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REPORT OF THE FUEL COMBUSTION CATALYST TRIAL M.S. CONUS, SEPTEMBER 1984 TO AUGUST 1985

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CONTENTS

INTRODUCTION

This report describes the results of an eleven month trial of a ferrous picrate combustion catalyst (CV300) in the bunkers of the Shell tanker, M.S. CONUS. The purpose of the trial was to confirm and better quantify the improved fuel economy and engine cleanliness reported during a similar trial in the M.V. CELLANA during 1983 and 1984 (1).

The report sections which follow first describe, with supporting technical evidence, the ferrous picrate catalyst, then the trial programme and the data retrieved therefrom and finally, the observed and measured changes in the ship's engine and boiler operations.

All independent analyses, reports and studies bearing on the trial and trial results are attached to the appropriate section as appendices.

A section dealing with the economic implications of the trial results concludes the report.

(1) Report on the effects of CV100 on main engine fuel consumption aboard M.T. Cellana over six months. February, 1984.

CONCLUSIONS and RECOMMENDATIONS

1. In spite of the comprehensive operating data available from the ship's engine log, the data variables make an accurate quantification of fuel savings from the fuel treatment difficult, even with advanced statistical means. However, the analyses clearly indicate that fuel treatment resulted in fuel savings.

2. Short term sea trials conducted for full power calculations and PUP valve efficiency have demonstrated that reliable efficiency data may be extracted by carefully taken measurements while at sea without disturbing the ship's operation.

3. The conclusions to be drawn from this report are that observable and measured improvements have been demonstrated in fuel combustion during the trial. These improvements are significant in two areas:

   a. There is clear evidence of improved combustion and boiler efficiency in the ship's boilers and I.G. system.

   b. There is a measurable improvement in both fuel combustion efficiency and reduced carbon deposits in the main engine and M.E. exhaust system.

4. These improvements in combustion translate into financial benefits; first through fuel savings and secondly, and perhaps even more significant, important maintenance benefits which will reduce costs and increase the efficiency and service life of major capital plant.

5. We recommend a series of short, well-controlled tests be run during the normal operating regime of the ship to better quantify the actual difference in fuel efficiency between treated and untreated fuel.

ACKNOWLEDGEMENTS

This study is a product of attentive interest and support given by the Shell Marine organization, the ship's officers and the various consulting and analytical groups, all of whom have given generously and courteously of their experience, knowledge and time.

Fuel Technology P/L

FUEL TECHNOLOGY PTY LTD
October 24, 1985

SECTION 1: THE FUEL CATALYST

The active ingredient added to the CONUS fuel is ferrous picrate dissolved in alcohol (15%). This is blended with a dispersing agent, toluene (85%). The product was first developed at the University of British Columbia and the earliest patents were applied for in 1944 and granted in 1950.

The manufacturer of the CV300 product supplied to the CONUS is Carvern Petrochemical Company of Fort Erie, Ontario. There are at least two other manufacturers of this general formulation.

CV300 is essentially a concentrate of CV100 which was used in the CELLANA trial. CV100 is normally blended at a ratio of one part CV100 to 1600 parts fuel. The same concentration of the active ingredient in fuel is derived from CV300 using a 1:3000 ratio. That means one litre of CV300 treats approximately three tonnes of fuel. Because the concentrate contains less toluene, fuel blending may not be equal to that achieved with CV100. During the CONUS trial, dosing rates 1:3000, 1:3300 and 1:2400 were used. The catalyst was measured and poured directly into the bunkers during fuelling operations.

Studies by the manufacturer and independent researchers (2), (3) describe three actions by which the product containing ferrous picrate improves combustion:

a. The toluene improves misting of fuel upon injection.

b. The heat in the combustion chamber vaporizes the small amount of alcohol in each fuel droplet, precipitating for an instant microcrystals of ferrous picrate. These ignite before and during the fuel burn, generating multiple flame centres.

c. The free Fe++ ions released by the action in step 2 act catalytically to promote oxidation by breaking hydrocarbon molecular bonds in fuel droplets and in any complex carbon deposits found in the combustion zone.

(2) Albert F. Bush, Professor of Engineering, U.C.L.A., School of Engineering, Report CPR 7, December 1971.

(3) Robert B. Sterns, Ferrous Corporation, U.S.A., The Motor Ship, December 1981.

If the process described in steps 1-3 is correct, the result of treating fuel with CV100/300 should be:

- a shorter ignition lag, reducing the time of the first phase of combustion,
- acceleration of the second and third phases of combustion,
- increased power from a set amount of fuel,
- reduced fuel consumption at a given load,
- reduced emissions of HC, C and CO in a given mass of engine exhaust, and
- a gradual elimination of combustion-zone carbon deposits.

As demonstrated by the curves, tables and photographs in Appendix 1, this is exactly what happens.

Appendix 1A: Curves 1-3 were developed by Mr. John Gould using a 7.5 kW dynanometer in the Mechanical Engineering Laboratory at the West Australian Institute of Technology (W.A.I.T.).

Graph 1: "Power vs Injection Timing" shows that as the concentration of active ingredient in fuel treated with CV100 increases from zero to a 1:1200 mixture, the maximum power value achieved from pure diesel injected at 35 degrees before TDC is matched by treated fuel at around 32 degrees because of reduced ignition lag. Power throughout the injection range is higher with treated fuel indicating more complete combustion in phases two and three.

Graph 2: "Power Comparisons" shows that power increases with increasing concentration of fuel additive.

Graph 3: "Fuel Consumption Comparisons" shows a decrease in fuel consumption with increasing concentration of the active ingredient. Consumption is measured in kilograms fuel per horsepower hour. Since the data for graphs 2 and 3 are taken from the same test, the power increase shown in graph 2 is actually developed at a decreased fuel consumption.

Graph 4: "Specific Fuel Consumption Trial" in a mining company's 650 kW engine shows two features

- an increase in pure diesel consumption over a three month period as a result of engine "ageing".
- a decrease in fuel consumption (approximately 4%) as a result of treating fuel with CV100.

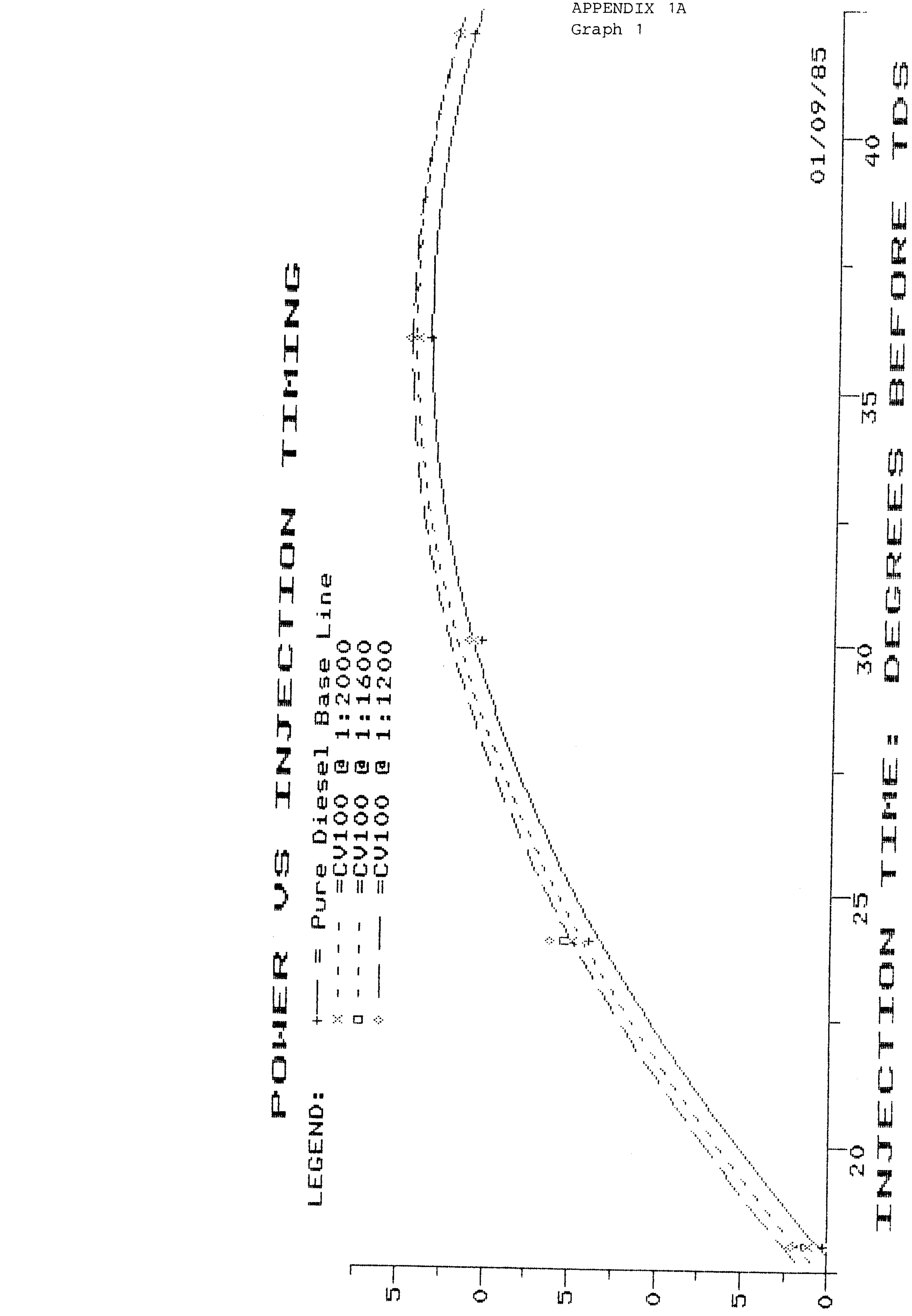
These consumption tests were run under the owner's supervision using the gravimetric fuel consumption method.

Appendix 1B: A 1978 report showing reduced CO and HC emissions from treated fuel by the testing laboratory of the New South Wales Department of Mines. The test measured emissions from a Perkins 3 cylinder diesel engine burning treated and untreated fuel. Since this report, Carbon Balance equipment has been used on numerous occasions measuring with similar results exhaust composition versus mass flow on a range of engines up to 15,000 kW capacity. Many of these reports have been submitted in previous communications and are available for inspection.

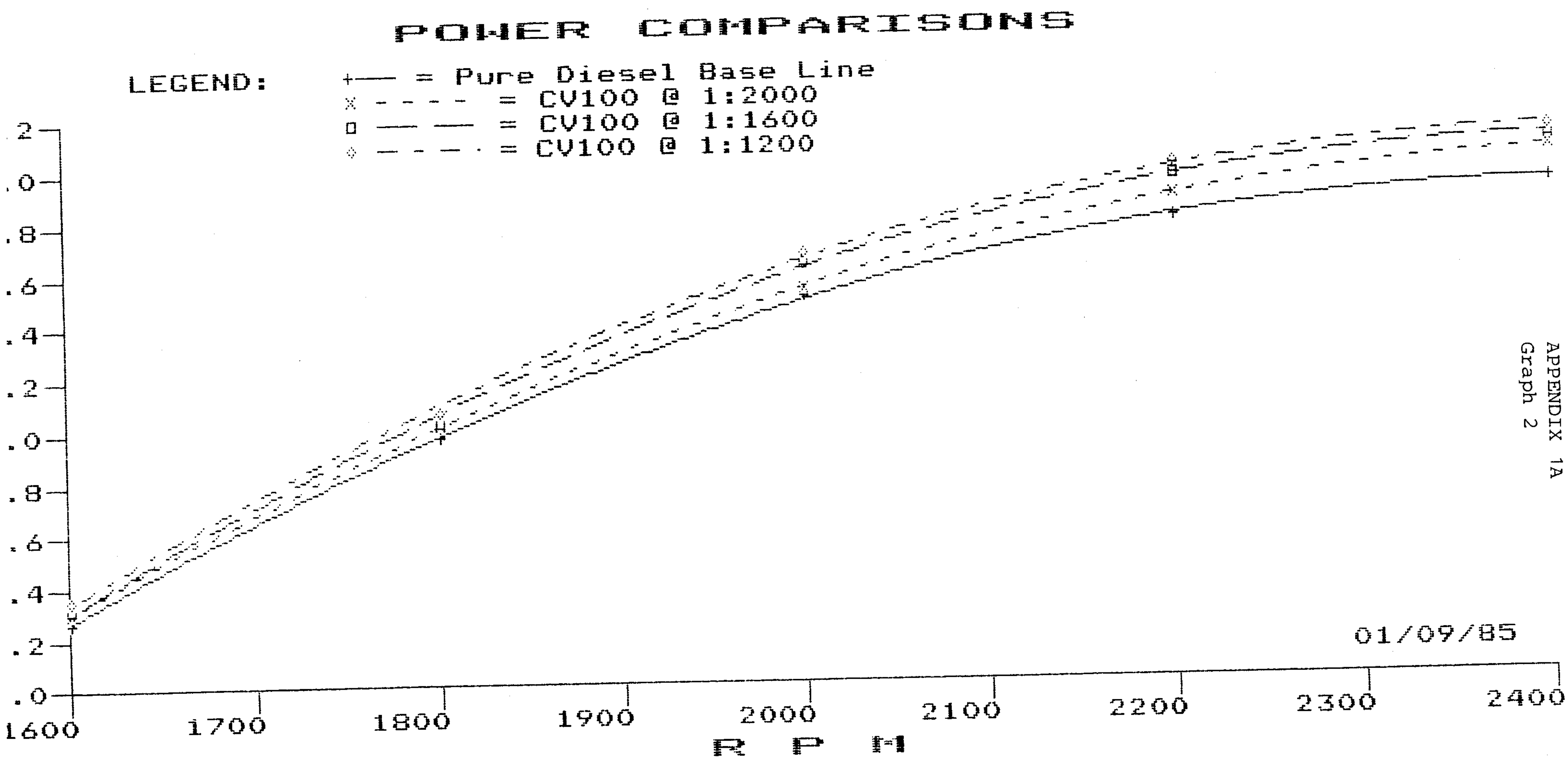
Appendix 1C: shows photographically the elimination of carbon deposits in a boiler resulting from the treatment of fuel with CV100.

The Sections which follow demonstrate that CV300 treatment of bunkers in the M.S. CONUS resulted in similar improvements to combustion.

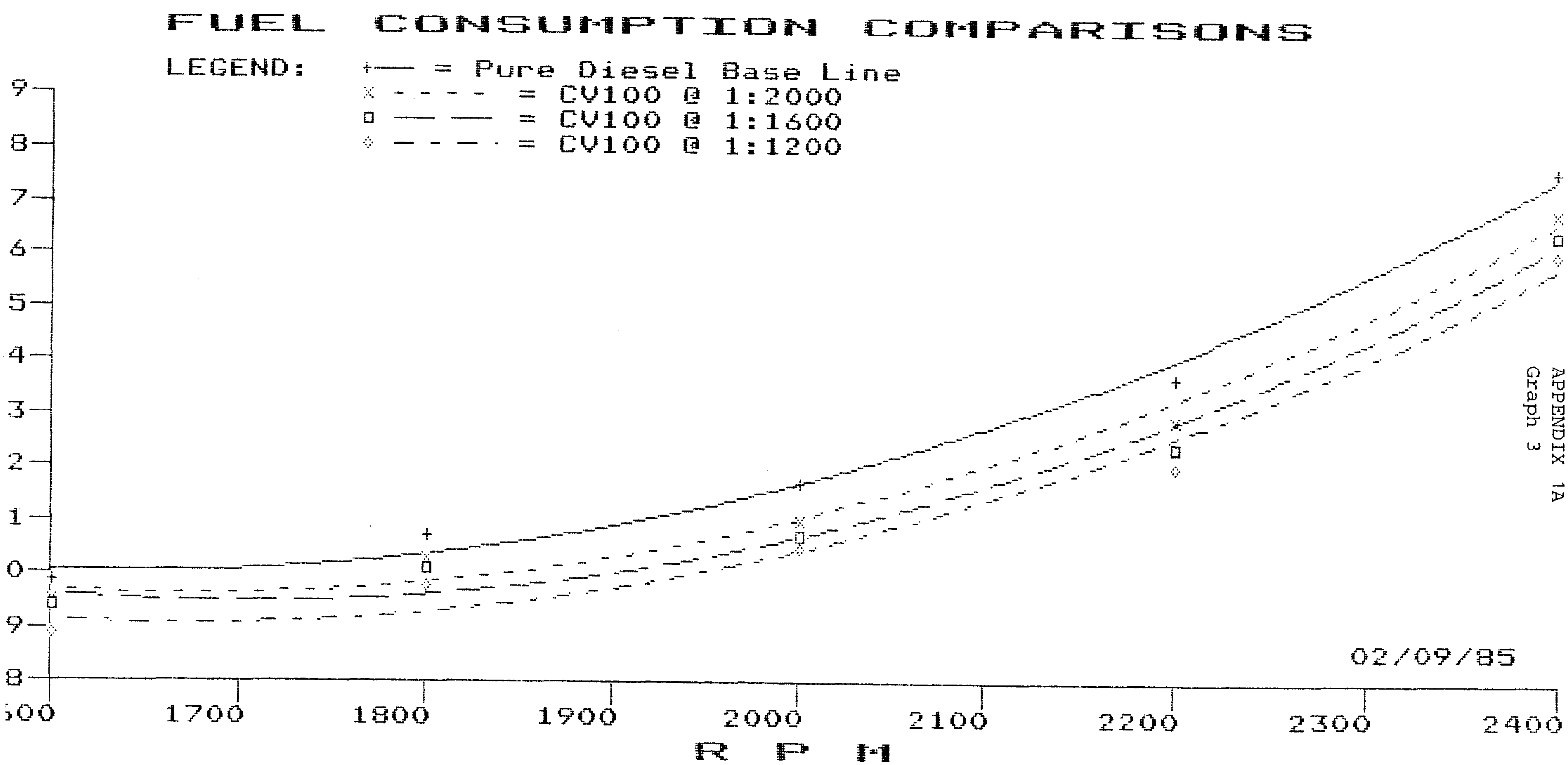
APPENDIX 1A
Graph 1



APPENDIX 1A
Graph 2



APPENDIX 1A
Graph 3



...munications To Be Addressed To

The Under Secretary,
Department of Mines,
State Office Block,
Phillip Street,
Sydney. 2000

All Samples To Be Forwarded To

Department of Mines
Chemical Laboratory
Joseph Street
LIDCOMBE NSW 2141

PO Box 76
LIDCOMBE NSW 2141

Telephone: 646 1644

3rd October ,1978

Dear Sir,

The sample(s) ~~submitted by you on~~ of exhaust gas taken by C. Ellis on 11.9.78 & 15.9.78 ~~and stated to be~~ from the dynamometer - mounted Perkins 3-152 engine at the Department's Testing Station at Londonderry

have been ~~examined, assayed,~~ analysed and results are shown on the Certificate below:

Mr D. Campbell
Golden Fleece Petroleum
P.O. Box 915
NORTH SYDNEY 2060

Yours faithfully,

G.M. MAXWELL
UNDER SECRETARY

per:

CERTIFICATE No. CL 78920 Page 1 of 2

Analytical equipment used for assessment of fuel additive CV100

GAS	EQUIPMENT
Carbon dioxide	M.S.A. LIRA 202 carbon dioxide analyser, with linear output, digital display.
Carbon monoxide	Grubb Parsons model SB2 Infra Red Gas Analyser.
Oxides of nitrogen (NO & $NO + NO_2$)	A.M.I. Model 40R Chemiluminescence Analyser.
Oxygen	Taylor Servomex Type OA272 Oxygen Analyser
Hydrocarbons	M.S.A. FID Total Hydrocarbon Analyser.

N.B. Engine speed and power are included for identification of test conditions. These are not in accordance with the terms of this laboratory's N.A.T.A. registration.

NATA

Acting Director

All Communications To Be Addressed To

The Under Secretary
Department of Mines
State Office Block
Phillip Street
SYDNEY NSW 2000

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Telephone: 646 1644

3rd October 1978

CERTIFICATE CL No. 78920

Fuel	Standard	Treated	Standard	Treated	Standard	Treated	Treated
Date	11.9.78	15.9.78	11.9.78	15.9.78	11.9.78	15.9.78	15.9.78
Engine Speed RPM	1200	1200	2000	2000	2000	2000	2000
Engine Power (BHP	22.5	22.5	36	36	37.5	37.5	38
Sample No. 7..L-	3384	3385	3386	3387	3388	3389	3390
Carbon Dioxide (%)	8.7	8.3	9.5	9.2	9.8	9.5	9.7
Carbon Monoxide (ppm)	530 ± 20	420 ± 20	1140 ± 40	1040 ± 40	1380 ± 50	1260 ± 50	1310 ± 50
Difference (ppm)	110 ± 15		100 ± 35		120 ± 35		-
Nitric oxide + nitrogen dioxide (NO + NO_2; ppm NO)	1880 ± 40	1840 ± 40	1180 ± 40	1180 ± 40	1250 ± 40	1210 ± 40	1300 ± 40
Nitric oxide (ppm NO)	1750 ± 40	1700 ± 40	1130 ± 40	1140 ± 40	1180 ± 40	1140 ± 40	1230 ± 40
Oxygen (%)	8.7 ± 0.2	9.3 ± 0.2	7.7 ± 0.2	8.0 ± 0.2	7.1 ± 0.2	7.4 ± 0.2	7.2 ± 0.2
Total hydrocarbons (ppm equivalent methane)	60 ± 5	25 ± 5	145 ± 10	110 ± 10	165 ± 10	125 ± 10	125 ± 10
Difference (ppm)	35 ± 5		35 ± 10		40 ± 10		-

Additional comments concerning accuracy.

The accuracies quoted in the results are those which would apply in the analysis of a gas mixture of unchanging and homogeneous composition. This is not the situation with an operating engine, even under constant load on a dynamometer. Caution must therefore be exercised in drawing conclusions, where there are small apparent changes in exhaust gas composition. Care was taken during the analyses to obtain an 'average' reading over about 30 seconds, thus reducing the effect of the more rapid changes in composition; however the possibility of slower changes remains.

Director
Chemical Laboratory

New South Wales Government

Department of Mines
CHEMICAL LABORATORY
Joseph Street,
Lidcombe, N.S.W.
P.O. Box 76
Lidcombe. 2141.

Our reference:

Your reference:

For further information
Telephone: 646 1644

Ring C. Ellis
Extension: 13

Mr D. Campbell,
Golden Fleece Petroleum,
P.O. Box 915,
NORTH SYDNEY. 2060

3rd October, 1978

Dear Sir,

Tests of Diesel Fuel Additive CV100

On 11th September and 15th September 1978, tests were carried out at the Londonderry Testing Station of this Department, to determine the effects of diesel fuel additive CV100 on exhaust gas composition.

A Perkins 3 cylinder diesel engine, of 152 cubic inches displacement, was operated on the dynamometer for about six hours, using standard diesel fuel. At the end of this period the exhaust gases were analysed.

The engine was then run for about 38 hours over the next four days, using the same fuel treated with additive CV100 in the proportion 1 to 1600. At the end of this period, the exhaust gas analyses were repeated.

The instruments used for analysis, and the results obtained, form a certificate attached to this report.

The tests after operation with the treated fuel showed the following:

1. A reduction in carbon monoxide emissions, of the order of 10% under the test conditions.

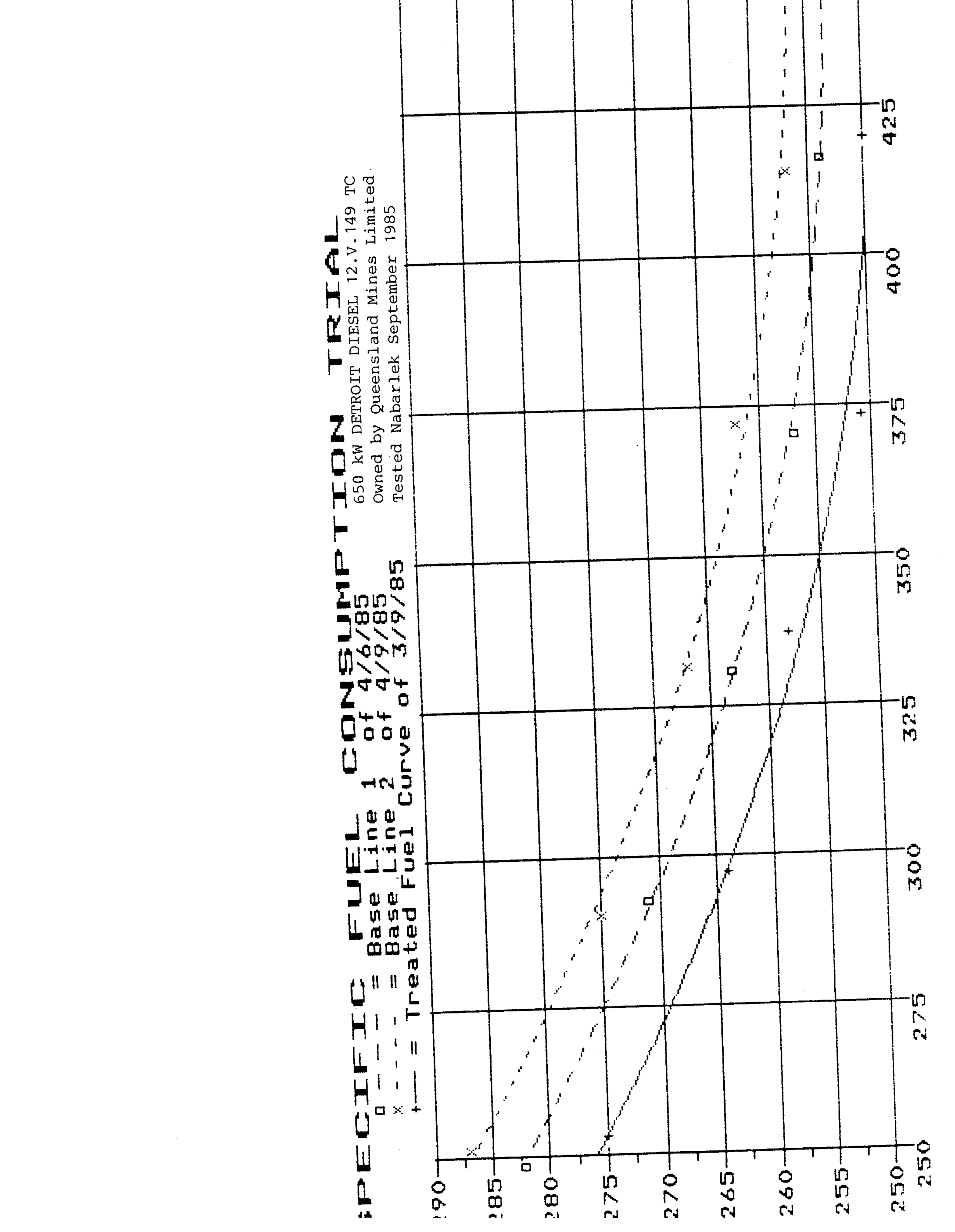
2. No significant change in oxides of nitrogen (or of nitric oxide).

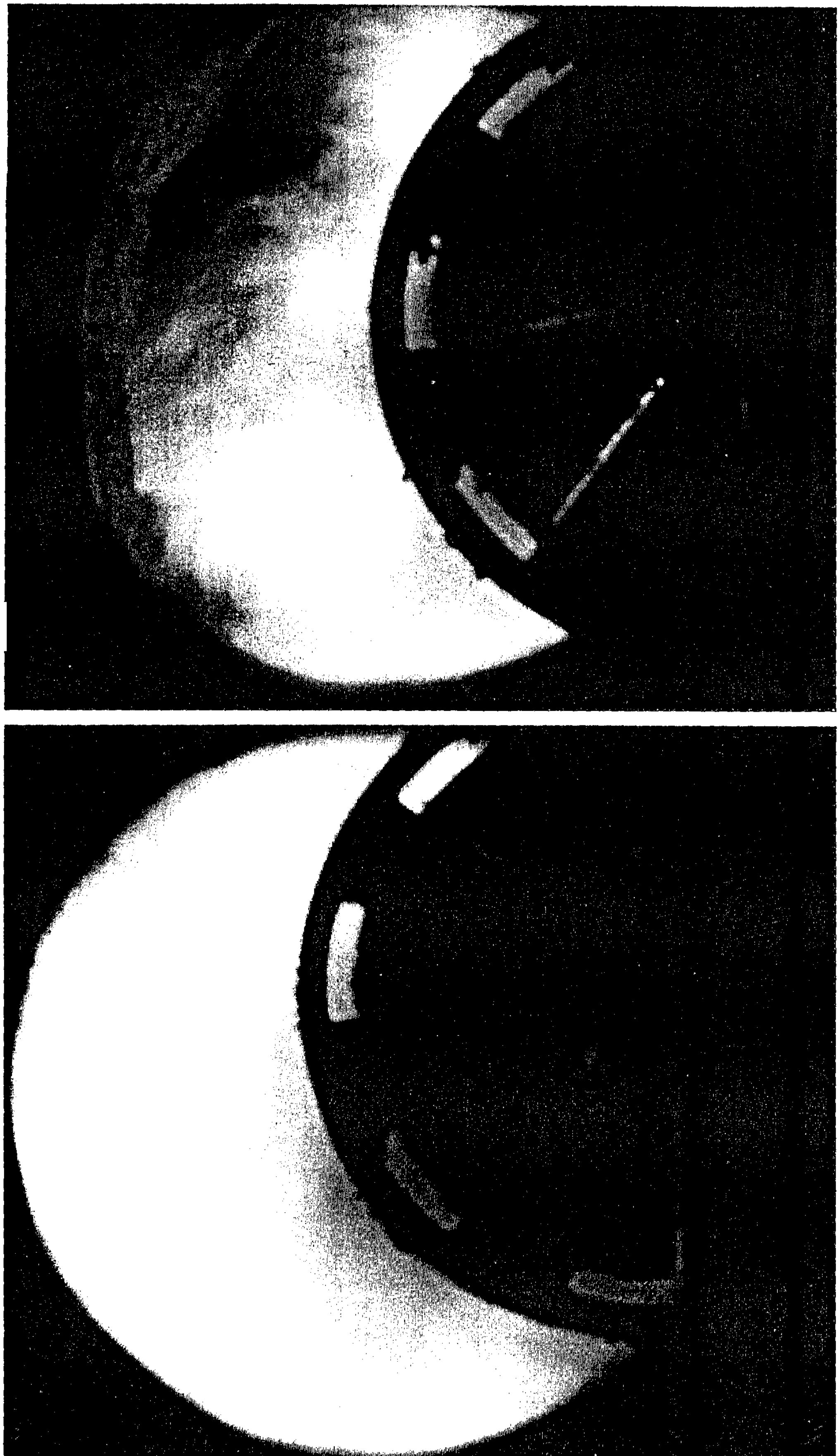
3. A reduction in hydrocarbon emissions of 25% or more, under the test conditions.

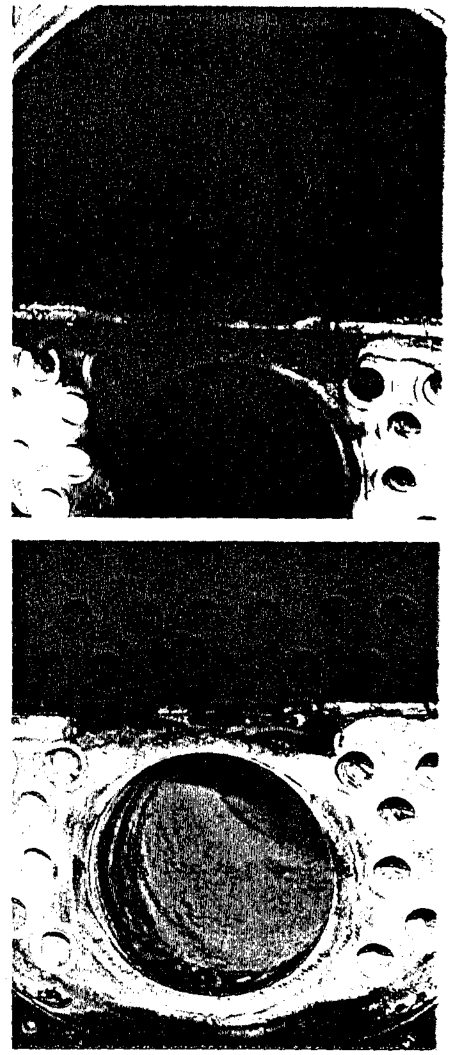
I would draw your attention to the accuracies quoted in the certificate, and to the additional comments at the end. These comments should explain the guarded manner in which I have expressed the results above.

"John McGlynn
for UNDER-SECRETARY"

APPENDIX 1A
Graph 4







Heat exchange surfaces before (top) and after (bottom) use of CV 100 in a low pressure boiler.

Flame profile in #6 Fuel Oil without C
100 (top left) and with CV 100 (bottom
left) without mechanical adjustment t
equipment.

SECTION 2

SECTION 2: THE TRIAL

The specification for the trial was set out in a letter from Shell Australia Limited dated May 22, 1984 to Fuel Technology Pty Ltd, Appendix 2A. Actual dosing of the ship's bunker commenced on September 12, 1984.

2.1 SHIP OPERATING DATA

Background operating data from the ship's main engine log were extracted for the period commencing January 16, 1984. This covered engine operation for the 2,969 hours between 11,003 and 13,972 M.E. hours, the latter being the total M.E. running time to September 12, 1984.

Similar operating data was extracted during the treatment period spanning 4,928 hours to September 12, 1985. However the last dosing of the bunkers was done on August 1, 1985 when 240 tonnes of oil was treated. The next fuelling date was August 13, 1985 so for the purpose of the trial, the Treatment Period Data is that from September 16, 1984 to August 10, 1985 which spans the 4,434 operating hours from 14,023 to 18,457 M.E. hours (even though the fuel system and engine condition will continue to contain declining amounts of the catalyst for a period).

All of the data extracted from the log is reproduced in the attached tabulation in Appendix 2B. Footnotes on pages 2 and 5 of this appendix explain the qualifications entered in the log which affect the data.

The measurement of fuel efficiency, FS, in the last column of the data is calculated by the ship's computer from data entered by the ship's engineers. In theory this value should be unaffected by any changes in the ship's hull or operation other than engine efficiency. The FS value is derived from dividing the corrected fuel flow by the adjusted horsepower. The adjusted horsepower is calculated from the Load (throttle setting) and RPM and then adjusted for fuel density and calorific value. FS thus has units of grams fuel per horsepower hour.

There are a number of input variables which effect the accuracy of this calculation. These include the precision of the entered RPM and Load values and to possibly a lesser extent the fuel flow, time and temperature taken at the pumps and engine. Fuel Density and Calorific values are also not apt to be precise because of the blending of old bunkers with those for which the values are given.

Load and RPM values listed are those accepted by the engineers as that used for most of the voyage. However, there is a period of at least one half hour at the beginning and end of each voyage during which the engine is run at reduced power and about 115 RPM. Because the engine efficiency curve is not a straight line the relationship between FS and RPM is also not linear. Thus "slow sailing", "reduced speed", "reduced power" which are conditions for only part of the voyage introduce an unquantifiable variable into the FS calculation.

Another variable to which the footnotes refer is the operation of the piston under-pressure (PUP) valves. The log footnotes indicate these have either malfunctioned or were purposefully shut for all or part of a voyage. According to the log, this has occurred more frequently during the Treatment period than in the Background period. While an attempt has been made to correct for this (4) condition in the calculation of FS this cannot be said to be precise in all cases.

The "ageing" effect of an engine introduces another time-related variable. All engines age, even those under constant and programmed servicing. They are less efficient after one year, two years, five years than when new. This is a variable that is difficult to recognize over a short period because it is incrementally small, persistent and not necessarily linear. Added to this is a transition period between the efficiency of untreated and treated fuel. This change can take over 1,000 hours of operation depending on the engine condition and service.

All of these variables make it impossible to directly compare fuel efficiency as calculated in FS during the Background with that calculated during the Treatment period. For this reason Shell Australia and Fuel Technology jointly commissioned a statistical approach to the evaluation of this data, the analysis and results of which are reported by The Melbourne University Statistical Centre in an Appendix (3B) to this report.

(4) The "PUP valve" correction factor is calculated to be 1.1 FS units or about 0.769% of FS (closed condition). This factor was derived from a trial on September 15, 1985 by Mr. O'Flaherty which corresponds closely to the data taken at 16,039 and 16,073 on two successive voyages in February, 1985.

2.2 ENGINEERING OBSERVATIONS

In addition to the ship's engine operating data, other measurements and observations were taken during the trial. These included most of the trial specification (Appendix 2A). Most of these observations were taken by the ship's engineers and reported on directly to the owners.

Fuel Technology however participated in a number of studies and observed several boiler and engine conditions, the data for which are in Appendix 2C and the results of which are described in the next section, The Trial Results.

Chemical analysis of fuel, sludge, boiler deposits and engine soot were commissioned by Fuel Technology at various stages during the trial.

The independent reports and analyses bearing on these studies are included in Appendix 2C and the results are summarized in Section 3.

B. L. KELLY

SHELL AUSTRALIA LIMITED
155 WILLIAM STREET
MELBOURNE 3000
TEL: 609 5300

22nd May, 1984.

Mr. I.B. Hilton,
General Manager,
Fuel Technology Ltd.,
7th Floor,
608 St. Kilda Road,
MELBOURNE. VIC. 3004

Dear Ian,

CV300 Fuel Treatment - M.S. Conus

Thank you for your letter of 18th May, 1984, advising price and availability of CV300 to be supplied for the forthcoming 12 month trial aboard M.S. Conus.

In respect of your Sales Engineer's contact with the Chief Engineers of M.S. Conus, this is to be co-ordinated by our Marine Operations Superintendent. We will be advising the Chief Engineer of M.S. Conus shortly of our intention to conduct this trial, thereafter contacting your Mr. Campbell to arrange a meeting on board the ship to clearly define procedures that will be adopted.

Having the facility to monitor performance and consumption more accurately on Conus, we require the following parameters to be taken into consideration when preparing your evaluation :-

1) Cylinder liner wear rates
2) Main engine fuel oil pump wear rates
3) Monitoring of main engine lub oil TBN number
4) Standard of bunker tank cleanliness
5) Operation of fuel oil centrifuge
6) Quality of fuel, i.e. calorific value, sludge content etc.
7) Correlation between S.H.P and main engine consumption
8) Boiler fireside conditions.

With reference to our payment for the CV300, whilst we are prepared to accept your invoice for the full year's supply, we reserve the right to return for credit any unused chemical should we deem it necessary, for technical or other reasons, to terminate the trial. Your confirmation in this respect would be appreciated.

Yours sincerely,

M.V. CONUS LOG EXTRACT: BACKGROUND 16/1/84 to 12/9/84 SCHEDULE 1

LOG					FUEL					CALC		
Date D/M	Total(1) M/E Hrs	M/E ExhT	Load IND	M/E rpm	SpG @ Mtr(2)	Cal Value	Kl Flow	Hrs Test	PSe Hp	Ft kg/hr	Fs g/hp/hr	EDIT NOTE
16/1	1003	394	6.2	142.9	9487	10101	129.3	81.7	10100	1501	147.2	-
19/1	1034	398	6.2	142.2	9467	10101	27.2	17.6	10059	1463	144.1	
20/1	1052	404	6.3	130.9	9467	10101	21.5	16.0	9525	1272	132.3	(6)
22/1	1069	404	6.2	142.4	9467	10101	23.3	15.1	10070	1461	143.7	
26/1	1142	399	6.2	143.1	9455	10101	108.3	70.4	10119	1454	142.3	
28/1	1182	390	6.2	143.4	9487	10101	56.5	36.0	10129	1489	145.6	
1/2	1204	394	6.4	142.7	9509	10046	18.3	11.5	10348	1513	144.0	
3/2	1228	394	6.3	141.6	9502	10046	32.8	21.5	10133	1450	140.9	
5/2	1264	392	6.3	142.7	9489	10046	49.8	31.9	10184	1481	143.3	
10/2	1302	396	6.4	143.3	9509	10050	7.1	4.5	10352	1500	142.8	
12/2	1327	372	6.5	142.4	9502	10050	30.0	18.9	10454	1508	142.2	
14/2	1347	396	6.3	142.5	9476	10050	15.2	9.8	10155	1470	142.6	
19/2	1444	350	5.5	1290	9489	9535	109.8	88.0	7546	1176	145.7	
22/2	1466	-	6.5	143.4	9496	9535	72.0	45.3	99.35	1509	142.0	
26/2	1486	340	6.6	143.9	9496	9535	31.6	19.5	10107	1539	142.3	(3)
29/2	1533	390	6.3	139.2	9489	9535	57.9	37.8	9462	1453	143.6	
2/3	1550	390	6.5	143.3	9459	9535	18.8	11.7	9942	1520	143.4	
4/3	1572	390	6.3	142.7	9466	9535	32.9	21.1	9665	1476	143.2	
6/3	1595	400	6.4	142.6	9466	9535	4.7	3.0	9781	1483	142.2	
8/3	1614	396	6.5	140.7	9427	9565	27.0	17.0	9798	1497	143.3	
10/3	1653	393	6.4	144.4	9440	9565	42.9	26.6	9918	1522	143.9	
15/3	1699	396	6.4	144.0	9521	9556	43.4	27.0	9958	1530	144.0	
19/3	1745	313	4.0	109.6	9488	9556	29.8	40.8	4227	693	153.6	(6)
21/3	1768	402	6.3	142.7	9495	9556	27.5	17.6	9741	1484	142.7	
23/3	1785	392	5.9	137.6	9495	9556	21.7	15.1	8937	1346	143.0	
28/3	1889	398	6.4	143.5	9495	9556	158.2	98.6	9916	1523	143.9	
31/3	1927	387	6.2	143.4	9489	10105	49.4	31.5	10185	1488	144.7	
2/4	1949	389	6.1	143.4	9457	10105	30.8	19.8	10047	1471	145.0	
2/4	1954	287	4.0	106.3	9437	10105	2.1	3.1	4300	639	147.3	(6)
3/4	1958	390	5.7	137.0	9444	10105	2.0	1.4	8993	1349	148.6	(7)
5/4	1977	386	6.1	143.6	9476	10105	19.8	12.8	10060	1466	144.4	
9/4	2024	388	6.2	143.4	9457	9554	63.0	39.9	9623	1493	145.3	
12/4	2070	324	4.6	118.1	9489	9554	38.8	39.9	5486	923	157.5	(6)
16/4	2146	396	6.0	142.9	9470	9554	100.8	66.3	9338	1440	144.4	
18/4	2164	394	6.3	142.4	9470	9554	18.2	11.5	9616	1499	145.3	
20/4	2188	350	6.1	144.4	9489	9509	33.4	21.5	9464	1474	145.2	
22/4	2226	392	6.1	143.0	9457	9509	47.9	31.0	9394	1461	145.0	
26/4	2273	392	6.3	143.5	9444	9509	61.0	38.5	9671	1496	144.2	
29/4	2313	398	6.0	140.9	9424	9509	50.5	33.6	9148	1416	144.3	
1/5	2355	375	5.6	129.0	9437	9509	46.7	36.0	7736	1224	147.5	(6)
3/5	2371	399	6.2	141.7	9450	9509	22.0	14.3	9444	1454	143.5	
4/5	2384	406	6.2	140.6	9359	9509	15.6	10.1	9324	1446	144.5	
11/5	2523	385	6.0	138.0	9424	9509	200.9	132.9	8973	1425	148.0	(7)
15/5	2584	390	6.0	137.8	9393	9582	45.7	31.6	9007	1358	141.7	(7)

16/5	2587	300	4.0	107.3	9393	9582	0.8	1.2	4079	626	144.2	(6)
18/5	2601	385	6.2	142.2	9393	9582	17.6	11.3	9451	1463	145.4	
18/5	2609	392	6.7	144.5	9386	9582	3.3	2.0	10222	1549	142.3	
23/5	2694	391	6.2	143.3	9386	9582	51.3	33.1	9559	1455	143.0	
25/5	2694	391	6.3	143.2	9354	9582	58.5	37.1	9655	1475	143.5	
30/5	2744	394	6.3	142.8	9360	9582	37.7	24.0	9653	1470	143.1	
31/5	2779	399	6.4	142.3	9393	9582	49.1	30.5	9772	1512	145.4	
3/6	2830	393	6.3	143.5	9386	9582	71.8	44.4	9963	1518	143.1	
6/6	2872	388	6.8	143.1	9354	9582	50.3	31.8	9668	1480	143.8	
11/6	2896	386	6.0	142.5	9334	9582	59.7	39.6	9227	1407	143.3	
14/6	2954	400	6.5	143.2	9367	9582	46.9	29.1	9924	1510	142.9	
19/6	3014	398	6.3	141.9	9373	9582	84.6	54.0	9595	1468	143.8	
20/6	3044	399	6.4	142.1	9321	9582	23.2	14.6	9699	1481	143.5	
24/6	3110	392	6.4	143.0	9347	9582	97.2	60.6	9785	1499	143.9	
26/6	3152	390	6.4	144.1	9360	9582	59.3	36.8	9855	1508	143.8	
30/6	3196	391	6.4	144.5	9393	9603	62.5	38.3	9934	1533	145.3	
01/7	3214	347	4.5	114.1	9347	9603	11.2	13.1	5105	799	147.4	(6)
03/7	3237	370	6.0	135.4	9386	9603	28.2	19.4	8909	1364	144.2	
07/7	3287	385	6.2	143.1	9373	9603	66.6	42.7	9583	1462	143.6	
15/7	3372	389	6.3	144.1	9376	9626	2.4	1.5	9787	1500	144.6	
19/7	3422	397	6.2	143.2	9343	9626	72.0	45.7	9573	1472	145.1	
20/7	3435	405	6.4	142.0	9259	9626	16.9	10.5	9692	1490	145.1	
21/7	3462	402	6.3	142.3	9298	9626	38.0	23.9	9617	1478	145.1	
23/7	3498	385	5.9	136.4	9330	9626	45.2	31.2	8779	1352	145.3	
26/7	3535	382	6.5	144.0	9376	9626	24.6	15.1	10041	1527	143.6	
03/8	3540	380	5.6	132.1	9369	9626	6.0	4.5	7977	1249	147.8	(6)
07/8	3556	398	6.3	143.1	9369	9626	21.6	13.6	9717	1488	144.5	
09/8	3579	380	5.7	136.1	9363	9626	29.2	21.0	8432	1302	145.7	
10/8	3598	395	6.3	142.7	9356	9626	20.9	13.3	9680	1470	143.3	
14/8	3617	396	6.4	142.4	9309	9592	23.6	14.8	9734	1484	143.4	
15/8	3620	320	4.0	105.8	9192	9592	1.0	1.4	3993	657	154.6	(6)
16/8	3638	397	6.3	142.6	9264	9592	19.6	12.4	9591	1464	143.6	
24/8	3721	389	6.3	142.7	9351	9592	115.6	73.0	9658	1482	144.3	
27/8	3761	390	5.9	137.0	9316	9592	48.4	33.5	8785	1346	144.1	
28/8	3776	400	6.4	142.9	9303	9592	22.9	13.8	9715	1496	144.9	
2/9	3851	401	6.5	143.1	9264	9592	117.0	71.8	9860	1510	144.0	
4/9	3894	395	6.3	143.3	9283	9592	58.8	36.8	9631	1483	144.8	
8/9	3932	393	6.3	143.3	9332	9592	49.2	31.0	9680	1481	144.0	
10/9	3955	394	6.4	142.9	9319	9597	35.1	21.9	9772	1494	143.8	
12/9	3972	393	6.2	142.5	9319	9597	18.4	11.8	9489	1453	144.0	

EDIT NOTES

(1) Hrs - 10,000 (add 10,000 to get actual hours).
(2) Density x 1,000 (divide by 1000 to get density).
Some errors exist in data list as a result of transposition from log. These do not affect the results.
(3) Full Power Calculation (from log).
(4) PUP Valves closed (from log).
(5) PUP Valves probably inoperative (from Exhaust Temp).
(6) Reduced Speed. RPM below 135.
(7) Reduced Speed. RPM above 135. FS value suspect.

(4) The PUP Valves correction factor used in Schedule 2:
From log Schedule 1 ME hrs 16039 & 16074

$$\frac{143.1 - 142.0}{143.1} = .769\%$$

M.V. CONUS LOG EXTRACT:TREATMENT 16/9/84 to 12/9/85 SCHEDULE 2

LOG					FUEL				CALC			
Date D/M	Total(1) M/E Hrs	M/E ExhT	Load IND	M/E rpm	SpG @ Mtr(2)	Cal Value	Kl Flow	Hrs Test	PSe Hp	Ft kg/hr	Fs g/hp/hr	EDIT NOTE
16/9	4023	352	4.9	124.0	9412	9573	46.2	44.2	6277	984	147.1	(6)
19/9	4071	356	4.8	120.3	9457	9573	42.0	41.7	5908	953	151.3	(6)
22/9	4110	392	6.0	139.6	9379	9573	50.3	33.5	9127	1408	144.8	
23/9	4127	411	6.3	141.7	9288	9573	24.8	15.7	9561	1467	144.0	
24/9	4141	401	5.3	129.4	9327	9573	13.7	11.2	7243	1141	147.8	(6)
1/10	4283	379	6.4	143.2	9392	9573	4.9	3.0	9849	1521	144.9	
5/10	4332	392	6.4	142.5	9392	9573	50.1	31.6	9808	1489	142.5	
7/10	4358	379	6.4	142.7	9451	9573	46.9	29.1	9786	1523	146.1	(5)
8/10	4374	385	6.6	143.7	9333	9540	18.3	11.0	10057	1553	144.4	(5)
10/10	4400	381	6.6	143.7	9261	9540	38.3	23.0	10072	1561	144.9	(5)
12/10	4421	393	6.6	143.7	9320	9540	26.5	16.0	10050	1544	143.6	
15/10	4470	385	6.6	142.6	9455	9540	65.5	40.1	10104	1544	143.0	
20/10	4551	375	6.5	142.4	9384	9532	118.4	73.0	9990	1538	143.8	(4)
22/10	4588	385	6.7	144.1	9260	9532	55.6	33.3	10214	1571	143.8	(4)
25/10	4608	373	5.4	133.5	9351	9532	20.4	16.0	7747	1209	145.8	(4)(6)
29/10	4683	382	6.5	141.0	9351	9532	116.5	72.6	9873	1521	144.0	(4)
01/11	4728	380	6.5	142.2	9371	9532	39.7	24.4	9964	1543	144.7	(4)
05/11	4765	392	6.4	142.5	9460	9522	50.1	31.4	9814	1509	143.6	
08/11	4788	398	6.3	142.6	9441	9522	32.4	20.6	9678	1485	143.2	
09/11	4790	366	4.9	118.2	9356	9522	1.0	1.0	5887	936	148.4	(6)
11/11	4807	393	6.4	141.4	9395	9522	18.5	11.6	9737	1498	143.7	
14/11	4854	395	6.4	142.3	9434	9522	48.0	30.0	9775	1509	144.2	
17/11	4901	330	4.8	116.7	9460	9522	40.4	42.2	5676	906	149.0	(6)
21/11	4953	407	6.4	142.1	9428	9522	73.6	46.2	9757	1502	143.7	
23/11	4984	411	6.3	141.3	9428	9522	42.6	27.3	9571	1471	143.5	
28/11	5076	403	6.3	139.8	9473	9522	132.0	85.5	9506	1462	143.6	
1/12	5094	399	6.4	140.5	9389	9552	19.5	12.3	9682	1488	144.0	
3/12	5122	399	6.3	138.5	9447	9552	39.2	25.5	9476	1452	143.5	
5/12	5146	364	4.8	116.9	9382	9552	19.0	19.8	5681	900	148.4	(6)
8/12	5198	402	6.6	141.7	9447	9552	73.2	44.5	10047	1554	144.8	
11/12	5249	405	6.4	140.2	9434	9552	68.0	43.4	9671	1478	143.1	
15/12	5295	403	6.3	142.3	9421	9552	67.6	43.2	9657	1474	143.0	
17/12	5330	400	6.4	142.2	9427	9552	46.4	29.0	9806	1508	144.0	
23/12	5418	402	6.5	142.8	9371	9559	64.5	39.6	9910	1526	144.3	
28/12	5458	392	6.5	140.2	9397	9559	54.0	33.9	9786	1497	143.3	(4)
29/12	5476	398	6.6	140.3	9358	9559	26.0	16.0	9890	1521	144.1	(4)
2/1	5551	397	6.6	142.0	9371	9559	120.6	72.8	9991	1552	145.6	(4)
5/1	5594	386	6.6	142.2	9352	9559	63.6	38.0	9995	1565	146.7	(4)
8/1	5639	387	6.6	142.1	9371	9563	63.2	38.6	10001	1534	143.8	(4)
11/1	5697	376	6.6	135.5	9423	9563	88.8	55.8	9651	1500	145.7	(4)
13/1	5733	370	5.8	130.6	9332	9563	41.6	30.9	8152	1256	144.5	(6)
19/1	5825	368	6.6	141.6	9301	9551	92.8	57.3	9862	1506	143.0	(4)
22/1	5849	394	6.8	141.8	9243	9551	32.1	19.1	10075	1553	144.4	(4)
24/1	5883	396	6.8	141.9	9249	9551	50.2	30.0	10081	1548	143.8	(4)

5958	392	6.6	141.7	9249	9551	118.8	72.5	9833	1516	144.3	(4)
6003	382	6.7	142.0	9230	9551	35.6	21.5	9955	1528	143.7	(4)
6039	406	6.5	140.7	9169	9525	47.4	30.0	9656	1468	142.0	
6073	386	6.5	140.7	9156	9525	46.7	29.3	9642	1478	143.1	(4)
6159	418	6.7	142.0	9223	9506	38.7	24.0	10021	1522	141.6	
6159	418	6.6	141.8	9227	9506	124.8	77.3	9887	1521	143.4	
6183	390	5.9	133.6	9240	9506	27.1	19.3	8485	1316	144.5	(6)
6201	394	6.2	133.1	9228	9506	22.8	15.6	8907	1366	142.9	(6)
6263	412	6.7	139.3	9227	9506	94.6	59.8	9864	1485	140.3	
6306	408	6.7	139.4	9194	9506	59.0	37.2	9835	1491	141.3	
6324	402	6.5	139.0	9275	9496	18.6	11.9	9640	1478	142.7	
6349	405	6.4	142.7	9275	9496	35.3	22.3	9727	1495	143.1	
6387	409	6.6	131.2	9282	9496	47.2	31.0	9312	1440	144.0	(6)
6428	402	6.5	140.5	9223	9496	47.5	30.5	9672	1470	141.5	
6452	403	6.4	140.2	9217	9496	34.2	22.4	9524	1438	140.6	
6470	403	6.4	140.8	9249	9496	17.3	11.0	9592	1484	144.1	
6525	411	6.1	133.4	9205	9501	69.2	47.6	9592	1370	145.5	(6)
6568	413	6.5	141.0	9166	9501	57.5	36.5	9646	1483	143.2	
6622	418	6.5	141.1	9185	9501	11.8	7.5	9672	1479	142.4	
6739	392	6.7	140.9	9198	9501	181.6	111.8	9923	1527	143.3	(4)
6756	405	6.5	140.3	9404	9503	18.4	11.6	9673	1492	143.7	
6791	400	6.4	140.8	9404	9503	50.5	32.4	9530	1466	143.3	
6814	368	4.6	118.3	9306	9503	19.0	19.0	5429	931	159.7	(6)
6852	408	6.4	141.0	9384	9503	51.3	32.5	9521	1481	144.9	
6901	407	6.5	140.4	9355	9532	67.2	42.6	9616	1476	143.4	
6943	412	6.5	140.7	9329	9532	56.1	35.2	9647	1487	144.0	
6983	418	6.5	140.6	9270	9532	53.3	33.5	9641	1475	143.0	
7001	420	6.5	140.1	9283	9532	24.1	15.2	9613	1472	143.1	
7035	408	6.5	139.6	9309	9532	48.4	30.5	9570	1477	144.2	
7091	408	6.5	138.0	9485	9532	83.4	52.9	9485	1469	144.7	
7136	390	5.9	133.0	9303	9532	53.3	38.6	8386	1285	143.1	(6)
7172	405	6.4	140.7	9283	9532	48.4	30.9	9543	1454	142.4	
7197	402	6.5	138.8	9315	9532	36.1	22.7	9572	1481	144.6	
7215	406	6.4	139.4	9303	9532	20.2	13.0	9456	1445	142.8	
7231	402	6.3	139.8	9283	9532	17.8	11.5	9382	1437	143.1	
7257	395	6.0	139.4	9182	9532	34.8	23.8	8985	1360	141.4	
7293	404	6.3	141.2	9299	9532	47.8	30.6	9442	1453	143.8	
7339	406	6.5	141.6	9292	9532	63.8	40.0	9646	1482	143.6	
7386	340	4.2	108.0	9338	9532	33.1	43.1	4362	717	153.6	(6)
7437	410	6.6	141.0	9318	9532	73.8	45.6	9784	1508	144.0	
7451	400	6.4	137.4	9273	9532	16.6	10.7	9372	1439	143.4	
7478	415	6.7	142.6	9292	9532	40.5	24.4	10039	1542	143.6	
7543	393	6.0	135.9	9305	9532	90.7	62.3	8766	1355	144.4	
7593	399	6.3	137.4	9312	9532	70.4	44.7	9211	1467	148.8	(7)
7610	410	6.4	140.8	9302	9532	19.3	12.1	9514	1484	145.7	(4a)
7636	403	6.3	138.4	9312	9532	37.2	24.3	9267	1425	143.8	(4)
7651	390	6.5	141.1	9325	9532	17.4	10.8	9659	1502	145.3	
7693	398	6.2	138.6	9318	9532	56.2	36.8	9149	1423	145.3	
7777	400	6.4	141.8	9367	9515	114.3	72.2	9621	1483	143.8	
7801	383	6.5	141.2	9360	9515	28.9	18.0	9705	1503	144.4	(4)
7831	383	6.4	141.4	9341	9515	42.7	27.3	9598	1461	142.0	

29/6	7886	392	6.4	141.2	9334	9515	37.6	24.0	9580	1462	142.4	
3/7	7926	390	6.7	141.1	9399	9515	53.8	33.2	9963	1523	142.6	(4a)
5/7	7977	403	6.5	141.8	9380	9515	61.7	38.6	9747	1499	143.5	
10/7	8016	375	6.0	137.0	9389	9489	47.2	32.3	8864	1372	144.0	
11/7	8041	380	5.7	122.1	9376	9492	29.6	23.0	7302	1207	153.8	
12/7	8045	388	6.1	133.1	9376	9492	2.0	1.4	8777	1339	142.0	
13/7	8062	400	5.8	139.1	9311	9492	17.5	12.2	8676	1336	143.3	
16/7	8110	363	5.4	127.9	9402	9492	49.9	41.2	7240	1139	146.4	
19/7	8151	371	5.6	132.4	9363	9492	47.6	35.2	7887	1266	149.4	
23/7	8198	388	6.2	137.2	9369	9492	68.6	45.4	9136	1416	144.2	(8)
28/7	8283	392	6.5	138.2	9402	9492	129.4	82.2	9532	1480	144.5	
31/7	8338	384	6.5	136.1	9428	9492	76.6	48.1	9418	1501	148.3	
03/8	8355	380	6.0	135.0	9383	9501	16.8	11.8	8750	1336	142.2	(4)(6)
05/8	8382	385	6.4	137.5	9409	9501	38.6	25.3	9400	1436	142.2	(4)(6)
07/8	8408	375	6.2	135.7	9357	9501	33.2	22.1	9057	1406	144.6	(4)(6)
10/8	8457	395	6.4	141.2	9390	9501	67.9	43.0	9604	1483	143.8	(4a)
13/8	8502	400	6.4	141.9	9146	9632	62.0	39.2	9539	1447	143.2	(3)
15/8	8540	400	6.4	142.3	9153	9632	54.4	34.0	9603	1464	144.0	(4a)
19/8	8591	405	6.5	142.0	9179	9632	73.9	46.1	9726	1471	142.8	(3)
26/8	8707	403	6.5	141.9	9140	9632	176.5	110.0	9692	1466	142.9	
29/8	8726	395	6.2	134.3	9308	9520	20.3	13.7	8937	1379	144.0	(4)(6)
31/8	8751	395	6.2	135.0	9440	9520	35.7	24.0	9080	1404	144.3	(6)
02/9	8773	395	6.6	140.8	9414	9520	29.3	18.0	9898	1532	144.5	(4)
05/9	8822	395	6.4	141.3	9395	9520	68.4	43.2	9661	1487	143.7	
09/9	8860	400	6.3	141.4	9369	9553	49.0	31.4	9541	1462	143.5	
11/9	8882	402	6.4	141.6	9363	9553	32.1	20.4	9685	1473	142.5	
12/9	8900	402	6.4	141.6	9324	9553	20.0	12.6	9664	1480	143.4	

EDIT NOTES

(1) Hrs - 10,000 (add 10,000 to get actual hours).
(2) Density x 1,000 (divide by 1000 to get density).
    Some errors exist in data list as a result of transposition from log. These do not affect the results.
(3) Full Power Calculation (from log).
(4) PUP Valves closed (from log).
(4a) PUP Valves closed part voyage (from log).
(5) PUP Valves probably inoperative (from Exhaust Temp).
(6) Reduced Speed. RPM below 135.
(7) Reduced Speed. RPM above 135. FS value suspect.
(8) Reduced Speed for turbine washing (approx 2 hrs) meaning red. speed for part of voyage.

(4) The PUP Valves correction factor used in Schedule 2:
From log Schedule 1 ME hrs 16039 & 16074

$$\frac{143.1 - 142.0}{143.1} = .769\%$$

M V CONUS

Analysis of Samples from Port Boiler

COMPOUND	CONUS SPALLING Hutchinson Labs Element%	A.I.R. (Newcastle) Compound%	TYPICAL HI HEAT REFRACTORY BRICK Compound%	CONUS BRICK NEW Compound%	SUNRAY TUBE SCALE (JUN 85) by A.I.R. Compound %
Loss on Ign	2.80	4.70	-	-	15.60
SiO_2	17.00	35.00	56.50	53.30	5.50
Al_2O_3	-	20.40	43.40	43.40	2.40
Fe_2O_3	4.40	4.80	1.20	1.30	5.60
TiO_2	-	0.60	1.80	1.20	0.25
CaO	4.20	6.60	0.10	0.30	6.80
MgO	0.70	1.50	0.40	0.20	3.10
K_2O	-	0.58	1.20	0.60	0.35
PbO	-	2.60	-	-	10.70
ZnO	3.10	0.24	-	-	3.15
NiO	-	2.20	-	-	4.75
SnO	-	0.34	-	-	0.15
BaO	0.20	0.24	-	-	0.25
V_2O_5	3.90	5.90	0	-	11.80
Na_2O	4.80	6.70	-	0.17	-
Cl	-	-	-	-	-
S	0.85	-	-	-	Tr
					70.4

APPENDIX 2C

AUSTRALIAN INDUSTRIAL REFRACTORIES LIMITED
(Incorporated in Victoria)

Head Office
Gavey Street Mayfield NSW 2304
Mail to P.O. Box 154 Mayfield 2304
Phone Newcastle (049) 68 0477
Telex AIREF AA 28111

Works
Mayfield, Gavey Street 2304
Thirroul, Wrexham Road 2515
Unanderra, Berkeley Road 2526

our ref. TR:JW

your ref.

March 6, 1985

Mr. R. Searls,
Chairman,
Fuel Technology Pty. Ltd.,
7th Floor,
608 St. Kilda Road,
MELBOURNE VIC. 3004

Dear Mr. Searls,

Enclosed with this letter are the analytical results obtained by our Laboratory on the sample of slag obtained from a marine boiler as discussed by our Mr. Glyn Cox and yourself.

The results are in general agreement with the elemental analysis supplied by you and indicate the slag to be a reaction product of the alumino - silicate boiler lining.

The predominant fluxing agent would have been the soda with lime, magnesia, vanadium pentoxide and iron oxides also contributing.

There is no evidence on which to base an assessment of the role, if any, of your CB300 product, particularly in view of the level of addition and the concentration of the active ferrous picrate component.

It is not known if CB300 contains any other material, for example alkalis, that could cause refractory wear but the presence of iron compounds at the level reported to be in CB300 would not on its own be expected to cause any noticeable increase in the rate or mode of wear of the boiler lining.

Yours faithfully,
AUSTRALIAN INDUSTRIAL REFRACTORIES LIMITED

T. Reeves
Principal Research Officer

SLAG EX MARINE BOILER

CHEMICAL ANALYSIS (%)			
Laboratory	A.I.R Dried Sample	FUEL LABORATORY ex Fuel Technology Pty. Ltd.	
SiO_2	35.0	Si	17.0
Fe_2O_3	4.80	Fe	4.4
Al_2O_3	20.4	-	
TiO_2	0.60	-	
CaO	6.6	Ca	4.0
MgO	1.5	Mg	0.7
Na_2O	6.7	Na	4.8
K_2O	0.58	-	
PbO	2.6	-	
ZnO	0.24	Zn	3.0
SnO	0.34	-	
BaO	0.24	Ba	0.2
V_2O_5	5.9	V	4.0
Cl and S	Present	S	0.8
LOSS ON IGNITION	4.7		

AUSTRALIAN INDUSTRIAL REFRACTORIES LIMITED
(Incorporated in Victoria)

Head Office
Gavey Street Mayfield NSW 2304
Mail to P.O. Box 154 Mayfield 2304
Phone Newcastle (049) 68 0477
Telex AIREF AA 28111

Works
Mayfield, Gavey Street 2304
Thirroul, Wrexham Road 2515
Unanderra, Berkeley Road 2526

our ref. TR:JW

your ref.

April 11, 1985

Mr. R. Searls,
Chairman,
Fuel Technology Pty. Ltd.,
7th Floor,
608 St. Kilda Road,
MELBOURNE VIC. 3000

Dear Mr. Searls,

Attached is the chemical analysis of the sample of firebrick supplied by yourself, that is of the type used in the lining of marine boilers as discussed by yourself and our Mr. Glyn Cox.

The analysis indicates a brick quality within the range defined by the High and Super Duty firebrick categories of alumino-silicate brick, typical analyses of which are included in the table.

These results are consistent with the comments made in my previous letter of 5th March, 1985.

Yours sincerely,

T. Reeves (Dr.)
Principle Research Officer

FIREBRICK ANALYSES

Sample	Firebrick ex R. Searls Marine Boiler Lining	Typical Data High Heat duty Firebrick	Typical Data Super Duty Firebrick
Chemical Analysis (%)			
SiO_2	52.3	56.5	50.5
Fe_2O_3	1.30	1.2	1.1
Al_2O_3	43.4	38.5	45.8
TiO_2	1.15	1.8	1.8
CaO	0.29	0.1	0.1
MgO	0.22	0.4	0.1
Na_2O	0.17	-	-
K_2O	0.60	1.2	0.2

BHP
Petroleum Laboratory

BHP Petroleum Pty. Ltd. (Incorporated in Victoria)
PO Box 264 Clayton Victoria Australia 3168
245 Wellington Road Clayton Victoria Australia
Telephone: (03) 560 7066 Telex: AA37958

Our Reference:
Your Reference:

06 Mar 1985

Robert Searls
Fuel Technology Pty. Ltd.
7th Floor
608 St. Kilda Road
MELBOURNE 3004

Dear Sir,

Re: Analysis of fuel oil ex. `CONUS'

Please find enclosed the results of our analyses on the 2 samples which you submitted on 06/02/85.

Yours faithfully,

for. Michael Tuminello
CHIEF CHEMIST.

Enc:

BHP
Petroleum Laboratory

BHP Petroleum Pty. Ltd. (Incorporated in Victoria)
PO Box 264 Clayton Victoria Australia 3168
245 Wellington Road Clayton Victoria Australia
Telephone: (03) 560 7066 Telex: AA37958

Our Reference:
Your Reference:

Report Title : Fuel Sample Analyses

Report Number : 205

Date Submitted : 17/01/85

Supplied by : Robert Searls

Customer Name : Fuel Technology Pty. Ltd.

Sample #	Sample Description
5906	Hot Oil Primary Strainers
5907	Hot Oil Purifier Sludge
5908	Hot Oil Service Tank Outlet
5909	Hot Oil M/E Filter Supply

Report Date : 06/03/85

Report By : B. W. Jackson

Approved By : [signature]

Report Pages : 3

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PO Box 264 Clayton Victoria Australia 3168
245 Wellington Road Clayton Victoria Australia
Telephone: (03) 560 7066 Telex: AA37958

Our Reference:
Your Reference:

Sample Number : 5906

Sample Name : Hot Oil Primary Strainers

Metals Analysis ICP

Aluminium	250 ppm
Calcium	160 ppm
Sodium	90 ppm
Vanadium	45 ppm
Iron	930 ppm
Silicon	0.06 wgt %

NATA Endorsement does not apply to this test.

Sample Number : 5907

Sample Name : Hot Oil Purifier Sludge

Metals Analysis ICP

Aluminium	1680 ppm
Calcium	1020 ppm
Sodium	780 ppm
Vanadium	42 ppm
Iron	1490 ppm
Silicon	0.30 wgt %

NATA Endorsement does not apply to this test.

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Our Reference:
Your Reference:

Sample Number : 5908

Sample Name : Hot Oil Service Tank Outlet

Metals Analysis ICP

Aluminium	260 ppm
Calcium	560 ppm
Sodium	150 ppm
Vanadium	40 ppm
Iron	1.4 wgt %
Silicon	0.15 wgt %

NATA Endorsement does not apply to this test.

Sample Number : 5909

Sample Name : Hot Oil M/E Filter Supply

Metals Analysis ICP

Aluminium	13 ppm
Calcium	30 ppm
Sodium	37 ppm
Vanadium	35 ppm
Iron	17 ppm
Silicon	2 ppm

NATA Endorsement does not apply to this test.

ASTM D4052-81

Density at 15.0 deg C	0.9801 g/ml
Specific gravity 60/60 deg F	0.9807
API gravity	12.8

IP 12/73

Heat of Combustion	42.46 KJ/Kg

NATA Endorsement does not apply to this test.

BHP Petroleum Laboratory

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245 Wellington Road Clayton Victoria Australia
Telephone: (03) 560 7066 Telex: AA37958

Our Reference:
Your Reference:

Sample Number : 5909 (cont'd)

Sample Name : Hot Oil M/E Filter Supply

ASTM D482-80

	Ash	1.2 wgt %
	Weight sample used	8.0024 gm

Comments:
Duplicate analyses could not be performed because of insufficient samp

BHP Petroleum Laboratory

BHP Petroleum Pty. Ltd. (Incorporated in Victoria)
PO Box 264 Clayton Victoria Australia 3168
245 Wellington Road Clayton Victoria Australia
Telephone: (03) 560 7066 Telex: AA37958

Our Reference:
Your Reference:

Report Title : Analysis of fuel oil ex. `CONUS'

Report Number : 218

Date Submitted : 06/02/85

Supplied by : Robert Searls

Customer Name : Fuel Technology Pty. Ltd.

Sample #	Sample Description
5944	F.O. sample after hot filter `CONUS' 2/2/85
5945	Economiser soot sample `CONUS' 15/1/85

Report Date : 06/03/85

Report By : [signature]

Approved By : [signature]

Report Pages : 1

NATA Endorsement does not apply.

BHP Petroleum Laboratory
BHP Petroleum Pty. Ltd. (Incorporated in Victoria)
PO Box 264 Clayton Victoria Australia 3168
245 Wellington Road Clayton Victoria Australia
Telephone: (03) 560 7066 Telex: AA37958

Our Reference:
Your Reference:

Sample Number : 5944

Sample Name : F.O. sample after hot filter `CONUS' 2/2/85

Metals Analysis by ICP

Aluminium	6.8 ppm
Calcium	37 ppm
Sodium	37 ppm
Vanadium	40 ppm
Iron	19 ppm
Silicon	2 ppm

NATA Endorsement does not apply to this test.

Sample Number : 5945

Sample Name : Economiser soot sample `CONUS' 15/1/85

Metals Analysis by ICP

Aluminium	0.05 wgt %
Calcium	2.4 wgt %
Sodium	0.5 wgt %
Vanadium	0.26 wgt %
Iron	1.8 wgt %
Silicon	0.11 wgt %

NATA Endorsement does not apply to this test.

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(Incorporated in Victoria)

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Works
Mayfield, Gavey Street 2304
Thirroul, Wrexham Road 2515
Unanderra, Berkeley Road 2526

our ref. JRW:JH

your ref.

4th July, 1985

Mr. R. Searls,
Fuel Technology,
608 St. Kilda Road,
MELBOURNE VIC 3004

Dear Sir,

Herewith the analysis of a sample of slag material from sun-ray tubes in a marine boiler.

Laboratory Number: E135

Analysis on a dried basis:-

Loss on Ignition (1000°C)	15.6
SiO_2	5.5
Fe_2O_3	5.6
Al_2O_3	2.4
TiO_2	.25
CaO	6.8
MgO	3.38
Na_2O	10.4
K_2O	.35
PbO	10.7
ZnO	3.15
NiO	4.75
SnO_2	.15
BaO	.25
V_2O_5	11.8
Total	81.08

Components such as PbO, ZnO, NiO, SnO_2, BaO and V_2O_5 are not normally present in refractory bricks except in minute trace amounts; CaO, MgO and Na_2O are normally present at 0.3%, or less in bricks of the type which you submitted recently (our Laboratory Number E127), and Fe_2O_3 is normally less than 1.5%.

It would appear that these substances must derive from the oil input to the furnace.

Yours faithfully,
AUSTRALIAN INDUSTRIAL REFRACTORIES LIMITED

J.R. White
Chief Analyst

Telephone: 335 9602
After Hours 450 3991

Unit 1, 1 Christina Pde
NORTH FREMANTLE 6159

HUTCHINSON LABORATORY SERVICES

PETROLEUM AND INDUSTRIAL CHEMISTS

REPORT

Customer: Fuel Technology Pty. Ltd.

Samples: Fuel Oil

1. ex SEC W.A. Redbank July 85

D_{15} = 0.9730

2. Bunker Fuel ex Conus, Geelong 17/6/85

D_{15} = 0.9820

Lead	46 ppm
Iron	13
Copper	1
Chromium	0
* Calcium	22
Aluminium	0
Silicon	12
Sodium	38
* Zinc	14
* Barium	30
* Magnesium	4
Vanadium	75

* Common Engine Oil Additive Metals

The additive metals, together with lead, would indicate the presence of waste oil.

J. Walden 24/7/85

BHP Petroleum Laboratory
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APPENDIX 2C

Our Reference:
Your Reference:

10 July 1985

Mr. R. Searls
Fuel Technology Pty.Ltd.
7th. Floor ,
608 St. Kilda Road,
Melbourne, 3004

Dear Bob,

Re: Analysis of Black Deposits

Please find enclosed the results of our analyses on the samples of economiser soot and burner tip deposit which you submitted on 12/06/85.

If the Laboratory can be of any further assistance, please do not hesitate to give me a call.

Yours Sincerely,

M. Tuminello

Michael Tuminello
CHIEF CHEMIST

SCHEDULE 1

Analysis of "Spalling" from Port Boiler Floor

Compound	CONUS Sample: Hutchinson Labs Element%	CONUS Sample: A.I.R. (Newcastle) Compound%	Typical Refractory Brick Compound%
Loss on Ign	2.8	4.7	-
SiO2	17.0	35.0	60.0
Al2O3	-	20.4	35.0
Fe2O3	4.4	4.8	1.5
TiO2	-	0.6	2.0
CaO	4.2	6.6	-
MgO	0.7	1.5	-
K2O	-	0.58	0
PbO	-	2.6	-
ZnO	3.1	0.24	-
NiO	-	2.2	-
SnO	-	0.34	-
BaO	0.2	0.24	-
V2O5	3.9	5.9	0
Na2O	4.8	6.7	-
Cl	-	-	-
S	0.85	-	-

FUEL TECHNOLOGY PTY. LTD.
Incorporated in Victoria
7TH FLOOR, 608 ST. KILDA ROAD, MELBOURNE, VICTORIA, 3004.
TEL. (03) 516278
(03) 529 4100
TELEX AA 92421

COPY APPENDIX 2C

MEMORANDUM 8th March, 1985

TO: Chief Engineer,
M.V. Conus

FROM: Robert Searls,
Fuel Technology Pty Ltd

We have examined the possible causes of the malfunction of your IG production system and the deterioration of refractories in your port and starboard boilers.

The samples of "spalling" or slag collected in October from the floor of the port boiler have been analysed by two laboratories as shown on the accompanying Schedule 1.

Advice we have received from suppliers of refractory brick suggests this type of spalling can be caused under reducing conditions by the presence of iron in the refractory or refractory slag. It is also known that the light elements including Na, K, Al and Va attack refractories.

The analysts, Australian Industrial Refractories Ltd do not believe the spalling could have been caused by CV300.

Analysis by the BHP research laboratories of oil, oil sludges and soot from your fuel system shows the presence of the following elements:

	Source of Sample					
Element	Pri.Screen	Purifier Sludge	Sludge Serv.Tank	M.E. Pri.Filt.	M.E. Eng.Fuel	Econ Soot
Al	250 ppm	1680 ppm	260 ppm	13 ppm	6.8 ppm	0.05%
Ca	160 ppm	1020 ppm	560 ppm	30 ppm	37 ppm	2.4%
Na	90 ppm	780 ppm	150 ppm	37 ppm	37 ppm	0.5%
Va	45 ppm	42 ppm	40 ppm	35 ppm	40 ppm	0.26%
Fe	930 ppm	1490 ppm	1.4%	17 ppm	19 ppm	1.8%
Si	0.06%	0.3% ppm	0.15%	2 ppm	2 ppm	0.11%
Ash				1.2%		

The CV300 combustion catalyst being added to the CONUS fuel contains (in addition to alcohol and toluene) ferrous picrate. When mixed with fuel at 3000:1, the level of the Fe++ ion in the fuel is about 60 ppbillion and picric 12 ppm. Occasionally an equal amount of iron oxides may be present from the oxidation of the 209-litre drum container. In any case this will not nearly account for the iron levels found in the reported samples of oil, sludge and slag.

From the evidence and advice we have been given it appears that fouling of the Sunray tubes and subsequent increase in the level of carbon particulate in the IG is a two-stage process which is feeding upon itself.

1. Scale and spalling from the boiler walls and floor are contributing soot and slag compounds that deposit in the cooler Sunray tubes.

2. Recognising a fall in differential pressure between the wind box and fire box, the automatic control on the boiler responds by increasing fuel flow.

3. The increased supply of fuel and reduced airflow creates a reducing environment resulting in further corrosion of the refractories and additional soot deposits in the tubes.

4. The scrubber in the IG system becomes overloaded and soot particles enter the IG flow.

We understand that the boiler walls are now relatively free of scale. This suggests that the CV300 fuel catalyst has predictably been promoting the burn-off of the hard carbon deposit. It is possible that the Sunray tube fouling in the port boiler in October and starboard boiler in November may have been aggravated by the migration of silica and other scale components liberated by the decarbonization of the boiler walls. However, the levels of recognised corrosive elements in the fuel systems suggest that there could be other, more significant, contributing causes.

Whatever the case, it is clear that the microprocessor system controlling the boiler should be arranged to respond to critical CO levels in the IG to prevent over-fuelling and the generation of excess soot in the first place. Continuous measuring IR systems are available for exhaust gas analysis. We operate such a system and would be happy to assist you with this modification.

Fuel Technology Pty Ltd
8th March, 1985.
Attach.

BHP
Petroleum Laboratory

BHP Petroleum Pty. Ltd. (Incorporated in Victoria)
PO Box 264 Clayton Victoria Australia 3168
245 Wellington Road Clayton Victoria Australia
Telephone: (03) 560 7066 Telex: AA37958

Our Reference:
Your Reference:

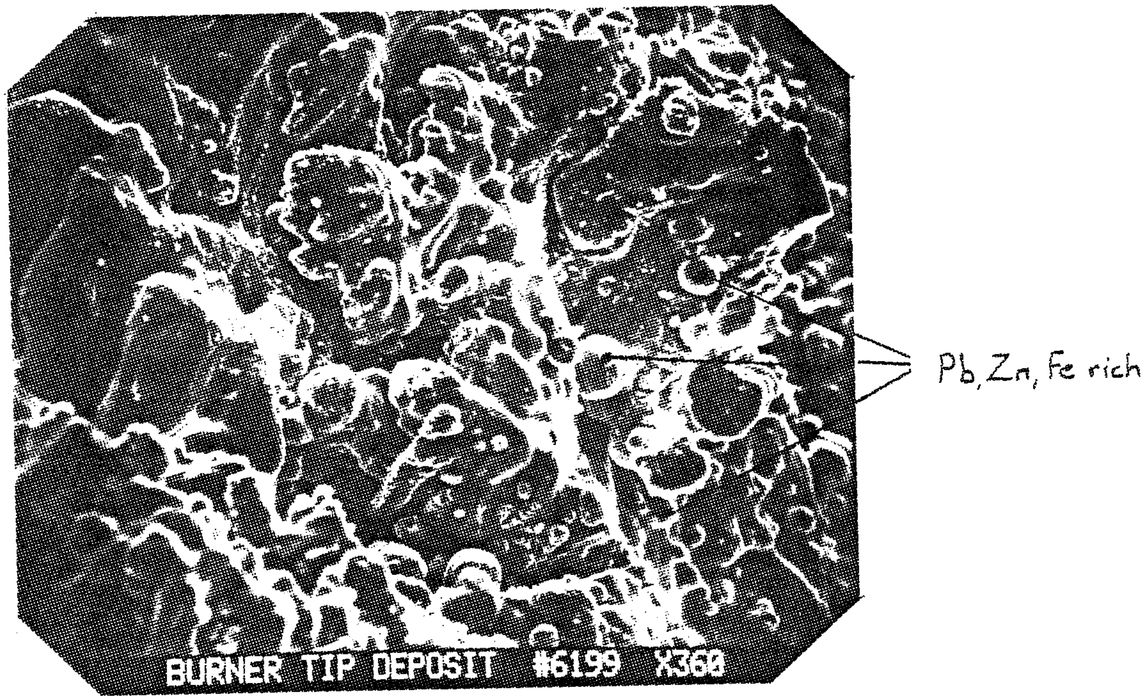
Sample Number : 6199 (cont.)

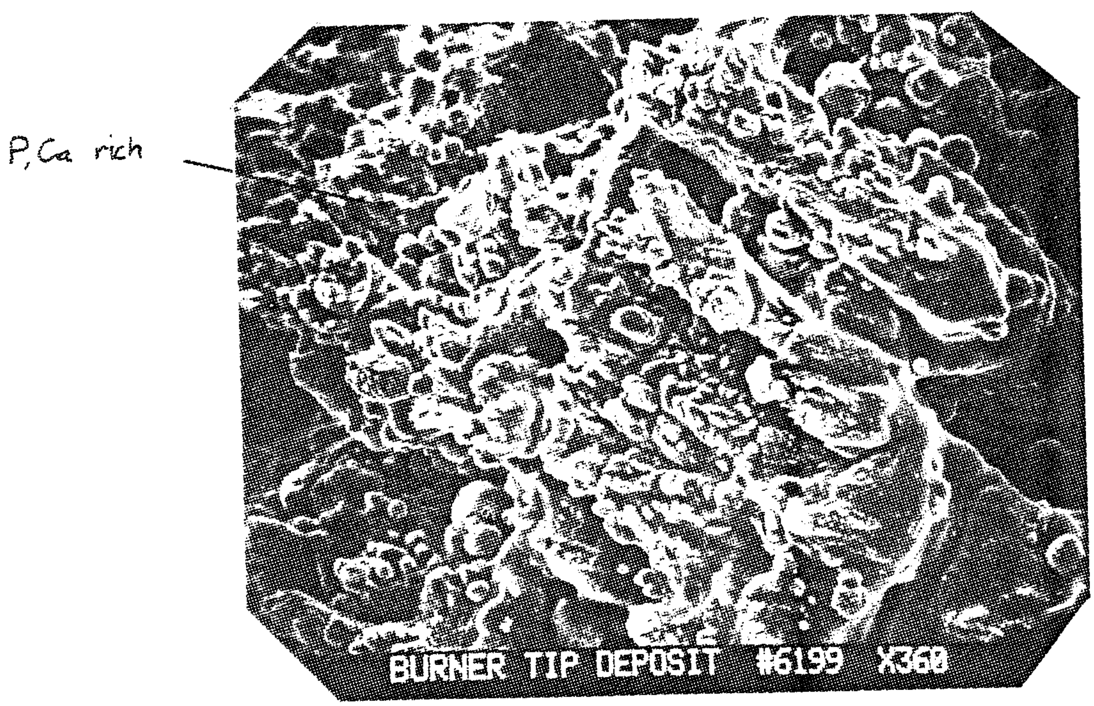
SEM Examination

Prior to examination by Scanning Electron Microscopy , the sample was washed in hexane to remove any oil present and then dried in an oven at 120 deg. C to remove the water which was obviously present. The hexane washings were very black following the extraction, indicating a significant amount of oil present in the original sample.

Observation of the burner tip deposit by SEM revealed a multiphase material as is evident in the attached micrographs. Semi-quantitative X- Ray microanalysis showed the bulk of the material to be very rich in Sulphur together with significant amounts of Phosphorus and a trace of Calcium. Small amounts of another material were also present - this material being rich in Lead, Zinc and Iron.

NATA Endorsement does not apply to this test.


Pb, Zn, Fe rich
BURNER TIP DEPOSIT #6199 X360


P, Ca rich
BURNER TIP DEPOSIT #6199 X360

BHP Petroleum Laboratory

BHP Petroleum Pty. Ltd. (Incorporated in Victoria)
PO Box 264 Clayton Victoria Australia 3168
245 Wellington Road Clayton Victoria Australia
Telephone: (03) 560 7066 Telex: AA37958

Our Reference:
Your Reference:

Sample Number : 6198

Sample Name : Economiser soot sample

Metals Analysis ICP

Aluminium	0.11 %
Calcium	11.40 %
Sodium	0.62 %
Vanadium	0.84 %
Iron	1.40 %
Silicon	insufficient sample

NATA Endorsement does not apply to this test.

Elemental Analysis

Ash @ 800 C	26.90 wgt %

NATA Endorsement does not apply to this test.

Sample Number : 6199

Sample Name : Burner tip deposit

Metals Analysis ICP

Aluminium	190 ppm
Calcium	900 ppm
Sodium	1480 ppm
Zinc	640 ppm
Vanadium	1180 ppm
Lead	1690 ppm
Iron	490 ppm
Sulphur	5.6 %

NATA Endorsement does not apply to this test.

Elemental Analysis

Ash @ 800 C	1.70 wgt %
Carbon	78.02 wgt %
Hydrogen	5.44 wgt %

NATA Endorsement does not apply to this test.

BHP Petroleum Laboratory

BHP Petroleum Pty. Ltd. (Incorporated in Victoria)
PO Box 264 Clayton Victoria Australia 3168
245 Wellington Road Clayton Victoria Australia
Telephone: (03) 560 7066 Telex: AA37958

Our Reference:
Your Reference:

Report Title : Analysis of Black Deposits

Report Number : 327

Date Submitted : 12/06/85

Supplied by : Mr. Robert Searls

Customer Name : Fuel Technology Pty. Ltd.

Sample #	Sample Description
6198	Economiser soot sample
6199	Burner tip deposit

Report Date : 10/07/85

Report By : [signature]

Approved By : [signature]

Report Pages : 2

NATA Endorsement does not apply.

SECTION 3

SECTION 3: THE TRIAL RESULTS

As suggested in Section 2, the results of the trial can be taken in two parts.

1. Engineering or operating observations.
2. Statistical analysis of the engine performance data.

3.1 OBSERVATIONS

Engineering and operating observations of the effect of fuel treatment were made in three principal areas.

(A) The boilers and IG system.
(B) The main engine exhaust system.
(C) The condition of cylinders and pistons in the main engine.

(A) Overall, the boilers and IG system have shown favourable changes after the commencement of fuel treatment. These improvements are seen best in the cleaned appearance of the boiler walls.

During the trial however several operating upsets were experienced and these were examined to determine if fuel treatment may have contributed to these problems. The documentation in Appendix 2C indicates that not to be the case.

The operating problems to which the documents refer were essentially:

i. Corrosion of the refractory brick floor of the boilers early in trial period;

ii. Fouling of the sunray tubes following i;

iii. Excess particulate carbon in the IG following ii;

iv. Excessive burner tip (and injector tip) deposits during parts of the trial period.

A1. Samples of the spalling on the corroded furnace floor were examined by Australian Industrial Refractories and compared with a sample of new brick. As summarized in a memorandum to the ship's engineers (Appendix 2C), the AIR report concludes that it is unlikely that the small amount of catalyst could have had any bearing on the problem. In any event the condition did not reoccur after the relining of the floor in April.

A2. The sunray tubes exhaust the boiler gases. When these gases contain corrosion products from the boiler floor, some will deposit in the cooler exhaust zone. This applies also to some compounds formed by the burning of impurities in the fuel. For example, vanadium is one of the elements found in fuel which forms such deposits. Physical scaling of the sunray tubes in May-June produced a scale product which when analysed (July 4 report) showed high amounts of Na, Mg, Pb, Zn and Ni, SiO_2, Fe_2O_3 and Al_2O_3.

These deposits were possibly the primary scale within the tube. Their presence plus the normal deposits of soot tend to reduce the thermal transfer efficiency of these tubes and at the same time restrict the flow of gas from the boiler. This leads directly to the problem of excess generation of unburned carbon in the IG system. It is extremely doubtful if the fuel catalyst contributes to these deposits. In fact, the improved combustion will tend to reduce the secondary carbon deposits.

A3. The fuel flow to the boiler is controlled by a microprocessor which is sensitive to the pressure differential between the fan box and boiler fire box. A drop in this differential prompts increased fuel flow. If the cause of the pressure drop is inefficient burning, fuel flow is increased rather than airflow accelerating the problem to the point where soot is being produced at a rate higher than the capacity of the IG scrubber. This allows particulate carbon to enter the IG system. The evidence is that the fuel catalyst helps prevent this condition and after the sunray tubes were thoroughly scaled there has been no recorded reoccurrence of this problem.

A4. Burner tip deposits, including injector tip "horns" or "trumpets", result from the gradual buildup of skeletonal structures of compounds derived from fuel impurities in the special injector tip environment. These structures trap oil which gradually burns leaving the compounds which add to this coral-like growth. (See report dated July 10, 1985 by BHP Research Laboratories in Appendix 2C.) Experience has shown that the improved misting and catalytic action of CV300 reduces these effects.

In summary, there is engineering evidence that the treatment of fuel improves boiler efficiency and reduces maintenance problems.

(B) Observations during the trial confirm that the treatment of fuel with CV300 reduces carbon buildup in the engine exhaust system. In mid-January 1985 the ship's engineer reported that the economizer soot was fine, powdery and easily removed by washing. An examination of the exhaust manifold on March 28 revealed softer carbon deposits than normally found and essentially no deposits on the fins in the turbine duct. Washing of the exhaust economizer fins during the later stages of the trial indicated a softer, loose soot than normal. Finally, upon opening cylinder No. 5 on July 31 the exhaust ports were seen to be unusually clean and essentially free of carbon deposits.

These observations correlate with the evidence of improved combustion and reduced deposits in the boilers and confirm the catalytic action of ferrous picrate described in Section 1.

(C) At least two cylinder inspections were carried out during the period of the trial; one about mid-trial when a cylinder head was removed and a second on July 31, 1985 when cylinder No. 5 was opened for survey and the piston removed. A short inspection of the head in the first instance showed granular carbon deposits which could be loosened by hand in the cylinder head. A more detailed examination of the No. 5 cylinder assembly was made on July 31 and a survey report including a measurement of liner wear was submitted to the owners.

The Chief Engineer, Mr. Hibgame, comments were essentially that the No. 5 cylinder head, liner, ports, piston crown, rings and lower piston area were cleaner than any inspected previously, all of which had less service than No. 5 which was opened after 18,000 operating hours for the first time since the ship was commissioned.

A photographic record of some of these July 31 observations is contained in Appendix 3A. These pictures compare the surfaces of the No. 5 cylinder assembly with a reconditioned piston held as a standby spare in the engine room.

The conclusions to be drawn from this individual cylinder survey are not simple. The cylinder assembly had operated a total of 18,283 hours of which only the last 4,311 hours were with treated fuel. Therefore the essentially negligible liner wear cannot be attributed wholly to fuel treatment. However what can be said is liner wear is aggravated by carbon deposits, by stuck piston rings and the effect these conditions have on lubrication. The absence of these deposits and the clean piston-ring grooves in this particular cylinder assembly are therefore evidence of the combination of good maintenance procedures and the decarbonizing action of the fuel catalyst. <u>The result indicates a significant increase in the efficiency and service life of a major item of capital investment</u>.

3.2 STATISTICAL ANALYSIS

This subsection has two parts; the results of the Fuel Technology plot of statistical trends (as in our preliminary report of April 1985) and the results from the more sophisticated statistical study of the Melbourne University Statistical Centre.

3.2.1 Using the data edit procedures indicated in the margin of the Engine Log Data Listing (Appendix 2B), Fuel Technology plotted with a powerful computer graphics program three trend-lines, Appendix 3B. These lines represent the best statistical fit by regression of three, approximately 2,000 hour periods in the engine's recent life:

a) The background trend from data over the period 11,003 hours to 13,972 hours;

b) The transition or "conditioning" period trend for the 1,800 hours (14,011 hours to 15,825 hours) immediately following the commencement of fuel treatment with the combustion catalyst; and

c) The treated period trend from 15,825 hours to 17,926 hours.

The extension line of the background trend shown in Appendix 3B forms the line of prediction, that is the trend-line of fuel consumption the ship's main engine would follow if nothing had been changed.

Within a reasonable period of time, and at any selected moment, the difference between the background trend and the treatment trend should be a reasonable measure of the change in fuel consumption resulting from the change in combustion efficiency and of course from any changes in the operation of the ship, such as the number of slow steaming voyages, which affect engine efficiency.

For example, taken at 17,000 hours the change in FS observed between these curves, is 1.6% less in the treatment period.

As can be seen from the spread of data points about these trend-lines, the confidence with which they can be used to accurately measure fuel savings is not going to be very high. It was for this reason that Shell and Fuel Technology jointly sponsored an analysis of the CONUS data by the Statistical Centre at Melbourne University.

3.2.2 The report of the Statistical Centre, attached as Appendix 3C, concludes that a small fuel saving is demonstrated in the treated period but variables within the operating data have made it difficult to determine the precise amount of improvement which, within a 95% confidence level, may be between a negative three or positive four per cent.
Dr. Timothy Brown of the Statistical Centre proposes a short series of controlled tests to raise the confidence level of the data and results.

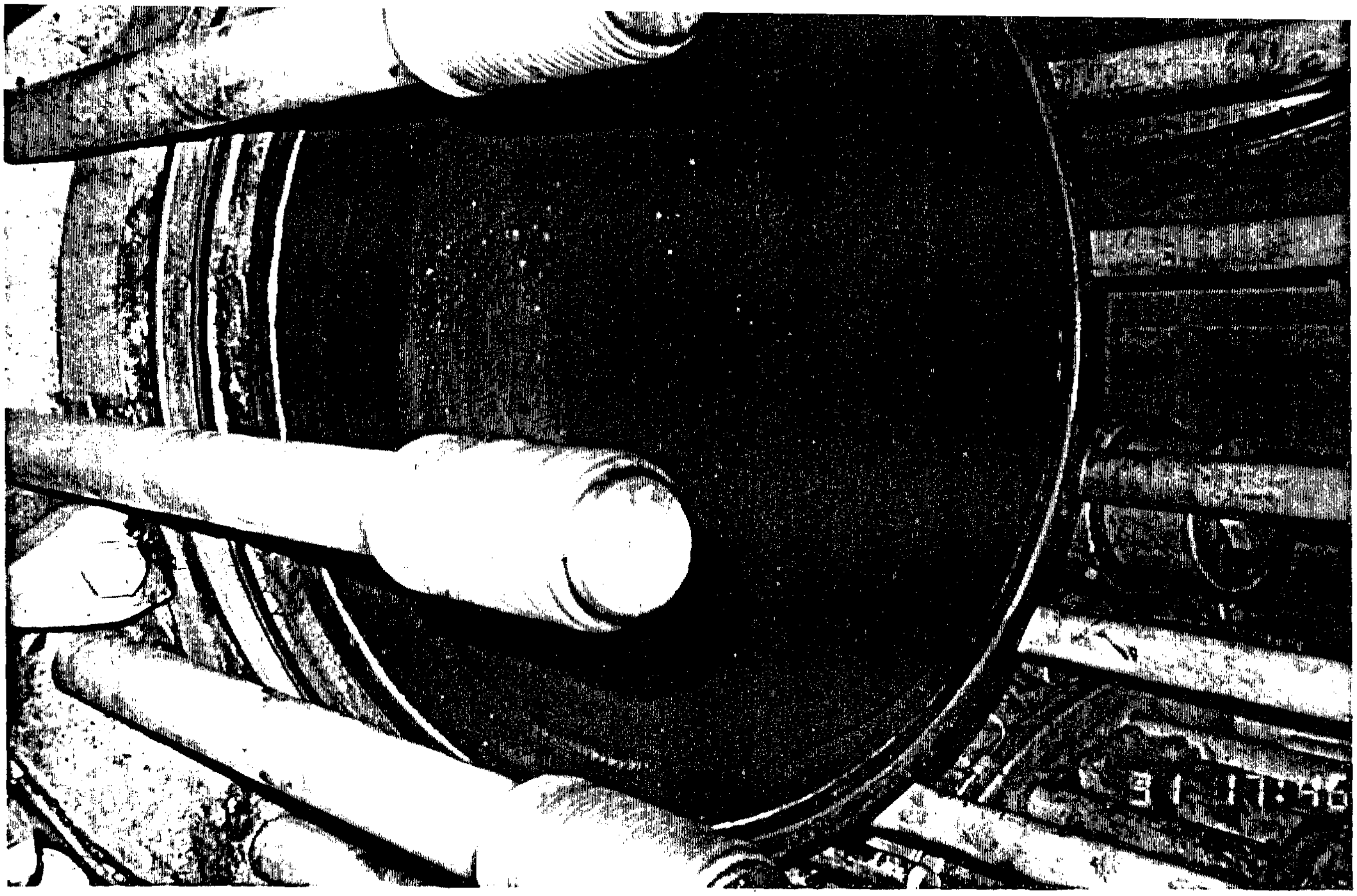
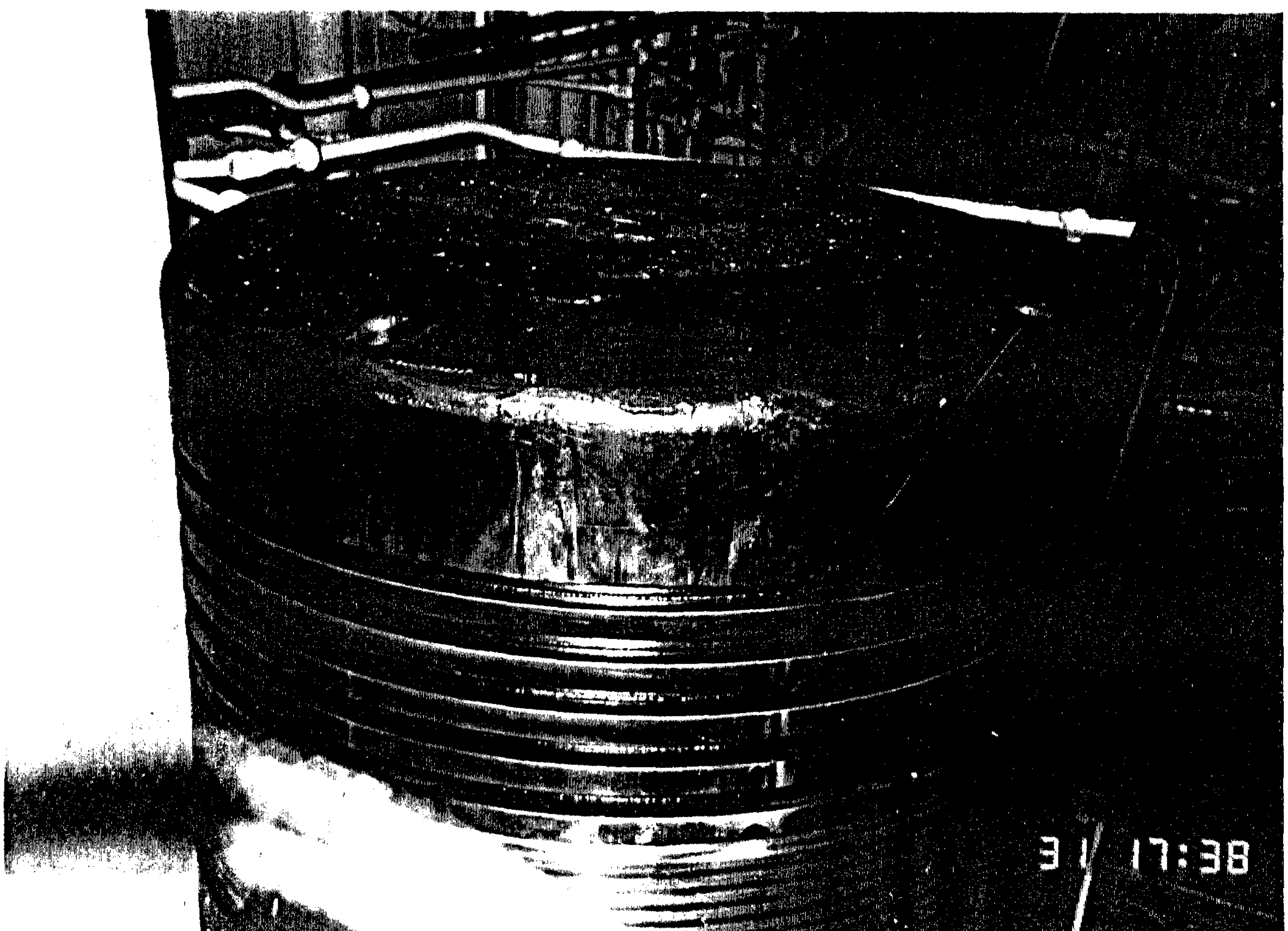


PHOTO 1: No. 5 piston crown on July 31, 1985 after 18,283 total operating hours of which last 4000 hours treated with CV300. The left side has been wiped with a cloth to expose clean, original metal (smudge marks on centre are footprints).

PHOTO 2: Spare piston with unknown service showing hard carbon lacquer remaining after polishing contrasts with no carbon residue in Photo 1.



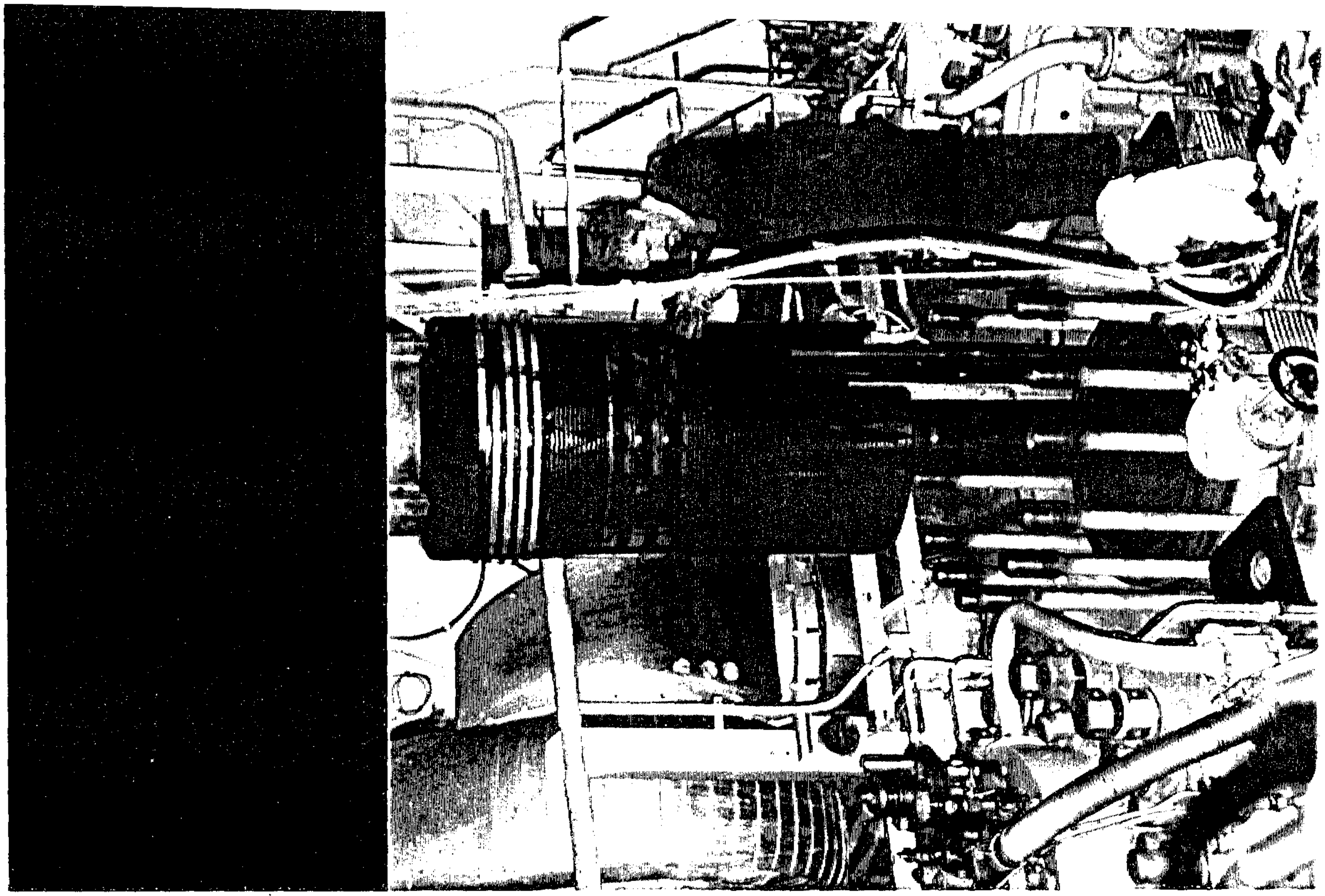
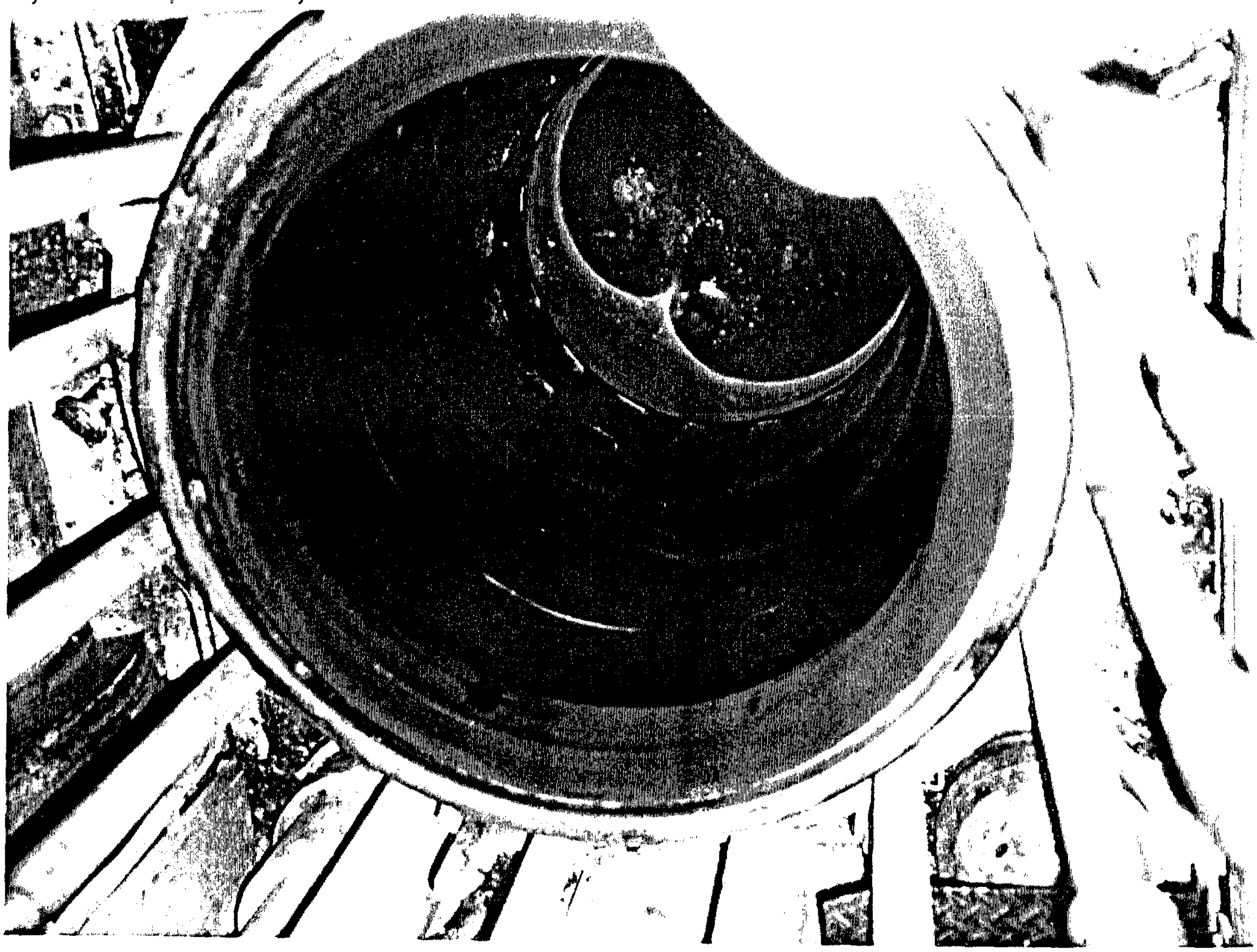


PHOTO 3: No. 5 piston assembly upon removal July 31, 1985. Piston rings are free in grooves and no hard carbon deposits are visible.

PHOTO 4: No. 5 cylinder (piston at BDC) showing exhaust and scavenger ports essentially clean of any carbon deposits. Cylinder walls are clean and unscoured.



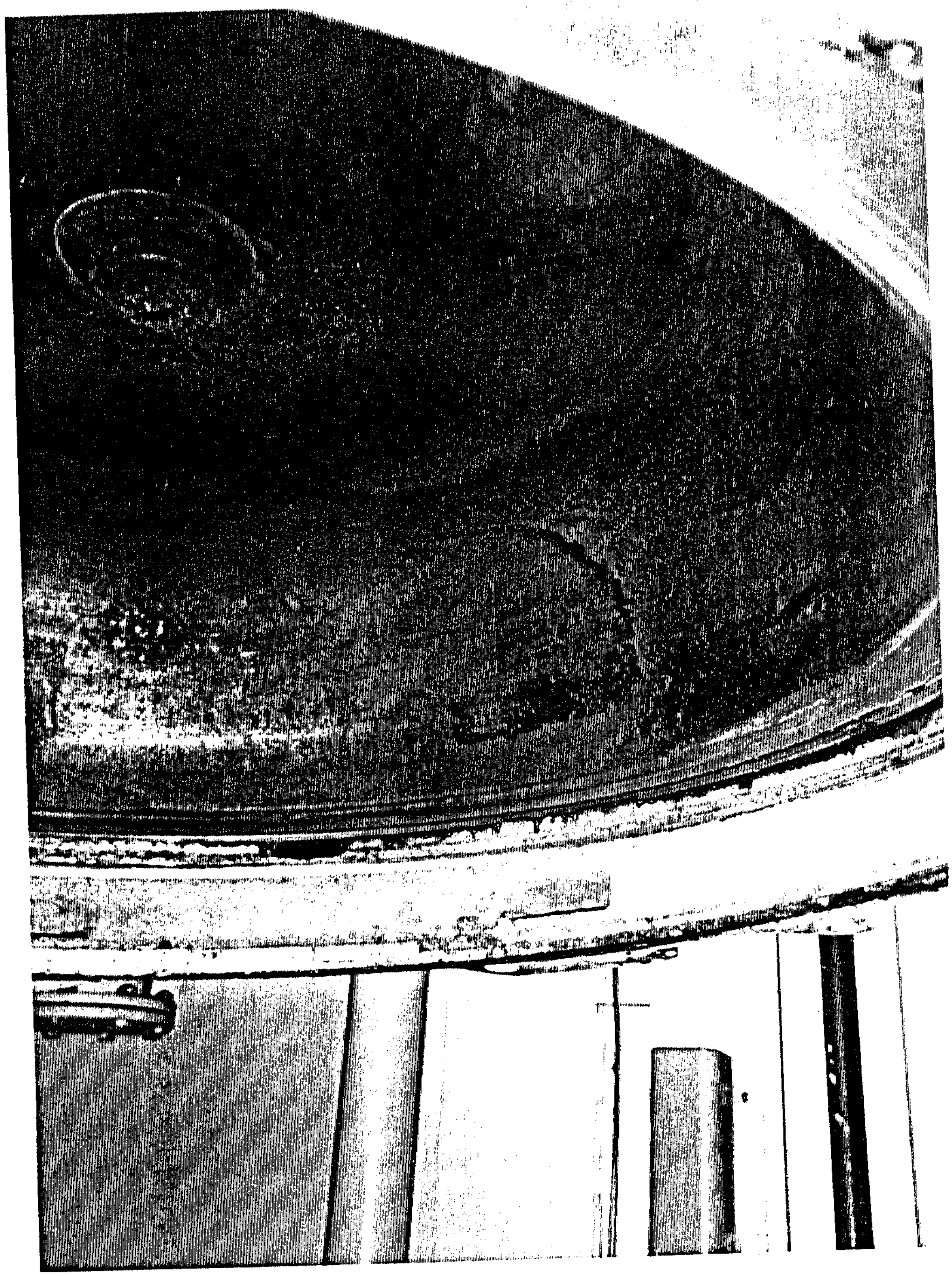
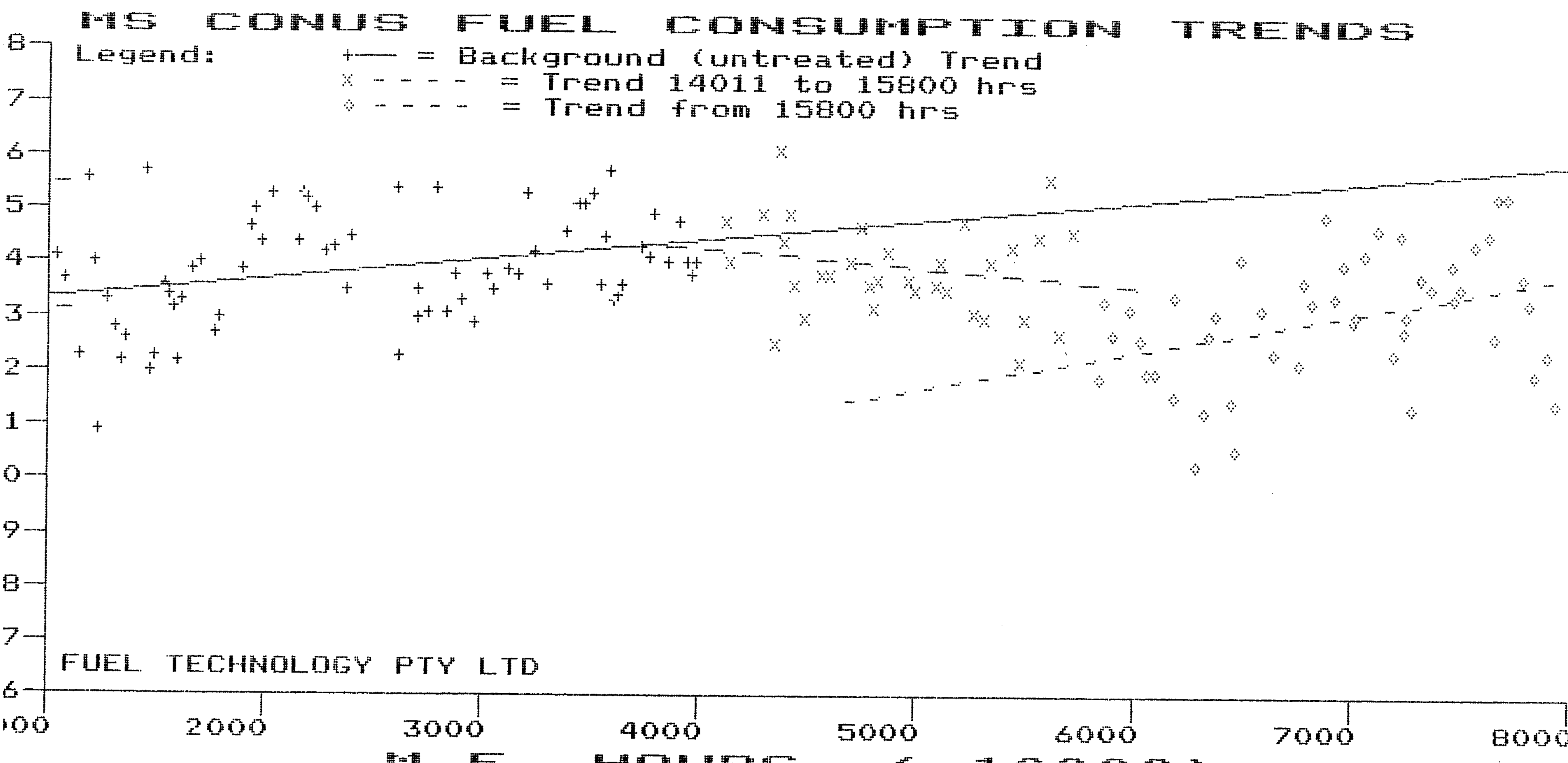


PHOTO 5: No. 5 cylinder head after 18,000 hours total service and 4,000 hours of fuel treatment. Other than black patches of soot from distorted spray (see injector "horn") the metal has been wiped bare with cloth.


MS CONUS FUEL CONSUMPTION TRENDS
Legend:
+—— = Background (untreated) Trend
x - - - - = Trend 14011 to 15800 hrs
◊ - - - - = Trend from 15800 hrs
8
7
6
5
4
3
2
1
0
9
8
7
6
2000
3000
4000
5000
6000
7000
8000
M.E. HOURS
FUEL TECHNOLOGY PTY LTD

STATISTICAL CONSULTING CENTRE

REPORT FOR

FUEL TECHNOLOGY PTY LTD

THE SHELL COMPANY OF AUSTRALIA LTD

REPORT NO. 35

EVALUATION OF CV300 TREATMENT

ON M.V. CONUS

BY

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G. ADAMS, M.SC.

1. SUMMARY

The data supplied shows that the fuel consumption decreased during the period of CV300 addition. The statistical analyses give estimates of the percent reduction in fuel consumption which range from 0.62 to 1.19. However, the corresponding 95 percent confidence limits for the reduction in the most satisfactory model are -3.19 percent to 4.29 percent, so that the data could be consistent with a reduction of, for example, 3 percent (or even an increase!). Thus it has not been possible to adequately judge the effect of CV300 from this data. It should be noted that the predicted fuel consumption values were based on a regression model which did not fit the data particularly well. More accurate results might possibly be obtained if a more accurate model could be found to describe the fuel consumption during the Background period.

However, it is felt that the main problems are with data recording: the noise created by the necessary averaging over voyages has made it difficult to detect with great precision any changes that CV300 might have had. The consultants recommend that the best method of obtaining accurate measures of fuel consumption changes is by controlled trials. For example, if all operating variables were controlled to certain levels during several periods without CV300 treatment and then, after a conditioning period, the operating variables were again set to the same levels, more reliable data is likely to emerge. As proof of this an increase of exactly 1.1 gm/hp/hr due to PUP valve closure was estimated on <u>two</u> separate occasions.

Shell may feel that the best method of obtaining a baseline assessment of the effect of CV300 is to continue with the trials in their current form. However, in the absence of a better fitting model to the data it is quite conceivable that it will never be possible to adequately estimate the effect of CV300 from operating data. So much noise exists in the consumption data that a Background and Treatment period might be needed of such great length that the effects of the ship's age (and possible death(!)) might dominate any Treatment/Background comparison.

2. INTRODUCTION & DATA DESCRIPTION

Data was supplied on the average fuel consumption of the Shell tanker M.V. CONUS over the period from January 18, 1984 to September 12, 1985. This period was split into three: a Background period from January 16, 1984 to September 12, 1984 (11003 to 13972 hours); a Treatment period from September 16, 1984 to August 10, 1985 (14023 to 18457 hours) where the fuel combustion catalyst CV300 was used; and an after treatment period from August 10, 1985 to September 12, 1985 (18502 to 18900 hours). This latter period was not used in the analysis.

The specific fuel consumption (in units of grams fuel per horsepower hour) was used as the measurement of fuel consumption. Data was also available on the Main Engine hours, the Main Engine RPM, the hours test, the Main Engine exhaust temperature, the Load (throttle setting), whether the trip was made at reduced speed and whether the piston-under-pressure (PUP) relief valves were closed.

The data base consisted of 85 cases for the Background period, 111 cases in the Treatment period and 11 cases in the after Treatment period. The Background period data was compiled from the engine log for all voyages during that period. Analysis of the data was carried out using the statistical package MINITAB.

3. DATA EDITING

The data for the after Treatment period were omitted from the analysis. Although the CV300 was no longer being added to the ship bunkers, the CV300 was still thought to be having some effect upon fuel consumption. This left 196 cases.

For one case RPM, hours test and fuel consumption readings were missing, while for another case the RPM reading was missing. These readings were treated as 'missing values' in all the statistical analyses and therefore had no effect.

Figures 1-3 shows plots of the specific fuel consumption versus Main Engine hours, Main Engine RPM and hours test, respectively. Each plot shows that there is considerable variation in the fuel consumption values. In particular, the fuel consumption values for those voyages made at reduced speed (RPM below 135) are highly variable (shown in figures 1-3 by the '+' symbol). Since (1) the statistical procedures used in section 4 to assess the effect of CV300 on fuel consumption is highly sensitive to extreme observations and (2) these observations are not indicative of normal operating conditions, it is necessary to eliminate them from the analyses. Two other cases, at hours 12523 and

12584 have also been eliminated. These were identified by Fuel Technology as being spurious observations.

Cases with test hours less than 10 were also eliminated. These cases were omitted because the start-up and slow-down periods account for a significant and variable amount of the test hours.

A total of 45 cases were eliminated. This left 151 cases (Background 66; Treatment 85) in the analyses.

A correction was also applied to the fuel consumption values when the PUP valves were closed. This correction factor was determined from readings at ME hours 16039 and 16073 to be about -1.1. A similar value for the PUP valve correction was obtained from a PUP valve test on September 15, 1985.

Table 1 shows the overall mean consumption for both the Background and Treatment periods (the figures in brackets representing the mean consumptions without elimination of the above cases).

Table 1

Mean fuel consumption (g/hp/hr) for the M.V. CONUS for the Background and Treatment periods. (Figures in brackets are mean fuel consumption before elimination of indicated cases.)

	Mean	Standard Deviation
Background	144.01 (144.47)	1.04 (2.86)
Treatment	143.38 (144.14)	1.17 (2.71)
ALL	143.65 (144.28)	1.16 (2.78)

It should also be noted that there is a discrepancy between total Main Engine hours and test hours. This discrepancy exists for both interpretations of the total Main Engine hours. If the total Main Engine hours is taken to be the total hours at the start of the voyage then, for example, at total hours 11444 the hours test is 88.0, while the next voyage is shown beginning at 11466, a difference of only 22 hours. On the otherhand, if total hours is taken to be the total hours at the end of the voyage, then for total hours 11466 the hours test is 45.3 while the total hours at the end of the previous voyage is 11444. Similar discrepancies occur at total Main Engine hours 12694, 12872, 14358 and 16159.

4. STATISTICAL ANALYSIS

To examine the effect of CV100 on fuel consumption a multiple regression model was fitted to the Background period data. This was then used to obtain predicted fuel consumptions for each case in the Treatment period. This predicted fuel consumption is then compared with the observed fuel consumption.

4.1 Background Period

Figures 4-6 show plots of fuel consumption versus total Main Engine hours, Main Engine RPM and hours test for the Background period.

Let $consumpt_i$ be the fuel consumption for case i, and let $tothrs_i$, rpm_i and $testhrs_i$ be the total Main Engine hours (minus 10,000 hours), the Main Engine RPM and the hours test, respectively. These three independent variables were identified by the ship's Chief Engineer Gary O'Flaherty as being those factors which would affect the ship's fuel consumption.

The multiple regression model is as follows

$$\ell n \; consumpt_i = \beta_0 + \beta_1 \; tothrs_i + \beta_2 \; rpm_i + \beta_3 \; testhrs_i + \varepsilon_i,$$

where ε_i is the random error term. The natural logarithm of the fuel consumption was used to improve the normality of the residuals: this normality is necessary to give valid confidence intervals for the conclusions.

The model was fitted using the statistical package MINITAB, given the equation:

$$\ell n\ \text{consumpt}_i = 5.004 + 0.000001659\ \text{tothrs}_i - 0.0002743\ \text{rpm}_i + 0.00004659\ \text{testhrs}_i$$

This model will be referred to as Model I. Examination of the model shows that the coefficients for tothrs_i and rpm_i have the appropriate sign - the fuel consumption increases with total hours reflecting an age affect and the fuel consumption decreases with increasing RPM. The coefficient of testhrs_i was positive, indicating that fuel consumption increases with hours test. These conclusions, however assume, that changes in one of the variables do not affect the other variables, i.e., the variables behave independently. It should also be noted that, statistically, none of the coefficients are significantly different from zero. In fact, $R^2 = 6.0\%$ for this model, so that the model only accounts for 6.0 percent of the variation in the $\ell n\ \text{consumpt}_i$ values. The three explanatory variables, therefore, do not adequately explain the variation in the fuel consumption.

At the suggestion of Fuel Technology, the Load (throttle setting) and the Main Engine exhaust temperature were also used as explanatory variables. Inclusion of Load led to a statistically significant improvement in the model. If we let load_i be the Load then the new model is given by the equation:

$$\ell n\ \text{consumpt}_i = 4.965 + 0.000001706\ \text{tothrs}_i + 0.0008010\ \text{rpm}_i + 0.00002899\ \text{testhrs}_i - 0.01826\ \text{load}_i$$

This model will be referred to as Model II. The coefficient of $load_i$ is negative indicating that the fuel consumption decreases as the Load increases. Note that the coefficient of rpm_i has changed sign - this is due to there being a significant correlation between RPM and Load ($r = 0.592$). Thus, the combined effect of RPM and Load needs to be considered in modelling consumption. The coefficient of $tothrs_i$ was again positive, ans so reflecting an age effect. Note also, that for this model, $R^2 = 19.8\%$, compared with $R^2 = 6.0\%$ for the Model I, and so the model now accounts for 19.8 percent of the variation in the $\ln consumpt_i$ values. This model is thus a statistically significant improvement on the model I. However, it still does not account for a very large proportion of the variation.

Inclusion of exhaust temperature in the Model I did not lead to a significant improvement in the model.

4.2 Treatment Period

The regression models developed in section 4.1 were used to predict a fuel consumption value for each case in the Treatment period. (The regression model actually gave a predicted log fuel consumption value which was then transformed to a predicted fuel consumption value.) The predicted fuel consumption values for each model are given in the Appendix.

Table 2 gives the mean observed and mean predicted fuel consumption for the Treatment period, with all data editing described so far.

Table 2

Table 2 shows mean observed and predicted consumption (g/hp/hr) figures for the treatment period.

	Fuel Consumption		
	Mean Observed	Mean Predicted Model I	Model II
Treatment Period	143.38	144.94	144.27
Treatment Period less first 1000 hrs	143.33	145.06	144.33

The mean observed and mean predicted fuel consumption for the treatment period less the first 1000 hours are also shown. This period was also considered following advice from Fuel Technology that CV300 would not start to show benefits in an older engine until after approximately 1000 hours of use.

4.2.1 Model I

The percent reduction in fuel consumption resulting from fuel treatment with CV300 is calculated to be

$$\frac{144.94 - 143.38}{144.94} \times 100 = 1.08\%$$

while for the adjusted treatment period, the percent reduction is

$$\frac{145.06 - 143.33}{145.06} \times 100 = 1.19\%$$

The addition of CV300 to the ship's fuel is thus having a positive effect in reducing fuel consumption.

4.2.2 Model II

The percent reduction in fuel consumption resulting from fuel treatment with CV300 is calculated to be

$$\frac{144.27 - 143.38}{144.27} \times 100 = 0.62\%$$

while for the adjusted treatment period, the percent reduction is

$$\frac{144.33 - 143.33}{144.33} \times 100 = 0.69\%$$

As for Model I, the addition of CV300 to the ship's fuel is having a positive effect in reducing fuel consumption, although the the magnitude of the effect is reduced.

4.3 Confidence Interval for the CV300 Effect

From the multiple regression model we may obtain confidence intervals for the CV300 effect. If we let z_i be the observed fuel consumption for case i (i = 1, 2, ..., 85) then the percent reductions, R say, in fuel consumption is given by

$$R = 100 \times (\bar{y} - \bar{z})/\bar{z} = 100 \times (1 - \bar{z}/\bar{y})$$

To obtain a confidence interval for R we first obtain a confidence interval for $\ell n(\bar{z}/\bar{y}) = \ell n\ \bar{z} - \ell n\ \bar{y}$, and then use the monotonicity properties of the logarithmic function.

For Model I the 95 percent confidence interval for $\ell n\ \bar{z} - \ell n\ \bar{y}$ = (-0.04784, 0.02611), which corresponds to a 95 percent confidence interval for R of (-2.65%, 4.67%). For the treatment period less the first 1000 hours the corresponding 95 percent confidence interval for R is (-2.73%, 4.97%).

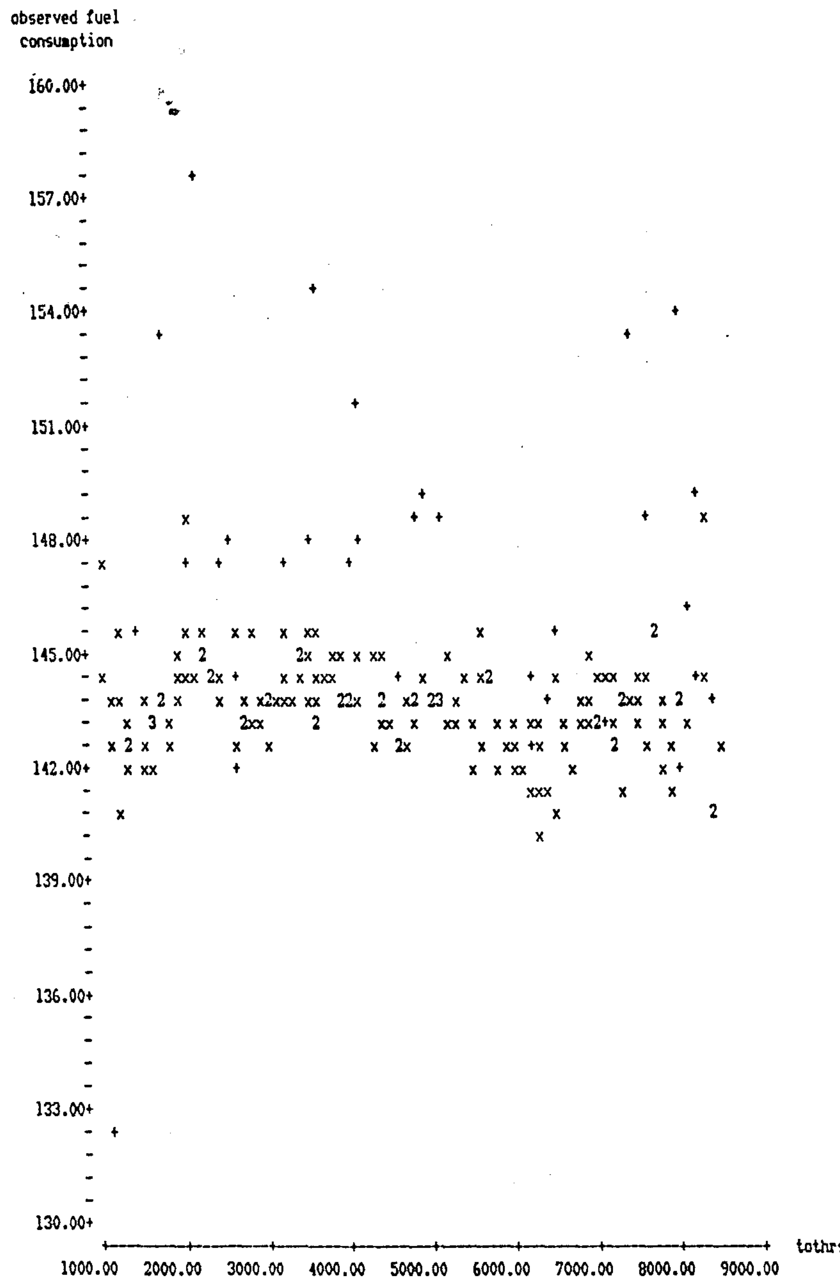
For Model II the 95 percent confidence interval for $\ell n\ \bar{z} - \ell n\ \bar{y}$ = (-0.04239, 0.02987), which corresponds to a 95 percent confidence interval for R of (-3.03%, 4.15%). For the treatment period less the first 1000 hours the corresponding 95 percent confidence interval for R is (-3.19%, 4.29%).

CASE	M/E TOTHRS	M/E RPM	HOURS TEST	FUEL CONSUMPTION OBSERVED	MODEL I LN(PREDICTED)	MODEL I PREDICTED	MODEL II LN(PREDICTED)	MODEL II PREDICTED
1	4110	139.6	33.5	144.8	4.9732	144.49	4.9754	144.81
2	4127	141.7	15.7	144.0	4.9718	144.29	4.9712	144.19
3	4332	142.5	31.6	142.5	4.9727	144.41	4.9708	144.14
4	4358	142.7	29.1	145.0	4.9726	144.40	4.9709	144.16
5	4374	143.7	11.0	143.3	4.9715	144.24	4.9676	143.68
6	4400	143.7	23.0	143.8	4.9721	144.32	4.9680	143.73
7	4421	143.7	16.0	143.6	4.9718	144.28	4.9678	143.71
8	4470	142.6	40.1	143.0	4.9733	144.50	4.9677	143.69
9	4551	142.4	73.0	142.7	4.9750	144.75	4.9705	144.09
10	4588	144.1	33.3	142.7	4.9727	144.42	4.9671	143.61
11	4683	141.0	72.6	142.9	4.9756	144.83	4.9695	143.96
12	4728	143.2	24.4	143.6	4.9731	144.47	4.9692	143.91
13	4765	142.5	31.4	143.6	4.9734	144.51	4.9715	144.24
14	4788	142.6	20.6	143.2	4.9729	144.44	4.9731	144.48
15	4807	141.4	11.6	143.7	4.9728	144.43	4.9701	144.05
16	4854	142.3	30.0	144.2	4.9735	144.53	4.9715	144.24
17	4953	142.1	46.2	143.7	4.9745	144.67	4.9719	144.31
18	4984	141.3	27.3	143.5	4.9738	144.58	4.9726	144.41
19	5076	139.8	85.5	143.6	4.9771	145.05	4.9733	144.50
20	5094	140.5	12.3	144.0	4.9735	144.54	4.9699	144.02
21	5122	138.5	25.5	143.5	4.9747	144.71	4.9706	144.11
22	5198	141.7	44.5	144.8	4.9749	144.73	4.9683	143.79
23	5249	140.2	43.4	143.1	4.9753	144.79	4.9708	144.15
24	5295	142.3	43.2	143.0	4.9748	144.72	4.9744	144.67
25	5330	142.2	29.0	144.0	4.9742	144.63	4.9722	144.34
26	5418	142.8	39.6	144.3	4.9747	144.70	4.9713	144.21
27	5458	140.2	33.9	142.2	4.9752	144.78	4.9691	143.90
28	5476	140.3	16.0	143.0	4.9744	144.66	4.9669	143.58
29	5551	142.0	72.8	144.5	4.9767	144.99	4.9700	144.03
30	5594	142.2	38.0	145.6	4.9750	144.76	4.9692	143.92
31	5639	142.1	38.6	142.7	4.9752	144.77	4.9692	143.92
32	5697	135.5	55.8	144.6	4.9779	145.17	4.9646	143.24
33	5825	141.6	57.3	141.9	4.9765	144.96	4.9697	143.98
34	5849	141.8	19.1	143.3	4.9747	144.70	4.9651	143.33
35	5883	141.9	30.0	142.7	4.9752	144.78	4.9656	143.39
36	5958	141.7	72.5	143.2	4.9774	145.09	4.9705	144.09
37	6003	142.0	21.5	142.6	4.9750	144.74	4.9675	143.66
38	6039	140.7	30.0	142.0	4.9758	144.86	4.9704	144.08
39	6073	140.7	29.3	142.0	4.9758	144.87	4.9704	144.09
40	6159	142.0	24.0	141.6	4.9753	144.80	4.9678	143.71
41	6159	141.8	77.3	143.4	4.9779	145.17	4.9710	144.17
42	6263	139.3	59.8	140.3	4.9779	145.17	4.9669	143.57
43	6306	139.4	37.2	141.3	4.9769	145.02	4.9664	143.50
44	6324	139.0	11.9	142.7	4.9759	144.87	4.9690	143.88
45	6349	142.7	22.3	143.1	4.9754	144.80	4.9741	144.62
46	6428	140.5	30.5	141.5	4.9765	144.96	4.9709	144.16
47	6452	140.2	22.4	140.6	4.9762	144.92	4.9723	144.36
48	6470	140.8	11.0	144.1	4.9755	144.83	4.9725	144.38
49	6568	141.0	36.5	143.2	4.9768	145.01	4.9717	144.27
50	6739	140.9	111.8	142.2	4.9806	145.57	4.9705	144.09
51	6756	140.3	11.6	143.7	4.9762	144.92	4.9708	144.13
52	6791	140.8	32.4	143.3	4.9771	145.05	4.9736	144.55
53	6852	141.0	32.5	144.9	4.9771	145.05	4.9739	144.59
54	6901	140.4	42.6	143.4	4.9778	145.16	4.9720	144.31
55	6943	140.7	35.2	144.0	4.9774	145.10	4.9721	144.33

APPENDIX (cont)

					FUEL CONSUMPTION			
					MODEL I		MODEL II	
CASE	M/E TOTHRS	M/E RPM	HOURS TEST	OBSERVED	LN(PREDICTED)	PREDICTED	LN(PREDICTED)	PREDICTED
56	6983	140.6	33.5	143.0	4.9775	145.10	4.9720	144.32
57	7001	140.1	15.2	143.1	4.9768	145.00	4.9711	144.19
58	7035	139.6	30.5	144.2	4.9777	145.14	4.9712	144.20
59	7091	138.0	52.9	144.7	4.9792	145.36	4.9707	144.12
60	7172	140.7	30.9	142.4	4.9776	145.13	4.9742	144.63
61	7197	138.8	22.7	144.6	4.9778	145.15	4.9706	144.12
62	7215	139.4	13.0	142.8	4.9772	145.07	4.9727	144.41
63	7231	139.8	11.5	143.1	4.9770	145.04	4.9748	144.72
64	7257	139.4	23.8	141.4	4.9778	145.15	4.9804	145.53
65	7293	141.2	30.6	143.8	4.9776	145.13	4.9766	144.98
66	7339	141.6	40.0	143.6	4.9780	145.19	4.9736	144.55
67	7437	141.0	45.6	144.0	4.9786	145.27	4.9716	144.26
68	7451	137.4	10.7	143.4	4.9780	145.18	4.9714	144.23
69	7478	142.6	24.4	143.6	4.9773	145.08	4.9705	144.10
70	7543	135.9	62.3	144.4	4.9810	145.61	4.9792	145.35
71	7610	140.8	12.1	144.6	4.9774	145.09	4.9744	144.67
72	7636	138.4	24.3	142.7	4.9787	145.28	4.9748	144.71
73	7651	141.1	10.8	145.3	4.9773	145.08	4.9729	144.44
74	7693	138.6	36.8	145.3	4.9793	145.37	4.9772	145.07
75	7777	141.8	72.2	143.8	4.9802	145.50	4.9773	145.08
76	7801	141.2	18.0	143.3	4.9779	145.16	4.9734	144.52
77	7831	141.4	27.3	142.0	4.9783	145.22	4.9757	144.86
78	7886	141.2	24.0	142.4	4.9783	145.22	4.9756	144.83
79	7926	141.1	33.2	141.5	4.9788	145.30	4.9704	144.08
80	7977	141.8	38.6	143.5	4.9789	145.32	4.9748	144.72
81	8016	137.0	32.3	144.0	4.9800	145.48	4.9800	145.47
82	8062	139.1	12.2	143.3	4.9786	145.27	4.9848	146.18
83	8283	138.2	82.2	144.5	4.9824	145.83	4.9737	144.56
84	8338	136.1	48.1	148.3	4.9815	145.69	4.9711	144.19
85	8457	141.2	43.0	142.7	4.9800	145.48	4.9771	145.05

NOTE : M/E TOTHRS is Main Engine hours less 10000



1 MISSING OBSERVATIONS

Figure 1 Figure 1 display the fuel consumption versus Main Engine hours (less 10000 hours) for both the Background period (1003 to 3972) and the Treatment period (4023 to 8457). The '+' values correspond to voyages made at reduced speed.

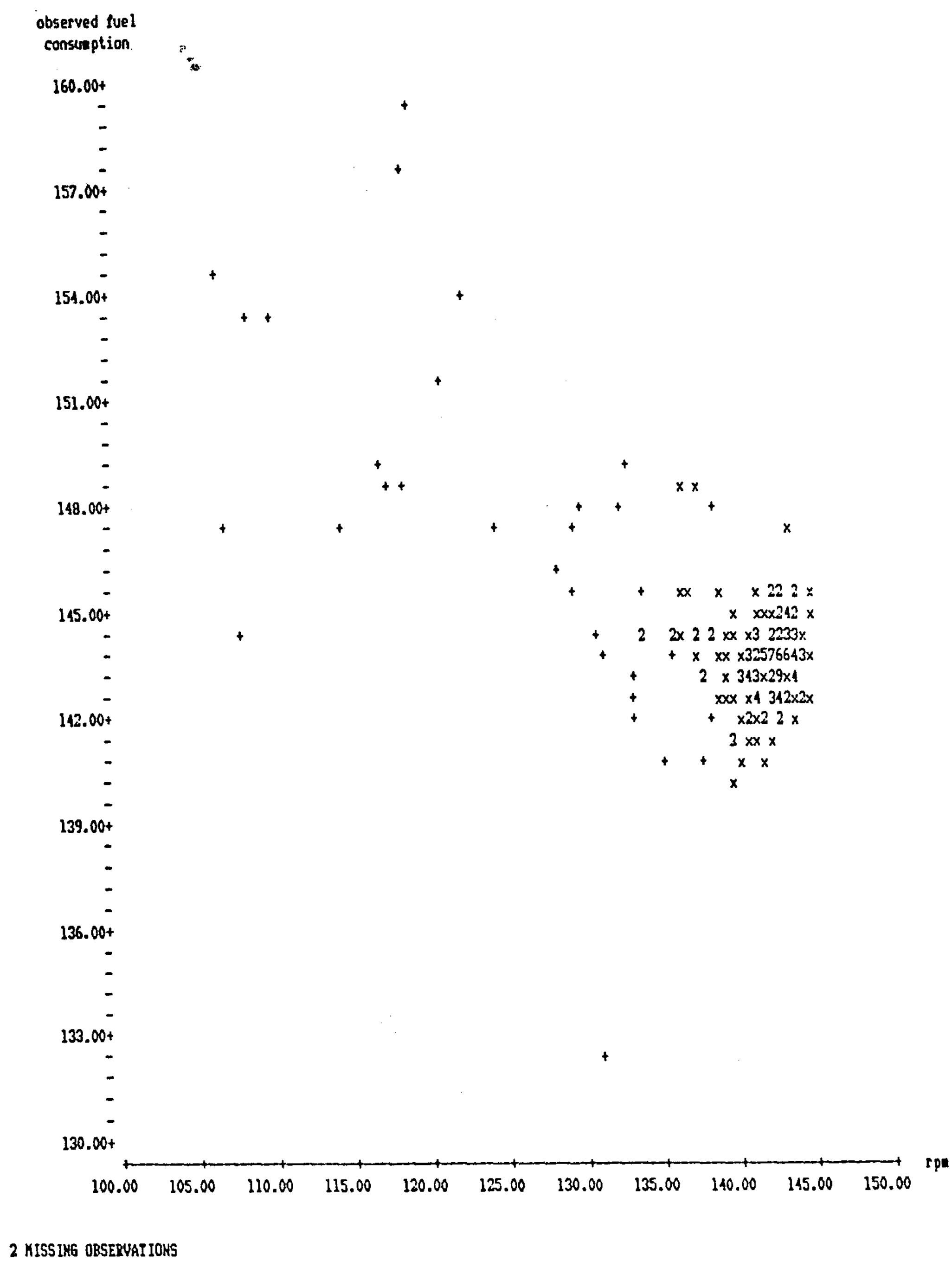
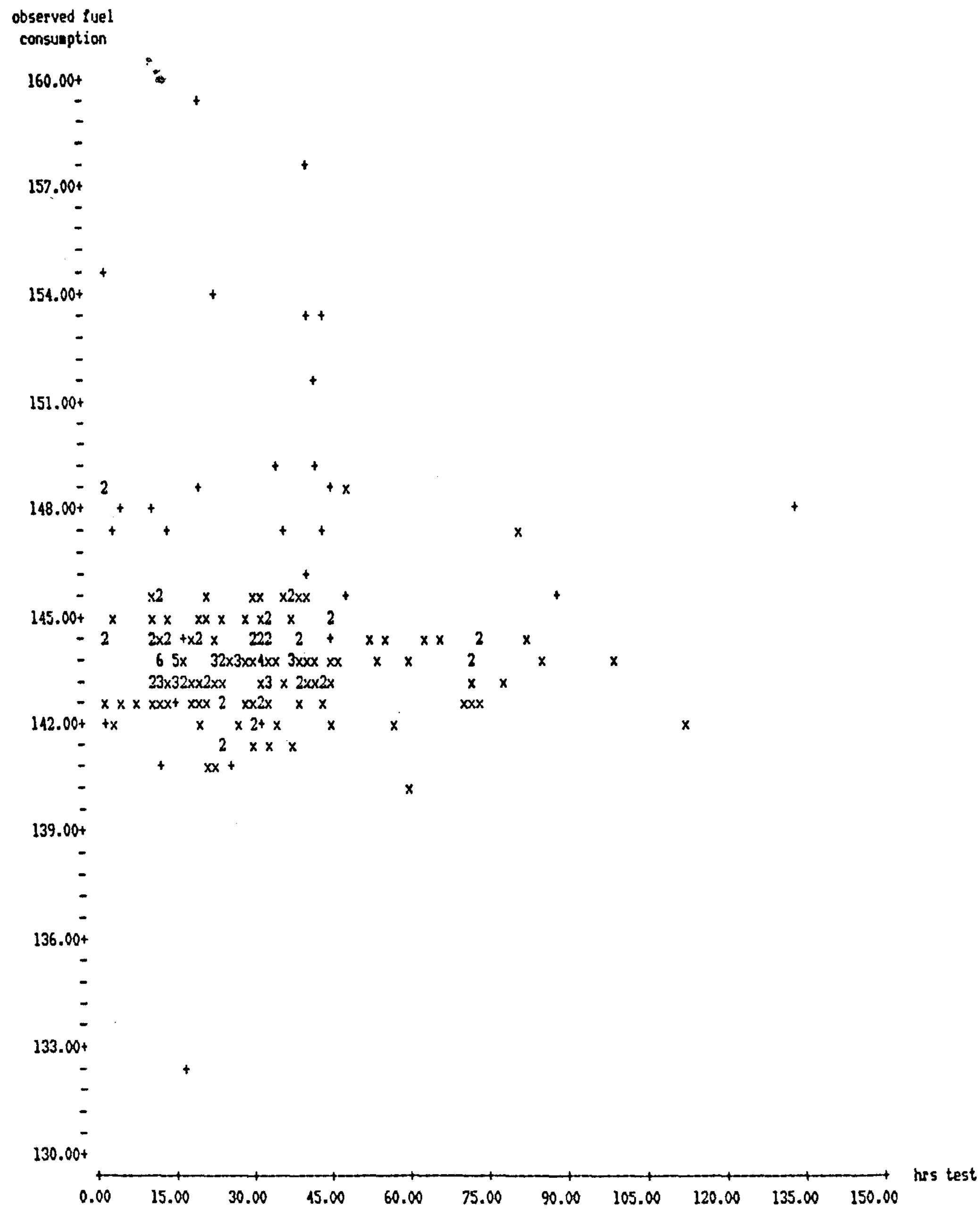


Figure 2 Figure 2 display the fuel consumption versus the Main Engine RPM for both the Background period (1003 to 3972) and the Treatment period (4023 to 8457). The '+' values correspond to voyages made at reduced speed.



1 MISSING OBSERVATIONS

Figure 3 Figure 3 display the fuel consumption versus the Hours test for both the Background period (1003 to 3972) and the Treatment period (4023 to 8457). The '+' values correspond to voyages made at reduced speed.

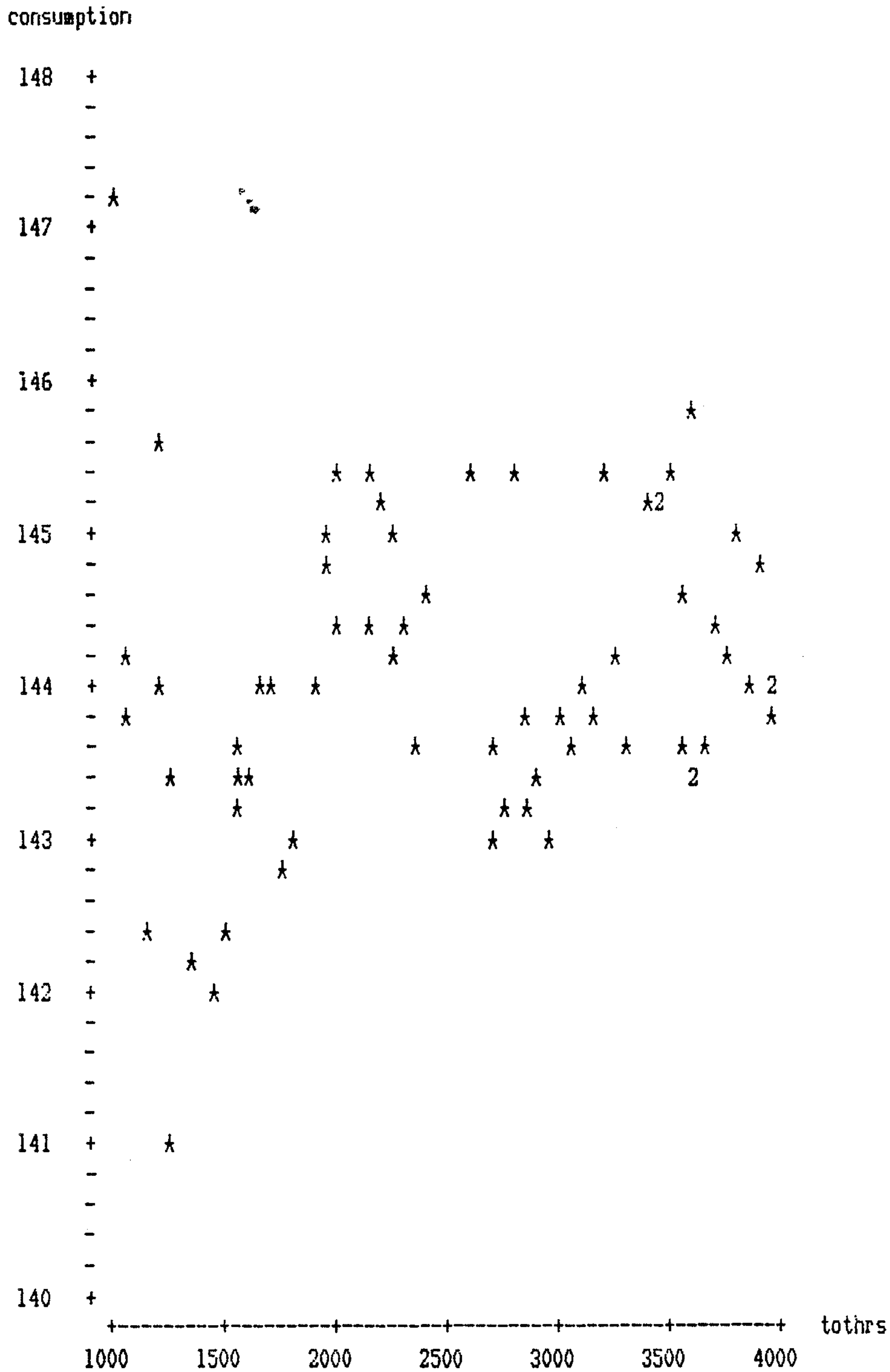


Figure 4 Figure 4 display the fuel consumption versus Main Engine hours (less 10000 hours) for the Background period. Voyages made at reduced speed or whose hours test are less than 10 are omitted.

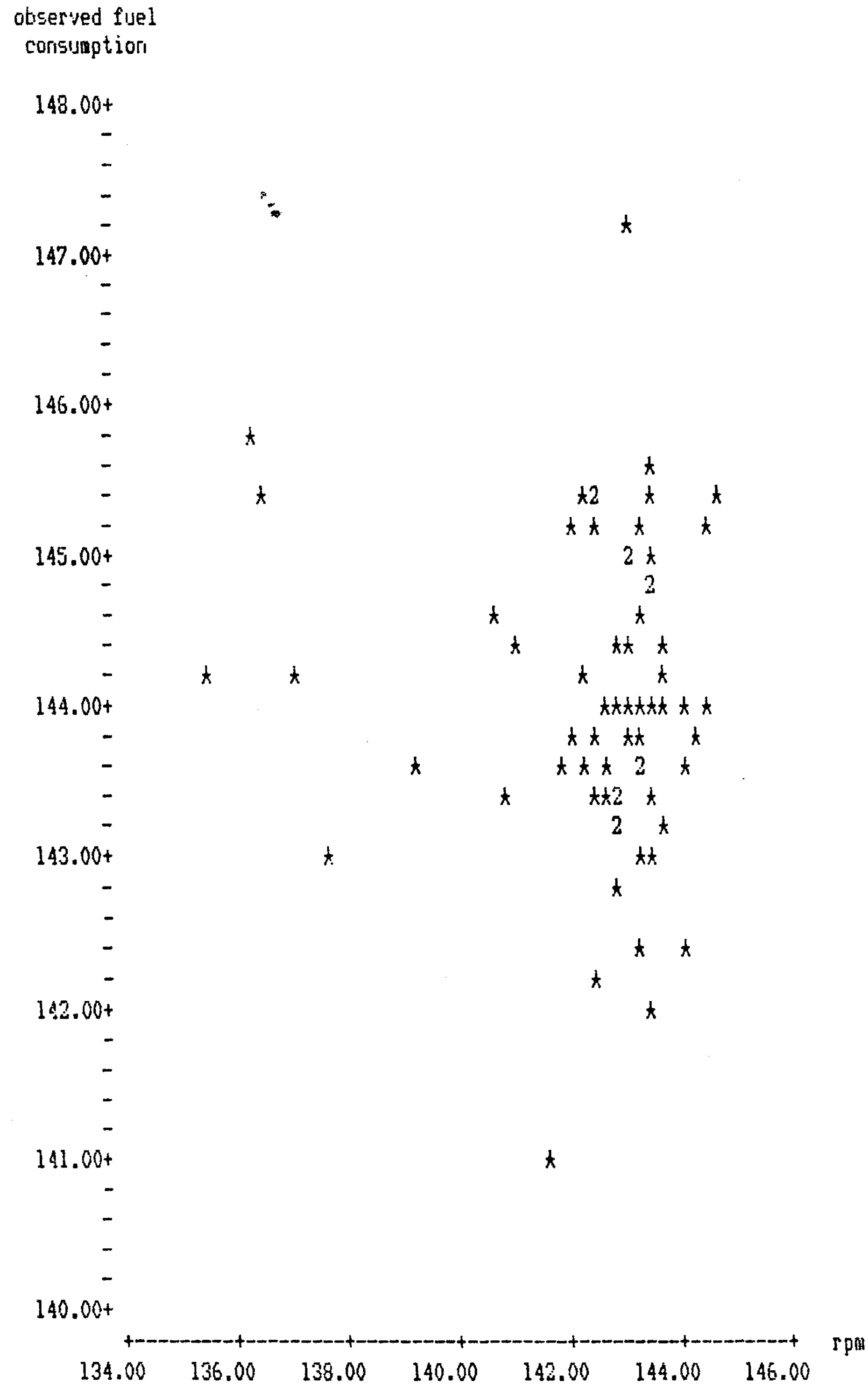


Figure 5 Figure 5 display the fuel consumption versus Main Engine RPM for the Background period. Voyages made at reduced spped or whose hours test are less than 10 are omitted.

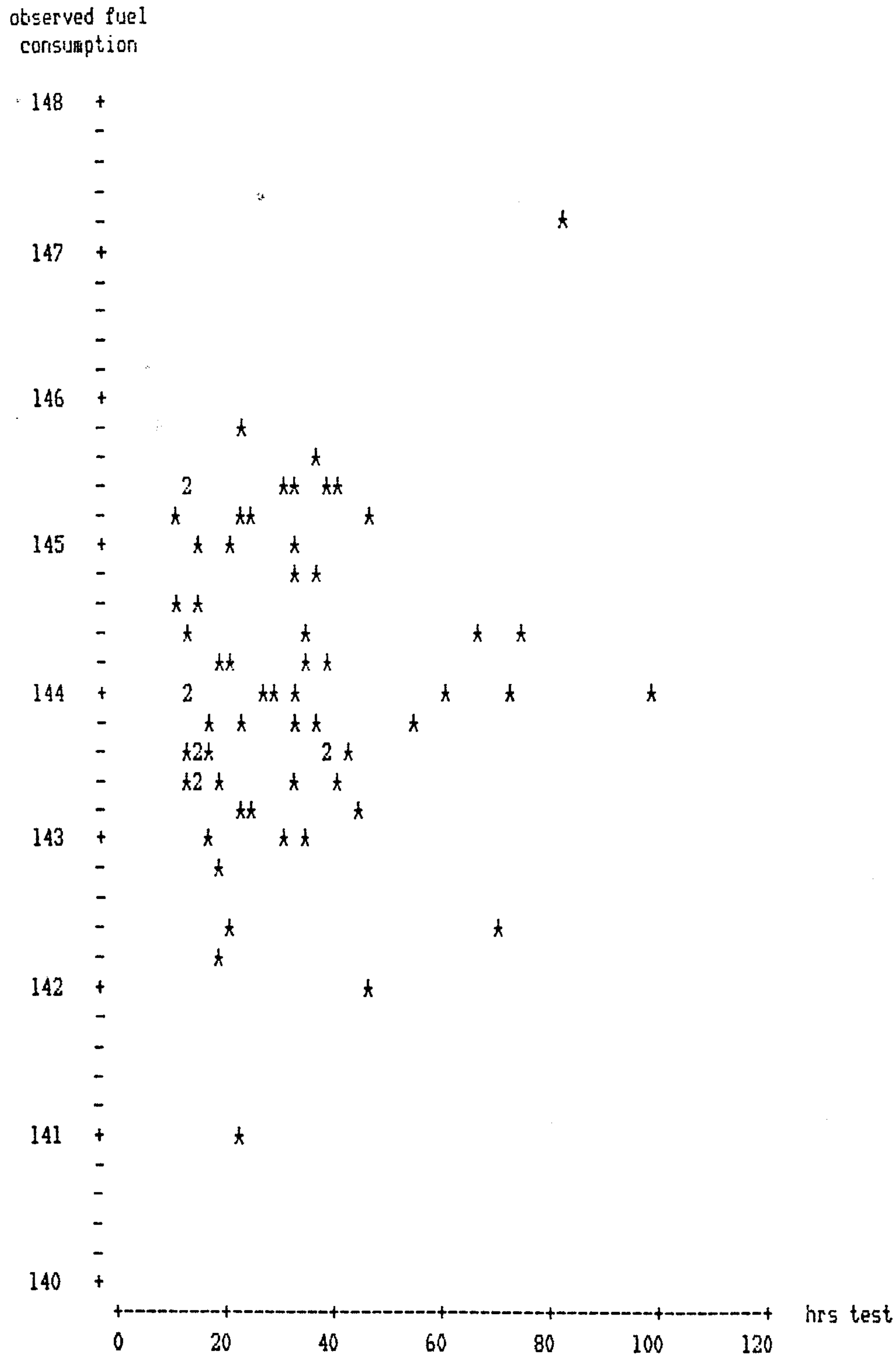


Figure 6 Figure 6 display the fuel consumption versus Hours test for the Background period. Voyages made at reduced speed or whose hours test are less than 10 are omitted.

SECTION 4

SECTION 4: ECONOMIC CONSIDERATIONS

4.1 MAINTENANCE and CAPITAL SAVINGS

The CONUS consumes approximately 40 tonnes of fuel oil and 2 tonnes of diesel per day or roughly 15,000 tonnes total fuel per annum. Treatment of this fuel with CV300 at a 3000:1 litre ratio would require about 5,100 litres of CV300 annually.

The price of CV300 during the trial was set at $7.50 per litre in May 1984. As a result of changes in exchange rates and other cost changes the current price of CV300 delivered to Winstanley Industries would be $9.60 per litre. (This price may reduce slightly in 1986 after the commencement of local manufacture based on imported active ingredient.) Handling and fuel treatment costs should be negligible, perhaps $0.20 per litre bringing the annual expense of treating all fuel on the CONUS to roughly $50,000.

Fuel Technology is not in a position to accurately estimate the maintenance and capital savings to the CONUS from this investment. However, our experience with power generation and heavy mine equipment would suggest annual maintenance labour and parts saving could exceed $10,000 leaving to question whether or not the possible increase in the service life of the vessel can be valued at about $40,000 per year.

These considerations of course do not take into account the unresolved saving in fuel expense.

4.2 FUEL SAVINGS

Priced at $9.60 per litre and assuming an all up treatment expense of $9.80 per litre of CV300, the cost of treating a litre of fuel (heavy oil or diesel) is 3,000 litres/980 cents or about 0.327¢.

It is understood that the CONUS fuel costs $320 per tonne which, adding the small amount of diesel used at say $400 per tonne, indicates an average cost of $324 per tonne or 31.8 cents per litre consumed.

The 0.327 cents treatment cost would be 1.03% of the fuel cost. Thus if fuel saved from treatment is:

- 1%, There would not be a net* fuel saving
- 2%, The annual net saving in fuel will be 145 tonnes or about $47,000
- 3%, The annual net saving in fuel will be 300 tonnes or about $98,000.

* net saving means saving, net of treatment costs.

It can be stated with a high degree of certainty that the diesel fuel consumed in CONUS power generation can be reduced between 3 and 4% by CV300 treatment. Also experience with boilers would suggest a 2-3% saving in CONUS fuel used in its boilers. What is presently unclear is just how much fuel consumption is being reduced in the main engine. The recommendation made by this report is to attempt to resolve that question with a series of short, controlled tests to be made during the normal operation of the ship.