Diesel Fuel Additives Testing Summary for Fishermen

An abstracted report from the Biofuels for the Fishing Industry project

prepared for:

The Sea Fish Industry Authority

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Executive Summary

This document provides a non-technical summary of fuel consumption tests on red diesel fuel additives, and comparison of these results with those from identical tests using red diesel alone. The test cycle used simulated a trawler operating a 20 hour 40 minute excursion from Newlyn and within this involved 3, 4 hour long trawl stages. This test cycle was established after discussion with local skippers from the Newlyn fleet and SeaFISH representatives. The tests were conducted at the Camborne School of Mines engine dynamometer test facility installed in the Holman's Test Mine in Cornwall. This facility was established as part of the Biofuels for Fishing Vessels project, commissioned by SeaFISH. Seven different diesel fuel additives were subjected to the trials.

The results of the work indicate that there was no significant effect of any of the additives tested on the fuel consumption of the test engine through the test cycle used. If the results from the tests are considered typical of real duty cycles, then use of additives would increase operating costs for fisherman as they would have to pay for the additive as well as for the fuel.

Results of tests using the same simulated test cycle but using bio-fuels revealed significant and appreciable differences in fuel consumption compared with the use of red diesel alone. However, sea trials in a ~10m potting boat conducted using the same 2 fuels revealed no identifiable differences in fuel economy. This highlights a need to determine real engine performance data from fishing vessels through direct observation. The engine dynamometer test cell could then be programmed with the observed duty cycles rather than simulated duty cycles to establish (with known levels of repeatability and confidence) whether the central finding of this report holds in the context of practical fishing operations.

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Preamble

Document Context

This report provides a non-technical summary of the results of fuel consumption performance trials on a series of diesel fuel additives carried out at the Camborne School of Mines (CSM) engine dynamometer test cell. CSM is an academic department of the University of Exeter. The work was commissioned by the Sea Fish Industry Authority (SeaFISH) with the aim of providing an independent assessment of the fuel consumption performance of the fuel additives, in comparison with the use of (red) diesel fuel alone.

This work on fuel additives was conducted in parallel with other work on Biofuels for the Fishing Industry, also commissioned by SeaFISH, and was reported to SeaFISH in December 2007. At the request of SeaFISH, a non-technical summary of the specific outcomes of the fuel additives test work are separately reported herein by means of abstracting the December 2007 report.

Thus the aim of this report is to provide an outline of the dynamometer set up, the test cycles adopted, and the results of the fuel additives testing without the reader becoming overly burdened with technical detail, or the broader scope of the overall Biofuels for the Fishing Industry project.

Readers of this report also interested in the wider biofuels scope should obtain a copy of the full December 2007 report submitted to SeaFISH.

Readers of this report requiring more technical detail on the fuel additives test work only should obtain a copy of the full technical report entitled: “Diesel Fuel Additives Testing”, (February 2008), from SeaFISH.

Scope

During the course of 2006 assistance was given to Seafish to produce a scope of work for trialling fuel additives using the engine dynamometer test cell. In March 2007 this developed into an order to carry out fuel additive performance tests for 7 distinct fuel additives, with the additive testing to take priority over bio-fuels testing. The 7 fuel additives are identified as additives A through G in this report. For further information regarding the source of these additives, the reader should contact SeaFISH.

Introduction

There are a number of fuel additives on the market that claim to enhance fuel consumption. It is extremely difficult to conduct standardised fuel consumption tests at sea since there are many variable factors other than the performance of the fuel. SeaFISH therefore commissioned the University of Exeter to conduct a series of standardised tests on a range of seven fuel additives provided by SeaFISH, using the University's underground test cell. This is shown in Figure 01 below.

Figure 01: Photograph of the bio-fuel engine test cell facility underground at the CSM Holman's Test Mine. The top of the photograph shows the test cell control cabin. The dynamometer is in the foreground in green, the test cell engine is in blue.

Bio-fuel engine test cell facility

The test cell is located in an underground chamber about 50 metres from the entrance to the mine in which it is located. This is a secure location with a relatively stable environment. The major equipment is based around a 6 cylinder, normally aspirated Perkins marine diesel engine with a nominal rating of 120hp. A dynamometer (Figure 02) is used to apply a load to the engine and to measure the torque. A computer-controlled system is used to run the engine through pre-defined tests in which engine speed and torque are specified. A set of instruments accurately records a wide range of data such as fuel consumption, engine oil pressure and temperature, coolant temperature, exhaust temperature, and environmental conditions.

Table 01: Test cell engine specification

Parameter:	**Specification:**
Manufacturer:	Perkins
Type:	6.3544M
Cylinders	6
Cubic capacity	5.8 litres
Compression ratio:	16:1
Bore:	98.4mm
Stroke:	127mm
Firing order:	1-5-3-6-2-4
Combustion system:	Direct injection
Cycle:	4 stroke
Output power:	89.5kW
@ Rotational speed	2800rpm

Table 02: Summary of dynamometer features

Parameter:	**Specification:**
Manufacturer:	Schenk
Type:	W230
Serial number:	LWH 0994
Date of manufacture:	1986
Resistance:	Eddy current
Torque transducer:	Load cell
Speed transducer:	60 tooth wheel / inductive cell
Calibration:	Dead weight arm

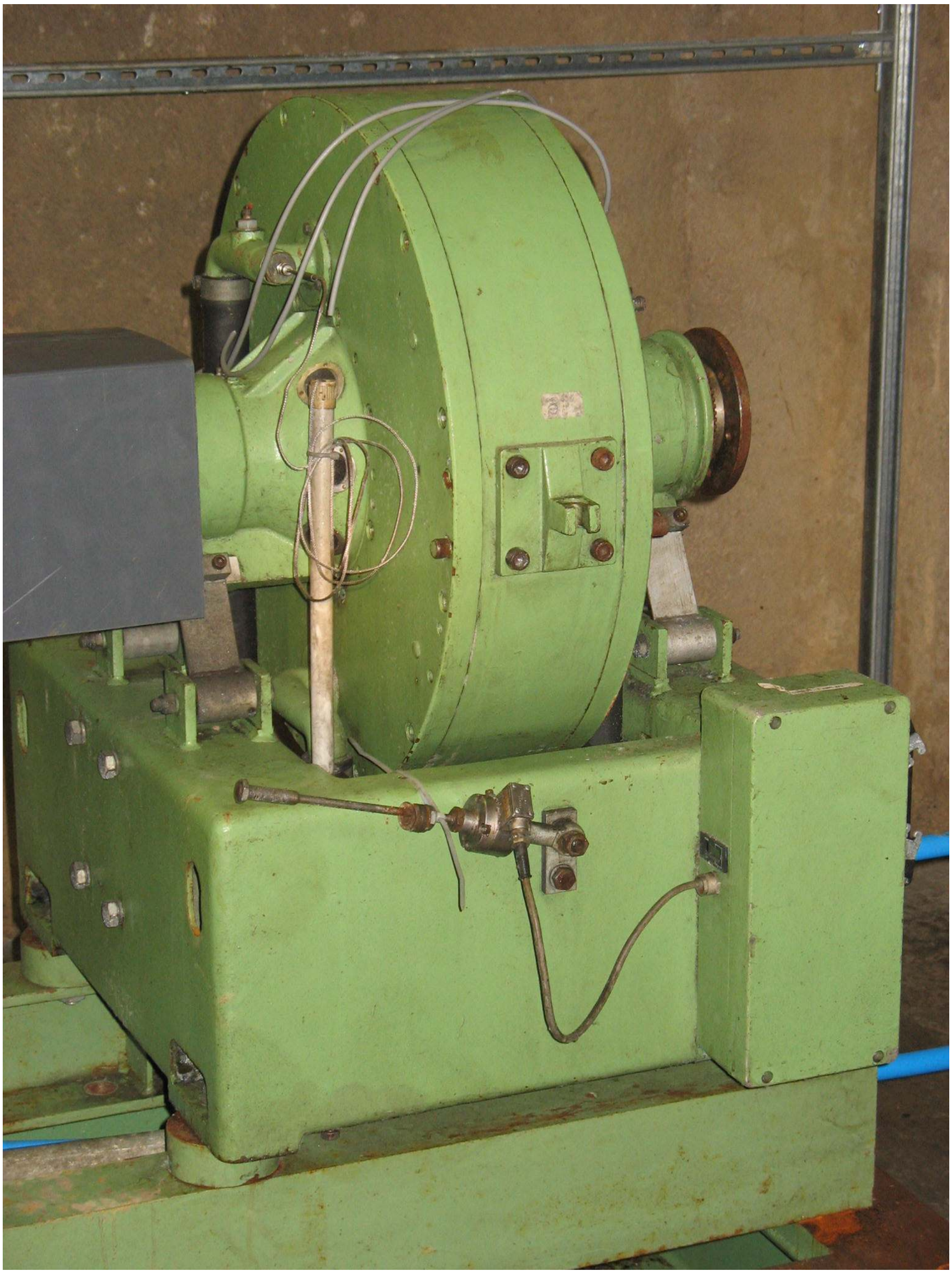


Figure 02: Dynamometer detail (N.B. Load cell unattached)

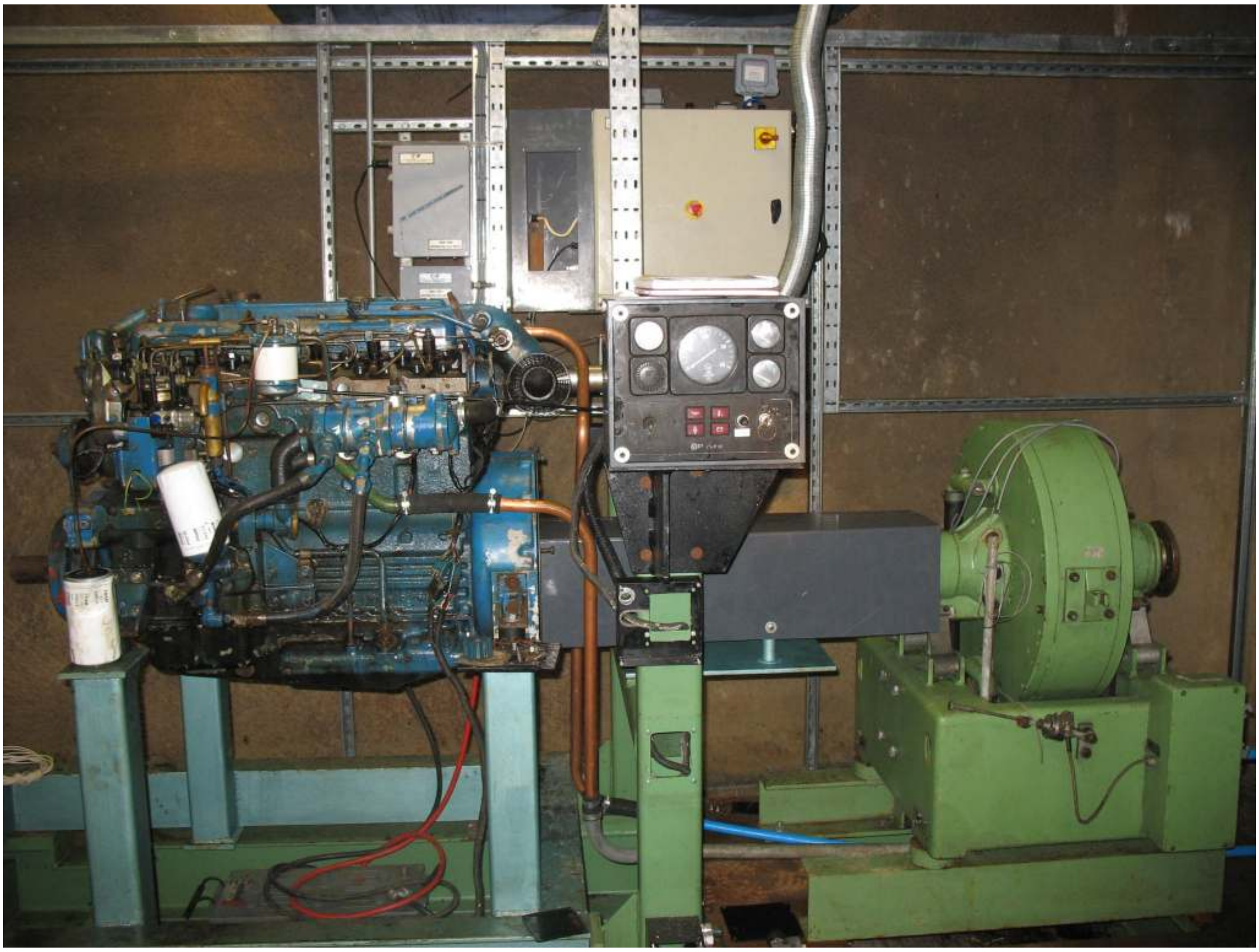


Figure 03: Foreground – Test engine (blue) and dynamometer (green). Background – data acquisition housing (RHS) and fuel measurement system housing (LHS).

FMS (Fuel Measurement System)1000

The FMS system employed is relatively simple in concept and operation. The system functions by dosing approximately 1 kg of fuel into a vessel that is in the fuel delivery line between the header tank and the engine. Return fuel from the engine is also delivered to this weighing vessel. When the predefined fill level is achieved the fuel delivery from the header tank to this vessel is suspended. The vessel sits upon a load cell and the mass of the vessel is logged at predefined time intervals to derive the fuel consumption in terms of mass. When a predefined lower level of fuel is achieved, data logging is suspended and the vessel is re-filled. The operation of the FMS is controlled by the dynamometer software and has hardware settings that intervene when appropriate.

Engine aspiration

The natural climate in underground workings and mines is reasonably constant all year round. The atmosphere is relatively unaffected by seasonal changes and weather patterns. The temperature remains constant at around 13.5° C +/- 1° C depending on the time of year due to the thermal mass of the rock. The humidity is high at around 80% due to the temperature, still air, presence of water and the absence of solar radiation. However the atmospheric pressure tracks the surface pressure as the mine is not a sealed environment.

When the results of engine tests are normalised according to ISO1585 the measured power is multiplied by a correction factor to derive a corrected power that is predicted to have occurred under standard temperature, humidity and pressure conditions. These corrections are particularly important when testing under widely variable ambient conditions.

The extent to which the results of this work depend upon the ISO1585 power correction factor were reduced by utilising the stability of the underground environment. The air intake has been routed outside of the engine test cell chamber to a drive in the mine where the temperature is unaffected by the engine (*see schematic diagram – Figure 04*). The air intake duct contains a cleanable K&N air filter as well as the atmospheric temperature and humidity instrumentation.

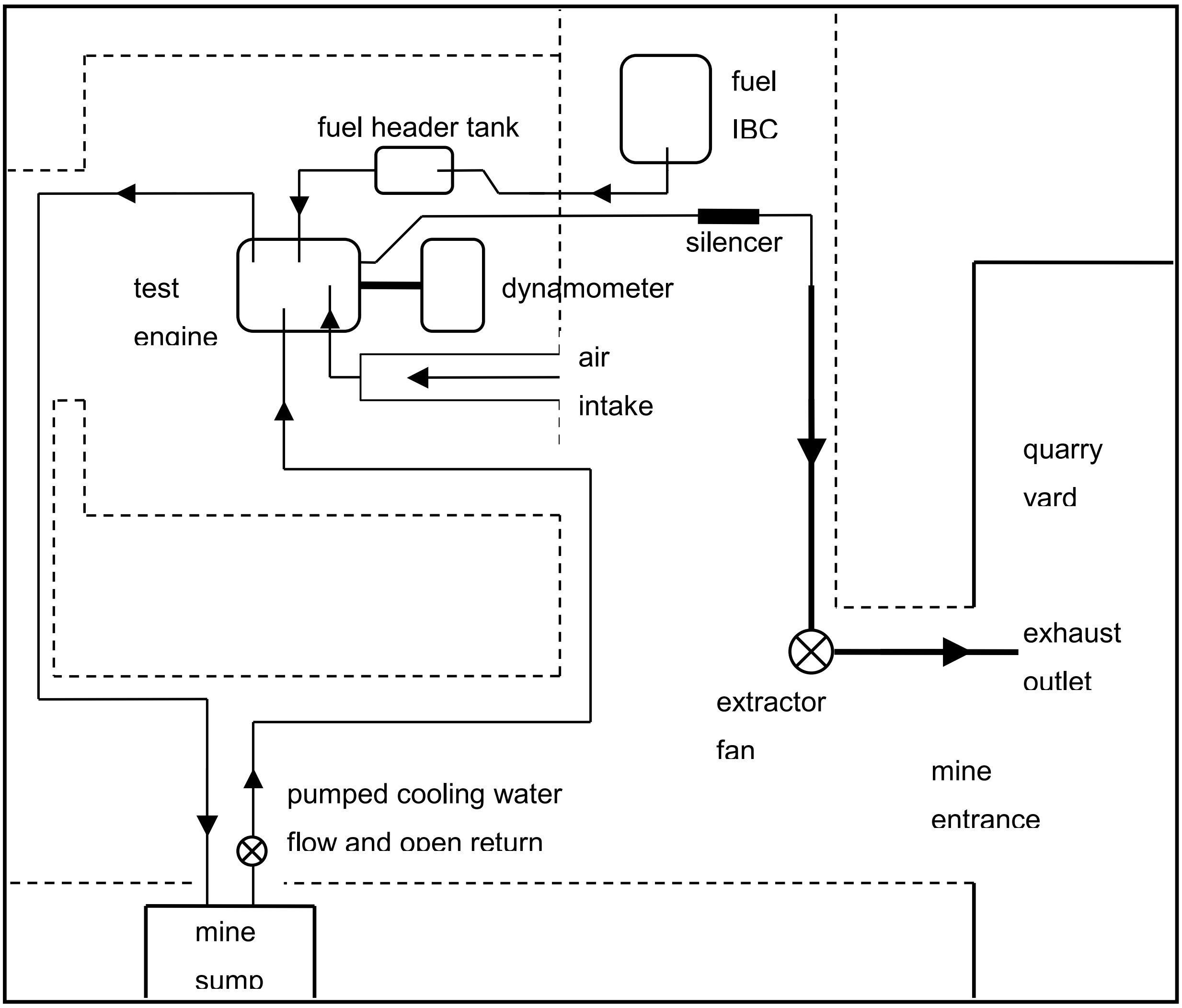


Figure 04: Schematic diagram of test infrastructure within the mine.

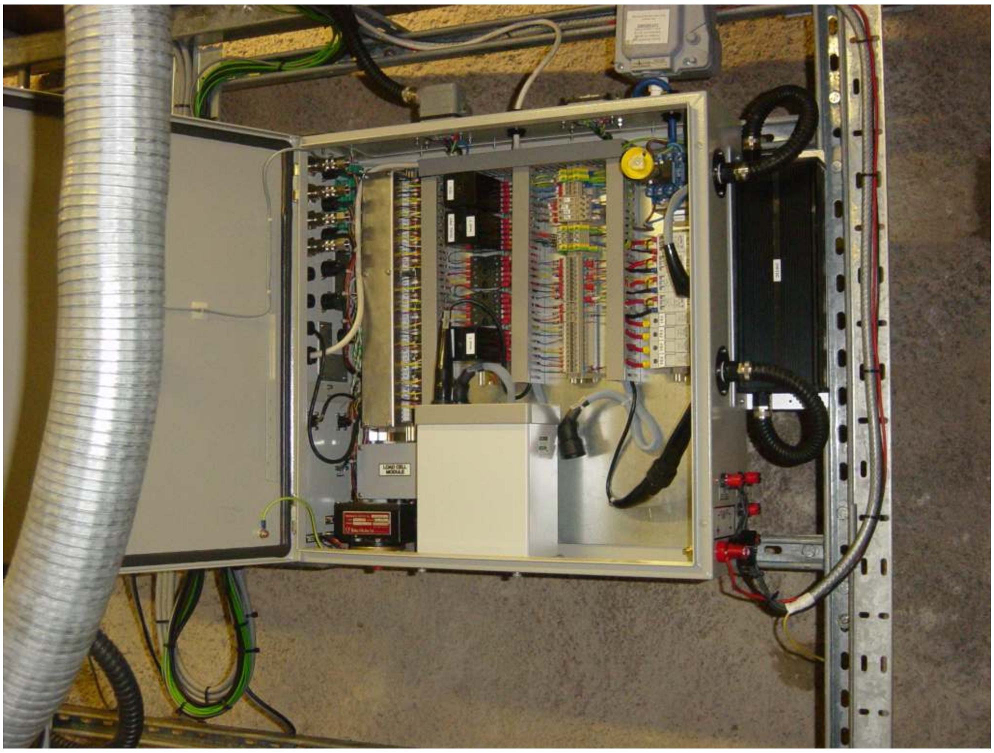


Figure 05: Completed wiring in test cell transducer box

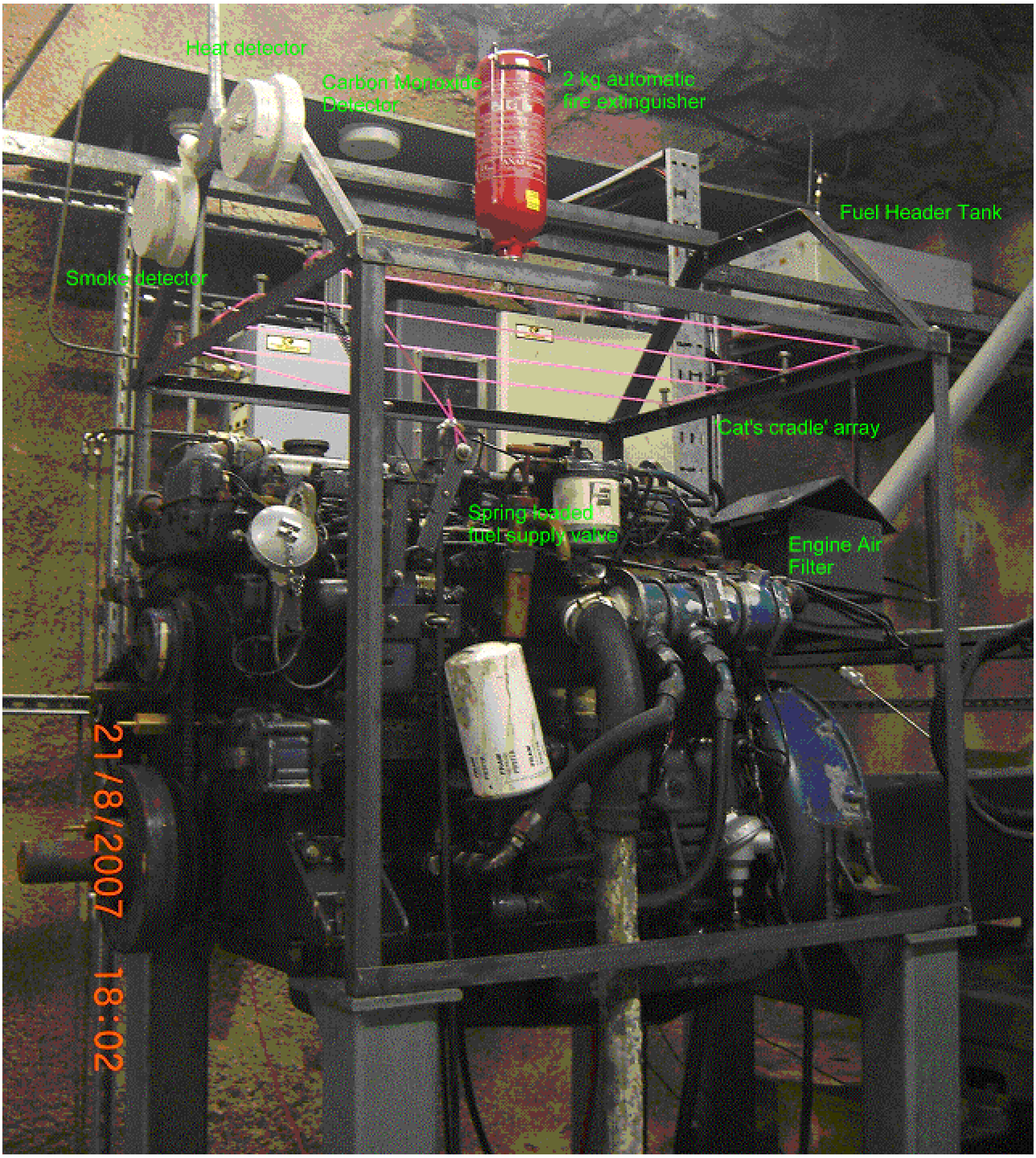


Figure 06: Test engine showing fire protection measures installed to support unattended operations for prolonged testing.

Testing procedures

In the test cell it was possible to conduct standardised tests to compare the performance of red diesel treated with the additives against untreated red diesel. The nature of the testing eliminated many of the possible variables that would be encountered at sea, whilst power correction factors (to ISO standard) were used to compensate for unavoidable variables such as humidity, temperature and atmospheric pressure. It should be noted that being underground, these environmental variables are more stable than would be the case above ground.

Under the guidance of Seafish, a standard test cycle of 20 hours and 40 minutes was devised. The test cycle was designed to give a simple representation of an inshore trawler leaving port, steaming to a fishing ground and carrying out 3 tows of 4 hours each, before returning to port. This was named the DayTrawl Cycle. Although the day trawl cycle as specified is inevitably a crude representation of real life, it did provide a standard test that has some relationship to engine use at sea. A statement of the sequential stages of engine set points comprising the cycle is provided in Table 03.

Table 03: Simplified specification of Day Trawl test cycle.

Stage	Set Point Description	Set Point duration (hh:mm:ss)	Engine Speed (rpm)	Engine Power (%)
1	15 minute tick over under zero load	00:15:00	1000	0.0
2	15 minute gentle cruise out to marker buoy	00:15:00	1300	6.3
3	2.5 hr steaming to trawl site	02:30:00	2000	12.3
4	5 min gentle cruise while shooting	00:05:00	1500	7.5
5	4 hour trawl	04:00:00	1750	63.7
6	20 min haul in of nets	00:20:00	1400	15.1
7	20 min tickover during net handling & unload	00:20:00	1000	0.0
8	5 min gentle cruise while shooting	00:05:00	1500	7.5
9	4 hour trawl	04:00:00	1750	63.7
10	20 min haul in of nets	00:20:00	1400	15.1
11	20 min tickover during net handling & unload	00:20:00	1000	0.0
12	5 min gentle cruise while shooting	00:05:00	1500	7.5
13	4 hour trawl	04:00:00	1750	63.7
14	20 min haul in of nets	00:20:00	1400	15.1
15	2.5 hr steaming to trawl site	02:30:00	2000	12.3
16	15 minute gentle cruise to port from marker buoy	00:15:00	1300	6.3
17	Tick over for 1 hour	01:00:00	1000	0.0
	Total test duration	**20:40:00**		

A sample set of results for a single DayTrawl test is presented in Figure 07. Several different plots of engine variables versus time are produced (torque, oil temperature & pressure, engine speed, fuel consumption, etc.) and used to compute fuel consumption figures that can be compared across different DayTrawl tests.

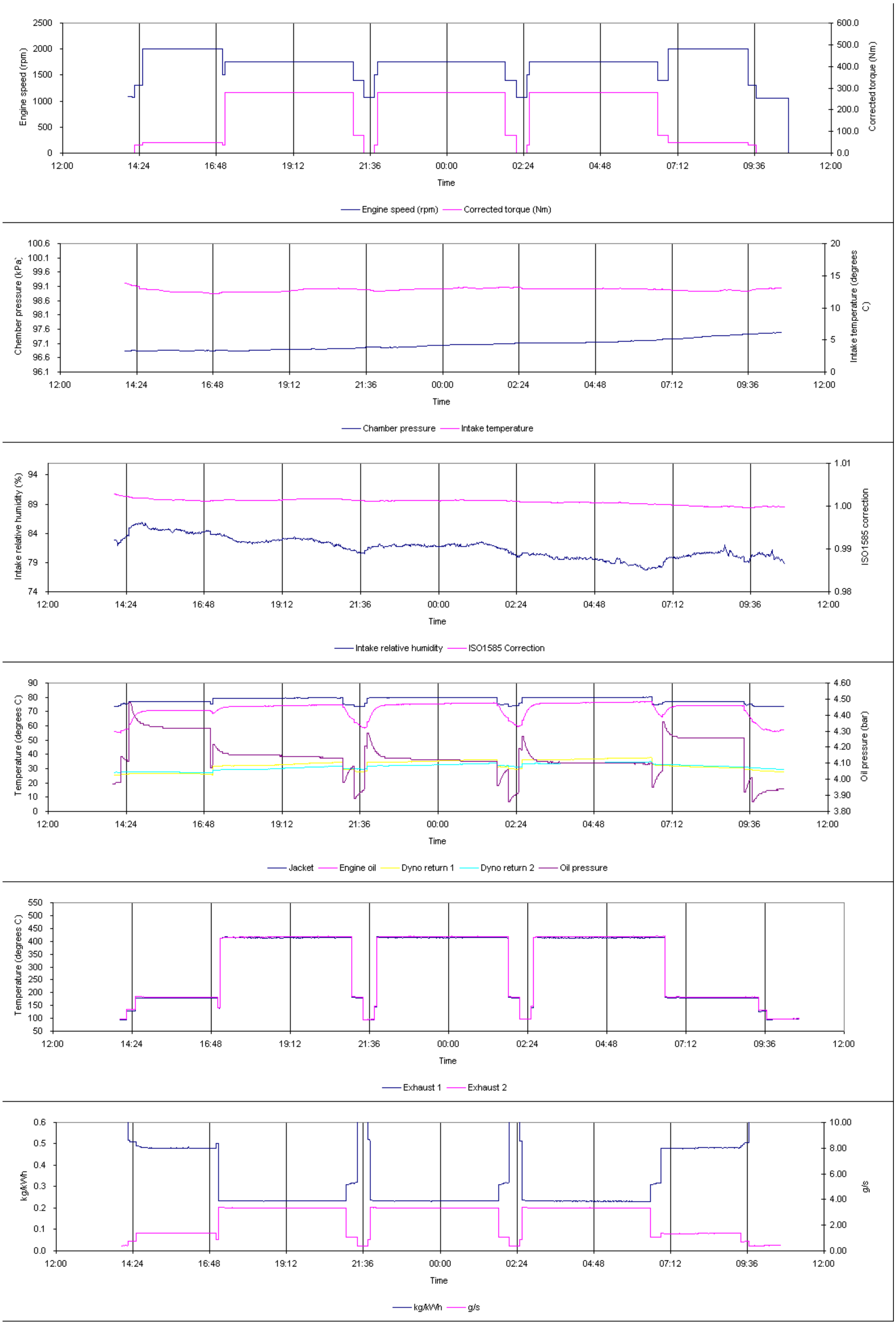
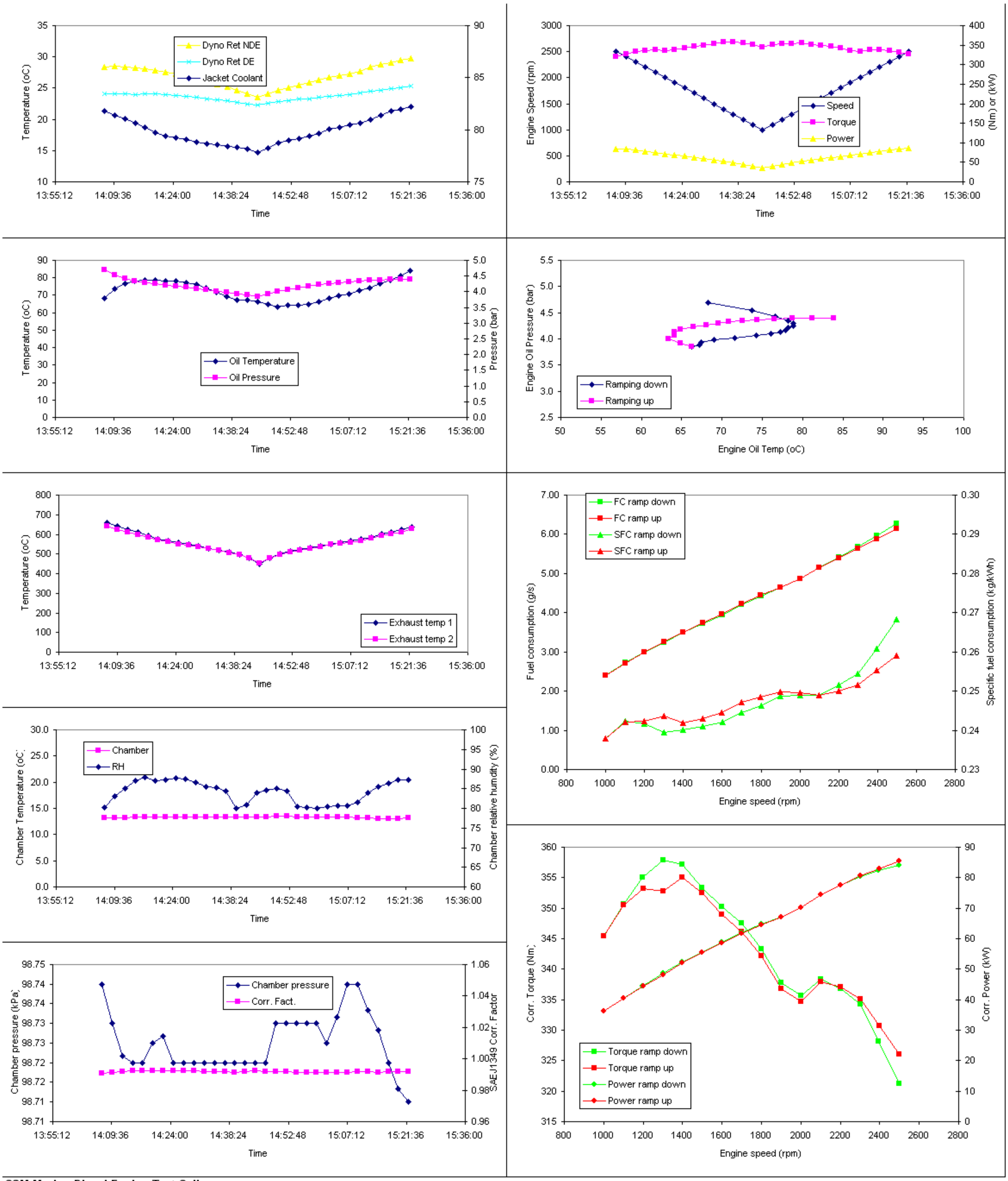


Figure 07: Typical time series traces produced from a DayTrawl test cycle.

Each fuel additive was also put through a baseline test cycle that plotted curves of maximum torque and fuel consumption over the full range of engine speeds. These curves provide a “fingerprint” to define maximum engine performance, and also allow fuel treated with the additives to be compared against untreated fuel under maximum power conditions. An example set of results from this test are presented in Figure 08.



CSM Marine Diesel Engine Test Cell
Baseline engine performance curves
Max power at 100% throttle at all set points
Date of test: 29/10/07

Figure 08: Example output from a Baseline test on the engine test cell.

Fuel Additives Testing

The additives were mixed into the red diesel at the concentrations recommended on the packaging.

Assessment of Baseline tests

After each test of fuel containing an additive, the Baseline test using untreated red diesel was repeated and compared with a known engine performance envelope. This allowed determination of whether or not the engine condition had returned to its state prior to any testing with additives and also whether not any engine failure or malfunction may have occurred during the prior Day Trawl test. It was found that the engine consistently returned to its original performance and that during the additives testing campaign the engine suffered no malfunction or deterioration of performance.

Table 04: Summary interpretation of Baseline test response to an immediately prior DayTrawl test fuelled by petroldiesel and additive.

Additive	Indication of possible engine failure or other system malfunction during preceeding DayTrawl (diesel with additive) cycle	Evidence of any after effect of the additive on performance with diesel only Baseline test
A	NO	NO
B	NO	Possible minor improvement between 1600 and 2000 rpm
C	NO	Possible very minor improvement between 1600 and 2000 rpm
D	NO	Possible minor improvement between 1600 and 2000 rpm
E	NO	NO
F	NO	Possible minor improvement between 2000 and 2500 rpm
G	NO	Possible very minor improvement between 2000 and 2500 rpm

Results of Day Trawl testing

The results of the testing provided multiple sets of data that were remarkably consistent. The equipment proved to be capable of a very high degree of repeatability, giving confidence that any significant variation in fuel performance would be detected. The high repeatability is a result of the precision (computer) control of the test schedule and the relatively stable environment in which the engine test cell operates. When the tests were repeated using a fuel known to be different (bio-diesel) significant differences in the results of both the baseline test and the day trawl cycle were observed.

Table 05: Summary of relative performance between fuel additives on DayTrawl cycle tests

Test Number	Cum Uncorr. Work (kWh)	Cum Correct Work (kWh)	Cenus fuel consumption (litres/kWh)	% different from BS590 average	Whole test fuel consumption (litres/kWh)	% different from BS590 average	Whole test fuel consumption (kg/kWh)	Whole test fuel consumption (kWh/kWh)	Whole test Efficiency (kWh / kWh)	Fuel
102	687.46	685.08	0.3045	-0.14	0.3006	-0.08	0.2598	3.1735	0.315	Batch 1 BS590 diesel only + Additive A
104	687.58	683.00	0.3043	-0.21	0.3001	-0.27	0.2593	3.1675	0.316	Batch 1 BS590 diesel only + Additive B
105	687.58	681.76	0.3042	-0.23	0.3004	-0.18	0.2595	3.1705	0.315	Batch 1 BS590 diesel only + Additive C
106	687.61	682.33	0.3046	-0.08	0.3002	-0.23	0.2594	3.1690	0.316	Batch 1 BS590 diesel only + Additive D
108	687.63	683.49	0.3050	0.04	0.3004	-0.15	0.2584	3.1941	0.313	Batch 2 BS590 diesel only + Additive E
109	687.59	688.96	0.3040	-0.29	0.3003	-0.20	0.2583	3.1926	0.313	Batch 2 BS590 diesel only + Additive F
110	687.66	688.45	0.3045	-0.12	0.3001	-0.27	0.2581	3.1903	0.313	Batch 2 BS590 diesel only + Additive G
Stdev	0.065	2.916	0.00033		0.00020		0.00068	0.01207		
101	687.38	683.13	0.3058	0.29	0.3021	0.42	0.2611	3.1894	0.314	Batch 1 BS590 diesel only
103	687.50	683.07	0.3042	-0.23	0.3003	-0.21	0.2594	3.1695	0.316	Batch 1 BS590 diesel only
107	687.61	684.84	0.3045	-0.13	0.3005	-0.13	0.2584	3.1949	0.313	Batch 2 BS590 diesel only
111	687.72	681.38	0.3051	0.07	0.3007	-0.08	0.2586	3.1965	0.313	Batch 2 BS590 diesel only
Stdev	0.145	1.412	0.00070		0.00085		0.00120	0.01245		
112	687.79	680.37	0.3486	14.34	0.3445	14.49	0.3028	3.2592	0.307	BS 14214 Standard Methyl Ester
113	687.68	688.49	0.3661	20.06	0.3590	19.32	0.3228	3.3243	0.301	Waste Oil Methyl Ester

N.B. (kWh/kWh) refers to kWh of fuel consumed per kWh of corrected work delivered.

The fuel consumption results for the DayTrawl tests using red diesel with each of the additives, red diesel alone and two different bio-diesels are presented in Table 05. Fuel consumption results are presented in terms of:

i) litres of fuel / kWh of work delivered by the engine over census stages of the test cycle (Column 4)
ii) litres of fuel / kWh of work delivered by the engine over the whole the test cycle (Column 6)
iii) kg of fuel / kWh of work delivered by the engine over the whole the test cycle (Column 8)
iv) kWh of fuel energy / kWh of work delivered by the engine over the whole test cycle (Column 9)

The results of the DayTrawl tests indicate that none of the diesel additives have reduced the fuel consumption over the test cycle by more than 0.29% over the census stages of the cycle or by more than 0.27% over the complete cycle.

Figure 09 presents the cumulative differences between all the Daytrawl test results graphically. Curves for the biofuels lie far to the right of those involving red diesel fuel. Curves for red diesel - with or without additives - are tightly clustered on the left. The graph shows very little difference in the quantity of red diesel fuel consumed (small spread of curve endpoints horizontally), for approximately the same amount of work delivered by the engine (small spread of curve endpoints vertically).

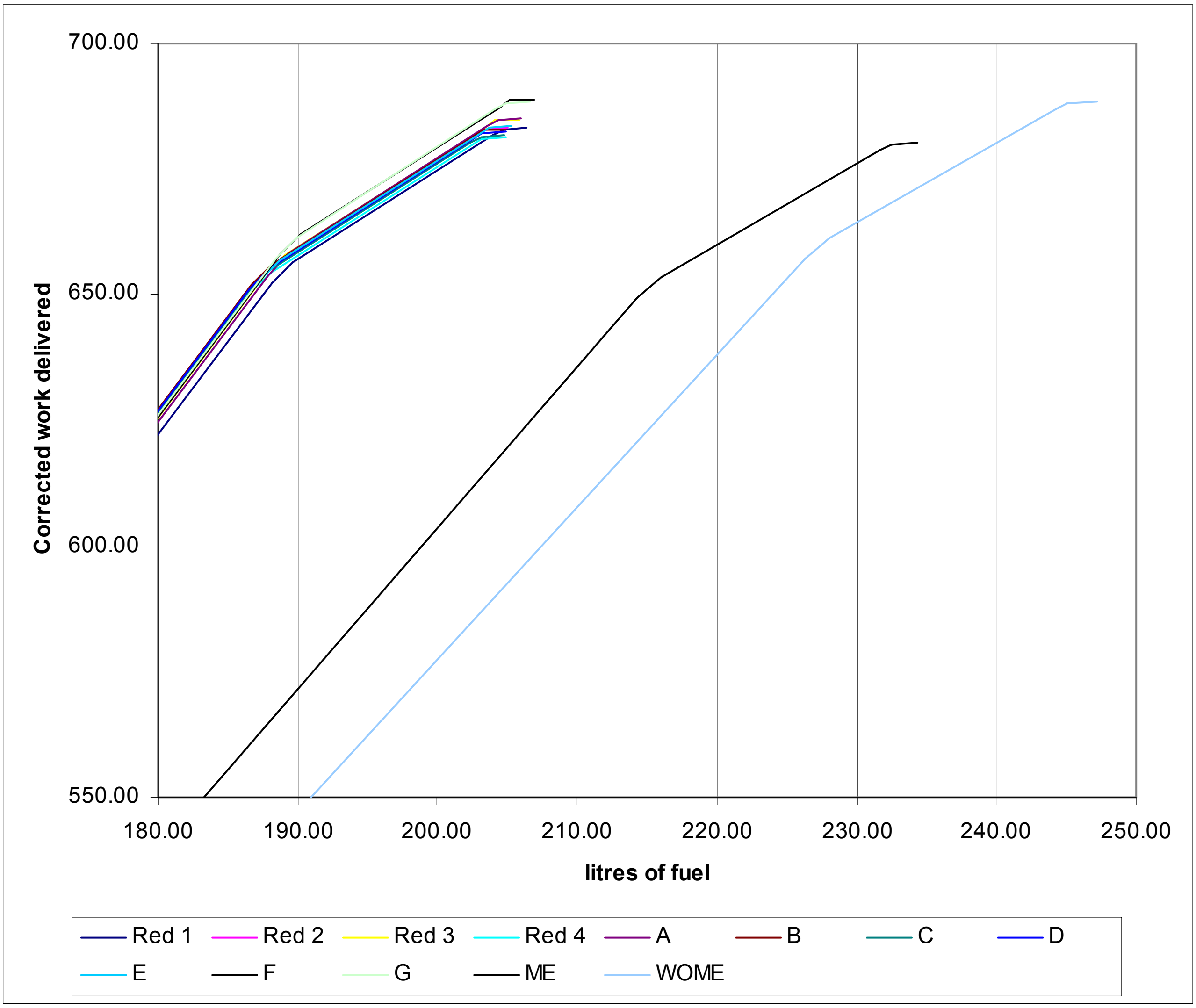


Figure 09: Comparison between fuel / fuel + additive cumulative performance over the DayTrawl test cycle. Corrected work delivered (kWh). Red X: DayTrawl test cycle with red diesel only. A – G: DayTrawl test cycle with red diesel and fuel additives A to G. ME: DayTrawl test cycle with BS 14214 methyl ester. WOME: DayTrawl test cycle with Waste Oil Methyl Ester (WOME).

Conclusions

The equipment proved to be capable of a very high degree of repeatability, giving confidence that any significant variation in fuel performance would be detected (as was the case with the bio-diesel tests – presented for comparison).

The results indicate that there is no significant effect of any of the additives tested on the fuel consumption of the engine through the DayTrawl test cycle.

It would cost fishermen more to run their vessels on BS590 diesel with additives because as well as paying for the base fuel, they would also have to pay for the additive.