THE FOLLOWING REPORT WAS PREPARED
AT THE REQUEST OF

BHPB Iron Ore operations in
Western Australia

It is a summary of the findings and conclusions from a total of 19 source documents, independent, tests and technical papers

Independent Evaluation of Fuel Technology Pty Ltd's Diesel Additives for Fuel Efficiency Improvement

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Conclusions and Recommendations

Based on a desk-top study and limited laboratory evaluation, the following conclusions have resulted and recommendations put forward to the management:

Conclusions:

1. The FTC/FPC diesel additive manufactured and marketed by Fuel Technology Pty Ltd is capable of improving both fuel efficiency and engine performance, which is supported by both combustion chemistry involving the additive and available laboratories and field trial data.
2. A fuel reduction of 2.5% across all types of engines (eg. trucks, light vehicles, mobile equipment, locos and utility generators) can be claimed with > 97% confidence based on statistical analysis. The full statistical analysis result is presented in Figure 1 below.
3. Laboratory analysis revealed that the key ingredient of the FTC/FPC additive product is ferrous picrate which, based on combustion chemistry, catalyses hydrocarbon combustion in engines resulting in shortened combustion times, increased peak flame temperatures, more complete combustion and thus greater engine efficiency.
4. There is sufficient evidence to prove that the FTC/FPC additive can also improve the mechanical performance of engines due to cleaner combustion with much reduced soot and unburnt hydrocarbon formation and soot deposition. This should result in maintenance savings as well.
5. However, the claimed reduction in NOx emissions (nitrogen oxides, chiefly NO and NO_2) could not be substantiated at this point of time. According to the well-established engine combustion theory, NOx emission increases with increasing engine efficiency and reduction in hydrocarbon and CO emissions.
6. Laboratory isothermal reactor testing showed that the diesel treated with the FTC/FPC additive has no noticeable effect on the performance of ANFO and can be used in manufacturing ANFO and heavy ANFO explosives for blasting in reactive ground containing pyritic shale. The effect of the additive treated diesel on the stability of emulsion explosives is currently being tested by Dyno Nobel at its Technical Centre at Mt Thorley.

Recommendations:

1. The FTC/FPC combustion catalyst additive manufactured and marketed by Fuel Technology Pty Ltd be deployed to treat all diesel imported to Newman, and potentially across the whole BHPB Iron Ore operations in WA, for use in all diesel fuelled engines.
2. Continuous monitoring of total diesel consumption on site, fuel consumption and maintenance records of selected engines be carried out so that the overall effectiveness of the FTC/FPC additive can be quanitified.
3. Hydrocarbon, CO and NOx emissions from engines using diesel treated with the FTC/FPC additive be subjected to further investigation so as to ascertain there is no hidden or currently unknown long term environmental damages resulting from the use of the diesel additive.

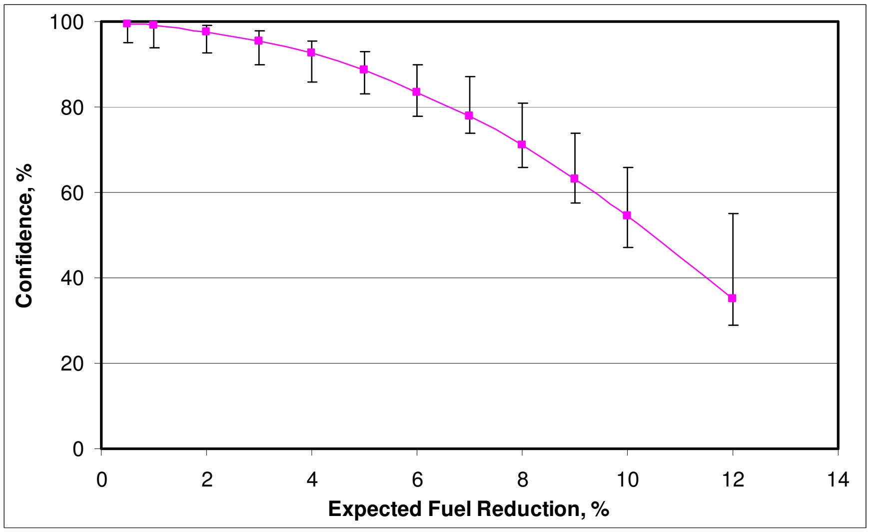

Figure 1 Statistical confidence over the expected fuel reduction

Background and Scope

Upon the request of Mr Dean White, the Residence Manager, the author was commissioned to undertake a desk-top study and independent evaluation of the effectiveness of the use of the FTC/FPC additive, manufactured and marketed by Fuel Technology Pty Ltd, in diesel fuel oil used in mining operations including trucks, light vehicles, mobile equipment and locos.

The evaluation covered a large body of information found in the open literature and various proprietary field trial reports as well as visits to and discussions with the additive manufacturer Fuel Technology Pty Ltd. A list of references cited is provided at the end of this report. There has also been a large volume of information from the internet as well as indirectly cited data covered in this evaluation, which is not given in the reference list.

The evaluation project commenced in April 2007 and covered fundamentals of the working of the combustion catalyst, examination of the various laboratory and field trial methods and statistical assessment of the results.

It was realised in July that the additive treated diesel would be used in manufacturing ANFO and other explosives for blasting for logistic considerations. The author was concerned that the ferrous ion as well as potential water used in the additive could affect the performance of the explosives, especially in pyritic shale reactive ground. It was decided further laboratory examination of the stability of the explosives manufactured from the treated diesel in reactive and non-reactive grounds and a brief chemistry speciation of the additive to be carried out so as to ascertain that the quality of the explosives is not adversely affected by the addition of the combustion catalyst.

This report details the findings of this evaluation study.

The Chemistry of Fuel Technology's Diesel Additives

The Material Safety Data Sheet of the FTC/FPC Fuel Additive manufactured by Fuel Technology is appended in Appendix A at the bottom of this report. The author's own chemical analysis using GCMS (Gas-Chromatograph Mass Spectrometry) showed that in addition to ferrous picrate, there is approximately 12% n-butanol, a complex mixture of short-chain alkyl benzenes (approx. 87%) and a small amount (approx 1%) of dioctyl adipate, a common plasticiser. The short-chain alkyl benzenes range from xylenes (C2 alkyl group) to tetramethylbenzenes (C4 alkyl group).

As far as the fundamental chemistry goes, ferrous picrate needs to be dissolved in water but such a solution will not fully dissolve in diesel causing phase separation. Therefore, another organic sorbent or sorbents have to be used so that the sorbents can form continuous phase with both picrate solution (water) and diesel. Alcohols are the obvious choice as they can mutually dissolve with both water and hydrocarbons and butanol is perhaps the best of all. Benzene or toluene and their derivatives are necessary additives that help improve the stability of the ferrous picrate-water-butanol-diesel solution, although they might present a minor issue in terms of health and environmental hazards. However, given the fact that the additive is dosed in extremely small quantities, e.g. 1:10,000 as proposed, this concern may not be significant considering the other potential benefits.

The FPC-2 Combustion Catalyst Picric acid or Trinitrophenol is, by far, one of the more dangerous chemicals being used today. Classified as a flammable solid when wetted with more than 30% water (UN1344, class 4.1) and a class A high explosive with less than 30% water (UN0154, class 1.1D), it has some very interesting properties. It is explosive but also highly shock, heat and friction sensitive. In fact, detonation with a speed and power superior to that of TNT can occur by a 2 kg weight falling onto solid picric acid from a height of 36 cm. Picric acid is toxic by all routes of entry, it's also a skin irritant and allergen and will produce toxic products on decomposition.

Picric acid is used primarily in the manufacture of explosives and as an intermediate in dye manufacturing. It is also present in many laboratories, for use as a chemical reagent. Water is added to picric acid to act as a desensitizer. The wetted product is significantly less shock sensitive than the dry acid. Picric acid is highly reactive with a wide variety of chemicals and extremely susceptible to the formation of picrate salts. Many of these salts are even more reactive and shock sensitive than the acid itself.

Picrate salts are formed by the reaction of picric acid with any of the following: metals, metal salts, bases, ammonia and concrete. Particular attention must be paid in order to prevent the formation of picrate salts during normal use of picric acid. Picric acid must never be allowed to dry out but even more importantly, it should never be allowed to dry out on metal or concrete surfaces. Metal picrates are particularly sensitive and can be formed with metals such as copper, nickel, lead, iron and zinc. Calcium picrate is formed by the reaction of picric acid with concrete.

Diesel Fuel consists mostly of hydrocarbons ranging from C8 to C24 with majority falling in the range of C10 – C18. The composition of diesel fuel may vary with changes in latitude or changes in season. This variability is provided by the refinery to control the volatility of the product. Diesel fuel has a flash point of 48 to 71 °C and explosive limits of 0.7% to 5%.

Combustion of diesel in compression ignition engines is complex and typically involves the following steps:

1. **Fuel injection** to form finely dispersed diesel droplets suspended in air within the cylinders.
2. **Ignition** of the diesel-air could occurs upon rapidly compression by the piston with, in vast majority of cases, each droplet forms its own *flame front or flamelet*.

3. In the **propagation** stage, the *flamelets* propagate throughout the entire diesel fume and air mixture as well as evaporate and burn the diesel droplets, explosively releasing chemical energy locked in the fuel.
4. The **peak flame temperature** is reached when the rate of the overall fuel combustion reaches its maximum,
5. As both fuel and air become exhausted, the intensity of combustion drops and the flue gas is discharged.

This completes a combustion cycle and the engine fuel efficiency depends on the peak flame temperature (the higher the better) and the time to complete the combustion cycle (the shorter the better). The diesel flame is diffusion controlled and therefore the rate of combustion depends on a number of factors including droplet size, the number droplets, the number of the flame fronts or flamelets and how quickly each of the *flamelets* burns.

The use of a diesel additive to improve fuel efficiency is possible by acting on one or all of these factors. It appears that the FTC/FPC diesel additive from Fuel Technology Pty Ltd only acts as a combustion catalyst that promotes the rate of burning at the flamelet level, by creating more flamelets.

A number of metal ions such as iron, cerium, nickel and tungsten as well as most precious metals are known to promote hydrocarbon combustion. In order to use one of these ions as diesel combustion catalyst, the product (the additive) has to be "dissolved" in diesel so that it can be rapidly dispersed into the droplets. This also naturally requires the ions to be present in a slat that decomposes very rapidly upon heating and the salt or its solution is dissolved in the diesel and does not present as particulates (which cause wearing and tearing in moving parts in the engine).

Therefore, ferrous picrate is a better choice among many conceivable options as it delivers the ferrous ions as the combustion catalyst and decomposes at extremely high rate up on heating and, at low concentrations, poses no explosion hazards at all whatsoever.

The ferrous picrate needs to be dissolved in water and butanol so that it can form a continuous phase with the diesel with benzene and its derivatives as well as a plasticiser (dioctyl adipate) which improve the stability of the ferrous picrate-water-butanol solution in diesel. The use of benzene presents a minor issue in terms of health and environmental hazards. Toluene is considered a better alternative. Nevertheless, given the fact that the additive is dosed in extremely small quantities, 1:10,000 as proposed, this concern may not be significant considering the other potential benefits.

In summary, the use of FTC/FPC combustion catalyst as a diesel additive to improve engine energy efficiency has a sound scientific basis.

Review of Reported Laboratory Studies and Field Trials

There exist a number of laboratory studies and field trial reports and Tim Riley of BHPB MKO has provided a concise and valuable summary of them in his report. The author therefore does not intend to repeatedly summarise these studies and trial reports but concentrates on the evaluation of the methodologies employed in each study and applies a statistical analysis on the raw data produced in these studies to obtain the confidence level of the claimed reduction in diesel fuel consumption after the application of the diesel additive.

Table 1 Comment on Research or Testing Methodologies in Various Studies

Project Details	Comments on methodology	Raw Data Availability
Curtin University (formerly WA Institute of Technology) 1985 Laboratory testing using Varimax TD35 Test & Research Engine (diesel).	Laboratory-based stationery engine tests under best controlled conditions with fuel consumption and power output measured. The ambient temperature was not controlled which would affect the results. Fuel saving: 2.5% and power output: increased by 2%. The lower the efficiency of use (throttle / revs) the greater the saving.	Available for statistical analysis.
Southwest Research Institute 1992 Laboratory Testing using EMD Generator for power absorption	Laboratory-based stationery engine tests under controlled conditions with fuel consumption and power output measured. The ambient temperature was not controlled which would affect the results. Fuel saving: 1.7%	Available for statistical analysis.
UWA (Rio Tinto) 2005 Laboratory Testing using 75 kVA and 100 kVA generator engines with load bank for power absorption	Laboratory-based stationery engine tests with decent planning but the program did not seem to be well executed. Fuel savings: 3 – 5% on older engine but no effect on the newer engine.	Available for statistical analysis.
Fuel Technology Pty Ltd and BHPB MKO 2005 Field trials involving trucks (CAT 793) and mobile equipment using various methods.	Various methodologies were employed as follows: Monthly Fuel Burn Trends: 2 x CAT992G ROM Loaders: 0% fuel saving CAT 793 (T1581) VIMS Data: 2.6% fuel saving Fuel Technology's Carbon Balance Method: 7.9% fuel saving Specific Fuel Consumption Tests based on fuel records (Fuel volume converted to density and corrected for temperature after laboratory testing.) (Trucks 1269 & 1581): 4.8% fuel saving In addition, significant improvement in "cleanness" of engines burning the additive treated diesel was observed. There exist a large number of uncontrollable variables in these tests, determined by the nature of a field trial.	Valuable results for bench marking against the statistical analysis.

It is necessary to comment on the Carbon Mass Balance method that is widely used by Fuel Technology Pty Ltd in determining fuel consumptions in field trials. The CMB measures HC, CO, CO_2 and O_2. The ambient and differential exhaust pressures and temperatures are also measured. A computer program then calculates the results in grams/sec; flow of carbon exiting the engine which equates to the mass of liquid fuel entering the engine. In theory, this is a sound method but in practice it is extremely difficult to execute accurately on the field due to the inherently low accuracy in the flow rate measurement, fluctuating nature of the flow and species concentrations and the lack of rapid responses to the changes of the instruments employed for the aforementioned measurements. The critical issue, even on a theoretical basis, with this method is that there is no independent checks of the mass balance, that is, there is no measure of how much carbon actually entering the engine.

Nevertheless, the field trials conducted at BHPB MKO represent an excellent effort given the complex and variable nature of the program. However, the data from the BHPB MKO field trials cannot be used in the author's statistical analysis but serve as a good bench mark.

Statistical Analysis of the Literature Data on Fuel Savings

As already noted in Tim Riley's report, the reported reductions in diesel consumptions due to the addition of the TFC/FPC combustion catalyst in various studies and field trials are so variable, ranging from negative up to 13% savings as claimed by Fuel Technology Pty Ltd, that it is too difficult to make a final call on the actual level of fuel saving potential. This further leads to difficulties in decision making. This difficulty or impossibility is due to the fact that

1. the field trials involve too many uncontrollable variables, such as loads, weather, road surface conditions and of course, the behaviour of the drivers, etc.
2. while laboratory based tests general employ better controlled testing conditions, they cannot be put together to compare as "apples to apples" due to varying engines and test methods employed, or at least, an effective method was not found.

The author devised a statistical method based on probability analysis to remove potential statistical bias in the various testing data. In brief, the analysis takes on the raw data presented and compounds them into two groups: the reference data group contains the performance data with un-treated diesel and the target data group contains the performance data with treated diesel. Data in both groups are then sorted according to a complex set of test conditions under which the results were obtained. The difference between the reference and targeted groups under any chosen condition is computed as fuel saving at that point, expressed in percent relative to the reference data. A fixed set of targeted performance data, termed "Expected Fuel Reduction", is assigned and the frequency of occurrence of measured data fall within 1% of the assigned "Expected Fuel Reduction" value regardless the test conditions under which the data were obtained is taken as the statistical "Confidence", expressed in percent, of the "Expected Fuel Reduction". Recognise that there is a degree of uncertainty in the Conference value thus determined, a sensitivity analysis is then applied by artificially varying the Confidence value up and down until 10% variation in the measured data set has to be incorporated in order to sustain the assigned "Expected Fuel Reduction" value. The up and lower boundaries of the Confidence thus determined give the error bar as presented in Figure 1 above.

The analysis involved some 27,000 data points and was a very time consuming process. However, the result is very neat and less subjective.

However, the use of the statistical results has to involve a degree of subjectivity. For example, if 97% Confidence provides the comfort, then 2.5% reduction in diesel fuel consumption is the value to accept or, at 95% Confidence, 4.4% fuel reduction is acceptable. Likewise, for a claim of 12% fuel reduction, one would have to feel comfortable with ca 34% Confidence, which for sure is hard for anyone who has to make the decision.

The author wishes to recommend 2.5% reduction in diesel fuel consumption when treated with the FTC/FPC combustion catalyst with 97% Confidence.

Economic Analysis

Assuming:
An operation's annual diesel consumption is 25,000,000 litres, Mt Whaleback at 98,000,000 litres and the whole BHPB IO in WA 235,000,000 litres
The diesel price is $0.47 per litre (provided by Brad Smith for 2009 to 2015 averaged forecast)
The Capex to install necessary diesel additive doping equipment is $14,000 per unit
The price of the diesel additive is $44.80 per litre
The doping ratio is 1:10,000.

The following Table summarises the economic analysis results:

Diesel Consumed (litres)	Fuel Saving %	Fuel Saved (Litres)	Cost Savings ($)	Payback Time (Month)	CO_2 Avoided (tonnes)
Hypothetical case 25×10^6	0.5	125,000	-52,690	-	336
	2.5	625,000	184,550	0.9	1,682
	5	1,250,000	481,100	0.35	3,363
Mt Whaleback 98×10^6	0.5	490,000	-206,545	-	1,318
	2.5	2.45×10^6	723,436	0.23	6,592
	5	4.9×10^6	1.89×10^6	0.09	13,183
BHPB IO WA 235×10^6	0.5	1.175×10^6	-495,286	-	3,161
	2.5	5.875×10^6	1.73×10^6	0.1	15,806
	5	11.75×10^6	4.52×10^6	0.04	31,612

Note that at a diesel price of $0.47 per litre, the break even point is 0.95% fuel saving which has a Confidence greater than 99%, any additional fuel saving represents a bonus. The author would claim a 2.5% diesel fuel saving with a comfortable 97% confidence.

Substantial diesel fuel savings and greenhouse gas (CO_2) reduction can therefore achieved with the employment of the FTC/FPC diesel fuel additive.

Use of Additive Treated Diesel in Explosives

Recognising that diesel used in manufacturing explosives for mining operation is more logistically conveniently drawn from the same tanks in which the diesel has been treated with the combustion catalyst, it is necessary to examine if the additive treated diesel poses any issue in the stability and performance of the explosives. A set of isothermal reactor tests were performed on ANFO manufactured from normal diesel (1-TK and 2*TK), the FTC/FPC additive alone (2+TK ad 2-TK) and diesel treated with the additive (3+TK and 9-TK), in the presence of a known reactive shale with pH of 4.0. The results are presented in Figure 2 below and Figure 3 shows typical photos of the occurrence of the reactions.

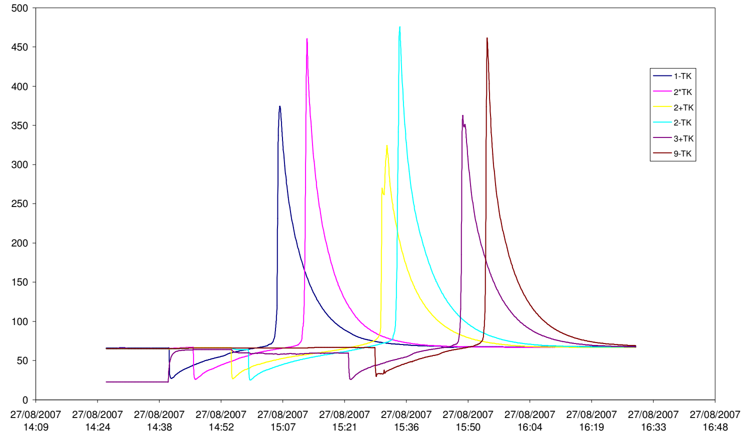

Figure 2 Isothermal reactor test results

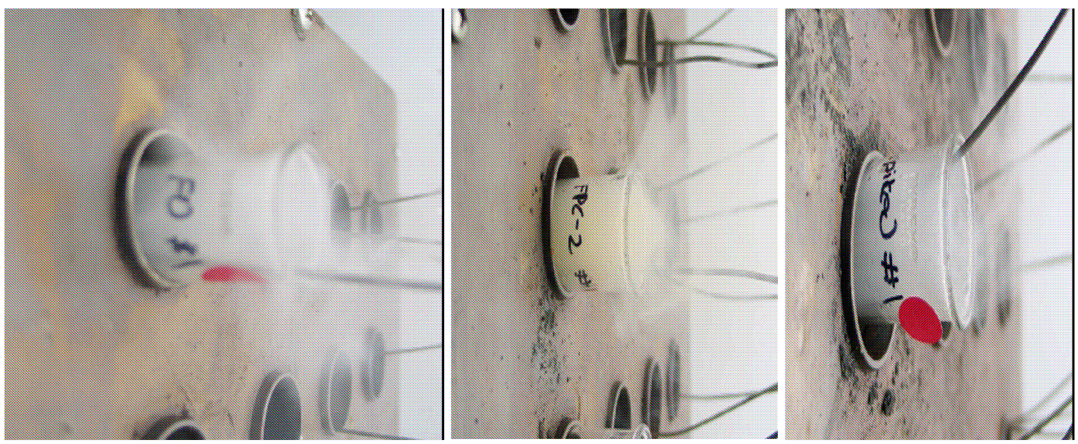

Figure 2 Isothermal reactor test results: from left to right ANFO with normal diesel, with FTC/FPC alone and with treated diesel, respectively.

Based on these tests as well as the detailed analysis of all events occurring during the isothermal reactor tests, there is no noticeable difference in the performance of the ANFO made with normal diesel and the additive treated diesel.

Therefore, it is confidently concluded that the additive treated diesel can be used to manufacture ANFO and various heavy ANFO explosives.

The effect of the FTC/FPC combustion catalyst on the stability of emulsion explosives cannot be assessed in the author's laboratory and is it understood that Fuel Technology Pty Ltd has commissioned Dyno Nobel to conduct such tests to make sure that the use of the additive will not adversely affect the performance emulsion explosives.

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