being burned in an internal combustion engine including turbines or open flame type applications. Ferox will improve the combustion efficiency, remove hard carbon deposits, and reduce fuel consumption and overall emissions in all types of applications and equipment. The trends will be the same regardless. The only thing that the type of equipment or type of fuel used will affect is the magnitude of the trends.

For example Ferox will improve fuel economy in a diesel application on the order of 7% while in a gasoline application the improvement will be on the order of 12%. Generally the lighter the fuel the greater the improvement in fuel economy that will show up. Also a dirtier engine will show greater improvement after it is cleaned up than a not so dirty engine. Another example is with particulate and smoke production. Ferox will reduce combined smoke and particulate in diesel applications on the order of 40% while reducing them in gasoline applications on the order of about 15%. Generally the heavier the fuel the greater the reduction in smoke and particulate emissions. In yet another example CO reduction in gasoline is high while CO reduction in diesel is lower partly due to the fact that CO emissions in diesel applications are naturally low in the first place. In all cases the trends are the same with only the degree of magnitude differing.

Once the chemistry of Ferox is understood it is not hard to predict with good accuracy the trends that one will see due to its use. The difficult part is predicting the magnitude of those trends. In most cases a ball park estimate can be given, but it is not until all the variables affecting the combustion environment are understood or controlled that a number can be declared. However, the trends will be the same regardless of the fuel type or the application.

GENERAL RESULTS OF FEROX FIELD TESTS

TYPE OF TEST	RESULTS
A comparison between matched vehicles carrying similar loads over the same route day in and day out for a combined total of 500,000 miles. (241,079 miles for the test group and 246,836 miles for the control group).	A 7.5% improvement in fuel economy over 10,000 miles and a significant reduction in soot, silicon, chrome and copper build-up in the oil of the Ferox treated vehicles as compared to the control group. Smoke, soot and particulates in the exhaust were visibly reduced.
A 500,000 mile warranty check of the injectors in eight (8) caterpillar engine powered vehicles. The vehicles carried the same coal loads over the same routes day in and day out for 3 years.	Clean engines with no trace of hard carbon build-up. Only two (2) of more than sixty (60) injectors needed to be replaced. At 800,000 miles all eight vehicles were still on the road without requireing extra ordinary maintenance procedures.
Fuel consumption in a limestone quarry operation.	A nine percent (9%) improvment in the fuel consumption.
An emissions and fuel economy test on a municipal fleet operation over a two year period. Included both gasoline and diesel vehicles.	A reduction in Smoke for the diesel vehicles and a reduction in octane requirement for the gasoline vehicles. An average of four cents ($.04) per gallon in fuel savings for the fleet.
Fuel consumption of the heavy equipment in a crushed stone quarry operation.	A reduction in fuel consumption from an average of 22.5 gallons per hour (gph) to 17.8 gph in dragline operations, and a 10% reduction in fuel consumption for front end loaders. The combustion chambers were clean and free of hard carbon build-up and the injectors were spotless.
Emissions from a municipal fire departments trucks.	A significant reduction of black smoke in the exhaust.

TYPE OF TEST

	RESULTS
Fuel consumption and maintenance of the equipment in a sand dredging operation	Fuel consumption was reduced by two (2) gph. Downtime for maintenance and repair costs have dropped significantly.
Fuel consumption and performance in heavy construction equipment.	Reduced fuel consumption and improved performance.
Fuel economy and maintenance with heavy equipment in an open pit mining operation.	A 4% reduction in fuel consumption. Zero carbon build-up present in the combustion chamber.
Preventive maintenance program with an equipment dealer.	"It appears the use of Ferox is keeping the tops of the pistons and valve stems remarkably free from carbon build-up and keeping all cylinders burning clean. We have witnessed no detrimental side effects."
Fuel economy test on equipment used in an open pit mine operation. Mine #1	A 7% to 8% improvement in fuel economy.
Fuel economy test on equipment used in an open pit mine operation. Mine #2	An 8.5% improvement in fuel economy.
Fuel economy test on equipment used in an open pit mine operation. Mine #3	An 8% to 10% improvement in fuel economy.

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