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# FUEL RESEARCH INSTITUTE

OF SOUTH AFRICA

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TECHNICAL MEMORANDUM NO. 37 OF 1973

## DUAL FUEL OPERATION OF A DIESEL ENGINE ON METHANE

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## DUAL FUEL OPERATION OF A DIESEL ENGINE ON METHANE.

### 1. SUMMARY

A Ford Trader diesel engine was operated on the dual fuel system, using diesel oil and methane. A considerable reduction in smoke generation and power loss could be obtained under operation at high altitudes by replacing approximately 25% of the liquid fuel by methane.

### 2. INTRODUCTION

In previous experiments*, virtually smokeless operations of diesel engines, operating with direct fuel injection (i.e. without a pre-combustion chamber) could be obtained at maximum output at Highveld altitudes (1400 .... 1500 m) by supplying approximately 75% of the fuel requirements by diesel oil and meeting any demands beyond this level by injecting LPG into the air intake manifold.

It was considered interesting to investigate whether methane would serve equally well as LPG, even though at present this fuel is not abundantly available.

### 3. EXPERIMENTAL PROCEDURE

On the whole, the equipment and test procedure followed were identical to that described in the Memorandum mentioned above, to which reference may be made for particulars. The instrumentation was supplemented by a Bosch Smoke Density meter to obtain a quantitative assessment of the exhaust smoke density. In this instrument, a pre-determined volume of exhaust gas is aspirated through a filter paper, the

/discoloration ....

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* Reported in Technical Memorandum No. 24 of 1972: "Eliminating Diesel Smoke with Liquefied Petroleum Gas",

discoloration of which is measured by means of a photometer and expressed in shades of blackness on a scale ranging from 0 to 10.

These figures may be related to more subjective visual observations as follows:

For comparatively small engines, like the model tested:

| | |
|---|---|
| Under 3,5 | Invisible |
| 3,5 - 4 | Barely noticeable |
| 4 - 5 | Light smoke |
| 5 - 6 | Easily visible |
| over 6 | Dense smoke |

The main particulars of the engine are indicated in Table No. 1. When tested, the engine was fitted with the normal auxiliaries such as a fan, a generator and a fuel injection pump.

During the experiments, the stroke of the fuel injection pump's control rod could be limited by an adjustable stop.

The gaseous fuel used was a raw synthetic mixture, containing 84% of methane. Its composition and other particulars are listed in Table No. 2.

During the experiments, this gas was stored in a number of high pressure cylinders (of 0,034 $m^3$ water capacity, maximum pressure 13,6 MPa). Three cylinders were used in parallel. The gas was passed through a Tartarini 2-stage pressure reducer (c.f. Figure No. 1), specifically designed for methane, from where it flowed at essentially atmospheric pressure to the intake manifold. Figure No. 2 supplies the main particulars of the gas and liquid fuel supply system while some details of the gas jet and the intake adaptor and mixer, fixed to the

/intake .....

intake manifold, are given in Figure No. 3. The jet was identical to that used for LPG but the regulating screw, by means of which the gas/air ratio could be altered, had to be opened more for methane, which has a considerably lower density than LPG.

During fuel consumption tests, the liquid fuel was drawn from a container of 20 litre capacity. The engine was operated for a period of approximately 30 minutes. The liquid and gas containers were weighed at the beginning and the end of this test period.

Proved by previous experience with dual fuel operation on LPG, the control rod of the fuel injection pump was limited to a stroke of 7,5 mm and the injection timing at 22 ... 23$^{o}$ before top dead centre. With this adjustment smokeless operation (Shade No. 2 on the Bosch meter) was obtained under all conditions. Performance data with these adjustments are presented in Table No. 3, Test No. 1 and Figure No. 4.

Gas was then admitted to the induced air in rasious proportions, c.f. Tests No. 2 - 14 and Figure No. 4.

Using LPG instead of methane, Test No. 15 was carried out for purposes of comparison.

## 4. DISCUSSION OF TEST RESULTS

The ambient air pressure at the test side is normally between 650 and 660 mm Hg or approximately 86% of the standard sea level figure. The mass of air, induced into the engine is reduced roughly to the same extent. One may thus expect that when operating on diesel oil only, the quantity of fuel injected and thus the output, must be reduced in the same proportion as the air quantity. The rated output of 47 kW at 2500 rpm would therefore on the Highveld be reduced to 40 ... 41 kW if a reasonable degree of smoke emission is required.

This expectation was confirmed: on diesel oil only, with the pump stop set at 9 mm, 40,2 kW was produced at 2500 rpm and some visible smoke (shade 4,7) was generated (c.f. Figure No. 5).

If the output is boosted by increasing the pump delivery, heavy smoke is generated. Increasing the pump stroke beyond 11,4 mm hardly increases the power but only the inefficiency of the combustion process.

Comparing the curves of Figure No. 5 with those of Figure No. 4, it is evident that a considerable improvement is obtained under dual fuel operations. The power curve for 9 mm, diesel oil only, can be achieved with dual fuel operation with a virtually clean exhaust. Alternatively, if a moderate smoke production is accepted, the sea level output can be nearly attained, c.f. curve 5 of Figure No. 4.

The engine operated smoothly on the dual fuel and no signs of knocking could be observed.

The carbon monoxide emission of a properly operated diesel engine is low (0,05 ... 0,1%) and this level was not significantly affected under dual fuel operation.

It may thus be concluded that for dual fuel operation methane is as effective as LPG.

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PRINCIPAL TECHNICIAN

G.A.W. VAN DOORNUM
CHIEF RESEARCH OFFICER

Pretoria.
24th July, 1973.
GAWvD/EMc

## TABLE 1

## SPECIFICATION OF TEST ENGINE

| | |
|---|---|
| Make and Type | Ford "Trader" |
| Engine No. | 500 E 38026 |
| Number of Cylinders | 4 |
| Bore | 100 mm |
| Stroke | 115 mm |
| Engine Capacity | 3,611 litres |
| Compression Ratio | 16 ÷ 1 |
| Rated Output | 47 kW (64 hp) at 2500 rpm |
| Rated Torque | 209 Nm (154 ft. lb.) at 1500 rpm. |

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/TABLE 2 .....

## TABLE 2

### COMPOSITION OF THE GASEOUS FUEL USED

| | | |
|---|---|---|
| Methane | $CH_4$ | 84% by volume |
| Carbon Monoxide | CO | 7 |
| Carbon Dioxide | $CO_2$ | trace |
| Nitrogen | $N_2$ | 3,9 |
| Oxygen | $O_2$ | 0,7 |
| Argon | Ar | 4,5 |

| | | | |
|---|---|---|---|
| Gross Calorific Value | (Calculated) | 34,4 MJ/kg | 31,9 $MJ/m_n^3$ |
| Density | (Calculated) | | 0,833 $kg/m_n^3$ |

**Some properties of Methane**

| | |
|---|---|
| Calorific Value | Gross 39,8 MJ/kg, Nett 36,8 MJ/kg |
| Density | 0,717 $kg/m_n^3$ |
| Octane Rating | 100 ............. 120 |
| Highest useful Compression Ratio | 10 ÷ 1 .......... 12 ÷ 1 |
| Air to gas ratio | 9,5 $m^3/m^3$ 17,2 kg/kg |
| Spontaneous Ignition Temperature | 650 ............. 800 °C |
| Explosive limits from | 5,3 .............. 6,3 % |
| (vol. % $CH_4$ in Air), to | 12 ............... 15 % |
| Energy Content of Theoretical Mixture | 3,8 $MJ/m_n^3$ |

**Some properties of Diesel Oil**

| | |
|---|---|
| Composition | 85,7% C, 13,4% H, 0,9% S - by mass |
| Density at 15 °C | 0,840 kg/litre |
| Correction per degree | -0,00068 kg/litre |
| Calorific Value | Gross 45,4 MJ/kg, Nett 42,4 MJ/kg |
| Theoretical air requirements | 14,8 kg/kg |

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/TABLE 3 .....

## TABLE 3

## SUMMARISED TEST RESULTS

ENGINE: FORD TRADER DIESEL — DUAL FUEL OPERATION ON METHANE

3,611 Litre, 16 ÷ 1 Compr. Ratio. Rated 47 kW at 2500 rpm, sea level.

| Test | Fuel | Ign/Inj Timing °BTDC | Pump Stroke mm | Gas Turns | Output and Efficiency 1500 kW | 2000 kW | 2500 kW | Torque N.m. | Fuel Consumption Gas g/min. | Liq. g/min. | CO % | Smoke Bosch No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | D | 23 | 7,5 | - | 21,4 | 28,0 | 28,3 | 136 | | | 0,05-0,1 | 1,9-2,1 |
| 2 | D&M | | | 4 | 26,8 | 36,3 | 40,8 | 170 | | | | |
| 3 | | | | 4½ | 27,2 | 36,8 | 42,7 | 173 | | | | 3,8 |
| 4 | | | | 5 | 27,2 | 39,7 | 44,9 | 173 | | | | 6 |
| 5 | | | | 5½ | 29,1 | 41,7 | 47,8 | 185 | | | | 6 |
| 6 | | | | 5½ | | 40,4 | | 192* | 55 | 121 | | 5,7-6 |
| 7 | | | | 4½ | | 40,8 | | 194* | 61 | 117 | | 4,5-5,9 |
| 8 | | | | 3¾ | | 38,6 | | 184* | 45 | 117 | | 4-4,3 |
| 9 | | | | 3½ | | 37,8 | | 179* | 43 | 123 | | 3,5 |
| 10 | | | | 3½ | 27,2 | 36,8 | 41,2 | 173 | | | | 3 |
| 11 | | | | 3½ | | 37,1 | | | 32 | 121 | | 3,5 |
| 12 | | | | 3½ | 26,1 | 35,6 | 40,7 | 166 | | 123 | | 3,7 |
| 13 | | 22 | | 3½ | 26,1 | 35,6 | 40,7 | 166 | | | 0,05-0,1 | 3,1-3,7 |
| 14 | | | | 3½ | 25,7 | 34,8 | 40,7 | 164 | | | 0,1 | |
| 15 | D&LPG | | | 2½ | 26,2 | 36,7 | 42,9 | 167 | 33 | 123 | 0,05-0,1 | 3-3,8 |

D: Diesel Oil, M: Methane

Torque at 1500 rpm unless marked *, when at 2000 rpm.

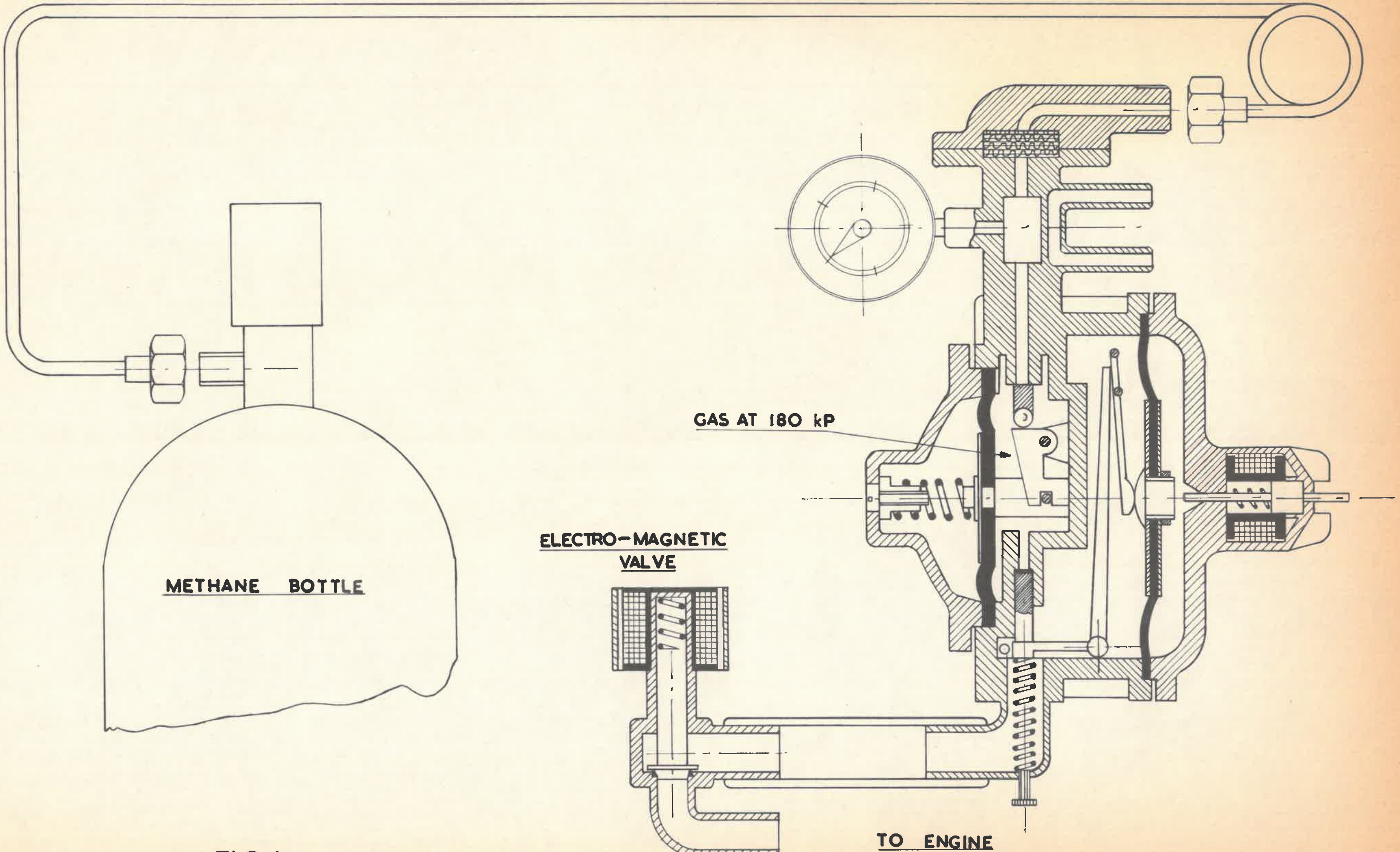

GAS AT 180 kP
ELECTRO-MAGNETIC
VALVE
METHANE BOTTLE
TO ENGINE

FIG. 1

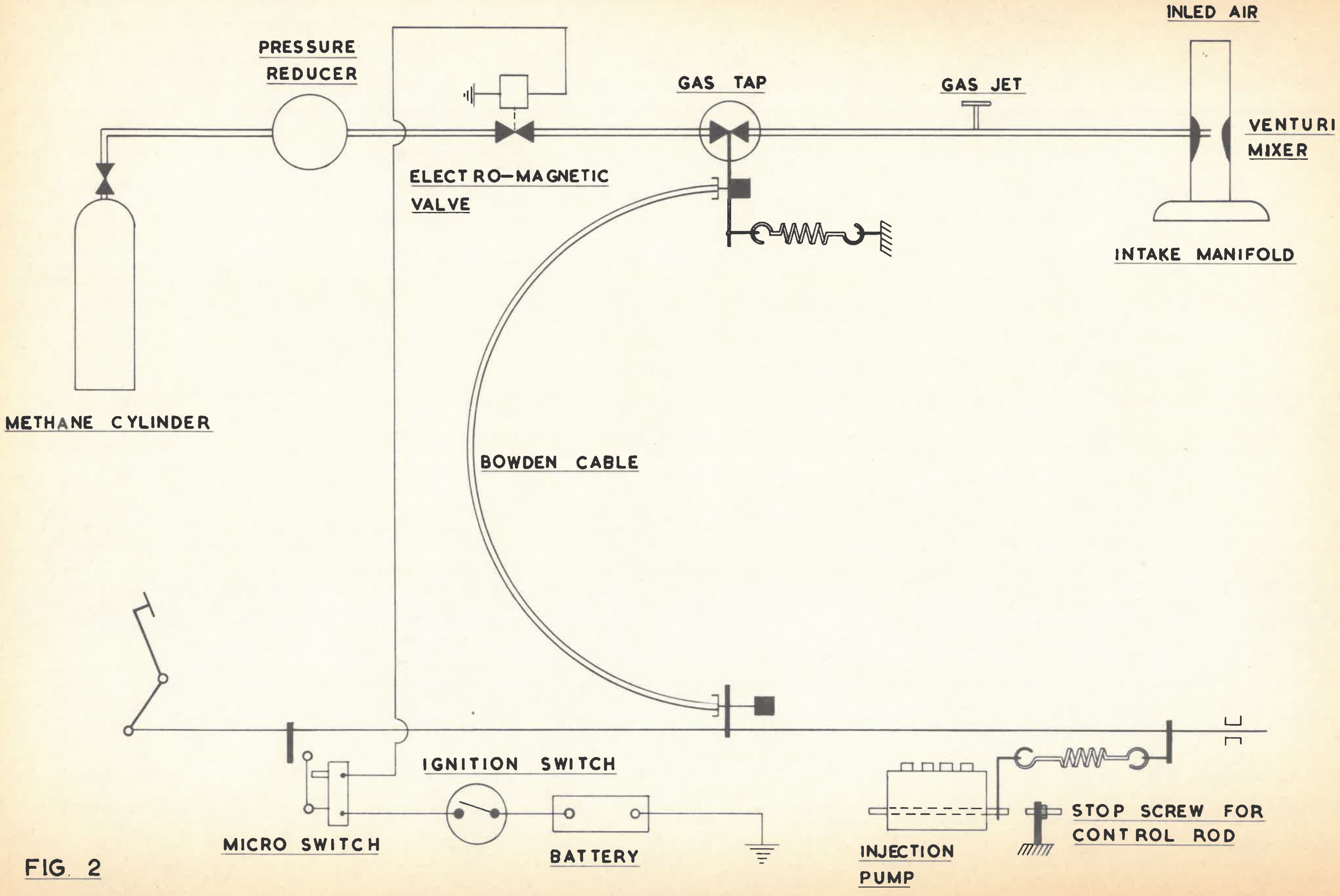
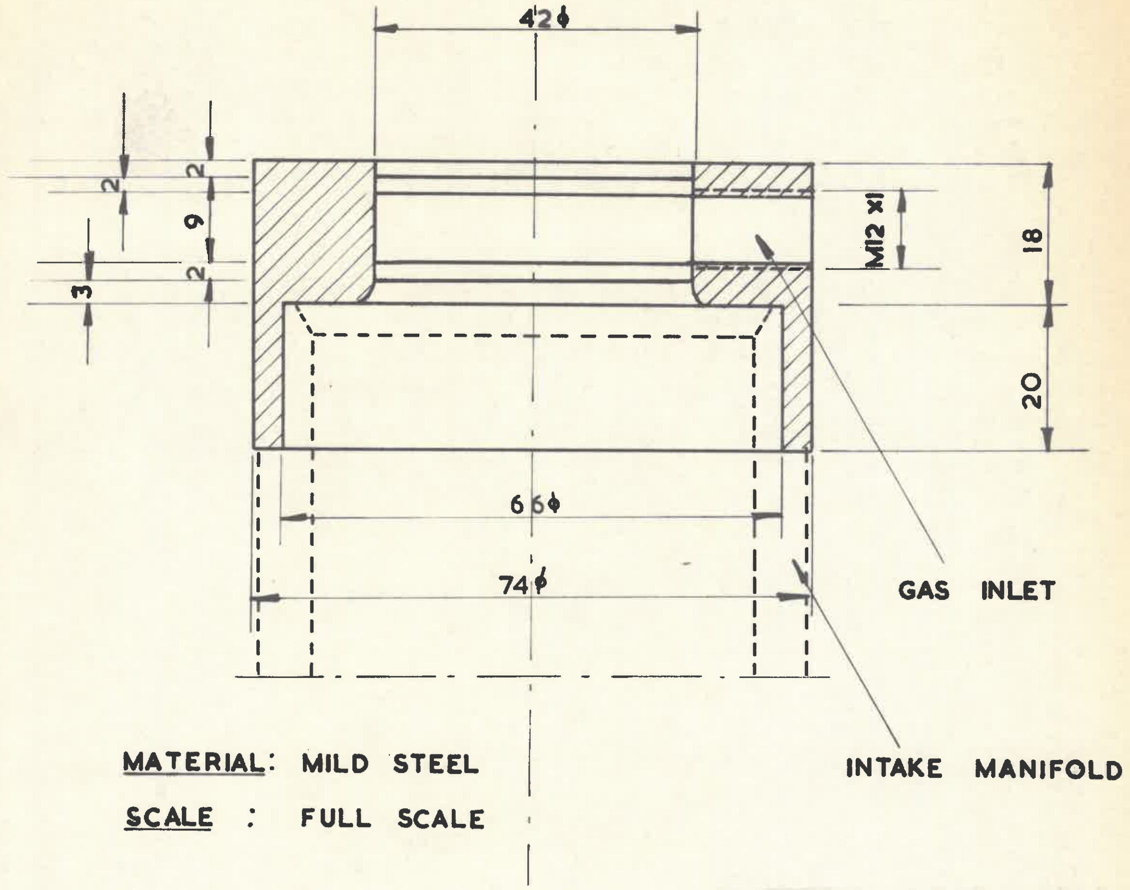

INLED AIR
PRESSURE
REDUCER
GAS TAP
GAS JET
VENTURI
MIXER
ELECTRO-MAGNETIC
VALVE
INTAKE MANIFOLD
METHANE CYLINDER
BOWDEN CABLE
IGNITION SWITCH
STOP SCREW FOR
CONTROL ROD
MICRO SWITCH
BATTERY
INJECTION
PUMP

FIG. 2



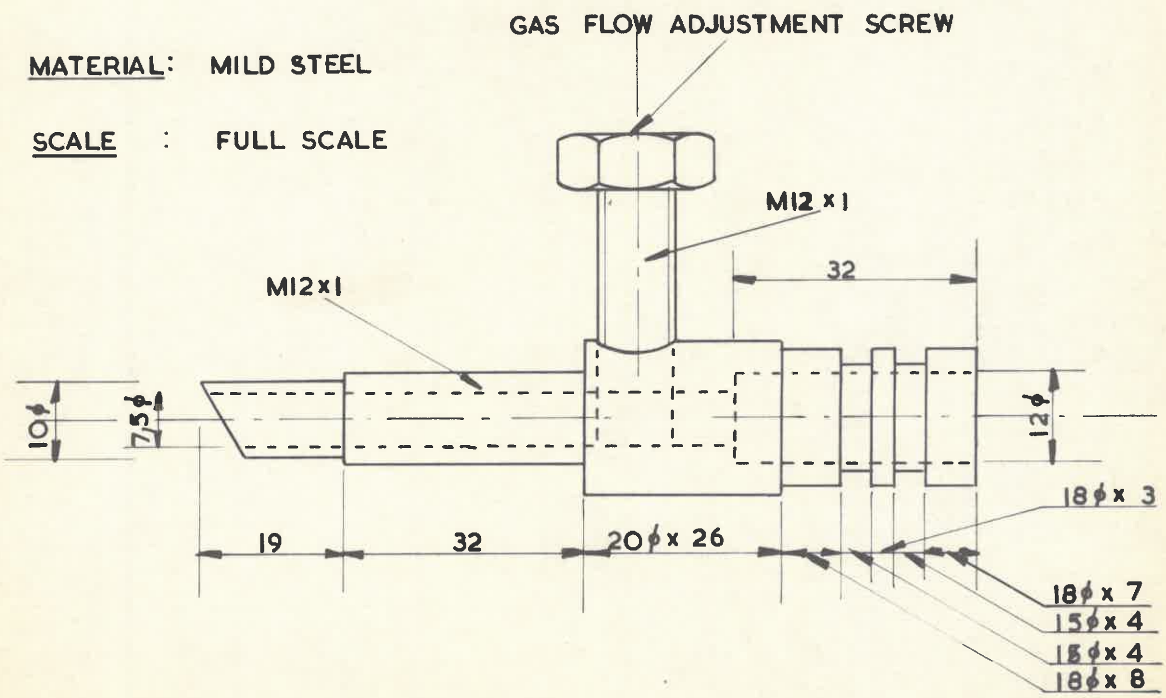
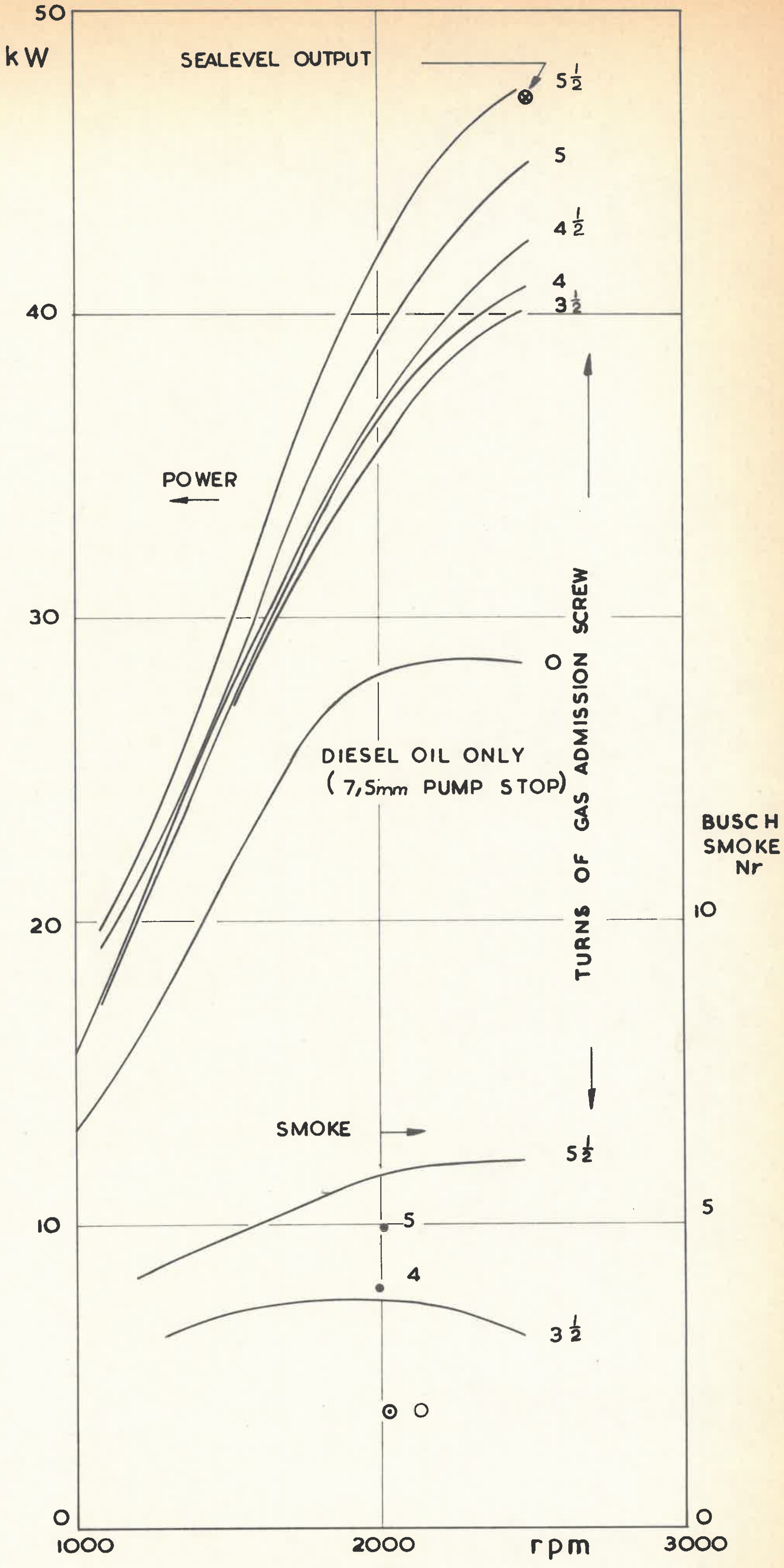
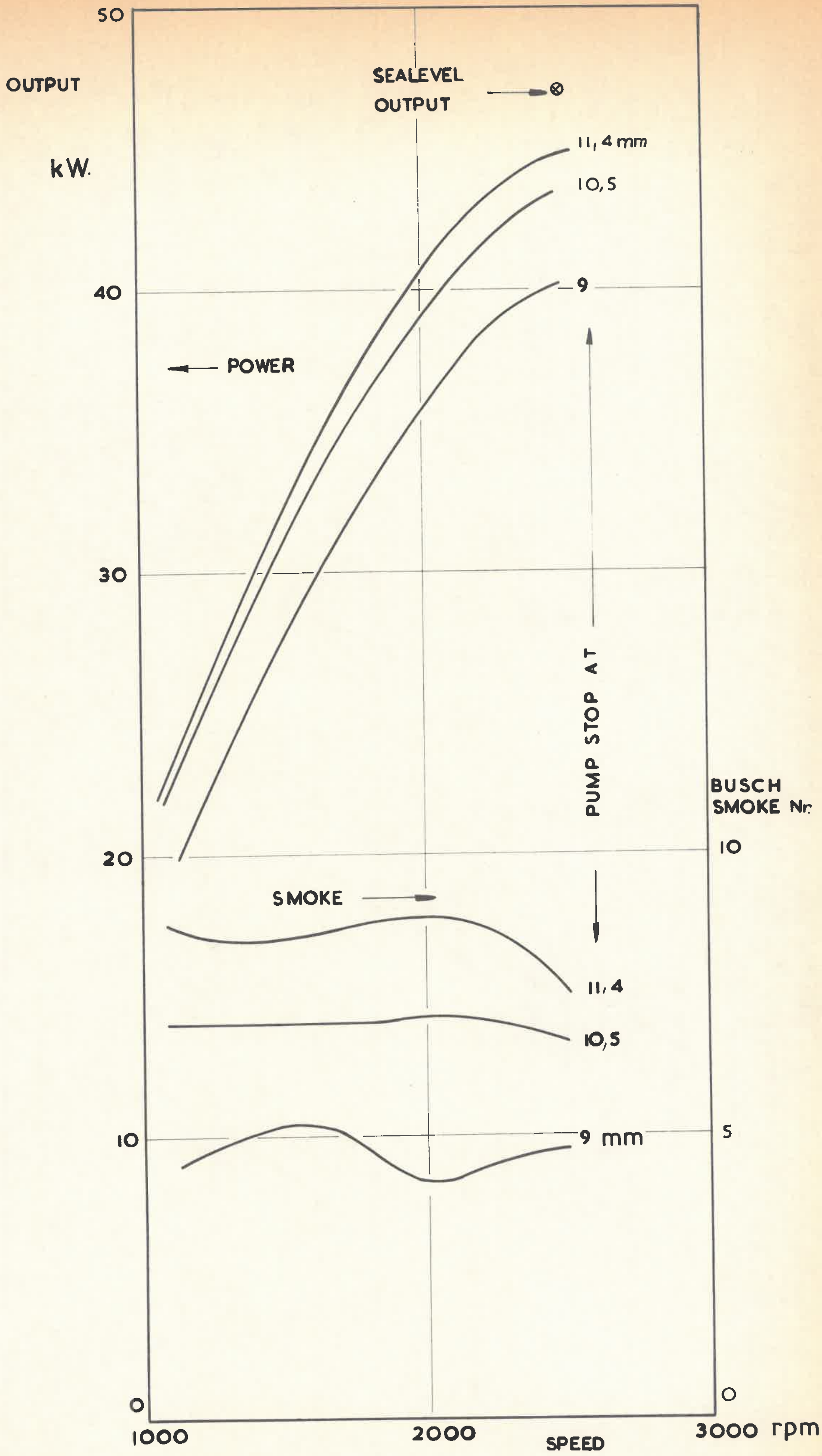




FIG. 3 GAS MAIN JET (FOR USE WITHOUT VENTURI MIXER)




DUAL FUEL OPERATION

FIG. 4




OPERATION ON DIESEL OIL ONLY

FIG. 5