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REPORT ON ENGINE TESTS WITH MODIFIED FUELS CONTAINING ADDITIVES 6.2, 3.24 AND 3.21

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CONTENTS

REPORT ON ENGINE TESTS WITH ADDITIVES 3.21, 3.24 AND 6.2

1. SUMMARY

A matrix of tests were carried out using the Ricardo E6 IDI engine on hydrated fuels containing additives 6.2, 3.24 and 3.21 with between 1 and 15% water. The additive 6.2 fuels were used for a wide range of different tests at various speeds and loads with measurements taken for power, fuel consumption, combustion temperature and gaseous CO and CO_2 exhaust emissions. Following experience with additive 6.2 fuels, we decided to concentrate on just two tests, both at a set speed, with additives 3.21 and 3.24. In addition to those values recorded in the first batch equipment, became available which enabled us to observe in-cylinder pressure variations - including the onset of combustion.

Results for the modified fuels were compared to a standard (pure diesel) by plotting the various values against engine speed and load. It became clear that the range of effects occurred at differing load rather than differing speed. The most immediate result showed that specific power, comparable to diesel, could be obtained at most conditions. Working against this is the observation that: the hydrated -fuels' flowed at a higher rate through the supply system for a given rack position. Lower exhaust temperatures and reduced CO and $C0_2$ emissions were also noted - these effects becoming more pronounced with higher water/additive concentrations.

In order to cover the broad range of fuels in the most efficient manner the second phase, with additives 3.24 and 3.21, concentrated on variable load tests at 1800 Rpm. As well as confirming the findings of phase 1, we observed that the start of combustion occurred earlier than diesel at a given condition. This phenomenon was more exaggerated at low water/additive ratios.

A number of hypotheses have been proposed to explain the observed effects.
The work is still at an early stage and a complete set of ground rules have yet to he established. More is being learnt of the characteristics of the fuels as equipment becomes available.

2. INTRODUCTION

The report details a series of tests with the Ricardo E6 engine which comprised the first stage in determining the operational characteristics of hydrated modified fuels designed at City University. These fuels are made up of three basic components diesel oil (DERV), distilled water and a quantity of additive. Sufficient additive is included in this mix to achieve a clear, stable emulsion. Three marks of additive were tested, the 6.2, 3.24 and 3.21. The water content of the fuels ranged between 1 and 15% of the initial amount of diesel.

The aims were:

a) to observe the way in which the modified fuels influence power output gaseous emissions, fuel flow, and rate of combustion, then to compare those results with normal diesel;

b) to ascertain the effects of individual fuel components on operating parameters in order that additive formulations can be optimised for a variety of applications.

The report describes the equipment used and outlines the experimental methods adopted for each test. Basic engine procedures remain standard for all tests and these are described in detail. The independent variables are load, speed or injection timing. A computer listing of each sequence is found in Appendix 1.

The ‘Formulation’ section gives relevant information on the proportions of fuel/water/additive in each of the 12 modified fuels under test.

The results and graphs for additives 6.2, 3.24 and 3.21 are contained in Appendices 2, 3 and 4 respectively. These correspond to Observations sections for each fuel. Numerical values for individual parameters are stated where appropriate, but this section is mainly a qualitative description of the various observed trends.

A survey of all results was made in order to highlight the consistent phenomena.

The main observations are considered in the ‘Discussion’ section. Various hypotheses are put forward to account for aspects of the fuels’ behaviour.

3. METHODS AND EQUIPMENT

3. 1 EQUIPMENT

ENGINE: Ricardo E6, variable compression ratio IDI engine with Comet Mk5 pre-swirl chamber and pintle type fuel injector. Swept volume 0. 507 litres. Compression Ratio 22: 1.

DYNAMOMETER: Thrige Scott 10 kw.

CONTROL AND SURVEILLANCE: Plint TE46 computer via BBC Master.

ELECTRONIC INDICATOR: Plint TE28 synchronised to crank angle by a Gaebridge optical encoder.

FUEL METERING: 25, 50, 100 ml sight tube.

TEMPERATURE MEASUREMENT: ‘K’ type thermocouples for water inlet and outlet and exhaust.

The main test conditions, engine speed, rack setting and dwell time are controlled by user defined test sequences programmed into the computer. A manual option is also available,

EXHAUST GAS ANALYSIS EQUIPMENT

Motorbranch Infra—Red Multigas Detector Type 581.
Ranges: CO 0—10%
$C0_2$ 0—20%
HC 0—2000 ppm
+
Incorporated 0_2 detector 0—25%

3.2 TEST SEQUENCES

6 test sequences were used for the tests. The independent variables were speed , load or injection timing.

Appendix one contains a complete listing of each sequence. There follows a short description.

REFERENCE: E6S
DESCRIPTION: Run at a constant part load condition at a rack position of 56% and speeds of between 800 and 2400 Rpm in increments of 200 Rpm.

REFERENCE: E6FS
DESCRIPTION: Run at a constant rack position of 80% (full load) at speeds of between 800 and 2400 Rpm in increments of 200 Rpm. Full load rack position was determined from an examination of the diesel smoke output and peak brake power.

REFERENCE: S12
DESCRIPTION: Run at a constant speed of 1200 Rpm and loads of 40 to 90% in increments of l0%. The 90% setting is beyond the normal full load position for a diesel engine whereby the mixture can be said to be over—rich.

REFERENCE: S18
DESCRIPTION: Run at a constant speed of 1800 Rpm at loads of 40 to 90% in increments of l0%.

REFERENCE: 524
DESCRIPTION: Run at a constant speed of 2400 Rpm at loads of 40 to 90% in increments of l0%.

REFERENCE: SI 1860
DESCRIPTION: Run at a constant speed of 1800 Rpm and a constant rack position of 60%. The static injection timing ranges from 34 degs to 42 degs BTDC. The normal position is 38 degs BTDC.

RECORDED PARAMETERS
The computer, as well as controlling the engine according to a test sequence, automatically records the brake power output, the exhaust temperature, torque and cooling water inlet/ outlet temperatures.

Those values that are recorded manually are fuel -flow timing by stop watch for 25 Ml, plus $C0_2$, 0_2, and Hydrocarbons from the NDIR analyser. The start of rapid pressure rise is obtained from the engine indicator display.

Note:1) the term ‘rack position’ is used interchangeably with load. The control system does not have a -Facility -for imposing a torque on the engine.

2) the fuel rack has been calibrated to work between 32 and 100%, but for this engine the realistic: idle and full load positions are at 40 and 80% respectively.

3.3 STANDARD PRACTICES IN ENGINE TESTING

In order to obtain reliable results, it is important that the test conditions are controlled to within acceptable limits. Certain procedures are adopted to ensure the maximum compatibility between tests.

Pre—Start checks.
Ensure that the dynamometer reads zero under no—load conditions. If not, re—calibrate the load cell to the instructions given in the Plint Service Manual.
Check oil level.
Check coolant water level.
Record air temperature and barometric pressure.
Manually check operation of fuel rack indicator and ensure that idle and full rack positions are available.

Warm—up to stable conditions.
The warm up-period is run with standard diesel until the values noted from previous experiments are obtained. These figures are listed below for the E6 engine.

@ 1800 Rpm 60% fuel rack :
Power 4.6 to 4.8 kw
Water temp 65 to 70 deg c
Exhaust temp 540 to 550 deg c
CO_2 12.2 to 12.4%
25 ml fuel consumed in 48.5 - 49.1 secs
SRPR 6.7 - 7 degs

Any significant changes in ambient conditions or engine performance are noted and taken into account when analysing the results. The warm up period lasts a minimum of 15 minutes regardless of whether these conditions have been met to ensure that the lub. oil temperature and viscosity have stabilised.

Steady state testing

A steady state must be assured for each test run. The ASME code requires that a steady state shall be proved and established by suitable preliminary observations which are made part of the test records. During the test run, the operating conditions should not deviate from the reported averages by more than specified amounts. Typical permissible deviations are: -

Torque +/- 2%
Rotational speed +/- 1%
Air temp. (abs) at inlet +/- 5%
Air pressure (abs) at inlet +/- 5%
Coolant temp. at outlet +/- 5 degs C
Coolant temp rise +/- 3 degs C

Recording of data.

It is usual that the first run is performed with automotive grade diesel fuel. 4 data points are taken at each condition at intervals of 5 seconds. By sampling a number of points it is possible to recognise and discard fluctuating data. When recording results manually it is necessary to ensure that conditions have stabilised completely - a good indicator of stability is the exhaust temperature. Throughout the test with diesel it is possible to check that the engine is performing satisfactorily by referring to previously obtained results. Atmospheric conditions vary little in the test lab and diesel fuel quality is regarded as constant. Therefore, any deviation from the reference data tends to indicate a mechanical fault of some kind.

Water Temperature

An electric pump circulates water through the engine. The coolant gives up heat to a heat exchanger fed by the water main. Water temperature is controlled by throttling the flow of the mains water through the heat exchanger. Coolant-out temperature will be in the region of 60-75 degs C in a typical test. The previously obtained standard figures for diesel should be used as a guide to the degree of throttling necessary to acquire' a coolant temperature to within the tolerance band stated above.

Determination of the Start of Rapid Pressure Rise

The X-base of the indicator oscilloscope should be set to external trigger and the Pressure/Crank angle diagram mode selected. The cursor position is reset to TDC and then moved, to the point at which the light trace deviates from a smooth path (BTDC) and begins to rise more rapidly. This position can be read off from the cursor display. The SRPR indicates the moment when the fuel begins to ignite.

Exhaust Gas

The values for CO_2, O_2 and HC tend to remain stable at a given engine condition which means that data may be recorded as soon as the engine parameters have been set. A sample is taken by opening the main exhaust tapping and the sample return valves then closing the air purge line. As soon as readings have stabilised the data should be recorded to minimise the risk of clogging the analyser passageways. This is more likely at the higher loads where the gas charge is particularly rich in sooty deposits. The filter should be replaced each day with a new piece of glass wool.

Exhaust Temperature

Exhaust temperature is measured by means of a K type thermocouple sited in the exhaust pipe. When conducting manual tests the exhaust temperature - reading is usually the last parameter to reach a stable position. It is therefore a good indicator of the point at which to record data.

Fuel Change over and Flushing

The same procedures are to be repeated for the test fuel . All traces of the previous -fuel, must burned off in the engine and a sufficient quantity of test fuel flushed through the system to ensure that all components i e fuel pump, injector, valves have settled into the new operating conditions before sampling data. About 100ml of fuel is used for this purpose . An alternative method is to create an airlock in the fuel line thereby dividing the two fuels without stopping the engine from turning. The intervening air can be purged from the head of the fuel pump by releasing one of the air bleed screws.

Running test fuels

Combustion temperatures may he significantly different from automotive diesel. It is therefore, necessary to control the cooling water temperature by throttling the valve to the heat exchanger to reproduce the cylinder wall temperatures of the control. Secondly, it should riot be assumed that a given rack position and speed will produce the same fuel flow rates for different fuels. Early results suggest that viscosity and density may have a marked effect on these parameters.

Diesel fuel is run through the engine directly after the test with the experimental fuel . This is done for two reasons:

1. To reproduce the conditions of the full control and obtain similar results for one or two data points to validate earlier readings.

2. To flush the system in case of possible detrimental effects of test fuel on engine components.

4. MODIFIED FUEL FORMULATIONS

The fuels were mixed using 2 litres of diesel as a starting point. The distilled water comprised a percentage of the diesel alone. Additive was mixed with the emulsion incrementally until a clear solution was obtained by stirring. The amount of additive stated in each case should be accurate to within **+/-** 20 ml of the minimum requirement.

TEST MATRIX ADDITIVE (ml) / ADDT:WATER RATIO

		3. 21	3.24	6.2
% WATER	1%	80 4.00		
	2%	120 3.00		140 3.50
	3%	220 3.67	150 2.50	
	5%	340 3.40	300 3.00	220 2.20
	7%		320 2.28	
	10%		440 2.20	320 1.60
	15%			540 1.80

Fuels referencing

ADDITIVE MARK/PERCENTAGE WATER IN DIESEL/VOLUME OF ADDITIVE (M1) e.g. the additive 6.2 fuel, with 15% water **=** 6.2/15/540

Notes

The additives were originally formulated to cope with different amounts of water. For this reason, the same percentages of water were not used for tests with each of the fuels. It was decided at an early stage to cover a wide range of water contents but to look at specific water concentrations with those additives designed for that particular range. The formulations of the additives were believed to be not so different as to have greatly dissimilar effects on engine performance. Therefore, it was assumed, for example, that a 5% 6.2 fuel will act in a similar way to a 5% 3.24 fuel when compared to diesel. The main objective of the first stage of testing was to produce a wide ranging survey of the modified fuel performance. Then, when the framework has been established, to look at the behaviour of the individual additives.

5. TESTS ON MODIFIED FUELS CONTAINING ADDITIVE 6.2

The test sequences used were E6S, E6FS, S12, S18, & S24.
During the early stages, the performance of the modified fuels was unknown and the test matrix was designed to cover a wide range of parameters and operating conditions. Some conditions appeared in 2 or more of the tests which provided a check on the accuracy of the test procedures.

A full set of results are available in Appendix 2.

OBSERVATIONS

Power Output.
For the most part, the brake power data is closely grouped with a maximum scatter of less than 10%. Results for the 10% solution are poor compared to all other fuels including the control. At part load, we note a close resemblance to diesel for all fuels. As the speed increases there is a tendency for the hydrated fuels to give slightly higher power output than diesel. At 2400 rpm results for diesel are the lowest of the sample. At full load, the 10% modified fuel once again performs poorly. Trends are closely matched up until the high speed range where the 5 and 15% solutions yield the highest power output compared to other fuels.

As a general rule, the low percentage fuels, 2 and 5%, performed the best in the low speed, variable load test. Results for these were in excess of diesel throughout the load range. The same cannot be said for the 10 and 15% solutions which showed a deficit of similar magnitude compared to the control. Results tended to converge at the over-rich loading. At 1800 Rpm, diesel gave the highest overall power closely matched by the low concentration solutions. The high concentrations gave generally poorer results. There is clear evidence of improved performance from all of the hydrated fuels at high speed. This is shown by the 2400 rpm test where all of the modified fuels are banded in a region above the results for diesel

Exhaust Temperature.
Part load exhaust temperature showed a general trend toward lower values for the high water/additive fuels. Temperature differentials between fuels seemed to be affected little by speed variation. A near constant gap of 45 degrees c is noted between diesel and the 15% modified fuel. At full load, the exhaust temperature data is more closely grouped with diesel, although the 10 and 15% solutions still consistently gave the lowest readings.

At low speed (test S12) the diesel did not produce the highest exhaust temperatures of the sample. The low concentration solutions gave higher temperatures throughout the load range. The 10 and 15% solutions produced the lowest exhaust temperatures. The typical exhaust temperature characteristic is exemplified by the test at 1800 rpm; lower exhaust temperatures occur with high water/additive fuels, greatest differentials appear at mid range loads and there is slight convergence of results at high loadings. At 2400 rpm the behaviour is more complex. While relative comparisons between the modified fuels are typical, the diesel figures traverse from being the lowest at low load to the highest at high load. All results are indistinguishable from one another at the maximum rack position.

CO Emissions

CO emissions become significant pollutants from diesel engines at high loads only and therefore the part load test is not assessed here. At full load CO rises gradually with speed. The results are clearly indistinguishable from one another with even, constant differentials separating them. The diesel shows the largest CO output followed by the 2, 5, 15 and 10% modified fuels respectively. At 2400 rpm, results are less clear with the 5% solution showing similar CO output to diesel. The underlying trend, however is the same as above. Results are mirrored in the 1800 and 1200 rpm tests with an identical order of CO outputs for the fuels. Scatter becomes wider as load increases implying a geometric relationship between loading and CO emissions.

CO_2 Emissions

CO_2 emissions at part load remain fairly constant at between 9 and 10% up until 1600 rpm where they begin to rise with an even gradient. For most speeds, diesel gives the highest emissions followed by the 2, 5, 15 and 10% modified fuels. However, at the top speed the diesel emissions are overtaken by all but the 10% solution. The same is evident at full load where the high speed behaviour is a reversal of lower speed trends. At a constant 1200 rpm, all except the 10% solution give similar CO_2 output throughout the load range. At 1800 rpm, there is a slightly wider spread of results with similar orders of emissions to those observed previously. The maxima occur at the 70% rack position. At 2400 rpm, results are more erratic. Unusually, the *5%* modified fuel gives the greatest overall emissions. It is not possible to identify a consistent trend for the other fuels. Note that the maximum CO_2 output occurs at the 60% rack position.

6. TESTS ON MODIFIED FUELS CONTAINING ADDITIVE 3.24

This series concentrated on two tests: a single speed variable load test at 1800 rpm (S18) and variable injection timing test at the same speed (SI186O). Four fuels based on additive 3.24 were studied containing between 3 and 10% water.

A full set of results are available in appendix 3.

OBSERVATIONS

Power

The mean results from all of the diesel control tests were compared against results from tests with the individual fuels. The most noticeable point is the close grouping of the 3, 5 and 7% fuels’ figures to those obtained from burning diesel.

This is the case at all loads except for the minimum load rack position, at which the diesel performance is the worst of the sample. The other clear phenomenon to arise from these tests is the relatively poor power output from the modified fuel with the highest water and additive concentration. The 10% solution lags the other fuels by a consistent mean of 0.25 kw.

The data obtained from the variable injection timing test is not so tightly grouped. The diesel fuel and the 3% solution provide the best performance of the sample at all conditions. There is a general tendency with all of the hydrated fuel to give higher power output at the more retarded injection timings

Fuel Flow

Fuel flow rises linearly with rack position. The figures are closely grouped at all conditions, yet it is possible to detect a consistent increase in fuel consumption for all of the modified fuels compared to diesel. This increase remains stable at all loads at about 0.1 l/hr between the most widely scattered of the sample. The fuel showing the highest flow rates is that with the highest water content.

Fuel flow was shown not to be influenced by injection timing to any measurable degree.

Exhaust temperature.

These fuels display the well established trends that have become typical for exhaust temperature differentials. The diesel combustion temperature is the greatest at all loads followed by fuels with respectively higher water contents. Results for the 3 and 5% fuels were remarkably similar in all cases. There was a slight tendency for the results to converge at the lean and over-rich conditions.

The variable timing test showed the 3% solution to behave in a similar manner to diesel. This included the tendency to produce slightly higher exhaust temperatures at the more advanced conditions. There was shown to be no significant change in temperatures across the range of modified fuels with greater water/additive concentrations.

CO Emissions.

Diesel fuel was seen to produce the highest Carbon Monoxide at all loads where emissions were significant. CO was lower for each modified fuel and seemingly inversely proportional to the water content. The 10% solution gave the greatest reduction, approximately 1% of TGV at rack position 80; or a decrease of 25% in relation to diesel emissions.

As the variable injection timing test was conducted at a constant low load part load condition, the CO emissions were negligible in all cases.

CO_2 Emissions

Diesel fuel results stand apart from the test fuels by approximately one percent of the total gas volume at mid and high loads. CO_2 emissions generally appear to reduce depending on the amount of water contained in the test fuel. Although results for the modified fuels are tightly banded, it is possible to detect consistently lower CO_2 output for the higher percentage water fuels. This trend is prevalent at mid and high load. There Is little difference in performance between any of the sample at low load.

There was shown to be no influence of injection timing on CO_2 emissions in test SI1860. Predictably, the fuels with the highest water and additive contents produced the least CO_2..

Start of rapid pressure rise

When plotted against static injection timing, the fuel with the least water content displayed the earliest point of combustion initialisation at all conditions of injection timing. The relationship between water/additive content, if any, is not clear from this data. A general description would suggest that the highest water content fuels tended to show the later start of rapid pressure rise i.e., nearer to top dead centre. The results for diesel fluctuate within the bandwidth of the modified fuels and therefore no firmer conclusions can be drawn at this stage. The diesel figures were plotted from a single test rather than mean values from a large sample as before; so the data set may not be representative of typical diesel performance.

When compared to load, slightly clearer relationships emerge. The SRPR is retarded furthest with diesel fuel and increases in proportion to the water content. At low load, results for all of the fuels are closely grouped and the widest differentials occur at mid to high range load. The peak ignition advance also appears at these points.

7. TEST ON MODIFIED FUEL CONTAINING ADDITIVE 3.21

The same tests as used with additive 3.24 were carried out using additive 3.21 i.e., S18 and SI1860. Four hydrated fuels were studied containing 1, 2, 3 and 5% of water.

A full set of results are available in appendix 4..

OBSERVATIONS

Power Output

The 3 and 5% fuels gave the best overall performance with behaviour closely akin to that of diesel. Once again, at low load, the pure diesel fuel produced the least torque of the sample. The 1% solution performed poorly with the 2% not faring much better. There was a general tendency for higher power output with increased water/additive content.

Fuel Consumption

The same general characteristic of linearity is evident with this sample as has been seen in previous trials. The scatter between the fuel with the lowest flow rate for a given rack position (diesel) and that with the highest (5% modified fuel) is slightly less than 0.1 l/hr. This value remains constant at all conditions.

Exhaust Temperature

Despite all of the fuels in this sample having similar water/additive contents compared to previous batches, the relationship between concentration and exhaust temperature is once again clear. Allowing for a pair of anomalous results from tests with the 3 and 5% fuels, the tendency is for these fuels to provide the lowest exhaust temperatures at all conditions. A mean scatter of 20 to 25 degrees C is noted.

CO

These results verify data recorded from previous tests. The CO content becomes significant at mid to high load. Emissions expressed as a percentage of total gas volume are reduced in the order of 0.8% maximum. CO reduces with increased water and additive concentration.

CO_2

The distinctive grouping of the hydrated fuels at a level below that of emissions from diesel fuel is repeated here. There is a general reduction in CO_2 of 8 to 9% at low and mid range loadings. The results for all fuels becomes progressively more tightly banded until at the low equivalence ratio point, the CO_2 content of the 3 arid 5% modified fuels surpasses that from diesel.

Start of Rapid Pressure Rise.

The tendency of combustion to occur earlier with the modified fuels is clearly illustrated here. A general advance of the point of rapid pressure rise of 1.5 degrees of crank angle is common amongst all fuels compared to diesel. From this data it is unclear which fuels cause the greatest advancement to occur. Results for the higher percentage fuels are erratic, but they do include the maximum reading of SRPR, whereas those for the low concentration fuels gave the highest values of SRPR in the most cases. Indeed, data from the tests with the 1 and 2% modified fuels was very consistent and predictable.

The Variable injection timing test showed the modified fuels to be closely banded at all conditions, with the 3% fuel producing the earliest combustion point; an advance of around 1.5% compared with the diesel control. This figure is constant at all conditions of static injection advance. The 5% fuel performs closest to the diesel figures with a mean advance of approximately 0.5 degrees. No other consistent trends are evident.

8. SUMMARY OF RESULTS

A total of twelve different additive/water combinations were tested using variable load, speed and injection timing tests.

The common characteristics of the results are outlined below.

8.1 Power Output

Improved performance for the modified fuels at low load compared to diesel.

Good high speed performance from 6.2 fuels.

There is no immediate correlation between additive/water concentration and power output. As a marker though, the 3 and 5% solutions were generally the fuels yielding the highest output.

Better power output obtained from hydrated fuels at the retarded injection settings.

The 6.2/10% fuel test produced highly unpredictable results which have not been repeated. This set should therefore be regarded with scepticism.

8.2 Fuel Flow Rate

Fuel flow is linear with rack position.

There is a constant differential between the most widely scattered fuels in the region of 0.1 l/hr for test S18.

Highest fuel flow rate for a given rack position is associated with the fuels having the highest water content.

Diesel consistently gives lower flow rates than any of the modified fuels.

8.3 Exhaust Temperature

Exhaust temperature is generally highest for diesel followed by fuels with respectively higher water contents. The one notable exception to this is at a constant 1200 rpm where exhaust temperature for all fuels were similar.

The largest temperature differentials between diesel and the modified fuels are seen at mid range load.

Temperature differentials tend to converge at low and high load.

Injection timing tended not to influence exhaust temperature.

8.4 CO Emissions

CO becomes significant at mid to high load only.

CO emissions are generally highest for diesel followed by fuels with respectively higher water contents.

The scatter between results widens as load increases.

CO emissions vary little with speed.

8.5 CO_2 Emissions

Maximum CO_2 emissions are achieved at the 70% rack position. Beyond this point CO_2 production for all fuels tends to be similar.

At high speed there are no consistent trends.

Throughout the load range at 1800 rpm, the modified fuels produce in the order of 1% of TGV less CO_2 compared to diesel.

Emissions are lower for high water content fuels.

Differences in CO_2 output at low load is negligible.

Injection timing was shown not to influence emissions to any measurable degree.

8.6 Start of Rapid Pressure Rise

The point of rapid pressure rise for all hydrated fuels was in advance of diesel. This differential averaged at approximately 1.5 degrees of crank angle at 1800 rpm (139 microseconds).

In general, the fuels that showed the greatest advance were those with the lowest water/additive contents. High water content fuels gave results more similar to diesel.

9. DISCUSSION

To draw any firm conclusions as to specific fuel characteristics would be misleading at this stage when only a moderate number of tests have been carried out. There are certain traits that can however he identified that are clearly typical of the hydrated fuels and these were summarised in the previous section. We have isolated increased power at certain conditions, curiously higher fuel flow rates, lower exhaust temperature, lower CO and CO_2 emissions and shorter ignition lag as characteristic qualities of the fuels as a whole.

The question of the penalty in specific power output is foremost when comparing a new fuel with the conventional. Results in this area appeared more fuzzy than would be hoped with no direct correlation between either additive or water concentration and engine torque. Certainly any differential between the control diesel, and the modified fuels was within experimental error, which for this parameter was set at 10% measured from the maximum scatter of a number of tests. An advance in the start of rapid pressure rise was noted for the modified fuels. The shorter ignition lag may go some way to explaining the observed improvement in high speed performance over diesel. This statement is reinforced by the improvement in power obtained from the modified fuels at retarded injection timings. The ignition lag or ignitability of a fuel is a prime measure of the Cetane number which, on this evidence, would he higher than diesel for all of the modified fuels.

Specific power is also dependent on the fuel flow through the supply system. As the modified fuels are higher viscosity fluids than diesel we would predict lower flow rates at a given condition due to increased friction. This was not the case. Viscosity of the modified fuels increases with water/additive concentration and from experiment so too did fuel flow rate. Differences were slight, in the region of 1 to 2% between the most widely disparate fuels, but consistent. Further-more, rather than rising proportionally with speed, the differential remained nearly constant across the speed range at approximately 0.1 l/hr. All fuels were supplied at room temperature to the fuel pump and all other conditions remained constant. Fuel viscosity has been identified as affecting fuel delivery in the following ways (Shipinski Et Al, Combustion Problems And Solutions When Burning A Wide Range Of Fuels In Reciprocating Engines,SAE Progress In Technology, Vol 11):

1) Decreased fuel viscosity in general means increased leakage by the plunger and thus reduced delivery of fuel as well as possible plunger lubrication problems.

2) Decreased fuel viscosity effectively causes the spill port to open earlier, reducing delivery of fuel.

3) Decreased viscosity can increase leakage past the plunger.

Also worth noting from this paper is the reference to a fuel density compensator and a correlation between kinematic viscosity and energy content per unit volume.

It will be interesting to compare this fuel flow behaviour with that in other systems such as distributor type pumps.

Exhaust temperature for the vast majority of conditions reduces with water/additive content. There are various ways to account for this phenomenon:

a) higher proportion of non combustible material in the fuel;

b) heat absorption by the water in the vapour phase;

c) higher specific heat of the gas charge.

Assuming that complete combustion is achieved when burning diesel then we would expect to see a deficit in power output when burning a fuel containing a proportion of non combustible material; which is not evident at this stage. So that leaves the additive whose combustion characteristics have yet to be isolated. This can only be done in an engine by running fuels containing diesel and additive alone then comparing the results with similar concentrations of hydrated fuel. Even then, an analysis of the individual components neglects any more complex interactions involving water. A fuel containing water will absorb heat at constant temperature as it passes through the vapour phase and turns to steam. The higher the water concentration, the more heat is absorbed. Raising the specific heat capacity of the gas charge, thereby absorbing more heat energy, is the aim of certain recognised pollutant reducing regimes such as exhaust gas regeneration. The main aim of EGR is to reduce NOx by suppressing the chamber temperatures which provide suitable conditions for its formation. Another scheme for reducing NOx emissions is to retard the injection timing introducing the need for very high pressure injection equipment if the same amount of fuel is to be injected on each cycle. A fuel, such as many of those tested here, that gives lower combustion temperatures and shows increased efficiency at retarded injection timings will not require this costly fuel injection equipment to achieve a reduction in NOx emissions. However, until suitable detectors are available for measuring these parameters, this remains speculation.

Another observation of the exhaust temperature characteristics is the tendency for convergence with diesel levels at high speed conditions. This may indicate prolonged combustion period for the modified fuels meaning that the fuel is still burning after the exhaust port has opened. The exhaust temperature sensor was sited some 200mm from the chamber and we cannot be sure that these readings are indicative of the higher temperatures reached during combustion. An adjustment of the valve timing may produce more satisfactory results, although this is not possible with the current system.

Carbon Monoxide emissions are another factor that reduce with increased water content. CO production becomes significant at high load only due to the excess of air used by diesel combustion at most conditions. Therefore, the contribution of diesel engines to the global problem of CO emissions is negligible compared to petrol engines. Nevertheless, this is an important result and could be point to reduced emissions from the petrol additive fuels. A model based on stoichiometric combustion, predicts a reduction of exhaust gas volume from a 10% modified solution of 11% over diesel. Remembering that the Infrared analyser measures concentration as a proportion of the total gas volume, rather than as an absolute figure, the reduction in CO and CO_2 emissions becomes all the more significant.

CO_2 is also reduced with the modified fuels tending to be distinct from diesel at all load conditions. There is characteristic peaking of CO_2 production at the 70% load setting which may reveal a more realistic full load condition than that previously established. Beyond the peak results for all fuels tend to be similar perhaps indicating that a saturation point has been reached and efficient combustion is stifled.

Differences between the three additives became apparent in the efficiency in dealing with given percentages of water. Clearly the Mk 6.2 is the most efficient on a volume for volume basis followed by the Mk 3.24 then 3.21 respectively. The additives could be most easily compared at the 5% mark, which was a common concentration for all additives in the sample. From these results, there is evidence to suggest that the additive, as well as the water, is active in suppressing exhaust temperatures, and reducing CO and CO_2 emissions as the modified fuel solutions with the highest additive/water concentration gave the best results. Even allowing for a possible wandering zero between tests, by normalising the results to standard fuel flow rate, the differences between the solutions remained.

There may be some relationship between the additive concentration and the ignition lag. As we have seen, combustion is earlier for all modified fuels at a given condition. Ignition delay appears to be shorter for the low concentration fuels, and there is a general tendency for additive/water efficiency to improve at higher concentrations. In other words, the additive water mixture, which is proportionately richer in additive at low concentrations, has the effect of advancing combustion borne out by the observation that behaviour of the high concentration fuels is more closely akin to diesel.

Engine roughness is a matter that was not presented as part of the Results sections, but it has not been neglected. No audible difference in engine noise, tone or rhythm has been noted when running the modified fuels compared to diesel. A more objective assessment can be obtained from the engine indicator which provides an automatic plot of pressure against crank angle. Micro explosions, or pre-detonation would be detectable by sharp peaks in the pressure trace. Polaroid photographs comparing a 5% modified fuels with diesel were taken at a mid range speed through a number of injection timings both advanced and retarded to the recommended norm. Unfortunately, the poor quality of these records means that reproduction in this report is not possible. Notably, and predictably, roughness increased for both the modified fuel and the control at the advanced settings. The only detectable difference in the qualitative picture were the slightly earlier point of combustion of the hydrated fuel and a more defined step effect due to pre-combustion in the swirl chamber. Apart from these observations, no other discrepancies have been found.

Determining the effect of each of the three basic components is more complex than first imagined. For example, when comparing a 5% modified fuel solution with a solution containing additive alone, is it valid to replace the water with additive or with diesel? And, which ratio should remain constant, additive to diesel or the additive the additive to total volume? It seems the only way to tackle this problem to try all permutations and, by a process of elimination, isolate the common attributes.

10. CONCLUSIONS

Testing is at an early stage. Much has been learned from the work done so far and this has mainly served to provide a platform for more detailed study. It is encouraging to discover that the specific power output from these fuels is comparable to diesel, that CO and CO_2 emissions are lower and that reduced combustion temperature and advanced ignition may well lead to improved NOx figures. On the negative side is the slight increase in fuel flow rate due to increased viscosity.

Given the relatively small number of tests performed against the number of fuels in the sample, it was necessary to present the results in a qualitative manner. Trends and patterns have been identified rather than a quantitative evaluations relating fuel formulation with specific phenomena. This can only be done when results have proven to be successfully reproduceable. It is hoped that the next phase of tests will clarify and further validate these results. Particular areas of interest are:

High and low speed performance.
Fuel flow characteristics in other systems.
Particulate emissions.
Performance of fuels contalning additive and diesel but not water.
General performance in a vehicle engine.

The performance of the fuels at high and low speed was only studied in this batch of tests with additive 6.2. At these extremes there appears to be convergence in the results for many of the parameters measured and further tests will be necessary to identify some of the phenomena. Quantifying the rate of combustion in terms of fuel formulation will be one of the aims.

The questlon of fuel flow rate being a function of pump design will be answered by running the fuels in systems apart from that fitted to the E6 Engine. Combined with this research there will be development of the additives to effect changes in viscosity.

Particulates are one of the exhaust emissions regulated by US and European law and are therefore of major concern. Particulate measurement with a dilution tunnel is beyond the reach of the Department so an alternative system has been designed and built which will provide a comparative assessment between fuels.

In order to isolate the macroscopic effects of the three main components of the fuel, results for modified fuels will be compared with those containing diesel and additive alone.

A Ford 2 litre vehicle engine will be used to assess the performance of the fuels. Although the instrumentation with this engine is more limited, it will let us examine fuel behaviour in a more practical setting.

As well as all the previous parameters being recorded for future tests, it is hoped that the instrumentation will be enhanced by the addition of NOx and Hydrocarbon detection equipment.

APPENDIX 1

TEST LISTINGS

Listing of test sequence file: 1.TF.E6S

STEP NO	SPEED (%)	LOAD (%)	THROTT (%)	TORQUE (%)	DWELL (secs)	NEXT STEP	REPEAT COUNT		
0	800	100	56	0	180	1	0	0	0
1	800	100	56	0	5	1	3	0	0
2	1200	100	56	0	150	3	0	0	0
3	1200	100	56	0	5	3	3	0	0
4	1600	100	56	0	120	5	0	0	0
5	1600	100	56	0	5	5	3	0	0
6	2000	100	56	0	120	7	0	0	0
7	2000	100	56	0	5	7	3	0	0
8	2400	100	56	0	120	9	0	0	0
9	2400	100	56	0	5	9	3	0	0
10	0	0	0	0	0	11	0	0	0
11	0	0	0	0	0	12	0	0	0
12	0	0	0	0	0	13	0	0	0
13	0	0	0	0	0	14	0	0	0
14	0	0	0	0	0	15	0	0	0
16	0	0	0	0	0	17	0	0	0
17	0	0	0	0	0	18	0	0	0
18	0	0	0	0	0	19	0	0	0
19	0	0	0	0	0	20	0	0	0
20	0	0	0	0	0	21	0	0	0
21	0	0	0	0	0	22	0	0	0
22	0	0	0	0	0	23	0	0	0
23	0	0	0	0	0	24	0	0	0
24	0	0	0	0	0	25	0	0	0
25	0	0	0	0	0	26	0	0	0
26	0	0	0	0	0	27	0	0	0
27	0	0	0	0	0	28	0	0	0
28	0	0	0	0	0	29	0	0	0
29	0	0	0	.0	0	30	0	0	0
30	0	0	0	0	0	31	0	0	0
31	0	0	0	0	0	32	0	0	0
32	0	0	0	0	0	33	0	0	0
33	0	0	0	0	0	34	0	0	0
34	0	0	0	0	0	35	0	0	0
35	0	0	0	0	0	36	0	0	0
36	0	0	0	0	0	37	0	0	0
37	0	0	0	0	0	38	0	0	0
38	0	0	0	0	0	39	0	0	0
39	0	0	0	0	0	40	0	0	0
40	0	0	0	0	0	41	0	0	0
41	0	0	0	0	0	42	0	0	0
42	0	0	0	0	0	43	0	0	0
43	0	0	0	0	0	44	0	0	0
44	0	0	0	0	0	45	0	0	0
45	0	0	0	0	0	46	0	0	0
46	0	0	0	0	0	47	0	0	0
47	0	0	0	0	0	48	0	0	0
48	0	0	0	0	0	49	0	0	0
49	0	0	0	0	0	50	0	0	0

Time=0, Step=1, Spd=2, Torq=3, Pwr=4, Extmp=5, Wtmp.in=6, Wtmp.out=7, None=9.

The chosen parameter number for automatic trip is 9, the trip level is set at 0 and the Test File to be executed when this trip occurs is called ‘ ‘.

Listing of test sequence file: 1.TF.E6FS

STEP NO	SPEED (%)	LOAD (%)	THROTT (%)	TORQUE (%)	DWELL (secs)	NEXT STEP	REPEAT COUNT		
0	800	100	80	0	150	1	0	0	0
1	800	100	80	0	5	1	3	0	0
2	1200	100	80	0	150	3	0	0	0
3	1200	100	80	0	5	3	3	0	0
4	1600	100	80	0	150	5	0	0	0
5	1600	100	80	0	5	5	3	0	0
6	2000	100	80	0	150	7	0	0	0
7	2000	100	80	0	5	7	3	0	0
8	2400	100	80	0	150	9	0	0	0
9	2400	100	80	0	5	9	3	0	0
10	0	0	0	0	0	11	0	0	0
11	0	0	0	0	0	12	0	0	0
12	0	0	0	0	0	13	0	0	0
13	0	0	0	0	0	14	0	0	0
14	0	0	0	0	0	15	0	0	0
16	0	0	0	0	0	17	0	0	0
17	0	0	0	0	0	18	0	0	0
18	0	0	0	0	0	19	0	0	0
19	0	0	0	0	0	20	0	0	0
20	0	0	0	0	0	21	0	0	0
21	0	0	0	0	0	22	0	0	0
22	0	0	0	0	0	23	0	0	0
23	0	0	0	0	0	24	0	0	0
24	0	0	0	0	0	25	0	0	0
25	0	0	0	0	0	26	0	0	0
26	0	0	0	0	0	27	0	0	0
27	0	0	0	0	0	28	0	0	0
28	0	0	0	0	0	29	0	0	0
29	0	0	0	.0	0	30	0	0	0
30	0	0	0	0	0	31	0	0	0
31	0	0	0	0	0	32	0	0	0
32	0	0	0	0	0	33	0	0	0
33	0	0	0	0	0	34	0	0	0
34	0	0	0	0	0	35	0	0	0
35	0	0	0	0	0	36	0	0	0
36	0	0	0	0	0	37	0	0	0
37	0	0	0	0	0	38	0	0	0
38	0	0	0	0	0	39	0	0	0
39	0	0	0	0	0	40	0	0	0
40	0	0	0	0	0	41	0	0	0
41	0	0	0	0	0	42	0	0	0
42	0	0	0	0	0	43	0	0	0
43	0	0	0	0	0	44	0	0	0
44	0	0	0	0	0	45	0	0	0
45	0	0	0	0	0	46	0	0	0
46	0	0	0	0	0	47	0	0	0
47	0	0	0	0	0	48	0	0	0
48	0	0	0	0	0	49	0	0	0
49	0	0	0	0	0	50	0	0	0

Time=0, Step=1, Spd=2, Torq=3, Pwr=4, Extmp=5, Wtmp.in=6, Wtmp.out=7, None=9.

The chosen parameter number for automatic trip is 9, the trip level is set at 0 and the Test File to be executed when this trip occurs is called ' '.

Listing of test sequence file: 1.TF.S12

STEP NO	SPEED (%)	LOAD (%)	THROTT (%)	TORQUE (%)	DWELL (secs)	NEXT STEP	REPEAT COUNT		
0	1200	100	40	0	180	1	0	0	0
1	1200	100	40	0	5	1	3	0	0
2	1200	100	50	0	150	3	0	0	0
3	1200	100	50	0	5	3	3	0	0
4	1200	100	60	0	150	5	0	0	0
5	1200	100	60	0	5	5	3	0	0
6	1200	100	70	0	150	7	0	0	0
7	1200	100	70	0	5	7	3	0	0
8	1200	100	80	0	150	9	0	0	0
9	1200	100	80	0	5	9	3	0	0
10	1200	100	90	0	150	11	0	0	0
11	1200	100	90	0	5	11	3	0	0
12	0	0	0	0	0	13	0	0	0
13	0	0	0	0	0	14	0	0	0
14	0	0	0	0	0	15	0	0	0
16	0	0	0	0	0	17	0	0	0
17	0	0	0	0	0	18	0	0	0
18	0	0	0	0	0	19	0	0	0
19	0	0	0	0	0	20	0	0	0
20	0	0	0	0	0	21	0	0	0
21	0	0	0	0	0	22	0	0	0
22	0	0	0	0	0	23	0	0	0
23	0	0	0	0	0	24	0	0	0
24	0	0	0	0	0	25	0	0	0
25	0	0	0	0	0	26	0	0	0
26	0	0	0	0	0	27	0	0	0
27	0	0	0	0	0	28	0	0	0
28	0	0	0	0	0	29	0	0	0
29	0	0	0	.0	0	30	0	0	0
30	0	0	0	0	0	31	0	0	0
31	0	0	0	0	0	32	0	0	0
32	0	0	0	0	0	33	0	0	0
33	0	0	0	0	0	34	0	0	0
34	0	0	0	0	0	35	0	0	0
35	0	0	0	0	0	36	0	0	0
36	0	0	0	0	0	37	0	0	0
37	0	0	0	0	0	38	0	0	0
38	0	0	0	0	0	39	0	0	0
39	0	0	0	0	0	40	0	0	0
40	0	0	0	0	0	41	0	0	0
41	0	0	0	0	0	42	0	0	0
42	0	0	0	0	0	43	0	0	0
43	0	0	0	0	0	44	0	0	0
44	0	0	0	0	0	45	0	0	0
45	0	0	0	0	0	46	0	0	0
46	0	0	0	0	0	47	0	0	0
47	0	0	0	0	0	48	0	0	0
48	0	0	0	0	0	49	0	0	0
49	0	0	0	0	0	50	0	0	0

Time=0, Step=1, Spd=2, Torq=3, Pwr=4, Extmp=5, Wtmp.in=6, Wtmp.out=7, None=9.

The chosen parameter number for automatic trip is 9, the trip level is set at 0 and the Test File to be executed when this trip occurs is called ‘ ‘.

Listing of test sequence file: 1.TF.S18

STEP NO	SPEED (%)	LOAD (%)	THROTT (%)	TORQUE (%)	DWELL (secs)	NEXT STEP	REPEAT COUNT		
0	1800	100	40	0	150	1	0	0	0
1	1800	100	40	0	5	1	3	0	0
2	1800	100	50	0	150	3	0	0	0
3	1800	100	50	0	5	3	3	0	0
4	1800	100	60	0	120	5	0	0	0
5	1800	100	60	0	5	5	3	0	0
6	1800	100	70	0	120	7	0	0	0
7	1800	100	70	0	5	7	3	0	0
8	1800	100	80	0	120	9	0	0	0
9	1800	100	80	0	5	9	3	0	0
10	1800	100	90	0	120	11	0	0	0
11	1800	100	90	0	5	11	3	0	0
12	0	0	0	0	0	13	0	0	0
13	0	0	0	0	0	14	0	0	0
14	0	0	0	0	0	15	0	0	0
16	0	0	0	0	0	17	0	0	0
17	0	0	0	0	0	18	0	0	0
18	0	0	0	0	0	19	0	0	0
19	0	0	0	0	0	20	0	0	0
20	0	0	0	0	0	21	0	0	0
21	0	0	0	0	0	22	0	0	0
22	0	0	0	0	0	23	0	0	0
23	0	0	0	0	0	24	0	0	0
24	0	0	0	0	0	25	0	0	0
25	0	0	0	0	0	26	0	0	0
26	0	0	0	0	0	27	0	0	0
27	0	0	0	0	0	28	0	0	0
28	0	0	0	0	0	29	0	0	0
29	0	0	0	.0	0	30	0	0	0
30	0	0	0	0	0	31	0	0	0
31	0	0	0	0	0	32	0	0	0
32	0	0	0	0	0	33	0	0	0
33	0	0	0	0	0	34	0	0	0
34	0	0	0	0	0	35	0	0	0
35	0	0	0	0	0	36	0	0	0
36	0	0	0	0	0	37	0	0	0
37	0	0	0	0	0	38	0	0	0
38	0	0	0	0	0	39	0	0	0
39	0	0	0	0	0	40	0	0	0
40	0	0	0	0	0	41	0	0	0
41	0	0	0	0	0	42	0	0	0
42	0	0	0	0	0	43	0	0	0
43	0	0	0	0	0	44	0	0	0
44	0	0	0	0	0	45	0	0	0
45	0	0	0	0	0	46	0	0	0
46	0	0	0	0	0	47	0	0	0
47	0	0	0	0	0	48	0	0	0
48	0	0	0	0	0	49	0	0	0
49	0	0	0	0	0	50	0	0	0

Time=0, Step=1, Spd=2, Torq=3, Pwr=4, Extmp=5, Wtmp.in=6, Wtmp.out=7, None=9.

The chosen parameter number for automatic trip is 9, the trip level is set at 0 and the Test File to be executed when this trip occurs is called ' '.

Listing of test sequence file: 1.TF.S24

STEP NO	SPEED (%)	LOAD (%)	THROTT (%)	TORQUE (%)	DWELL (secs)	NEXT STEP	REPEAT COUNT		
0	2400	100	40	0	150	1	0	0	0
1	2400	100	40	0	5	1	3	0	0
2	2400	100	50	0	150	3	0	0	0
3	2400	100	50	0	5	3	3	0	0
4	2400	100	60	0	120	5	0	0	0
5	2400	100	60	0	5	5	3	0	0
6	2400	100	70	0	120	7	0	0	0
7	2400	100	70	0	5	7	3	0	0
8	2400	100	80	0	120	9	0	0	0
9	2400	100	80	0	5	9	3	0	0
10	2400	100	90	0	120	11	0	0	0
11	2400	100	90	0	5	11	3	0	0
12	0	0	0	0	0	13	0	0	0
13	0	0	0	0	0	14	0	0	0
14	0	0	0	0	0	15	0	0	0
16	0	0	0	0	0	17	0	0	0
17	0	0	0	0	0	18	0	0	0
18	0	0	0	0	0	19	0	0	0
19	0	0	0	0	0	20	0	0	0
20	0	0	0	0	0	21	0	0	0
21	0	0	0	0	0	22	0	0	0
22	0	0	0	0	0	23	0	0	0
23	0	0	0	0	0	24	0	0	0
24	0	0	0	0	0	25	0	0	0
25	0	0	0	0	0	26	0	0	0
26	0	0	0	0	0	27	0	0	0
27	0	0	0	0	0	28	0	0	0
28	0	0	0	0	0	29	0	0	0
29	0	0	0	.0	0	30	0	0	0
30	0	0	0	0	0	31	0	0	0
31	0	0	0	0	0	32	0	0	0
32	0	0	0	0	0	33	0	0	0
33	0	0	0	0	0	34	0	0	0
34	0	0	0	0	0	35	0	0	0
35	0	0	0	0	0	36	0	0	0
36	0	0	0	0	0	37	0	0	0
37	0	0	0	0	0	38	0	0	0
38	0	0	0	0	0	39	0	0	0
39	0	0	0	0	0	40	0	0	0
40	0	0	0	0	0	41	0	0	0
41	0	0	0	0	0	42	0	0	0
42	0	0	0	0	0	43	0	0	0
43	0	0	0	0	0	44	0	0	0
44	0	0	0	0	0	45	0	0	0
45	0	0	0	0	0	46	0	0	0
46	0	0	0	0	0	47	0	0	0
47	0	0	0	0	0	48	0	0	0
48	0	0	0	0	0	49	0	0	0
49	0	0	0	0	0	50	0	0	0

Time=0, Step=1, Spd=2, Torq=3, Pwr=4, Extmp=5, Wtmp.in=6, Wtmp.out=7, None=9.

The chosen parameter number for automatic trip is 9, the trip level is set at 0 and the Test File to be executed when this trip occurs is called ‘ ‘.

APPENDIX 2

RESULTS FOR FUELS CONTAINING ADDITIVE 6.2

DATE 2/5/91 DESCRIPTION
TEST CYCLE E6S DATA FILE E6S02
FUEL DIESEL

SPEED (RPM)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
800.00	414.20	1.40	0.57	0.41	290.00	0.05	9.10	10.10	10239.00	25.31	1.95
1200.00	453.65	2.30	0.92	0.40	350.00	0.06	9.20	9.70	15045.00	23.08	1.78
1600.00	532.54	3.60	1.32	0.37	426.00	0.05	9.90	8.30	20792.00	22.40	1.72
2000.00	508.87	4.30	1.69	0.39	459.00	0.03	10.60	7.80	23613.00	19.79	1.52
2400.00	512.82	5.20	2.11	0.40	510.00	0.03	11.10	7.70	28993.00	19.51	1.50

DATE 2/5/91 DESCRIPTION
TEST CYCLE E6S DATA FILE E6S03
FUEL 6.2/10/320

SPEED (RPM)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
800.00	414.20	1.40	0.57	0.41	257.00	0.05	8.10	10.90	10239.00	25.27	1.94
1200.00	394.48	2.00	0.87	0.44	289.00	0.05	9.20	11.10	15045.00	24.37	1.87
1600.00	488.16	3.30	1.39	0.42	372.00	0.06	9.20	9.50	20792.00	21.25	1.63
2000.00	497.04	4.20	1.82	0.43	431.00	0.04	10.10	8.10	23613.00	18.41	1.42
2400.00	581.85	5.90	2.11	0.36	494.00	0.04	11.20	7.40	28993.00	19.51	1.50
		0.98	1.02		368.60	1.14	0.96	1.07			8.37

DATE 2/5/91 DESCRIPTION
TEST CYCLE E6FS DATA FILE E6FS02
FUEL DIESEL

SPEED (RPM)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
800.00	650.89	2.20	1.03	0.47	483.00	1.24	13.30	2.60	10239.00	14.10	1.08
1200.00	670.61	3.40	1.59	0.47	585.00	1.86	13.70	1.70	15045.00	13.38	1.03
1600.00	710.06	4.80	2.18	0.45	633.00	2.42	13.60	1.30	20792.00	13.53	1.04
2000.00	674.56	5.70	2.85	0.50	673.00	3.39	13.20	1.00	23613.00	11.73	0.90
2400.00	670.61	6.80	3.51	0.52	708.00	3.91	13.10	0.80	28993.00	11.69	0.90
					616.40						

DATE 2/5/91 DESCRIPTION
TEST CYCLE E6FS DATA FILE E6FS03
FUEL 6.2/10/320

SPEED (RPM)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
800.00	621.30	2.10	1.08	0.51	451.00	0.97	14.00	2.80	10239.00	13.48	1.04
1200.00	631.16	3.20	1.63	0.51	558.00	1.30	14.10	2.40	15045.00	13.05	1.00
1600.00	665.68	4.50	2.21	0.49	605.00	1.52	14.10	1.70	20792.00	13.35	1.03
2000.00	603.55	5.10	2.93	0.57	654.00	2.55	14.00	1.60	23613.00	11.43	0.88
2400.00	660.75	6.70	3.75	0.56	689.00	3.46	14.00	0.80	28993.00	10.95	0.84
		0.94	1.04		591.40	0.75	1.05	1.28			4.79

DATE 2/5/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1802
FUEL DIESEL

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	131.49	1.00	0.85	0.41	219.00	0.00	4.10	14.60	22881.00	37.94	2.92
50.00	420.78	3.20	1.20	0.38	346.00	0.00	7.40	10.80	22881.00	26.95	2.07
60.00	565.42	4.30	1.63	0.38	484.00	0.00	7.00	10.30	22881.00	19.85	1.53
70.00	683.76	5.20	2.07	0.40	618.00	0.19	13.70	2.60	22881.00	15.67	1.21
80.00	696.91	5.30	2.48	0.47	657.00	2.68	13.20	1.00	22881.00	13.06	1.00
90.00	696.91	5.30	2.82	0.53	647.00	4.57	11.90	0.80	22881.00	11.49	0.88
					495.17						

DATE 2/5/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1803
FUEL 6.2/10/320

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	197.24	1.50	0.86	0.57	220.00	0.00	4.70	13.80	22881.00	37.85	2.91
50.00	381.33	2.90	1.25	0.43	311.00	0.03	7.00	11.10	22881.00	25.98	2.00
60.00	565.42	4.30	1.65	0.38	423.00	0.05	9.50	8.10	22881.00	19.67	1.51
70.00	644.31	4.90	2.11	0.43	541.00	0.12	12.10	4.50	22881.00	15.39	1.18
80.00	696.91	5.30	2.48	0.47	619.00	1.39	13.40	1.90	22881.00	13.07	1.01
90.00	696.91	5.30	2.85	0.54	637.00	3.44	12.70	1.10	22881.00	11.36	0.87
					506.20	ERR	1.05	1.36			6.57

DATE 3/5/91 DESCRIPTION
TEST CYCLE S12 DATA FILE S1202
FUEL DIESEL

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	-1.97	-0.01	ERR	ERR	140.00	0.08	3.00	17.50	15045.00	ERR	ERR
50.00	256.41	1.30	0.65	0.50	243.00	0.00	6.50	14.20	15045.00	32.71	2.52
60.00	473.37	2.40	0.99	0.41	378.00	0.07	9.80	11.20	15045.00	21.54	1.66
70.00	591.72	3.00	1.30	0.43	523.00	0.20	13.40	7.40	15045.00	16.38	1.26
80.00	611.44	3.10	1.61	0.52	589.00	2.18	13.70	5.50	15045.00	13.26	1.02
90.00	611.44	3.10	1.86	0.60	593.00	4.11	12.80	4.90	15045.00	11.44	0.88
					411.00						

DATE 3/5/91 DESCRIPTION
TEST CYCLE S12 DATA FILE S1203
FUEL 6.2/10/320

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	-19.72	-0.10	ERR	ERR	151.00	0.00	2.00	17.20	15045.00	ERR	ERR
50.00	256.41	1.30	0.65	0.50	211.00	0.00	5.90	14.40	15045.00	32.71	2.52
60.00	473.37	2.40	0.99	0.41	328.00	0.07	8.80	11.80	15045.00	21.54	1.66
70.00	591.72	3.00	1.30	0.43	460.00	0.14	11.50	8.70	15045.00	16.38	1.26
80.00	650.89	3.30	1.61	0.49	549.00	1.11	13.50	6.00	15045.00	13.26	1.02
90.00	650.89	3.30	1.86	0.56	571.00	3.18	13.00	5.00	15045.00	11.44	0.88
		1.03	1.00		423.80	ERR	0.93	1.07			7.33

DATE 15/5/91 DESCRIPTION
TEST CYCLE S24 DATA FILE S24021
FUEL DIESEL

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
40.00	138.07	1.40	1.14	0.82	283.00	0.00	5.70	13.70	28993.00	35.89	2.76
50.00	374.75	3.80	1.71	0.45	409.00	0.00	9.00	9.80	28993.00	24.06	1.85
60.00	571.99	5.80	2.55	0.44	561.00	0.00	12.60	5.80	28993.00	16.09	1.24
70.00	660.75	6.70	2.97	0.44	705.00	1.22	15.60	0.70	28993.00	13.85	1.07
80.00	670.61	6.80	3.47	0.51	697.00	4.56	13.50	0.50	28993.00	11.83	0.91
90.00	660.75	6.70	4.19	0.62	676.00	6.60	12.10	0.40	28993.00	9.81	0.75
					555.17						

DATE 15/5/91 DESCRIPTION
TEST CYCLE S24 DATA FILE S24031
FUEL 6.2/10/320

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
40.00	325.44	3.30	1.60	0.48	350.00	0.03	7.00	11.10	28993.00	25.72	1.98
50.00	502.96	5.10	2.07	0.41	455.00	0.04	9.50	8.20	28993.00	19.88	1.53
60.00	641.02	6.50	2.62	0.40	578.00	0.05	12.50	4.60	28993.00	15.70	1.21
70.00	700.20	7.10	3.03	0.43	669.00	0.71	14.00	1.70	28993.00	13.58	1.04
80.00	710.06	7.20	3.46	0.48	698.00	3.48	13.40	0.60	28993.00	11.87	0.91
90.00	710.06	7.20	4.30	0.60	683.00	5.47	12.20	0.80	28993.00	9.55	0.73
		1.06	1.06		616.60	ERR	0.99	1.45			5.43

DATE 23/5/91 DESCRIPTION
TEST CYCLE E6S DATA FILE E6S022
FUEL DIESEL

SPEED (RPM)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
800.00	473.37	1.60	0.66	0.41	329.00	0.06	10.30	8.60	10239.00	21.92	1.69
1200.00	493.10	2.50	1.03	0.41	394.00	0.05	10.50	8.10	15045.00	20.74	1.60
1600.00	502.96	3.40	1.37	0.40	434.00	0.03	10.40	8.00	20792.00	21.47	1.65
2000.00	568.05	4.80	1.94	0.40	530.00	0.03	12.40	5.70	23613.00	17.27	1.33
2400.00	542.41	5.50	2.41	0.44	575.00	0.03	13.10	4.90	28993.00	17.07	1.31
					452.40						

DATE 23/5/91 DESCRIPTION
TEST CYCLE E6S DATA FILE E6S04
FUEL 6.2/05/220

SPEED (RPM)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
800.00	502.96	1.70	0.66	0.39	312.00	0.10	9.40	8.70	10239.00	21.92	1.69
1200.00	493.10	2.50	1.03	0.41	364.00	0.09	9.20	8.70	15045.00	20.76	1.60
1600.00	502.96	3.40	1.40	0.41	402.00	0.08	9.50	8.40	20792.00	21.10	1.62
2000.00	603.55	5.10	2.01	0.39	503.00	0.07	11.20	6.40	23613.00	16.61	1.28
2400.00	621.30	6.30	2.50	0.40	603.00	0.05	13.10	4.20	28993.00	16.43	1.26
		1.05	1.02		436.80	2.03	0.92	1.02			7.45

DATE 23/5/91 DESCRIPTION
TEST CYCLE E6FS DATA FILE E6FS022
FUEL DIESEL

SPEED	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(RPM)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
800.00	591.72	2.00	1.19	0.60	473.00	2.56	13.30	2.10	10239.00	12.18	0.94
1200.00	650.89	3.30	1.80	0.55	587.00	3.68	13.50	1.70	15045.00	11.84	0.91
1600.00	665.68	4.50	2.41	0.54	625.00	3.83	13.60	1.00	20792.00	12.23	0.94
2000.00	627.22	5.30	3.12	0.59	665.00	4.66	13.20	0.80	23613.00	10.71	0.82
2400.00	670.61	6.80	4.07	0.60	675.00	6.22	12.40	0.70	28993.00	10.09	0.78
					605.00						

DATE 23/5/91 DESCRIPTION
TEST CYCLE E6FS DATA FILE E6FS04
FUEL 6.2/05/220

SPEED	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(RPM)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
800.00	650.89	2.20	1.19	0.54	469.00	2.41	12.90	2.50	10239.00	12.18	0.94
1200.00	670.61	3.40	1.86	0.55	579.00	2.98	13.10	1.70	15045.00	11.46	0.88
1600.00	680.47	4.60	2.42	0.53	631.00	3.18	13.30	1.50	20792.00	12.18	0.94
2000.00	686.39	5.80	3.08	0.53	662.00	2.11	13.50	1.20	23613.00	10.85	0.83
2400.00	700.20	7.10	4.07	0.57	680.00	4.97	12.60	0.70	28993.00	10.09	0.78
		1.06	1.00		604.20	0.77	0.99	1.24			4.37

DATE 29/5/91 DESCRIPTION
TEST CYCLE S24 DATA FILE S24022
FUEL Diesel

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	256.41	2.60	1.85	0.71	336.00	0.00	7.30	10.80	28993.00	22.26	1.71
50.00	483.23	4.90	1.87	0.38	480.00	0.00	6.90	10.30	28993.00	21.93	1.69
60.00	621.30	6.30	2.59	0.41	651.00	0.06	14.40	3.00	28993.00	15.85	1.22
70.00	650.89	6.60	3.23	0.49	707.00	2.62	14.30	0.90	28993.00	12.72	0.98
80.00	650.89	6.60	3.93	0.60	684.00	5.72	12.20	0.50	28993.00	10.44	0.80
90.00	641.02	6.50	4.48	0.69	668.00	7.16	11.20	0.50	28993.00	9.17	0.71
					587.67						

DATE 29/5/91 DESCRIPTION
TEST CYCLE S24 DATA FILE S2404
FUEL 6.2/05/220

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	374.75	3.80	1.85	0.49	412.00	0.00	9.50	9.10	28993.00	22.26	1.71
50.00	522.68	5.30	2.33	0.44	531.00	0.03	12.50	6.00	28993.00	17.61	1.35
60.00	650.89	6.60	2.90	0.44	665.00	0.37	15.60	2.10	28993.00	14.18	1.09
70.00	710.06	7.20	3.46	0.48	694.00	3.05	14.50	0.90	28993.00	11.87	0.91
80.00	660.75	6.70	4.19	0.62	679.00	5.15	13.00	1.00	28993.00	9.81	0.75
90.00	650.89	6.60	4.50	0.68	664.00	6.16	12.20	0.50	28993.00	9.13	0.70
		1.12	1.08		607.52	ERR	1.23				

DATE 29/5/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S18022
FUEL DIESEL

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	262.98	2.00	0.92	0.46	249.00	0.00	5.82	12.10	22881.00	35.19	2.71
50.00	499.67	3.80	1.38	0.36	405.00	0.04	9.00	8.60	22881.00	23.46	1.80
60.00	644.31	4.90	1.86	0.38	558.00	0.08	12.50	4.30	22881.00	17.47	1.34
70.00	710.06	5.40	2.34	0.43	651.00	1.85	14.00	1.20	22881.00	13.87	1.07
80.00	710.06	5.40	2.81	0.52	652.00	3.94	12.50	0.70	22881.00	11.55	0.89
90.00	696.91	5.30	3.19	0.60	637.00	6.03	11.30	0.70	22881.00	10.18	0.78
					525.33						

DATE 29/5/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1804
FUEL 6.2/05/220

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	276.13	2.10	0.85	0.40	245.00	0.00	6.00	12.80	22881.00	38.18	2.94
50.00	473.37	3.60	1.42	0.40	369.00	0.03	8.80	9.40	22881.00	22.79	1.75
60.00	618.01	4.70	1.84	0.39	502.00	0.08	11.60	5.90	22881.00	17.62	1.36
70.00	657.46	5.00	2.33	0.47	619.00	0.99	14.00	2.20	22881.00	13.89	1.07
80.00	657.46	5.00	2.81	0.56	644.00	3.57	13.30	1.50	22881.00	11.55	0.89
90.00	670.61	5.10	3.23	0.63	637.00	5.16	12.20	1.00	22881.00	10.05	0.77
		0.96	0.99		502.67	0.81	1.01				

DATE 29/5/91 DESCRIPTION
TEST CYCLE S12 DATA FILE S12022
FUEL DIESEL

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	-3.94	-0.02	ERR	ERR	139.00	0.04	3.90	14.20	15045.00	ERR	ERR
50.00	256.41	1.30	0.79	0.61	243.00	0.05	7.50	10.10	15045.00	27.08	2.08
60.00	473.37	2.40	1.15	0.48	382.00	0.11	10.80	6.10	15045.00	18.52	1.42
70.00	591.72	3.00	1.49	0.50	522.00	0.79	13.40	2.70	15045.00	14.33	1.10
80.00	611.44	3.10	1.84	0.59	590.00	3.59	12.20	1.30	15045.00	11.61	0.89
90.00	611.44	3.10	2.13	0.69	594.00	5.55	10.90	0.90	15045.00	10.02	0.77
					411.67						

DATE 29/5/91 DESCRIPTION
TEST CYCLE S12 DATA FILE S1204
FUEL 6.2/05/220

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	118.34	0.60	ERR	ERR	155.00	0.00	3.80	14.70	15045.00	ERR	ERR
50.00	374.75	1.90	0.79	0.42	272.00	0.04	7.30	10.80	15045.00	26.84	2.06
60.00	571.99	2.90	1.14	0.39	455.00	0.10	10.20	7.20	15045.00	18.70	1.44
70.00	650.89	3.30	1.49	0.45	535.00	0.56	13.10	3.30	15045.00	14.31	1.10
80.00	650.89	3.30	1.84	0.56	579.00	3.04	12.80	2.20	15045.00	11.60	0.89
90.00	650.89	3.30	2.11	0.64	578.00	4.95	11.80	1.10	15045.00	10.08	0.78
		1.18	1.00		429.00	0.84	1.01				

DATE 3/6/91 DESCRIPTION
TEST CYCLE E6S DATA FILE E6S023
FUEL DIESEL

SPEED (RPM)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
800.00	502.96	1.70	0.66	0.39	337.00	0.06	10.10	8.00	10239.00	21.92	1.69
1200.00	512.82	2.60	1.00	0.38	397.00	0.05	10.10	7.30	15045.00	21.37	1.64
1600.00	517.75	3.50	1.32	0.38	423.00	0.03	10.20	7.70	20792.00	22.32	1.72
2000.00	568.05	4.80	1.85	0.39	512.00	0.04	11.90	6.10	23613.00	18.09	1.39
2400.00	571.99	5.80	2.33	0.40	577.00	0.04	12.80	4.60	28993.00	17.60	1.35
		18.40	7.16	1.94	449.20	0.22	55.10	33.70			7.79

DATE 3/6/91 DESCRIPTION
TEST CYCLE E6S DATA FILE E6S05
FUEL 6.2/02/140

SPEED (RPM)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
800.00	502.96	1.70	0.67	0.40	316.00	0.08	9.90	7.30	10239.00	21.58	1.66
1200.00	493.10	2.50	1.01	0.40	375.00	0.07	9.70	7.40	15045.00	21.05	1.62
1600.00	488.16	3.30	1.35	0.41	411.00	0.04	9.80	7.10	20792.00	21.76	1.67
2000.00	556.21	4.70	1.98	0.42	514.00	0.06	11.90	5.10	23613.00	16.89	1.30
2400.00	631.16	6.40	2.59	0.40	627.00	0.05	14.10	2.60	28993.00	15.88	1.22
		18.60	7.61	2.04	448.60	0.30	55.40	29.50			7.47

DATE 3/6/91 DESCRIPTION
TEST CYCLE E6FS DATA FILE E6FS023
FUEL DIESEL

SPEED (RPM)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
800.00	621.30	2.10	1.17	0.56	479.00	2.84	13.60	1.80	10239.00	12.37	0.95
1200.00	631.16	3.20	1.79	0.56	584.00	3.76	14.00	1.10	15045.00	11.91	0.92
1600.00	665.68	4.50	2.36	0.53	632.00	4.04	14.50	1.00	20792.00	12.47	0.96
2000.00	639.05	5.40	3.11	0.58	666.00	4.89	12.80	0.90	23613.00	10.74	0.83
2400.00	660.75	6.70	3.71	0.55	682.00	6.00	13.10	0.40	28993.00	11.08	0.85
		21.90	12.15	2.77	608.60	21.53	68.00	5.20			4.51

DATE 3/6/91 DESCRIPTION
TEST CYCLE E6FS DATA FILE E6FS05
FUEL 6.2/02/140

SPEED (RPM)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
800.00	650.89	2.20	1.18	0.53	455.00	2.55	12.90	1.90	10239.00	12.34	0.95
1200.00	631.16	3.20	1.83	0.57	568.00	3.45	12.70	1.30	15045.00	11.63	0.89
1600.00	636.09	4.30	2.40	0.56	624.00	3.53	13.00	1.00	20792.00	12.25	0.94
2000.00	639.05	5.40	3.15	0.58	663.00	4.43	12.80	1.10	23613.00	10.60	0.82
2400.00	660.75	6.70	3.70	0.55	670.00	5.52	12.00	1.00	28993.00	11.09	0.85
		21.80	12.27	2.80	596.00	19.48	63.40	6.30			4.45

DATE 4/6/91 DESCRIPTION
TEST CYCLE S24 DATA FILE S24023
FUEL DIESEL

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
40.00	236.69	2.40	1.40	0.58	341.00	0.00	7.50	9.40	28993.00	29.32	2.26
50.00	433.92	4.40	1.93	0.44	468.00	0.00	10.50	6.70	28993.00	21.25	1.63
60.00	591.72	6.00	2.36	0.39	626.00	0.05	14.20	3.30	28993.00	17.43	1.34
70.00	631.16	6.40	3.28	0.51	706.00	2.97	14.50	0.80	28993.00	12.51	0.96
80.00	641.02	6.50	3.93	0.60	677.00	5.80	12.30	0.70	28993.00	10.45	0.80
90.00	621.30	6.30	4.33	0.69	662.00	7.14	11.20	0.70	28993.00	9.48	0.73
		32.00	17.23	3.22	580.00	15.96	70.20	21.60			7.73

DATE 4/6/91 DESCRIPTION
TEST CYCLE S24 DATA FILE S2405
FUEL 6.2/02/140

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
40.00	404.34	4.10	1.75	0.43	413.00	0.04	8.70	8.20	28993.00	23.52	1.81
50.00	542.41	5.50	2.18	0.40	509.00	0.04	10.80	5.70	28993.00	18.87	1.45
60.00	641.02	6.50	2.49	0.38	606.00	0.04	12.60	4.10	28993.00	16.48	1.27
70.00	690.33	7.00	2.92	0.42	693.00	1.92	14.10	0.70	28993.00	14.05	1.08
80.00	700.20	7.10	3.78	0.53	688.00	4.67	12.50	0.50	28993.00	10.85	0.83
90.00	660.75	6.70	4.22	0.63	664.00	7.21	14.30	0.30	28993.00	9.73	0.75
		36.90	17.35	2.79	595.50	13.92	73.00	19.50			7.19

DATE 4/6/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1805
FUEL DIESEL

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
40.00	210.39	1.60	0.87	0.54	230.00	0.00	5.20	11.40	22881.00	37.46	2.88
50.00	486.52	3.70	1.35	0.36	382.00	0.00	8.90	7.50	22881.00	24.09	1.85
60.00	618.01	4.70	1.68	0.36	515.00	0.04	12.10	4.50	22881.00	19.33	1.49
70.00	670.61	5.10	2.28	0.45	638.00	1.33	14.30	1.40	22881.00	14.21	1.09
80.00	670.61	5.10	2.63	0.52	648.00	4.24	12.60	1.60	22881.00	12.32	0.95
90.00	670.61	5.10	3.16	0.62	638.00	5.60	11.90	0.60	22881.00	10.27	0.79
		25.30	11.96	2.84	508.50	11.21	65.00	27.00			9.05

DATE 4/6/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1805
FUEL 6.2/02/140

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
40.00	289.28	2.20	0.96	0.43	274.00	0.00	5.80	11.50	22881.00	33.93	2.61
50.00	499.67	3.80	1.41	0.37	395.00	0.04	8.70	7.80	22881.00	22.98	1.77
60.00	631.16	4.80	1.84	0.38	527.00	0.08	11.80	4.50	22881.00	17.63	1.36
70.00	670.61	5.10	2.33	0.46	633.00	1.60	13.50	1.90	22881.00	13.91	1.07
80.00	644.31	4.90	2.65	0.54	653.00	3.99	12.40	1.10	22881.00	12.25	0.94
90.00	657.46	5.00	3.16	0.63	646.00	5.38	11.40	1.00	22881.00	10.27	0.79
		25.80	12.34	2.82	521.33	11.09	63.60	27.80			8.54

DATE 4/6/91 DESCRIPTION
TEST CYCLE S12 DATA FILE S12023
FUEL DIESEL

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	98.62	0.50	ERR	ERR	157.00	0.00	3.40	13.00	15045.00	ERR	ERR
50.00	414.20	2.10	0.76	0.36	286.00	0.04	7.20	9.70	15045.00	27.89	2.15
60.00	611.44	2.90	1.10	0.36	433.00	0.09	10.90	5.80	15045.00	19.31	1.49
70.00	690.33	3.30	1.44	0.41	464.00	0.78	13.60	2.20	15045.00	14.80	1.14
80.00	690.33	3.30	1.82	0.52	592.00	3.52	12.40	1.60	15045.00	11.74	0.90
90.00	650.89	3.20	2.09	0.63	577.00	5.61	10.90	1.10	15045.00	10.22	0.79
		16.00	ERR	ERR	418.17	10.04	58.40	33.40			ERR

DATE 4/6/91 DESCRIPTION
TEST CYCLE S12 DATA FILE S1205
FUEL 6.2/02/140

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	118.34	0.60	ERR	ERR	166.00	0.00	3.70	13.40	15045.00	ERR	ERR
50.00	394.48	2.00	0.79	0.40	285.00	0.04	7.20	9.40	15045.00	26.86	2.07
60.00	571.99	2.90	1.15	0.39	432.00	0.11	10.40	5.90	15045.00	18.62	1.43
70.00	650.89	3.30	1.49	0.45	550.00	0.84	13.10	2.60	15045.00	14.28	1.10
80.00	650.89	3.30	1.82	0.55	578.00	3.36	12.30	1.30	15045.00	11.74	0.90
90.00	631.16	3.20	2.14	0.67	576.00	5.14	11.10	1.00	15045.00	9.97	0.77
		15.30	ERR	ERR	431.17	9.49	57.80	33.60			ERR

DATE 10/6/91 DESCRIPTION
TEST CYCLE E6S DATA FILE E6S024
FUEL DIESEL

SPEED	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(RPM)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
800.00	473.37	1.60	0.65	0.41	315.00	0.06	9.90	6.00	10239.00	22.22	1.71
1200.00	473.37	2.40	1.01	0.42	374.00	0.06	9.90	6.20	15045.00	21.05	1.62
1600.00	488.16	3.30	1.35	0.41	425.00	0.04	10.30	5.90	20792.00	21.83	1.68
2000.00	556.21	4.70	1.88	0.40	515.00	0.03	11.90	4.50	23613.00	17.77	1.37
2400.00	552.27	5.60	2.29	0.41	566.00	0.03	12.60	3.70	28993.00	17.91	1.38
		17.60	7.19	2.05	439.00	0.22	54.60	26.30			7.75

DATE 10/6/91 DESCRIPTION
TEST CYCLE E6S DATA FILE E6S06
FUEL 6.2/15/540

SPEED	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(RPM)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
800.00	502.96	1.70	0.67	0.40	294.00	0.08	9.10	6.50	10239.00	21.58	1.66
1200.00	473.37	2.40	1.01	0.42	333.00	0.07	8.90	7.00	15045.00	21.05	1.62
1600.00	473.37	3.20	1.35	0.42	366.00	0.05	9.10	6.60	20792.00	21.76	1.67
2000.00	544.38	4.60	1.98	0.43	456.00	0.06	10.70	5.20	23613.00	16.89	1.30
2400.00	591.72	6.00	2.59	0.43	564.00	0.05	12.80	3.60	28993.00	15.88	1.22
		17.90	7.61	2.10	402.60	0.31	50.60	28.90			7.47

DATE 10/6/91 DESCRIPTION
TEST CYCLE E6FS DATA FILE E6FS024
FUEL DIESEL

SPEED	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(RPM)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
800.00	562.13	1.90	1.15	0.61	467.00	2.93	12.10	1.90	10239.00	12.61	0.97
1200.00	591.72	3.00	1.77	0.59	472.00	3.60	12.70	0.90	15045.00	12.04	0.93
1600.00	636.09	4.30	2.45	0.56	618.00	4.40	14.20	0.70	20792.00	12.27	0.94
2000.00	639.05	5.40	3.10	0.57	650.00	4.89	12.80	0.90	23613.00	10.79	0.83
2400.00	621.30	6.30	3.96	0.63	670.00	5.57	13.10	0.40	28993.00	10.37	0.80
		20.90	12.38	2.96	575.40	21.39	64.90	4.80			4.47

DATE 10/6/91 DESCRIPTION
TEST CYCLE E6FS DATA FILE E6FS06
FUEL 6.2/15/540

SPEED	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(RPM)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
800.00	621.30	2.10	1.22	0.58	458.00	2.03	12.20	2.80	10239.00	11.90	0.92
1200.00	650.89	3.30	1.85	0.56	547.00	2.30	13.10	1.90	15045.00	11.54	0.89
1600.00	650.89	4.40	2.45	0.56	604.00	2.48	13.30	1.50	20792.00	12.03	0.93
2000.00	674.56	5.70	3.26	0.57	644.00	3.47	13.00	1.40	23613.00	10.27	0.79
2400.00	650.89	6.60	4.11	0.62	677.00	4.16	13.10	0.60	28993.00	10.00	0.77
		22.10	12.88	2.89	586.00	14.34	64.70	8.20			4.29

DATE 11/6/91 DESCRIPTION
TEST CYCLE S24 DATA FILE S24024
FUEL DIESEL

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	236.69	2.40	1.36	0.57	338.00	0.00	6.80	8.60	28993.00	30.27	2.33
50.00	473.37	4.80	1.99	0.42	485.00	0.03	10.80	5.40	28993.00	20.61	1.59
60.00	611.44	6.20	2.64	0.43	652.00	0.11	14.70	2.00	28993.00	15.55	1.20
70.00	641.02	6.50	3.29	0.51	689.00	3.19	13.90	0.90	28993.00	12.47	0.96
80.00	641.02	6.50	3.95	0.61	677.00	5.78	11.80	0.70	28993.00	10.39	0.80
90.00	631.16	6.40	4.52	0.71	656.00	6.84	10.80	0.80	28993.00	9.08	0.70
		32.80	17.76	3.23	581.17	15.95	68.80	18.40			7.57

DATE 11/6/91 DESCRIPTION
TEST CYCLE S24 DATA FILE S2406
FUEL 6.2/15/540

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	AIR FLOW	A/F RATIO	EQ RATIO
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	(L/HR)	STOICH'=13	
40.00	374.75	3.80	1.88	0.49	383.00	0.00	8.30	7.20	28993.00	21.91	1.69
50.00	522.68	5.30	2.34	0.44	481.00	0.03	10.60	5.40	28993.00	17.56	1.35
60.00	631.16	6.40	2.86	0.45	596.00	0.10	13.20	2.90	28993.00	14.38	1.11
70.00	670.61	6.80	3.44	0.51	674.00	1.73	14.00	1.20	28993.00	11.94	0.92
80.00	670.61	6.80	4.01	0.59	683.00	3.89	13.10	0.80	28993.00	10.25	0.79
90.00	650.89	6.60	4.81	0.73	647.00	5.24	12.10	0.70	28993.00	8.53	0.66
		35.70	19.33	3.21	577.33	10.99	71.30	18.20			6.51

DATE 11/6/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S18024
FUEL DIESEL

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
40.00	236.69	1.80	0.89	0.49	259.00	0.04	5.40	9.40	22881.00	36.57	2.81
50.00	499.67	3.80	1.41	0.37	404.00	0.04	8.90	6.70	22881.00	23.06	1.77
60.00	618.01	4.70	1.86	0.40	551.00	0.07	12.20	3.80	22881.00	17.46	1.34
70.00	670.61	5.10	2.31	0.45	649.00	1.86	13.40	1.50	22881.00	14.04	1.08
80.00	670.61	5.10	2.76	0.54	648.00	4.43	11.90	1.10	22881.00	11.74	0.90
90.00	644.31	4.90	3.18	0.65	635.00	6.05	10.80	0.80	22881.00	10.18	0.78
		25.40	12.40	2.90	524.33	12.49	62.60	23.30			8.70

DATE 11/6/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1806
FUEL 6.2/15/540

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
40.00	157.79	1.20	1.07	0.90	225.00	0.00	5.40	10.00	22881.00	30.18	2.32
50.00	394.48	3.00	1.43	0.48	334.00	0.04	8.20	7.70	22881.00	22.60	1.74
60.00	552.27	4.20	1.88	0.45	458.00	0.10	10.80	5.10	22881.00	17.22	1.32
70.00	618.01	4.70	2.39	0.51	578.00	0.55	13.70	2.50	22881.00	13.54	1.04
80.00	631.16	4.80	2.79	0.58	617.00	3.00	13.20	1.50	22881.00	11.61	0.89
90.00	618.01	4.70	3.21	0.68	617.00	4.45	12.30	1.00	22881.00	10.10	0.78
		22.60	12.79	3.60	471.50	8.14	63.60	27.80			8.10

DATE 11/6/91 DESCRIPTION
TEST CYCLE S12 DATA FILE S12024
FUEL DIESEL

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
40.00	78.90	0.40	ERR	ERR	155.00	0.00	3.60	11.00	15045.00	ERR	ERR
50.00	374.75	1.90	0.76	0.40	278.00	0.03	7.10	8.20	15045.00	27.87	2.14
60.00	552.27	2.80	1.11	0.40	430.00	0.08	10.50	5.10	15045.00	19.23	1.48
70.00	631.16	3.20	1.45	0.45	558.00	0.91	13.20	2.20	15045.00	14.71	1.13
80.00	650.89	3.30	1.77	0.54	582.00	3.34	12.30	1.40	15045.00	12.03	0.93
90.00	591.72	3.00	2.11	0.70	581.00	5.29	10.90	0.90	15045.00	10.11	0.78
		14.60	ERR	ERR	430.67	9.65	57.60	28.80			ERR

DATE 11/6/91 DESCRIPTION
TEST CYCLE S12 DATA FILE S1206
FUEL 6.2/15/540

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	AIR FLOW (L/HR)	A/F RATIO STOICH'=13	EQ RATIO
40.00	000.00	0.00	ERR	ERR	152.00	0.00	3.50	11.20	15045.00	ERR	ERR
50.00	276.13	1.40	0.79	0.57	247.00	0.03	7.30	8.40	15045.00	26.87	2.07
60.00	473.37	2.40	1.14	0.48	366.00	0.10	10.10	6.20	15045.00	18.62	1.43
70.00	571.99	2.90	1.50	0.52	484.00	0.33	12.90	3.50	15045.00	14.26	1.10
80.00	611.44	3.10	1.80	0.58	544.00	2.25	13.50	1.90	15045.00	11.85	0.91
90.00	631.16	3.20	2.10	0.65	555.00	3.95	12.80	1.20	15045.00	10.17	0.78
		13.00	ERR	ERR	391.33	6.66	60.10	32.40			ERR

APPENDIX 3

RESULTS FOR FUELS CONTAINING ADDITIVE 3.24

DATE 5/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1810
FUEL 3.24/05/300

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
40.00	249.84	1.90	0.94	0.49	257.00	0.00	5.60	13.10	34.49	2.64	6.50
50.00	460.22	3.50	1.40	0.40	370.00	0.04	8.30	11.90	23.19	1.77	7.60
60.00	591.72	4.50	1.85	0.41	505.00	0.11	11.20	10.30	17.51	1.34	8.70
70.00	631.16	4.80	2.33	0.48	611.00	1.34	13.20	7.60	13.94	1.07	8.70
80.00	631.16	4.80	2.77	0.58	632.00	3.76	12.10	7.90	11.71	0.89	8.70
90.00	618.01	4.70	3.17	0.67	620.00	5.16	11.00	3.90	10.23	0.78	7.30

DATE 5/7/91 DESCRIPTION
TEST CYCLE SI1810 DATA FILE MANUAL
FUEL 3.24/05/300

STATIC INJ (°'s BTDC)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
34	578.57	4.40	1.86	0.42	518.00	0.07	11.80	8.80	17.45	1.33	5.00
36	565.42	4.30	1.85	0.43	518.00	0.09	12.20	10.20	17.49	1.34	7.20
NORM.38	565.42	4.30	1.84	0.43	511.00	0.11	11.90	10.30	17.64	1.35	8.50
40	565.42	4.30	1.83	0.42	504.00	0.14	11.70	10.00	17.74	1.36	9.60
42	552.27	4.20	1.83	0.44	515.00	0.14	11.40	10.80	17.70	1.35	11.00

DATE 5/7/91 DESCRIPTION
TEST CYCLE SI1860 DATA FILE MANUAL
FUEL DIESEL

STATIC INJ (°'s BTDC)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
34	644.31	4.90	1.85	0.38	555.00	0.05	13.00	9.10	17.57	1.34	4.70
36	631.16	4.80	1.84	0.38	552.00	0.05	13.90	5.40	17.63	1.35	6.30
NORM.38	631.16	4.80	1.85	0.39	559.00	0.05	12.60	9.20	17.51	1.34	8.80
40	591.72	4.50	1.86	0.41	568.00	0.15	13.50	9.40	17.40	1.33	10.00
42	591.72	4.50	1.86	0.41	572.00	0.15	13.30	9.40	17.39	1.33	10.70

DATE 9/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1812
FUEL 3.24/03/150

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
40.00	262.98	2.00	0.95	0.48	265.00	0.00	5.60	12.50	33.96	2.60	6.70
50.00	473.37	3.60	1.39	0.39	387.00	0.00	8.50	10.70	23.38	1.79	8.00
60.00	604.87	4.60	1.85	0.40	523.00	0.08	11.60	8.30	17.54	1.34	8.40
70.00	644.31	4.90	2.33	0.48	626.00	1.61	13.30	6.50	13.90	1.06	8.70
80.00	644.31	4.90	2.79	0.57	645.00	3.79	12.00	5.70	11.63	0.89	8.70
90.00	618.01	4.70	3.18	0.68	641.00	5.23	10.90	2.40	10.20	0.78	8.30

DATE 9/7/91 DESCRIPTION
TEST CYCLE SI1860 DATA FILE MANUAL
FUEL 3.24/03/150

STATIC INJ (°'s BTDC)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
34	631.16	4.80	1.87	0.39	551.00	0.09	11.90	6.50	17.35	1.33	5.60
36	631.16	4.80	1.84	0.38	545.00	0.07	11.60	6.70	17.65	1.35	7.10
NORM.38	618.01	4.70	1.88	0.40	553.00	0.11	11.90	7.70	17.22	1.32	8.80
40	604.87	4.60	1.88	0.41	558.00	0.16	11.90	7.50	17.20	1.31	10.40
42	578.57	4.40	1.91	0.43	561.00	0.19	11.70	6.30	17.00	1.30	11.70

DATE 9/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S18027
FUEL DIESEL

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
40.00	197.24	1.50	0.95	0.63	257.00	0.00	5.90	10.90	34.22	2.62	6.70
50.00	460.22	3.50	1.38	0.39	400.00	0.00	9.50	7.30	23.53	1.80	7.50
60.00	618.01	4.60	1.85	0.40	545.00	0.03	13.00	3.80	17.48	1.34	7.20
70.00	657.46	4.90	2.29	0.47	642.00	1.48	14.60	1.30	14.16	1.08	7.30
80.00	644.31	4.90	2.74	0.56	643.00	4.24	12.30	1.30	11.81	0.90	7.30
90.00	631.16	4.80	3.17	0.66	627.00	5.73	10.80	7.80	10.22	0.78	7.30

DATE 10/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S18028
FUEL DIESEL

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
40.00	197.24	1.50	0.88	0.58	252.00	0.00	5.20	10.90	37.03	2.83	6.60
50.00	460.22	3.50	1.39	0.40	396.00	0.00	8.70	7.40	23.39	1.79	7.10
60.00	618.01	4.70	1.84	0.39	547.00	0.00	12.10	4.10	17.65	1.35	7.60
70.00	657.46	5.00	2.32	0.46	643.00	1.68	13.40	2.10	14.00	1.07	7.50
80.00	644.31	4.90	2.77	0.57	645.00	4.13	11.70	2.60	11.71	0.89	7.50
90.00	631.16	4.80	3.21	0.67	629.00	5.77	10.40	3.80	10.10	0.77	6.40

DATE 10/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1813
FUEL 3.24/07/320

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
40.00	276.13	2.10	0.89	0.42	255.00	0.00	5.10	10.80	36.38	2.78	6.50
50.00	460.22	3.50	1.43	0.41	376.00	0.03	8.40	7.90	22.74	1.74	7.30
60.00	604.87	4.60	1.88	0.41	504.00	0.09	11.10	7.90	17.25	1.32	8.40
70.00	657.46	5.00	2.34	0.47	609.00	1.15	13.10	5.70	13.88	1.06	8.40
80.00	657.46	5.00	2.79	0.56	634.00	3.52	12.10	3.80	11.62	0.89	8.10
90.00	644.31	4.90	3.19	0.65	632.00	4.99	11.20	4.70	10.18	0.78	7.30

DATE 10/7/91 DESCRIPTION
TEST CYCLE SI1860 DATA FILE MANUAL
FUEL 3.24/07/320

STATIC INJ (°'s BTDC)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
34	604.87	4.60	1.79	0.39	493.00	0.06	10.50	7.80	18.06	1.38	5.00
36	604.87	4.60	1.79	0.39	495.00	0.08	10.30	8.10	18.09	1.38	6.60
NORM.38	604.87	4.60	1.85	0.40	505.00	0.10	11.00	8.10	17.53	1.34	8.40
40	578.57	4.40	1.78	0.40	483.00	0.09	10.30	8.00	18.20	1.39	9.20
42	565.42	4.30	1.82	0.42	500.00	0.12	10.50	7.90	17.83	1.36	11.10

DATE 11/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S18029
FUEL DIESEL

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
40.00	203.81	1.55	0.90	0.58	263.00	0.00	5.80	12.60	35.91	2.75	6.70
50.00	433.93	3.30	1.37	0.42	398.00	0.00	9.00	8.50	23.66	1.81	7.30
60.00	552.27	4.20	1.81	0.43	543.00	0.06	12.40	4.20	17.88	1.37	7.80
70.00	591.72	4.50	2.27	0.50	644.00	1.71	13.70	1.30	14.27	1.09	7.80
80.00	618.01	4.70	2.74	0.58	637.00	4.32	12.10	2.10	11.82	0.90	7.40
90.00	604.87	4.60	3.09	0.67	624.00	5.83	10.90	7.20	10.49	0.80	7.40

DATE 11/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1814
FUEL 3.24/10/440

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
40.00	223.54	1.70	0.99	0.58	253.00	0.03	5.70	11.70	32.85	2.51	6.70
50.00	407.63	3.10	1.44	0.46	363.00	0.05	8.40	9.80	22.50	1.72	7.30
60.00	539.12	4.10	1.88	0.46	487.00	0.12	10.80	7.90	17.24	1.32	7.80
70.00	604.87	4.60	2.36	0.51	601.00	1.06	12.80	6.10	13.74	1.05	7.80
80.00	591.72	4.50	2.78	0.62	627.00	3.25	12.10	4.90	11.65	0.89	7.40
90.00	591.72	4.50	3.16	0.70	618.00	4.72	11.20	5.10	10.27	0.78	7.40

DATE 10/7/91 DESCRIPTION
TEST CYCLE SI1860 DATA FILE MANUAL
FUEL 3.24/10/440

STATIC INJ (°'s BTDC)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
34	591.72	4.50	1.85	0.41	498.00	0.09	11.10	4.60	17.50	1.34	4.50
36	598.29	4.55	1.87	0.41	499.00	0.10	11.10	4.70	17.31	1.32	6.60
NORM.38	578.57	4.40	1.87	0.43	496.00	0.11	10.70	8.20	17.32	1.32	7.70
40	571.99	4.35	1.85	0.43	497.00	0.13	10.60	8.10	17.48	1.34	9.50
42	558.84	4.25	1.87	0.44	497.00	0.14	10.40	7.60	17.32	1.32	10.90

APPENDIX 4

RESULTS FOR FUELS CONTAINING ADDITIVE 3.21

DATE 22/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S18030
FUEL DIESEL

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	A/F RATIO	EQ RATIO	SRPR
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	STOICH=13.08		(DEGS)
40.00	210.39	1.60	0.87	0.55	252.00	0.00	5.30	12.40	37.08	2.83	4.00
50.00	473.37	3.60	1.38	0.38	403.00	0.00	9.00	9.50	23.41	1.79	7.00
60.00	604.87	4.60	1.85	0.40	552.00	0.05	12.40	8.60	17.56	1.34	7.10
70.00	631.16	4.80	2.30	0.48	638.00	1.86	13.20	7.60	14.09	1.08	7.00
80.00	644.31	4.90	2.74	0.56	633.00	4.34	11.60	7.80	11.82	0.90	6.60
90.00	631.16	4.80	3.17	0.66	621.00	5.74	10.20	8.50	10.23	0.78	6.10

DATE 22/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1815
FUEL 3.21/03/220

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	A/F RATIO	EQ RATIO	SRPR
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	STOICH=13.08		(DEGS)
40.00	302.43	2.30	0.99	0.43	268.00	0.00	6.00	11.30	32.74	2.50	6.80
50.00	447.07	3.40	1.40	0.41	345.00	0.03	8.20	10.40	23.19	1.77	7.20
60.00	631.16	4.80	1.84	0.38	510.00	0.06	11.00	7.60	17.63	1.35	7.70
70.00	670.61	5.10	2.20	0.43	618.00	1.40	13.30	5.80	14.74	1.13	7.70
80.00	657.46	5.00	2.74	0.55	643.00	3.66	12.30	5.50	11.83	0.90	7.90
90.00	631.16	4.80	3.21	0.67	637.00	5.23	11.20	5.70	10.09	0.77	7.90

DATE 22/7/91 DESCRIPTION
TEST CYCLE SI1860 DATA FILE MANUAL
FUEL 3.21/03/220

STATIC INJ	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	A/F RATIO	EQ RATIO	SRPR
(°'s BTDC)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	STOICH=13.08		(DEGS)
34	591.72	4.50	1.85	0.41	498.00	0.09	11.10	4.60	17.50	1.34	5.90
36	598.29	4.55	1.87	0.41	499.00	0.10	11.10	4.70	17.31	1.32	7.50
NORM.38	578.57	4.40	1.87	0.43	496.00	0.11	10.70	8.20	17.32	1.32	9.20
40	571.99	4.35	1.85	0.43	497.00	0.13	10.60	8.10	17.48	1.34	10.30
42	558.84	4.25	1.87	0.44	497.00	0.14	10.40	7.60	17.32	1.32	11.90

DATE 26/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S18031
FUEL DIESEL

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	A/F RATIO	EQ RATIO	SRPR
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	STOICH=13.08		(DEGS)
40.00	223.54	1.70	0.89	0.52	253.00	0.00	5.80	14.10	36.42	2.78	4.20
50.00	486.52	3.70	1.38	0.37	400.00	0.00	9.00	12.00	23.42	1.79	6.70
60.00	631.16	4.80	1.86	0.39	546.00	0.05	12.40	9.60	17.44	1.33	6.70
70.00	683.76	5.20	2.33	0.45	641.00	1.70	13.70	7.10	13.92	1.06	6.70
80.00	670.61	5.10	2.68	0.53	643.00	4.30	12.10	8.20	12.08	0.92	6.70
90.00	644.31	4.90	3.19	0.65	625.00	5.85	10.90	9.00	10.15	0.78	6.30

DATE 26/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1816
FUEL 3.21/05/360

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	A/F RATIO	EQ RATIO	SRPR
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	STOICH=13.08		(DEGS)
40.00	262.98	2.00	0.99	0.49	261.00	0.00	5.60	13.30	32.82	2.51	6.40
50.00	499.67	3.80	1.42	0.37	380.00	0.00	8.20	11.80	22.77	1.74	7.30
60.00	631.16	4.80	1.89	0.39	509.00	0.09	11.20	10.10	17.19	1.31	8.40
70.00	670.61	5.10	2.35	0.46	569.00	1.39	13.10	8.60	13.79	1.05	8.40
80.00	670.61	5.10	2.70	0.53	637.00	3.43	12.20	8.80	12.01	0.92	7.60
90.00	670.61	5.10	3.22	0.63	629.00	4.90	11.10	8.70	10.06	0.77	7.70

DATE 26/7/91 DESCRIPTION
TEST CYCLE SI1860 DATA FILE MANUAL
FUEL 3.21/05/360

STATIC INJ	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	A/F RATIO	EQ RATIO	SRPR
(°'s BTDC)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	STOICH=13.08		(DEGS)
34	618.01	4.70	1.85	0.39	533.00	0.09	11.50	10.10	17.50	1.34	4.90
36	618.01	4.70	1.87	0.40	533.00	0.09	11.40	10.00	17.31	1.32	6.80
NORM.38	618.01	4.70	1.87	0.40	541.00	0.12	11.50	9.80	17.32	1.32	8.40
40	604.87	4.60	1.85	0.40	538.00	0.13	11.40	10.00	17.49	1.34	9.70
42	578.57	4.40	1.87	0.43	533.00	0.16	11.20	10.10	17.32	1.32	11.10

DATE 29/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S18032
FUEL DIESEL

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	A/F RATIO	EQ RATIO	SRPR
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	STOICH=13.08		(DEGS)
40.00	197.24	1.50	0.89	0.59	254.00	0.00	5.30	14.50	36.42	2.78	4.10
50.00	460.22	3.50	1.40	0.40	402.00	0.00	8.90	11.90	23.21	1.77	6.70
60.00	618.01	4.70	1.86	0.39	548.00	0.05	12.30	9.40	17.47	1.34	6.70
70.00	670.61	5.10	2.30	0.45	641.00	1.60	13.90	7.90	14.09	1.08	6.70
80.00	670.61	5.10	2.72	0.53	638.00	4.26	12.10	8.30	11.90	0.91	6.70
90.00	631.16	4.80	3.19	0.66	622.00	5.85	10.90	8.50	10.16	0.78	6.70

DATE 29/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1817
FUEL 3.21/02/120

RACK POS	BMEP	POWER	FUEL FLOW	SFC	EXH.TEMP	CO	CO2	O2	A/F RATIO	EQ RATIO	SRPR
(%)	(KN/M^2)	(KW)	(L/HR)	(L/KW.HR)	(DEGS.C)	(%)	(%)	(%)	STOICH=13.08		(DEGS)
40.00	276.13	2.10	0.86	0.41	272.00	0.00	5.40	12.90	37.69	2.88	6.60
50.00	479.95	3.65	1.40	0.38	396.00	0.03	8.10	11.40	23.21	1.77	7.60
60.00	604.87	4.60	1.85	0.40	535.00	0.09	11.50	9.00	17.48	1.34	8.30
70.00	631.16	4.80	2.29	0.48	635.00	1.68	12.80	8.30	14.14	1.08	8.30
80.00	618.01	4.70	2.76	0.59	647.00	3.78	11.30	8.80	11.75	0.90	8.30
90.00	604.87	4.60	3.18	0.69	636.00	5.15	10.60	8.50	10.20	0.78	8.30

DATE 29/7/91 DESCRIPTION
TEST CYCLE SI1860 DATA FILE MANUAL
FUEL 3.21/02/120

STATIC INJ (°'s BTDC)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
34	604.87	4.60	1.85	0.40	544.00	0.07	11.60	8.00	17.50	1.34	5.60
36	591.72	4.50	1.87	0.42	545.00	0.08	11.50	8.00	17.31	1.32	7.00
NORM.38	591.72	4.50	1.87	0.42	541.00	0.10	11.50	8.20	17.32	1.32	8.30
40	565.42	4.30	1.85	0.43	543.00	0.12	11.40	7.90	17.48	1.34	9.90
42	552.27	4.20	1.87	0.45	545.00	0.14	11.30	8.00	17.32	1.32	11.50

DATE 31/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S18033
FUEL DIESEL

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
40.00	197.24	1.50	0.86	0.57	241.00	0.00	5.30	12.50	37.59	2.87	4.50
50.00	460.22	3.50	1.39	0.40	397.00	0.00	8.80	10.00	23.39	1.79	6.60
60.00	604.87	4.60	1.83	0.40	541.00	0.06	12.20	7.00	17.71	1.35	6.80
70.00	644.31	4.90	2.31	0.47	644.00	1.88	13.30	5.70	14.01	1.07	6.80
80.00	644.31	4.90	2.72	0.55	641.00	4.34	11.80	6.00	11.92	0.91	6.90
90.00	604.87	4.60	3.20	0.70	627.00	5.92	10.60	6.50	10.13	0.77	6.90

DATE 31/7/91 DESCRIPTION
TEST CYCLE S18 DATA FILE S1818
FUEL 3.21/01/80

RACK POS (%)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
40.00	276.13	2.10	0.91	0.43	268.00	0.00	5.70	11.60	35.56	2.72	6.50
50.00	420.78	3.20	1.39	0.43	399.00	0.03	8.50	9.70	23.34	1.78	7.50
60.00	565.42	4.30	1.83	0.43	544.00	0.07	11.50	7.40	17.70	1.35	8.20
70.00	578.57	4.40	2.30	0.52	636.00	1.80	12.50	6.30	14.08	1.08	8.20
80.00	565.42	4.30	2.75	0.64	644.00	4.09	11.30	6.90	11.79	0.90	8.20
90.00	552.27	4.20	3.18	0.76	636.00	5.32	10.60	6.90	10.19	0.78	8.20

DATE 31/7/91 DESCRIPTION
TEST CYCLE SI1860 DATA FILE MANUAL
FUEL 3.21/01/80

STATIC INJ (°'s BTDC)	BMEP (KN/M^2)	POWER (KW)	FUEL FLOW (L/HR)	SFC (L/KW.HR)	EXH.TEMP (DEGS.C)	CO (%)	CO2 (%)	O2 (%)	A/F RATIO STOICH=13.08	EQ RATIO	SRPR (DEGS)
34	539.12	4.10	1.85	0.45	555.00	0.08	11.70	8.00	17.50	1.34	5.80
36	552.27	4.20	1.87	0.45	557.00	0.08	11.60	8.00	17.31	1.32	7.40
NORM.38	552.27	4.20	1.87	0.45	563.00	0.12	11.70	7.90	17.32	1.32	8.50
40	525.97	4.00	1.85	0.46	560.00	0.13	11.60	7.90	17.48	1.34	10.00
42	499.67	3.80	1.87	0.49	558.00	0.15	11.40	7.90	17.32	1.32	11.70