© Copyright Statement

MACMAHON CONTRACTORS
FUEL EFFICIENCY TRIAL
GIRALAMBONE OPERATIONS

November, 1996

Report prepared by:

R A Platt
Fuel Technology Pty Ltd
6a Nairn Street
(PO Box 1271)
FREMANTLE WA 6160

Tel (09) 335 6899
Fax (09) 430 5403
E-Mail 100251.2466@Compuserve.com

ACN 063 561 151

CONTENTS

Appendices

EXECUTIVE SUMMARY

Fuel Technology Pty Ltd initiated trials with F K Kanny & Son in Western Australia mid 1987. Initial carbon balance trials were conducted on two low loader prime movers. Following the success of these trials in reducing fuel consumption under a given load condition, trials were conducted at the Golden Valley minesite in Western Australia on a fleet of Caterpillar 773 dump trucks which showed a 7.4% reduction in fuel consumption following FTC treatment of fuel.

A number of further tests were conducted at Kanny then MacMahon contract sites, namely Eneabba, Orebody 25, Alcoa, Youanmi and Kurara.

The fuel at all MacMahon contract minesites in Western Australia is FTC treated.

Following discussion with MacMahon's Eastern Region Maintenance Management, agreement was reached to evaluate the performance of FTC in a Caterpillar 777C at Giralambone minesite employing the engineering standard Specific Fuel Consumption test procedure.

The baseline data collection was initiated on 11th September, 1996 on truck number 2287, operating in the Murrawombie pit. This pit was selected because of its maturity and the deep haul out. Mining in this pit is intermittent and a return for treated tests was delayed until 14th November, 1996.

The reduction in fuel consumption measured following FTC treatment was ***7.6%*** following correction for variation in inlet air temperature.

TEST PROCEDURE

The purpose of the Haul Truck Volumetric Fuel Measurement test is to accurately measure the actual volume of fuel consumed corrected to mass in kilograms against the work done, tonnes hauled.

A start point at a given distance from base of pit ramp and a finish point at the top of the ramp was marked with sighting posts. The distance between the two, namely 947 metres, was measured by a surveyors wheel and this distance used as the test cycle.

Flow transducers fitted with thermocouple probes were fitted to Dump Truck No. 2287 fuel tank outlet and inlet pipework (*Photograph No. 1*).

These transducers, calibrated to $\pm$ 0.25% by a NATA Certified Laboratory, were then coupled to a Minitrol totaliser mounted in the cab (*Photograph No. 2*).

Because the temperature of engine return fuel is considerably higher than inlet fuel together with the fact that the fuel temperature continues to rise during the working cycle which results in density variations, the fuel temperatures at each flow transducer was measured via a Fluke dual readout digital thermometer also mounted in the cab.

Prior to the test commencing a fuel sample was drawn from the test truck and density measured at observed temperature. Density was then corrected to industry standard of 15°C using the Institute of Petroleum Density Correction Table, Volume VIII, Tables 53B and 54B.

Following loading of truck 2287 for each cycle and allowing the load monitor to register, load in kilograms (kg) was recorded from the truck's onboard Payload Monitoring System (*Photograph No. 3*). Upon arrival at pit ramp marker the test truck stopped and the Minitrol totaliser and stop watch were zeroed. At signal "*GO*" the driver accelerated and the test engineer activated the stop watch and Minitrol totaliser.

To avoid any driver variables the test truck was driven at full throttle over the pit haul ramp test circuit which allowed the test truck to automatically change from first to second gear only. Fuel temperatures were recorded and upon arrival at the ramp top marker the stop watch and Minitrol were stopped and readings recorded.

Tests were conducted throughout the day on all available runs.

TEST RESULTS
CATERPILLAR 777C DUMP TRUCK; MURRAWOMBIE PIT

FTC-1 treated and untreated fuel consumption has been calculated in kilograms from the litres consumed, corrected for fuel temperatures and density. Kilograms of fuel per tonne of ore moved has then been calculated and the arithmetic mean determined. As there was a substantial average ambient temperature difference from baseline at 14°C and treated at 33.5°C, Caterpillar correction factors have been applied to the data which result in a change of efficiency. A copy of Correction Table is included in Appendix "B".

SPECIFIC FUEL CONSUMPTION TRUCK TRIAL

Customer: Macmahon Giralambone
Truck No: 2287 Eng Hrs 7267 Ambient Temp; 14 Deg. C (57.2F)
Date: 11/09/96 Correction Factor 0.983

Fuel Sample	Density	Temp Deg C
	0.845	25.3
Corrected	0.852	15

UNTREATED

Run No	Time	Load kg	Haul Time		Haul Time	Fuel (Lt)		Fuel (Lt)	Fuel Temp		Density		Fuel (kg)		Fuel (kg)	Fuel (kg)	Correction
			Mins	Secs	Mins	In	Out	Consumed	In	Out	In	Out	In	Out	Consumed	Per Tonne	For Amb;
1	7.10	106000	5	45	5.75	81.02	65.59	15.43	21.7	35.8	0.848	0.838	68.66	54.94	13.73	0.1295	0.1317
2	7.3	112000	5	04	5.07	86.98	70.75	16.23	26.1	39.5	0.844	0.835	73.45	59.07	14.38	0.1284	0.1306
3	8.4	119000	6	03	6.05	86.97	70.61	16.36	36.7	46.8	0.837	0.830	72.79	58.59	14.19	0.1193	0.1213
4	9.00	118000	6	06	6.10	87.37	70.84	16.53	39.4	49.2	0.835	0.828	72.95	58.66	14.29	0.1211	0.1232
5	10.30	114000	6	03	6.05	87	70.36	16.64	47.0	52.4	0.830	0.826	72.18	58.10	14.07	0.1234	0.1256
6	10.55	111000	5	45	5.75	81.1	65.32	15.78	48.2	54.4	0.829	0.824	67.22	53.85	13.37	0.1204	0.1225
7	11.45	114000	6	04	6.07	87.2	70.59	16.61	49.1	56.1	0.828	0.823	72.21	58.11	14.10	0.1237	0.1258
8	12.45	110000	5	43	5.72	81.24	65.83	15.41	35.5	46.6	0.838	0.830	68.06	54.63	13.43	0.1221	0.1242
9	1.05	124000	6	15	6.25	89.11	72.37	16.74	38.2	52.7	0.836	0.826	74.49	59.75	14.74	0.1189	0.1209
10	1.25	123000	6	15	6.25	89.19	72.44	16.75	40.9	52.3	0.834	0.826	74.38	59.83	14.55	0.1183	0.1203
11	1.45	127000	6	13	6.22	88.54	71.83	16.71	44.0	54.3	0.832	0.825	73.65	59.22	14.42	0.1136	0.1155
12	2.05	111000	5	45	5.75	82.14	66.70	15.44	46.5	55.1	0.830	0.824	68.18	54.95	13.22	0.1191	0.1212
13	2.25	115000	6	11	6.18	88.54	71.83	16.71	48.3	55.7	0.829	0.824	73.37	59.15	14.22	0.1237	0.1258
14	2.50	102000	5	53	5.88	83.19	67.13	16.06	50.0	58.6	0.828	0.821	68.84	55.14	13.70	0.1343	0.1366
15	3.10	123000	6	09	6.15	87.75	71.01	16.74	51.3	58.7	0.827	0.821	72.53	58.33	14.21	0.1155	0.1175
16	3.40	81000	4	57	4.95	70.93	57.53	13.40	52.7	57.6	0.826	0.822	58.56	47.30	11.26	0.1391	0.1415
Mean		113125			5.89			16.10							13.867	0.1231	0.1253
Std Dev		10941.51			0.3913			0.8779							0.8204	0.0067	0.0069
C.V		9.7%			6.6%			5.5%							5.9%	5.5%	5.5%

Date: 14/11/96 Eng Hrs 7540 Ambient Temp; 33.5 Deg. C (92.4F)
Correction Factor 1.013

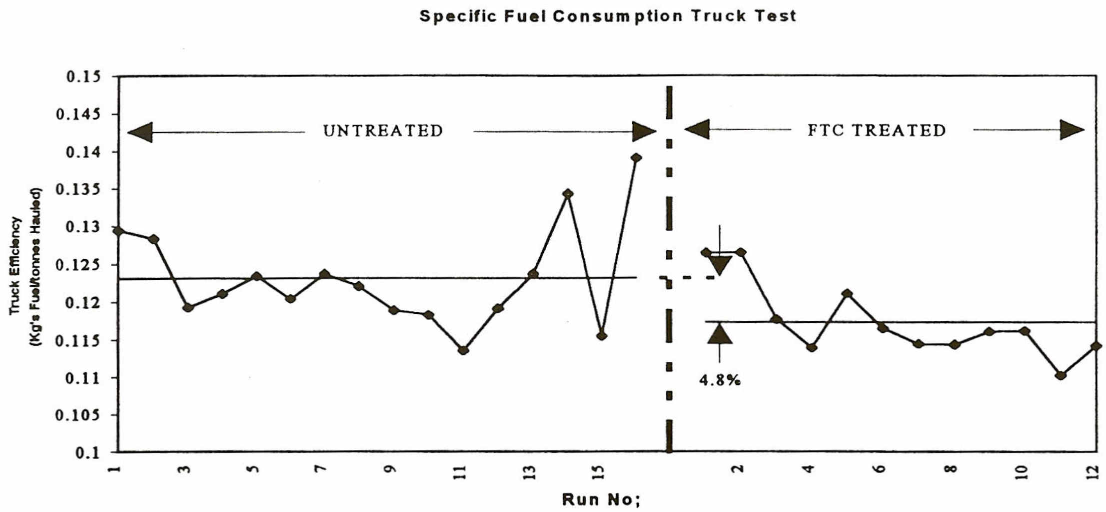
Fuel Sample	Density	Temp Deg C
	0.839	32.8
Corrected	0.851	15

TREATED

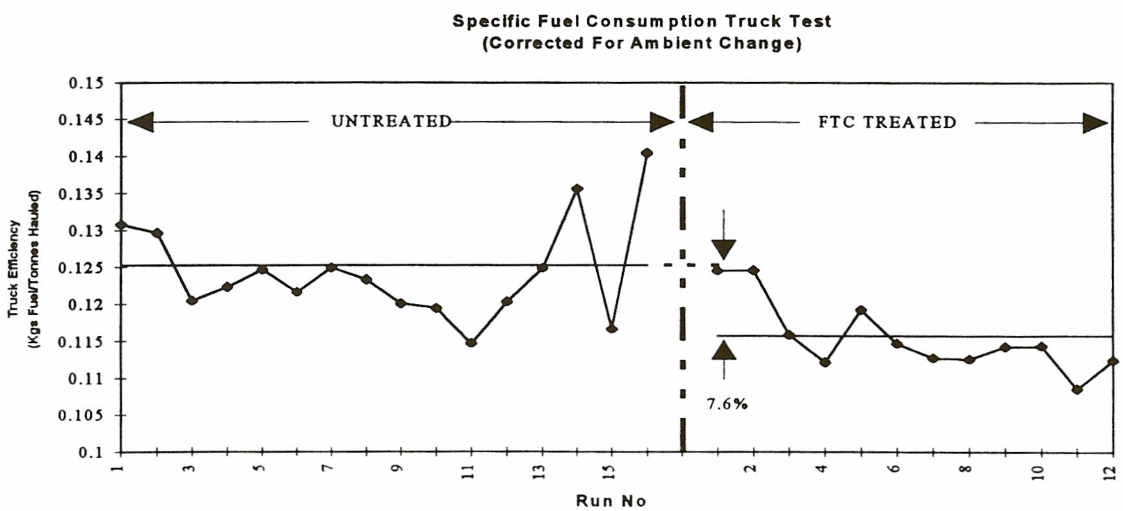
Run No	Time	Load kg	Haul Time		Haul Time	Fuel (Lt)		Fuel (Lt)	Fuel Temp		Density		Fuel (kg)		Fuel (kg)	Fuel (kg)	Correction
			Mins	Secs	Mins	In	Out	Consumed	In	Out	In	Out	In	Out	Consumed	Per Tonne	For Amb;
1	11.00	97000	5	36	5.60	78.10	63.43	14.67	60.5	65.9	0.819	0.816	64.00	51.73	12.26	0.1264	0.1248
2	11.25	100000	5	36	5.60	78.38	63.18	15.20	61.2	65.7	0.819	0.816	64.19	51.54	12.65	0.1265	0.1249
3	11.5	114000	5	45	5.75	80.54	64.37	16.17	62.0	66.0	0.818	0.816	65.91	52.49	13.41	0.1177	0.1161
4	1.10	116000	5	44	5.73	80.36	64.83	15.53	49.4	57.4	0.827	0.822	66.47	53.26	13.21	0.1139	0.1124
5	1.50	102000	5	31	5.52	77.46	62.65	14.81	57.4	61.5	0.822	0.819	63.64	51.29	12.35	0.1211	0.1195
6	2.10	112000	5	44	5.73	80.19	64.70	15.49	55.6	62.2	0.823	0.818	65.98	52.94	13.04	0.1165	0.1150
7	2.35	125000	6	17	6.28	88.73	71.72	17.01	56.8	63.2	0.822	0.818	72.94	58.63	14.30	0.1144	0.1130
8	2.55	116000	6	11	6.18	87.37	71.61	15.76	58.5	64.8	0.821	0.816	71.71	58.46	13.26	0.1143	0.1128
9	3.20	112000	5	49	5.82	88.03	72.57	15.46	59.8	66.0	0.820	0.816	72.18	59.18	12.99	0.1160	0.1145
10	3.40	112000	6	05	6.08	86.67	71.15	15.52	61.3	67.2	0.819	0.815	70.97	57.96	13.01	0.1161	0.1146
11	4.00	130000	6	19	6.32	88.51	71.32	17.19	62.3	67.5	0.818	0.814	72.41	58.08	14.33	0.1102	0.1088
12	4.20	121000	6	06	6.10	86.64	70.03	16.61	63.2	67.8	0.818	0.814	70.83	57.02	13.81	0.1141	0.1127
Mean		113083			5.89			15.79							13.219	0.1173	0.1158
Std Dev		9839.238			0.2838			0.8072							0.6687	0.0050	0.0049
C.V		8.7%			4.8%			5.1%							5.1%	4.3%	4.3%

% CHANGE: Treated-Baseline	Load kg			Haul Time Mins		Fuel (Lt) Consumed		Fuel (kg) Consumed	Fuel (kg) Per Tonne	Fuel (kg) Per Tonne
Baseline	0.0%			0.1%		-1.9%		-4.7%	-4.8%	-7.6%

Graph 1 plots the truck's fuel efficiency over each test phase.



Graph 2 plots the truck's fuel efficiency over each test phase when Caterpillar correction factors are applied.



FUEL EFFICIENCY CHANGE

	Fuel Efficiency Kg/Tonne	
	Uncorrected for inlet air temp	Corrected for inlet air temp.
Untreated	0.1231	0.1244
FTC-1 Treated	0.1173	0.1155
% CHANGE	**- 4.8**	**- 7.6**

STUDENT'S t-TEST

To prove the statistical significance of the difference in means between baseline and treated test a Student's t-Test was performed.

Formula:

$$t = \frac{x_1 - x_2}{\sqrt{\dfrac{(n_1 - 1) S_1{}^2 + (n_2 - 1) S_2{}^2}{(n_1 - n_2 - 2)} \quad \dfrac{1 + 1}{n_1 + n_2}}}$$

Hypothesis: $H_0 : U_1 - U_2 = 0$

$H_1 : U_1 - U_2 \neq 0$

where:-

Baseline	**Treated**
$x_1 = 0.1253$	$x_2 = 0.1158$
$n_1 = 16$	$n_2 = 12$
$S_1 = 0.006861369$	$S_2 = 0.004934616$

Confidence Level	=	99%
α	=	0.005
degrees of freedom	=	26
Critical t value	=	2.779
t	=	-4.06

Since -4.06 is outside the range +/- 2.779 we reject H_0 and accept H_1 and conclude that the difference between truck efficiency means is significant at a 99% confidence level.

T-test spreadsheet is included in the appendices.

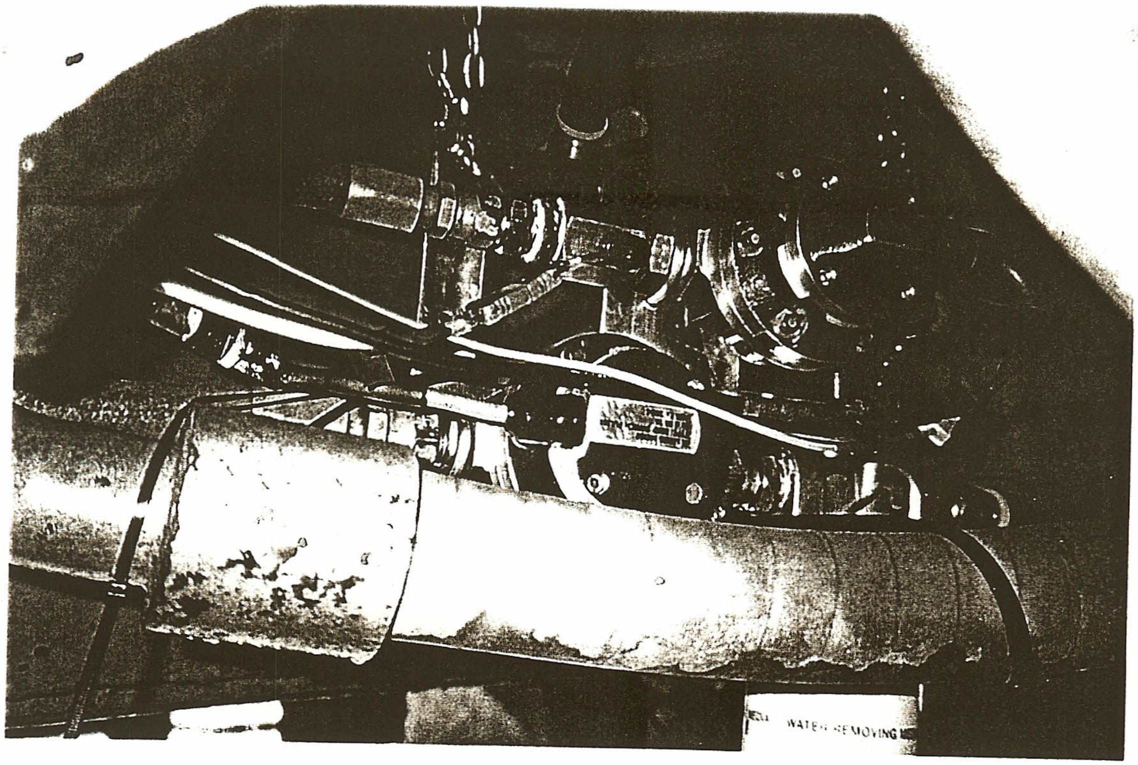
CONCLUSION

Fuel efficiency studies applied at MacMahon Contractors Giralambone site provide clear evidence of reductions in fuel consumption following the introduction of Fuel Technology's Combustion Catalyst, FTC-1.

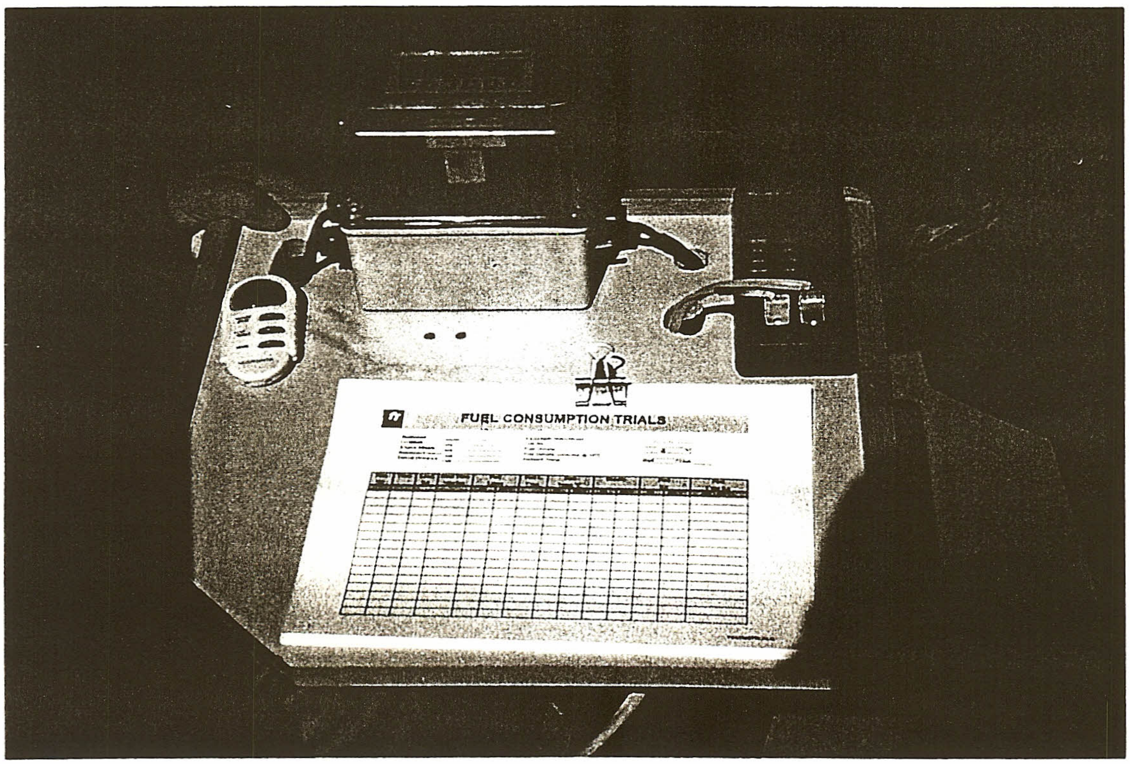
This efficiency gain measured in a normal working environment correlates well with previous tests conducted for MacMahon Contractors by the "Carbon Balance" AS2077 method.

The measured average reduction in kgs fuel per tonne of ore moved represents an ***7.6%*** efficiency gain following the introduction of FTC-1.

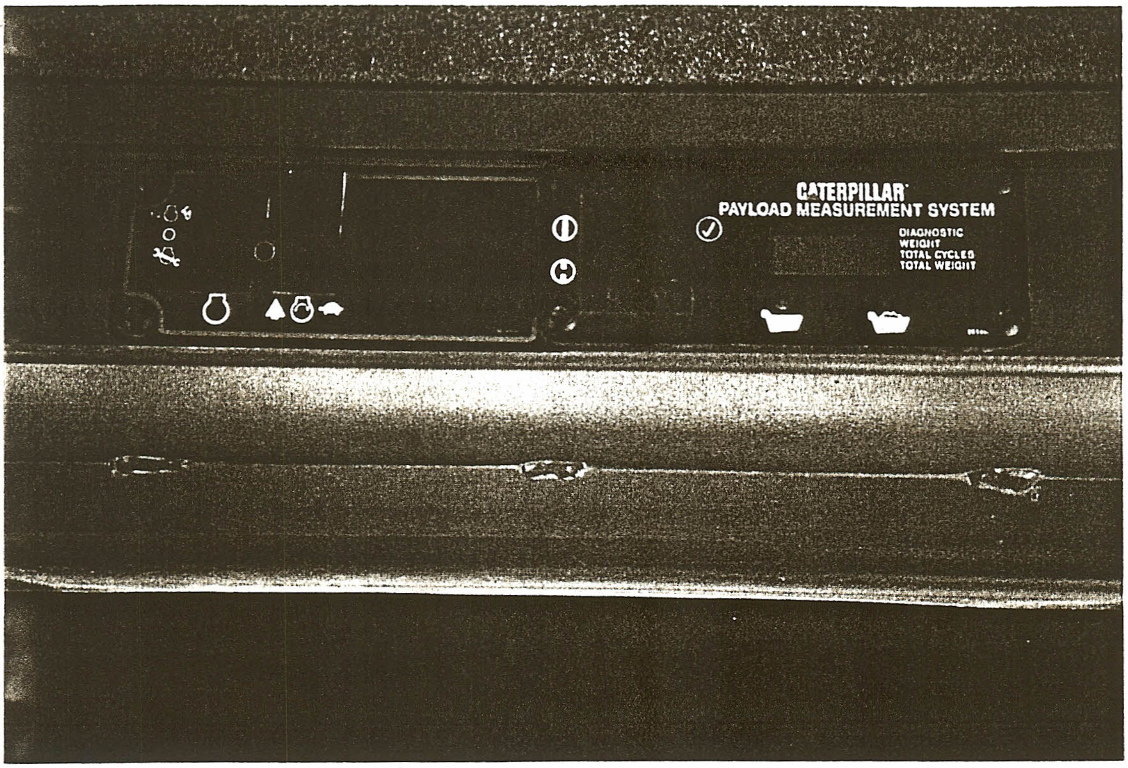
The Student t-Test confirms that the difference between untreated and treated tests are significant at a 99% confidence level.



Photograph No. 1 - MacNaught Model M5 flow transducers installed on the test truck



Photograph No. 2 - The in cab work station, Minitrol rate meter, Fluke digital thermometer and quartz crystal stop watch.



Photograph No. 3 -Truck on board payload measurement system.

Appendix "*A*"

TEST WORKSHEETS

(1

FUEL CONSUMPTION TRIALS

Customer	MACMAHON	Equipment Make/Model	CAT 777
Location	GIRILAMBONE	Unit No.	2287
Engine Hours	7267	Fuel Density	.845 @ 25.3°C
Baseline/~~Treated~~	11 - 9 - 96	Fuel Density corrected @ 15°C	0.852
Circuit Distance	947 m	Ambient Temp	Start 10° Finish 15°

HELD IN 2nd GEAR.

Run No	Time	Load Kg	Haul Time Min/Sec	Fuel Litres		Fuel L Cons	Fuel Temp °C		Density		Fuel Kg		Fuel Cons Kg
				IN	OUT		IN	OUT	IN	OUT	IN	OUT	(IN - OUT)
1	7.10	106000	5.45	81.02	65.59	15.43	21.7	35.8					
2	7.30	112000	5.04	86.98	70.75	16.23	26.1	39.5					
3	8.40	119000	6.03	86.97	70.61	16.36	36.7	46.8					
4	9.00	118000	6.06	87.37	70.84	16.53	39.4	49.2					
5	10.30	114000	6.03	87.00	70.36	16.64	47	52.4					
6	10.55	111000	5.45	81.1	65.32	15.78	48.2	54.4					
7	11.45	114000	6.04	87.2	70.59	16.61	49.1	56.1					
8	12.45	110000	5.43	81.24	65.83	15.41	35.5	46.6					
9	1.05	124000	6.15	89.11	72.37	16.74	38.2	52.7					
10	1.25	123000	6.15	89.19	72.44	16.75	40.9	52.3					
11	1.45	127000	6.13	88.54	71.83	16.71	44	54.3					
12	2.05	111000	5.45	82.14	66.70	15.44	46.5	55.1					
13	2.25	115000	6.11	88.54	71.83	16.71	48.3	55.7					
14	2.50	102000	5.53	83.19	67.13	16.06	50	55.6					
15	3.10	123000	6.09	87.75	71.01	16.74	51.3	58.7					

(2

FUEL CONSUMPTION TRIALS

Customer MAEA
Location GARILAMBONE
Engine Hours 7267
Baseline/~~Treated~~ 11-9-96
Circuit Distance 947 M

Equipment Make/Model CAT 777C
Unit No. 2287
Fuel Density @ °C
Fuel Density corrected @ 15°C
Ambient Temp Start Finish

Run No	Time	Load Kg	Haul Time Min/Sec	Fuel Litres		Fuel L Cons	Fuel Temp °C		Density		Fuel Kg		Fuel Cons Kg
				IN	OUT		IN	OUT	IN	OUT	IN	OUT	(IN - OUT)
16	3·40	81000	4·57	70·93	57·53	13·4	52·7	57·6					

FUEL CONSUMPTION TRIALS

Customer	MACA	Equipment Make/Model	
Location	[illegible]	Unit No.	
Engine Hours	7540	Fuel Density	.839 @ 32.8°C
~~Baseline~~/Treated	4 .. 96	Fuel Density corrected @ 15°C	0.851
Circuit Distance	947 M	Ambient Temp	Start 31 Finish 36

Run No	Time	Load Kg	Haul Time Min/Sec	Fuel Litres		Fuel L Cons	Fuel Temp °C		Density		Fuel Kg		Fuel Cons Kg
				IN	OUT		IN	OUT	IN	OUT	IN	OUT	(IN - OUT)
1	11.00	97	5.36	78.1	63.43	14.67	60.5	65.9					
2	11.25	100	5.36	78.38	63.18	15.20	61.2	65.7					
3	11.50	114	5.45	80.54	64.37	16.17	62	66					
4	1.10	116	5.44	80.36	64.83	15.53	49.4	57.4					
5	1.50	102	5.31	77.46	62.65	14.81	57.4	61.5					
6	2.10	112	5.44	80.19	64.7	15.49	55.6	62.2					
7	2.35	125	6.17	88.73	71.72	17.01	56.8	63.2					
8	2.55	116	6.11	87.37	71.61	15.76	58.5	64.8					
9	3.20	112	5.49	88.03	72.57	15.46	59.8	66					
10	3.40	112	6.05	86.67	71.15	15.52	61.3	67.2					
11	4.00	130	6.19	88.51	71.32	17.19	62.3	67.5					
12	4.20	121	6.06	86.64	70.03	16.61	63.2	67.8					

Appendix "*B*"

CATERPILLAR AIR TEMPERATURE CORRECTION TABLE

Correction Factors

As explained in the first section of this guide, engine power will be affected when the conditions in which an engine is operated or tested are different than the Standard Test Conditions. When you test an engine for a performance complaint, it is important that test conditions be evaluated to determine their possible effect on power. This can be accomplished in two ways by using correction factors. A percentage effect can be calculated, or if wheel horsepower is measured, a corrected wheel horsepower can be calculated. In either case, the use of correction factors will provide you specific information to help explain to the customer how the operating environment of the engine affects its power.

In simple form, Standard Test Conditions are:

- Fuel Density: 35 API corrected to 60°F
- Fuel Temperature: 85°F measured at the secondary fuel filter
- Air Pressure: 29.61 inches of mercury
- Air Temperature: 77°F at turbo intake for JWAC (110°F in the inlet manifold for ATAAC)

As part of a loaded engine test, these variable must be measured at each test speed for proper evaluation of test conditions. The test conditions may change enough during the test to affect power at a given test speed.

A Correction Factor Chart is provided for each variable to determine the individual correction factors. The individual correction factors are then multiplied together to obtain a Total Correction Factor. A Correction Factor Worksheet, procedure number 2000R is provided to simplify the calculation of the Total Correction Factor for each test speed. The Total Correction Factor for each test speed is then easily converted to represent a percentage effect on power or multiplied by the Observed Wheel Horsepower to determine Corrected Wheel Horsepower.

An example of the use of Correction Factors is given below:

Example:

The engine rating is 400 HP at 2100 RPM with jacket water aftercooler (JWAC).

This equals a 21 HP net effect on power because of a difference in Actual Test Conditions versus Standard Tests Conditions. If the engine was tested on a chassis dynamometer with Standard Test Conditions, the Observed Wheel Horsepower at 2100 RPM would have been 341 Wheel Horsepower and the Total Correction Factor would have been 1.00.

The Total Correction Factor can also be a number less than 1.00 To determine the percentage effect on power, subtract the Total Correction Factor from 1.00 and multiply by 100. Corrected Wheel Horsepower is still calculated by multiplying the Observed Wheel Horsepower by the Total Correction Factor When the Total Correction Factor is less than 1.00, the actual test/operating conditions cause the power to be better than the power at standard conditions. This is one reason why a complete Customer Problem Description obtained during the Customer Interview is so important. Power can vary substantially from a cold day to a warm day or from one tank fill to the next. The Customer Problem Description asks: Under what conditions the problem exists? Your knowledge of Correction Factors will help you formulate the type of questions to ask during the Customer Interview.

NOTE

Correction Factor charts for both Heavy Duty and Medium Duty Engines have been included in this guide.

ACTUAL TEST CONDITIONS AND OBSERVED WHEEL HP AT 2100 RPM

Fuel Temperature at Filter	Air Temperature at Turbo Intake	Air Pressure (Barometric)	Fuel API at 60° F	Wheel Horsepower
100° F	85° F	30 "Hg	40	320
1.015 CF x	1.015 CF x	1.004 CF x	1.031 CF	= 1.066 TCF

A Total Correction Factor of 1.066 equals a 6.6% effect on performance.

320 Observed Wheel HP x 1.066 = 341 Corrected Wheel HP.

CF = Correction Factor
TCF = Total Correction Factor

CORRECTION FACTORS FOR HEAVY DUTY ENGINES

INLET MANIFOLD AIR TEMPERATURE[1] CORRECTION FACTORS FOR ATAAC ENGINES

INLET MANIFOLD TEMPERATURE °F	CORRECTION FACTOR
45	.957
50	961
55	.964
60	967
65	.970
70	.974
75	.977
80	.980
85	.984
90	.987
95	.990
100	993
105	.997
110[2]	1.000
115	1.003
120	1.007
125	1.010
130	1.013
135	1.016
140	1.020
145	1.023
150	1 026

Measure downstream of the aftercooler.
Standard value

INTAKE AIR TEMPERATURE CORRECTION FACTORS FOR JWAC ENGINES[1]

INTAKE AIR TEMPERATURE °F	CORRECTION FACTOR
-10	923
-5	928
0	933
5	937
10	942
15	946
20	951
25	955
30	.960
35	964
40	968
45	.973
50	.977
55	981
60	986
65	990
70	994
75	998
77[2]	1 000
80	1 003
85	1.007
90	1 011
95	1 015
100	1 019
105	1.023
110	1.027
115	1 031
120	1 035

1 Measure between air cleaner and turbo intake
2 Standard value.

Appendix "*C*"

STUDENT'S t-TEST

t test: Two Sample Assuming Equal Population Variances

Company	MacMahon Contractors
Site	Giralambone
Test:	Untreated

Record		kg Load	kg Fuel	kg Fuel/Tonne Load	Correction For Amb.
	1	106000	13.7263	0.1295	0.1317
	2	112000	14.3767	0.1284	0.1306
	3	119000	14.1930	0.1193	0.1213
	4	118000	14.2913	0.1211	0.1232
	5	114000	14.0719	0.1234	0.1256
	6	111000	13.3659	0.1204	0.1225
	7	114000	14.1006	0.1237	0.1258
	8	110000	13.4306	0.1221	0.1242
	9	124000	14.7384	0.1189	0.1209
	10	123000	14.5473	0.1183	0.1203
	11	127000	14.4237	0.1136	0.1155
	12	111000	13.2221	0.1191	0.1212
	13	115000	14.2211	0.1237	0.1258
	14	102000	13.6991	0.1343	0.1366
	15	123000	14.2065	0.1155	0.1175
	16	81000	11.2644	0.1391	0.1415
Mean		113125	13.87	0.1231	0.1253
Std Dev		10941.51117	0.820350727	0.006744726	0.006861369
Observations					16

Test:	FTC Treated

Record		kg Load	kg Fuel		kg Fuel/Tonne Load
	1	97000	12.26	0.1264	0.1248
	2	100000	12.65	0.1265	0.1249
	3	114000	13.41	0.1177	0.1161
	4	116000	13.21	0.1139	0.1124
	5	102000	12.35	0.1211	0.1195
	6	112000	13.04	0.1165	0.1150
	7	125000	14.30	0.1144	0.1130
	8	116000	13.26	0.1143	0.1128
	9	112000	12.99	0.1160	0.1145
	10	112000	13.01	0.1161	0.1146
	11	130000	14.33	0.1102	0.1088
	12	121000	13.81	0.1141	0.1127
Mean		112364	13.17	0.1176	0.1158
Std Dev		9982.71233	0.673589447	0.00513948	0.004934616
Observations					12

	kg of Fuel/Tonne Corrected For Amb.
Mean % change	-7.6%
Confidence Interval	99%
Alpha	0.005
Degrees Of Freedom	26
t Critical Value	2.779
Hypothesis	$H_0: u_1 - u_2 = 0$
	$H_1: u_1 - u_2 <> 0$
t=	4.06

Conclusion:

Since t= 4.06, is outside the range +/- 2.779 we reject H_0 and accept H_1 and conclude that the difference between FTC treated and untreated test means are significant at a 99 % confidence level.