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Report on
OPERATION "BACKFIRE"

VOLUME II
Technical Report

Prepared for Printing by the Ministry of Supply

THE WAR OFFICE, LONDON, S.W.1

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Report on Operation "BACKFIRE"

MAY TO OCTOBER, 1945

CONTENTS

Volume 2.

		PAGE
	INTRODUCTION	9
SECTION 1.	Propulsion System	17
SECTION 2.	Assembly	74
SECTION 3.	Mechanical Tests	98
SECTION 4.	Electrical Installations, Test Desks and Control	124
SECTION 5.	Vehicles and Ancillaries	163
SECTION 6.	Warhead and Igniter	179
SECTION 7.	Fuels	183

INDEX

	Para
A-4 rocket—special vehicles for	15
Air charging and stop valves—to test	132
Air supply	96
Air valve assembly—solenoid operated	63
Air valve—high pressure—hand operated	66
Air valves—solenoid operated	64
Alcohol...	309
Defuelling valve	53
Drain valve—hand operated	65
To test	127
Pumping set	289
Tanker	288
Alignment of fins—tail unit—to test	147
Alignment test on combustion unit	143
Alternators, motor	175–177
Amplifier, control	191–198
Ancillaries and special vehicles	285–302
Apparatus—electrical control	151
Assembled rocket—lifting of...	94
Assemblies—transport of during manufacture ...	89
Assembly—	
Air valve—solenoid operated	63
Material available for	97–99
Steam unit	42–49
Trim motor	204–206
Assembly bogies	95
Assembly of—	
A-4 rocket	...85–109
Rocket—times taken	109
Assembly, propulsion—tackle for	92
Assembly section—	
Alcohol tank	106
Oxygen tank	105
No. 1—stripping and examination	99
No. 2—tail unit	100
No. 3—thrust ring	101
No. 4—propulsion unit	102
No. 5—control compartment	103
No. 6—centre section	104
No. 7—complete assembly	107–109
Assembly test—steam unit	144
" Backfire " operation—	
Object of	2
Radio control not used	6
Steering of rockets	5
Bars, lifting—tail unit	91
Batteries—intermediate distribution frame	169–171
Bogies, assembly	95
Box, valve	302
Button, main stage—functioning	83
Centre section—	
A-4 rocket	11
Assembly section 6	104
Centrifugal switch (turbine overspeed trip) ...	27
Chamber, reaction	72
Check valve—non-return valve	62
Combustion Chamber—	31–41
Connections from pumps...	29–30
Matching procedure—note for	142
Operation	32
Section 1	33
Section 2	34
Sections 3, 5 and 7	34
Section 4	35
Section 5, 7 and 8...	36
Steels used...	40
To test	140
Combustion unit—alignment test	143
Compartment, control—A-4 rocket	10
Complete assembly—assembly section 7 ...	107–109
Contact—	
Pressure operated—steam unit—to test... ...	128
Switch D2R—diaphragm operated	73
Control—	
Amplifier	191–198
Compartment—	
A-4 rocket	10
Assembly section 5	103
Radio—none used for " BACKFIRE " operation	6
Cooling connecting pipes—combustion chamber ...	38
Coupling, 5-way	76
Cross-connecting field—main distribution frame ...	164
Defuelling—alcohol valve	53
Description of warhead	9
Design of A-4 rocket	3
Desks, test	209–284
Diaphragm operated contact switch D2R	73
Dimensions of A-4 rocket	7
Distribution frame—electrical system—	
Intermediate	168–171
Main	163–167
Distribution valve—oxygen	57
Test of	116–121
Drain valve—alcohol—hand operated	65
Test of	127
Electrical control apparatus	151
Electrical power for operating steering system ...	152
Electrical system A-4 rocket	150–184

INDEX *(cont).*

Para

Energy to start rocket—initial 19
Exchanger, heat—exhaust steam line for turbine ... 41
Explosives—pyrotechnic igniter 303-307

Final stage—functioning of propulsion unit ... 84
Fins—alignment of—tail unit—to test 147
Firing platform and trailer 301
Five-way coupling 76
Frame—electrical system—
  Intermediate distribution... 168–171
  Main distribution 163–167
Frequency regulators 178–181
Fuel—
  Delivery of to the combustion chamber—
    Stage 1—ignition of 17
    Stage 2—operation of relays in control compartment 18
  Ignition of —stage 1 17
Fuelling—oxygen valve 60
  Test of 122
Fuels—
  Transfer to rocket... 314
  Transport and transfer to rocket ... 308–314
  Transport of 313
Fuel system, including turbine driven pumps ... 20–22
Fuel tank valve—alcohol 52
Fuel valves 159–162
Functioning of propulsion unit 77–82
  Final stage 84

Gear—
  Lifting—thrust ring 90
  Tank lifting 93
Ground connecting plugs—main distribution frame 166
Ground connection plugs and sockets—intermediate distribution frame 172–174
Ground connection sockets 174
Gyroscopes 185–190

Hand operated—
  Alcohol drain valve 65
  High pressure air valve 66
  Stop valve—air supply line 55
Heat exchanger—exhaust steam line from turbine ... 41

Para

Heater and reducing valve—steam unit 67
High pressure—
  Air valve—hand operated 66
  Reducing valve fittings—steam unit 68
  Stop valve—Solenoid operated 51
Horizontal tests 148
Hydrogen peroxide 311
  Feed valve—steam unit 71
  Line—valve in—steam unit 70
  Tanker 298
Hydrogen peroxide and permanganate tanks—
  Non-return valve for draining and washing ... 75
  Pressurising lines—non-return valve in... ... 74

Igniter, pyrotechnic—explosive 303–307
Ignition of fuel in stage 1 of delivery of fuel to combustion chamber 17
Initial energy to start rocket 19
Inspection and tests of rocket as assembled at Krupps 110–149
Intermediate distribution frame—electrical system 168–171
Introduction 1–15

Layout of assembly shops 85–109
Layout of propulsion unit—A-4 rocket 16
Lifting—assembled rocket 94
Lifting bars—tail unit 91
Lifting gear—thrust ring 90
Liquid oxygen tanker... 290–296

Main alcohol valve 54
  Test of 124
Main distribution frame—
  Electrical system 163–167
  Ground connecting plugs 166
  Miscellaneous 167
  Relay assembly 165
Mainstage button—functioning 83
Manufacture—transport of assemblies during ... 89
Matching—
  Of pump 28
  Procedure—combustion chamber—note for ... 142
Material available for assembly 97–99
Meilerwagen 300
Miscellaneous—main distribution frame 167

INDEX *(cont)*.

Para

Motor alternators 175–177
Motor, servo 200

Non-return valves—
Draining and washing—Hydrogen peroxide and permanganate tanks 75
Pressurising lines—Hydrogen peroxide and permanganate tanks 74

Object of " BACKFIRE " operation 2
Operation—
" BACKFIRE "—object of 2
Of relays in control compartment 18
Oxygen— 310
Distribution valve... 57
Test of 116–121
Fuelling valve 60
Test of 122
Pump ... ... 24 and 297
Tank vent valve 56
Test of 123
Tanker 290–296
Tanks—assembly section... 105
To test 134

Peroxide pre-heater 299
Pipes—connecting venturi to annuli—cooling ... 38
Potentiometers—tail unit 201–203
Pre-heater, peroxide 299
Pressure operated contact—steam unit—to test ... 128
Pressurising lines hydrogen peroxide and permanganate tanks—
Non-return valve 74
Pressurising valves—
Type A—solenoid operated 59
Type B—solenoid operated 58
Programme of work for tests 113
Proof tower—vertical tests 149
Propulsion assembly tackle 92
Propulsion unit—
A-4 rocket 12
Assembly section 4 102
Construction 16–84
Functioning 77–82
Layout 16

Para

Pump—
Alcohol 26
Liquid oxygen 297
Oxygen 24
Turbine 23
Pumping set, alcohol 289
Pumps—
Connections to combustion chamber 29–30
Matching 28
Pump unit—to test 136–139
Pyrotechnic igniter—explosives 303–307

Radio control—none used for " BACKFIRE " operation 6
Reaction Chamber 71
Reducing valve and heater—steam unit 67
To test 129
Regulators, frequency... 178–181
Relay—
Assembly—main distribution frame 165
Valve—pressure operated to test 133
Relays and switches 207–208
Relief valve—to test 130
Rocket—steering 153–158
Rocket, A-4—
Assembled—lifting of 94
Assembly of 85–109
Design of 3
Dimensions of 7
Initial energy to start 19
Speed of 14
Special vehicles for 15
Stabilisation of 4
Weight of 8
Rockets, steering of—" BACKFIRE " operation ... 5
Rods, spacing—combustion chamber 37
Running test 145

Section centre—A-4 rocket 11
Sequence or time switch 182–184
Servo motor 200
Servo unit—to test 140
Shops, assembly of rocket—layout 85–88
Sockets—ground connection—intermediate distribution frame 174
Sodium permanganate 312
Solenoid operated—
Air valve assembly... 63
Air valves 64

INDEX *(cont).*

Para

Solenoid operated—(*cont*).
High pressure stop valve... 51
Pressurising valves—
Type A 59
Type B 58
Valve in hydrogen peroxide line... 70
Valves—to test 131
Spacing rods—combustion chamber 37
Special vehicles and ancillaries 285–302
Speed of A-4 rocket 14
Stabilisation of A-4 rocket 4
Steam unit—
Assembly 42–49
Test of 144
High pressure reducing valve fittings 68
Pressure operated contact—to test 128
Reducing valve and heater 67
Test of 129
Tests—using liquids instead of air 146
Valve—
Feed—hydrogen peroxide 71
Hydrogen peroxide line 70
Vent valve—hydrogen peroxide or permanganate tanks 69
Steels used for combustion chamber 40
Steering of rockets—" BACKFIRE " operation ... 5
Steering system—electrical power for operating ... 152
Steering the rocket 153–158
Stop valve—air supply line—hand operated ... 55
Stripping and examination—assembly section 1 ... 99
Supply-air 96
Switch—
Centrifugal... 27
Contact, D2R—diaphragm operated 73
Switches and relays 207–208
System—
Electrical—A-4 rocket 150–154
Fuel—including turbine driven pumps... ... 20–22
Steering—electrical power for operating ... 152

Tackle—propulsion assembly 92
Tail unit—
A-4 rocket 13
Assembly section 2 100
Lifting bars 91
Potentiometers 201–203
Tanks—
Alcohol—to test 135
Oxygen—to test 134
Tank lifting gear 93
Tank, oxygen—vent valve 56
To test 123

Para

Tanker—
Alcohol 288
Hydrogen peroxide 298
Liquid oxygen 290–296
Test desks 209–284
Tests and inspection of rocket—as assembled at Krupps 110–149
Tests—programme of work 113
Thrust ring—
Assembly section 3 101
Lifting gear 90
Time or sequence switch 182–184
Times taken for assembly of rocket 109
Topping-up valve—oxygen 61
Trailer and firing platform 301
Transport and transfer of fuel to rocket 314
Transport of assemblies during manufacture ... 89
Transport vehicles for rocket and fuel 15
Treatment of welds 39
Trim motor assembly... 204–206
Turbine 25
Turbine pump unit 23

Unit—
Combustion—alignment test 143
Propulsion—A-4 rocket 12
Functioning 77–82
Layout 16
Pump—to test 136–139
Servo—to test 140
Steam—
Assembly tests... 144
High pressure reducing valve fittings ... 68
Pressure operated contact—to test 128
Reducing valve and heater 67
To test 129
Tests using liquids instead of air 146
Valve, feed—hydrogen peroxide 71
Valve in hydrogen peroxide line 70
Vent valve hyd. per. or permanganate tanks 69
Steam assembly 42–49
Tail—A-4 rocket 13
Potentiometers... 201–203
Turbine pump 23

Valve box 302
Valves—
Air—
Assembly—solenoid operated 63
Charging and stop—To test 132

INDEX *(cont)*.

Para

Valves—(*cont*).
Air—
High pressure—hand operated 66
Solenoid operated 64
Alcohol—
Defuelling 53
In fuel tank 52
To test 125
Main 54
To test 124
Tank pressurising 50
To test 126
Check—non-return valve... 62
Drain—alcohol—hand operated 65
To test 127
Fuel 51
High pressure stop valve—solenoid operated 159–162
Hydrogen peroxide feed—steam unit 71
Hydrogen peroxide line —steam unit 70
Non-return—
For drainage and washing—H_2 O_2 and permanganate tanks 75
Pressurising lines—Hydrogen peroxide and permanganate tanks 74
Oxygen—
Distribution 57
Test of 116–121
Fuelling 60
Test of 122
Topping-up 61

Para

Valves—(*cont*).
Pressurising—
Type A—solenoid operated 59
Type B—solenoid operated 58
Propulsion system... 50–75
Reducing and heater—steam unit 67
Test of 129
Relay—pressure operated—To test 133
Relief—To test 130
Solenoid operated—To test 131
Stop—hand operated—air supply line 55
Vent—
Hydrogen peroxide or permanganate tanks—steam unit 69
Oxygen tank 56
Test of 123
Vehicles—
For transport of rocket and fuels... 15
Special and ancillaries 285–302
Vertical tests—as carried out in special proof tower 149

Warhead—description of ... ... 9 and 307
Weight of A-4 rocket and components 8
Welding and treatment of 39
Work—
Four sections for descriptive purposes... 114–115
Programme of for tests 113

Technical Report

By

MINISTRY OF SUPPLY TECHNICAL OFFICERS

THE GERMAN LONG RANGE ROCKET A-4 AS BUILT FOR

OPERATION "BACKFIRE"

INTRODUCTION

1. This report is intended to supplement previous descriptions of the A-4 rocket which have been drawn up from the examination and reconstruction of the remains of rockets which had been fired. It is hoped that certain gaps in the knowledge contained in these previous descriptions may be filled with the information gained from Operation "BACKFIRE."

2. The object of the operation was to take damaged rockets and components collected from German factories or stores, and from salvaged parts and replacements to reassemble and test for firing. To this end eight rockets were built of which three were tried and successfully launched. The assembly and testing methods were, of necessity, somewhat primitive by comparison with German industry, owing to lack of technical data and to the fact that the engineering facilities available were not comparable with either a works or experimental establishment. That they were, in general, satisfactory is shown by the successful launchings achieved.

3. The A-4 rocket was designed to carry a pay load of 1,000 kilograms (normally a warhead filled H.E.) to a range of approximately 300 kilometres. It is propelled by a bi-fuel propulsion unit employing alcohol and liquid oxygen. Delivery of these fuels to the combustion chamber in the final stage is by centrifugal pumps which are turbine driven. Steam for the turbine is delivered from a hydrogen peroxide reaction unit delivering superheated steam. Initial energy for this latter unit is by way of compressed air stored in cylindrical containers.

4. Stabilisation is by four large fins on the tail (R.A.E. Report 228/4, para. 3-5) and the rocket is controlled on its trajectory by four carbon rudders operating in the flame, together with four control vanes at the extremities of the fins. Two of these external vanes are coupled to the corresponding carbon rudders through a chain drive and lie in the vertical plane or line of flight and control roll and yaw. The external vanes in the horizontal plane are driven by geared electric trim motors and chain drive, and act as supplementary roll control. The two internal carbon rudders lying in this plane control pitch. Movement of the internal rudders and the two external vanes I and II (Plate 1) is by electrically driven servo motors. A schematic layout of this arrangement is shown at Plate 2.

5. The steering of the rockets built for Operation "BACKFIRE" was controlled by two electrically driven gyroscopes, one for yaw and roll and one for pitch. These operated through a control amplifier to feed signals to the servo motors and thence if necessary to the trim motors. To deviate the rocket from the vertical and set it on its correct trajectory the pitch gyroscope was fitted with a programme motor (see Section 4). The steering control was powered by 500 cycle/sec. obtained from motor alternators driven from a lead acid battery fitted in the rocket.

6. No radio control was used, and fuel cut-off and the operation of solenoids when the rocket was airborne was by means of a sequence or time switch. This was judged to be the simplest form of control which could be fitted with the components available.

7. The main dimensions of the rocket are as follows:—

Overall length	46 ft. 1 in.
Maximum dia. of shell	5 ft. 5 in.
Dimension across fins	11 ft. 8 in.

8. The weight unfuelled is 4 tons, which can be apportioned as under:—

(*a*) The Warhead	2204·6 lb.
(*b*) The Control Compartment	1025 lb.
(*c*) Centre Section with Fuel Tanks	1640 lb.
(*d*) Propulsion Unit	2065 lb.
(*e*) Tail Unit	1800 lb.
(*f*) Cables, etc.	226 lb.

The above breakdown is also a convenient one from the point of description, and Plate 1 shows the location of the five main assemblies, a brief description of which is given in the following paragraphs.

9. The WARHEAD (detailed description Section 6) (Plate 3)

The warhead is conical in shape and carries the nose fuse at its front end, in addition to a base fuse. The warhead proper consists of a conical mild steel welded shell filled with H.E. Screwed adaptors are positioned diametrically opposite each other about midway on the nose to accommodate the lifting bolts necessary to support the rocket when it is being manœuvred into the vertical test tower. There is a further tube running through the warhead which connects through the control compartment to the alcohol tank pressurising valve. The method of attachment of the warhead to the control compartment is by means of twenty screws inserted through counter bored holes drilled round the periphery of the base and screwing into the flange of the control compartment.

10. CONTROL COMPARTMENT (detailed description of components, Section 4)

This is located immediately behind the warhead and houses the batteries and steering control apparatus, and the air

bottles necessary to pressurise the alcohol tank. This compartment had also housed the radio control used by the Germans in some instances. The compartment takes the form of a truncated cone divided into four equal sections by means of radial plywood sheets. These are supported at the centre by means of four steel angles bolted back to back and at the external edges by means of built up members which are constructed to receive panels and are attached by means of sheet steel brackets to steel frames at the front and rear ends. The relative positions of the four sections in relation to the line of flight can be seen from section C-D, Plate 1. The panels are of two types. Those covering the compartments housing the distribution box and air bottles are in one piece and are bolted in position. The others are in the form of hinged doors, each panel being two doors, opening from the centre. The one-piece panels are insulated from the main framework and are used as aerials when radio control is fitted. It is through a spring-loaded flap in one of these panels that the ground connecting plugs from the electrical equipment are located (Plate 1) and when the rocket is fired connection to the ground is broken by releasing solenoid operated clips in the plugs, which are then thrown clear by a spring-loaded plate. Further details of this compartment are given in R.A.E. Report 228/4, para. 5.

11. CENTRE SECTION (Fig. 1) (Detailed description, Section 2)

The centre section consists of the assembly of the oxygen and alcohol tanks housed in a shell constructed in two halves, the constructions of these shells is described in R.A.E. Report 228/4, para. 2-5. Briefly they consist of sheet steel (German Spec. 1263) ·025 in. thick with strengthening ribs, similar to aircraft construction, spot welded, or in the case of the heavier sections riveted in position. Ports in the half sections ensure that the internal air pressure between the skin and the tanks is the same as the external air pressure. When assembled by German industry these sections were given an initial stress. The special steel quoted was used owing to failures experienced in the early development, when, during the descent of the rocket ruptures and cleavage of the skin was common if mild steel was used.

12. PROPULSION UNIT (Figs. 2 and 3) (Detailed description, Section 1)

This unit consists of the combustion chamber and venturi on which is mounted a tubular framework which houses the turbine driven pump unit and valves, compressed air battery, hydrogen peroxide steam unit and oxygen tank pressurising system. The complete unit is then married to the centre section, and the tail unit which forms the outer casing is placed in position.

Investigations on the question of tolerances in the performance of the various units of the propulsion unit revealed that characteristics varied as much as ± 10 per cent. It was essential that the units be matched if accurate firing was to result. In manufacture each unit was subjected to test, and data sheets compiled. A set of nomographs was composed from theoretical calculations and practical deductions, and from these and the data sheets the various units were matched to give a standard performance.

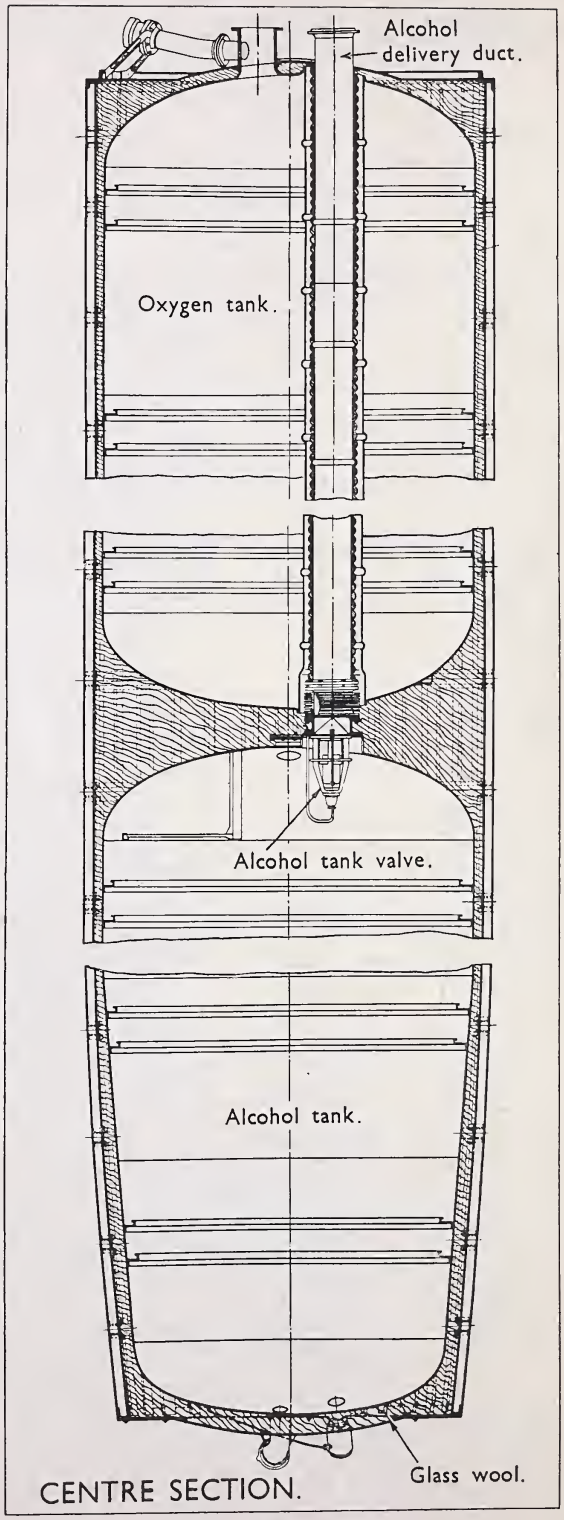
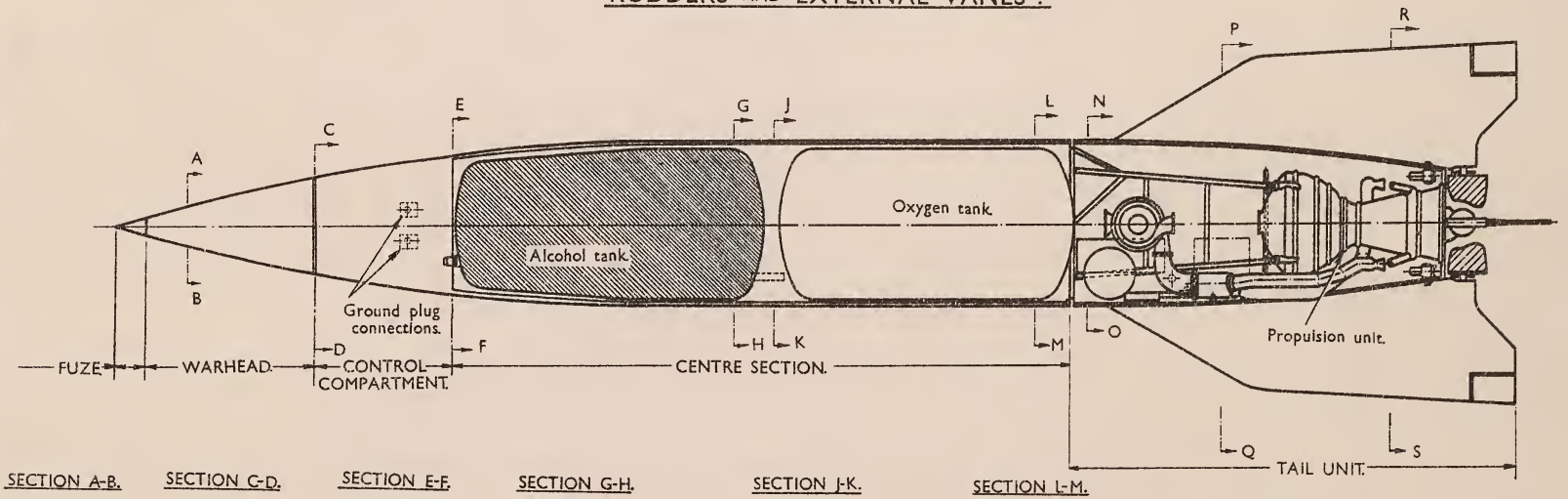


Fig. 1

RUDDERS AND EXTERNAL VANES.



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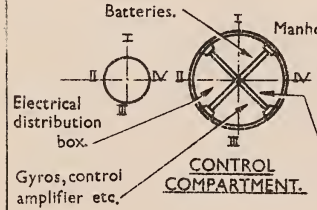

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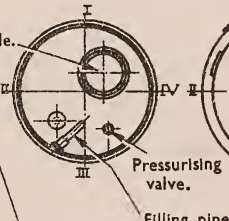

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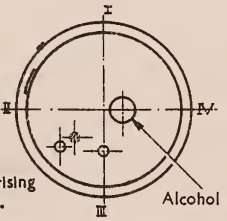

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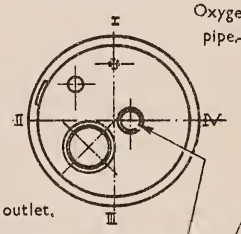

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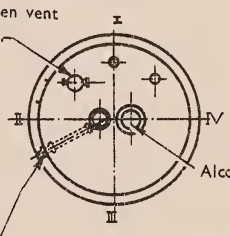
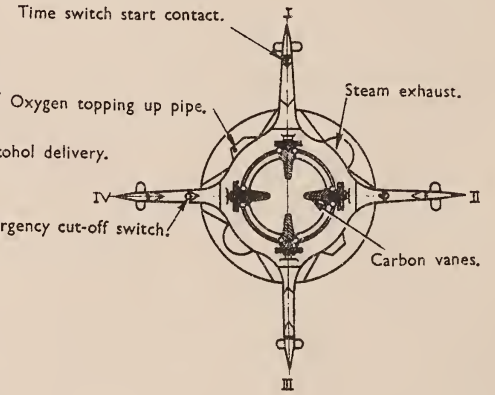
SECTION L-M.





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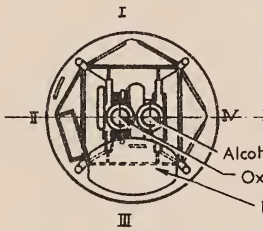

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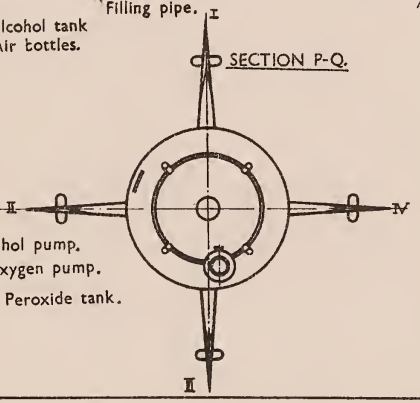

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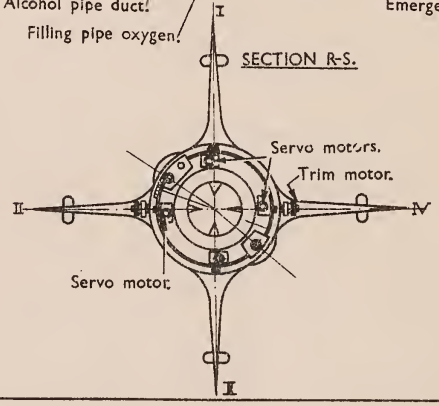


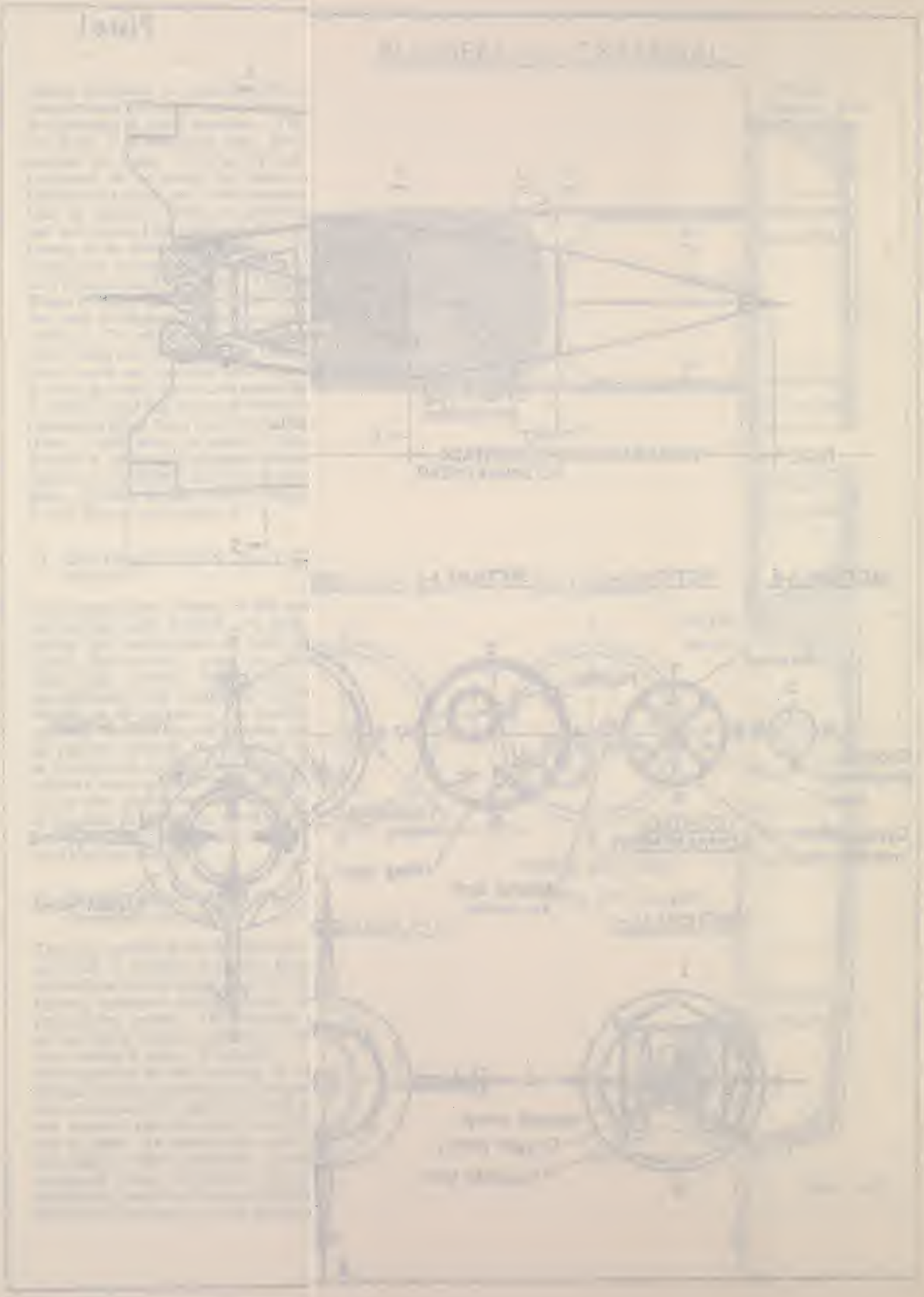
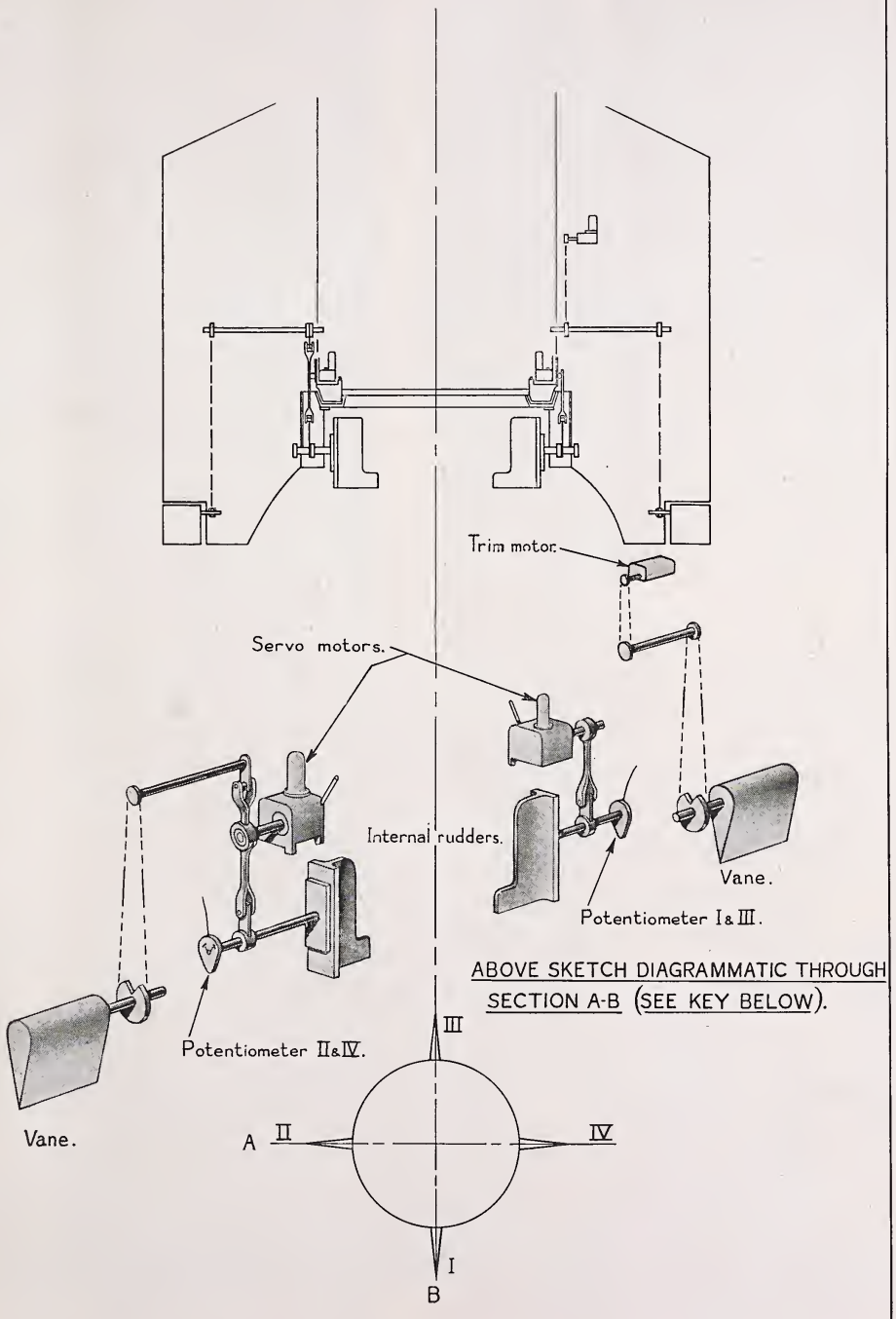


Plate 2.

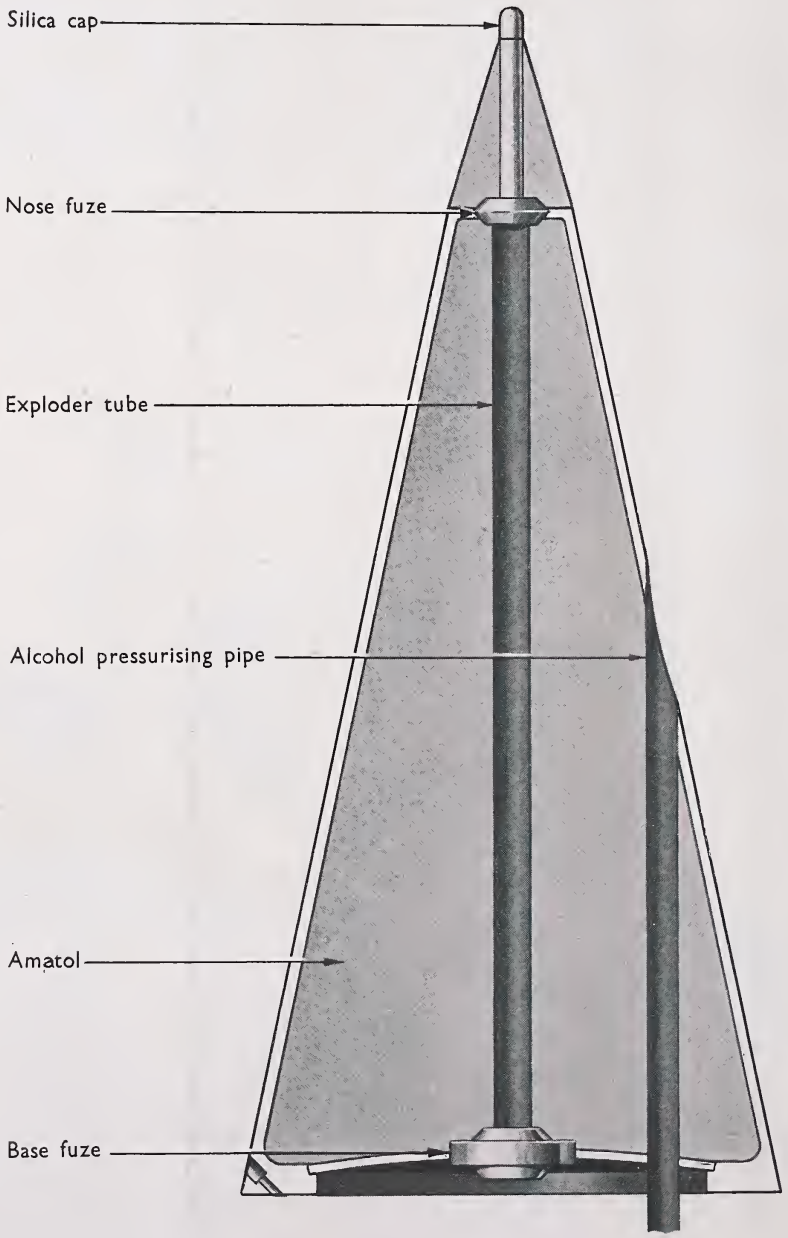
SCHEMATIC LAYOUT OF VANE & RUDDER DRIVES.



ABOVE SKETCH DIAGRAMMATIC THROUGH SECTION A-B (SEE KEY BELOW).

Plate 3.

THE WARHEAD



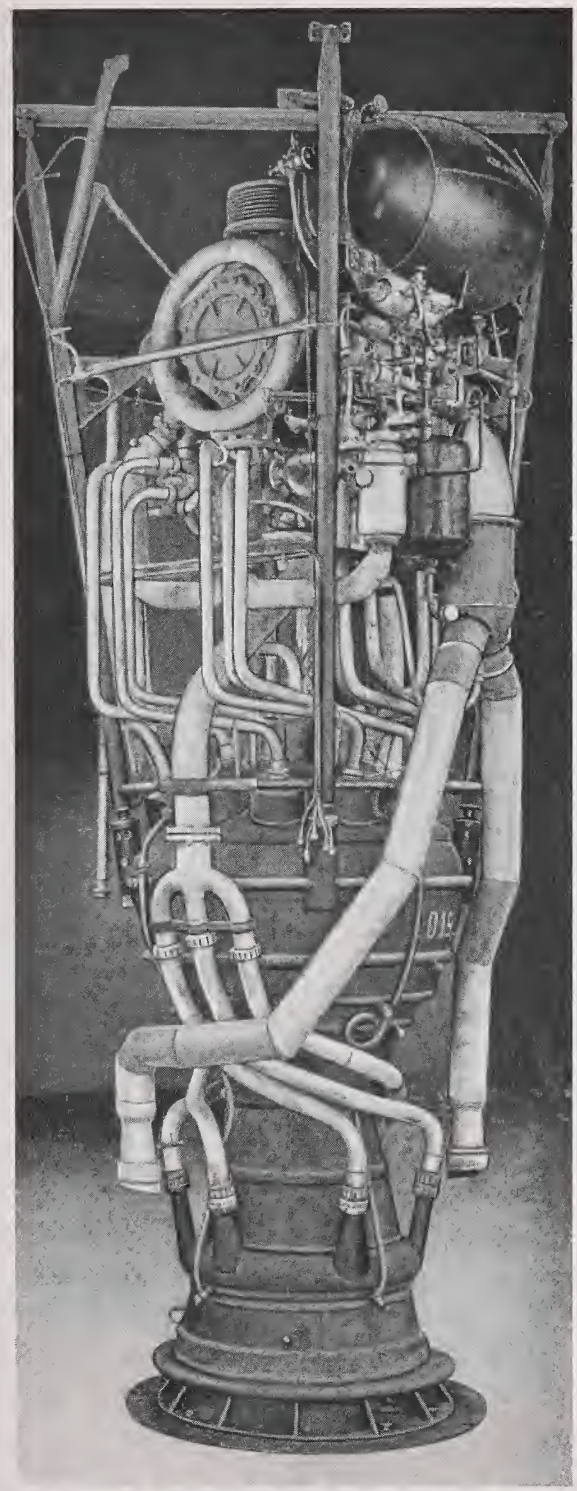


Fig. 2. Combustion Unit, View showing Steam Unit

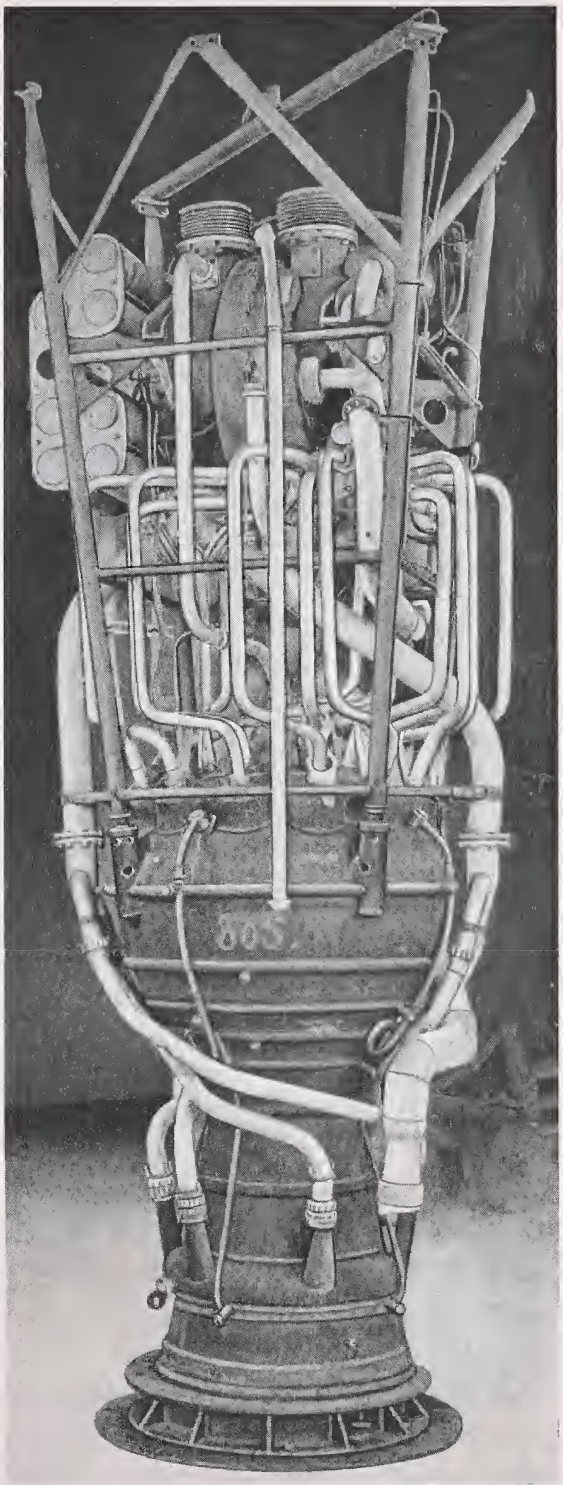


Fig. 3. Combustion Unit, View showing Air Bottles

Fig. 4
View of Tail Unit,
Showing Venturi End
and Carbon Rudders

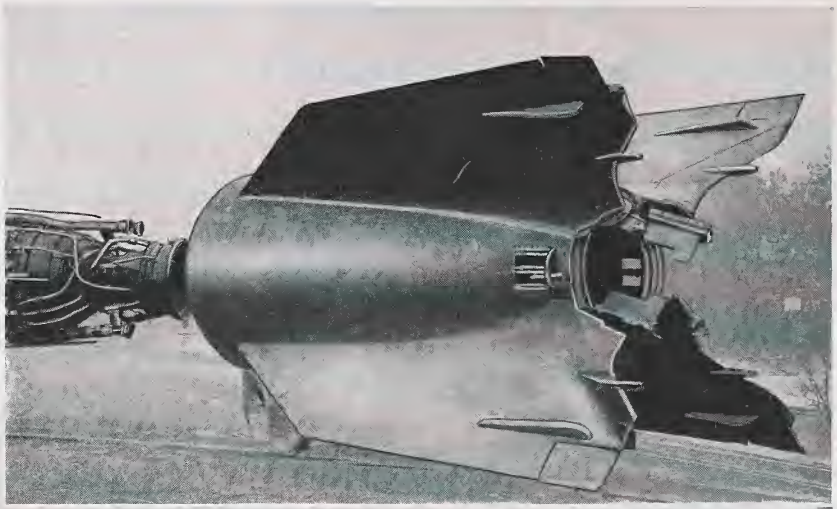
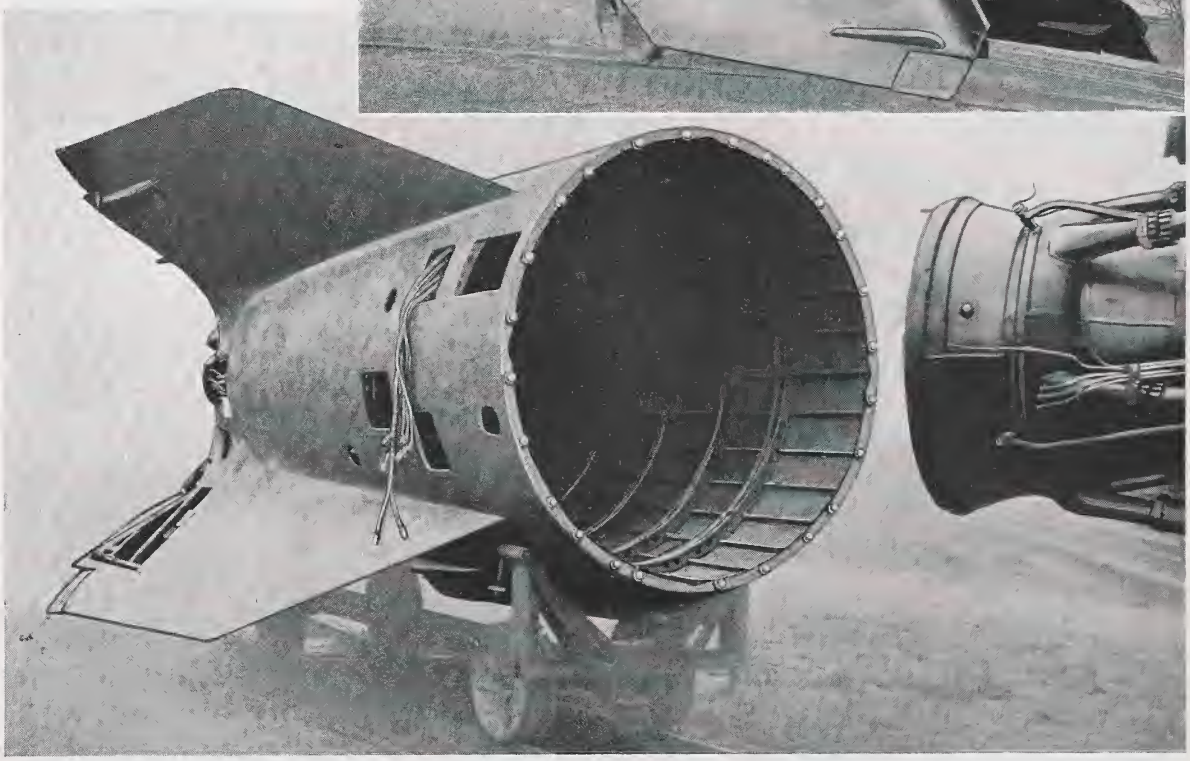


Fig. 5
View of the Tail Unit,
Showing Mating Flange for the
Centre Section



Small faults in the calibration of the components affect the trajectory of the rocket inasmuch as they alter the thrust and therefore the initial acceleration. In effect the rate of inclination during the initial trajectory may be influenced, thus affecting the height at point of cut-off for an equivalent thrust. Two other important factors arising from inaccurate matching are variation in fuel ratio and in steam unit pressure. Both fuel pumps were fitted with restricting throats of 125 mm. dia. in the delivery line. Final matching of the pump unit is carried out by the insertion of a sharp edged orifice in whichever pump is found to require reduction in delivery.

13. TAIL UNIT (Figs. 4 and 5)
This unit acts as a fairing for the power unit, and is not intended to transmit thrust loads. It carries the stabilising fins and control surfaces with their servo and electric motors. The centre is constructed of light gauge sheet (German Spec. 1263) spot welded to longitudinal ribs and supported by circular formers. The fins are manufactured with their fairings and then attached to the body. These fins are located as shown in Plate 1, and carry within their structure the chain drive necessary to operate the external control vanes. At the rear a light alloy ring carries the servo motors and the flanges of the carbon rudders. This

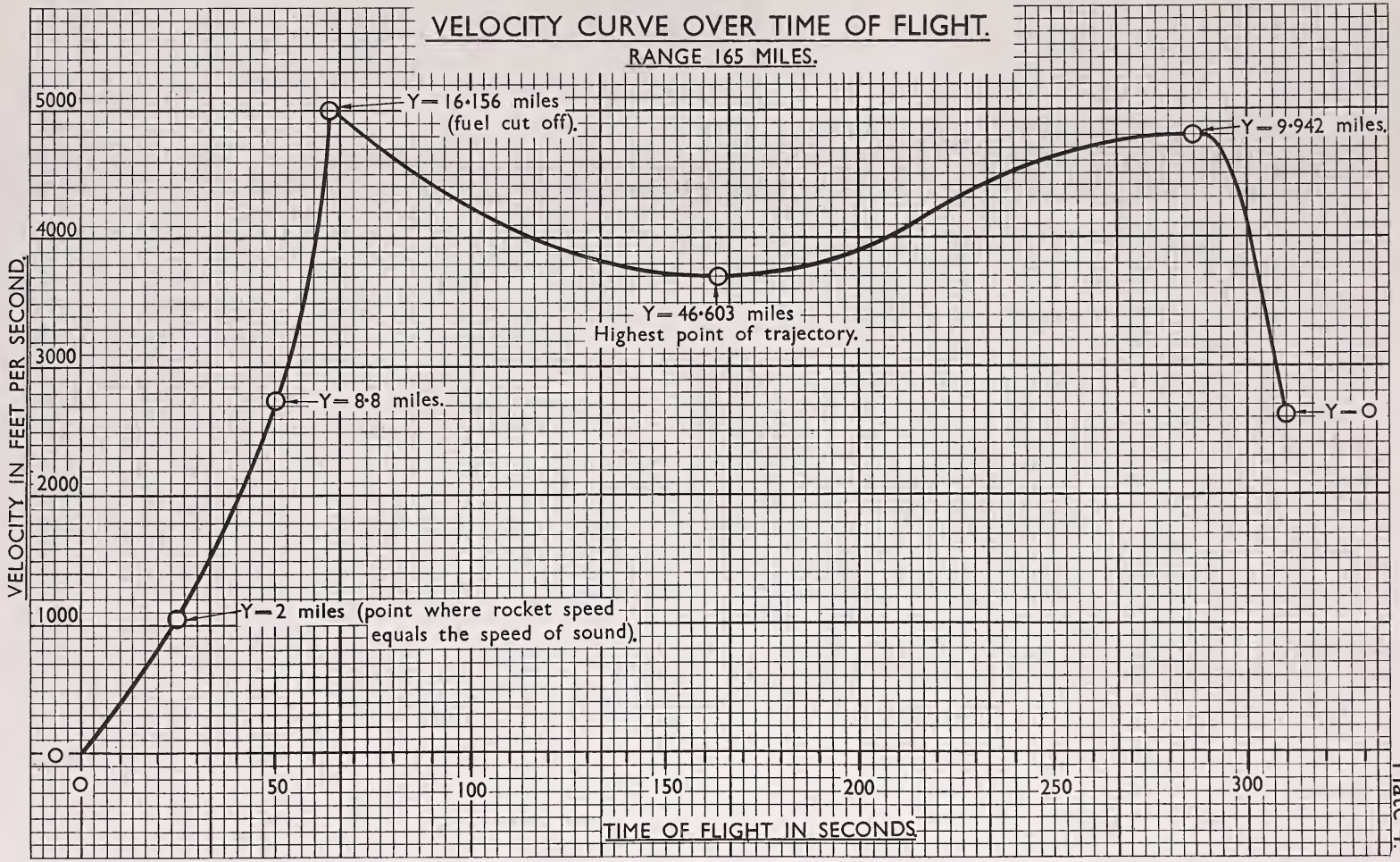

VELOCITY CURVE OVER TIME OF FLIGHT.
RANGE 165 MILES.
Y = 16·156 miles (fuel cut off).
Y = 9·942 miles.
Y = 46·603 miles Highest point of trajectory.
Y = 8·8 miles.
Y = 0
Y = 2 miles (point where rocket speed equals the speed of sound).
VELOCITY IN FEET PER SECOND.
5000
4000
3000
2000
1000
0
0
50
100
150
200
250
300
TIME OF FLIGHT IN SECONDS.

Plate 4.

TRAJECTORY OF THE ROCKET (RANGE 300 KM-185 MILES).

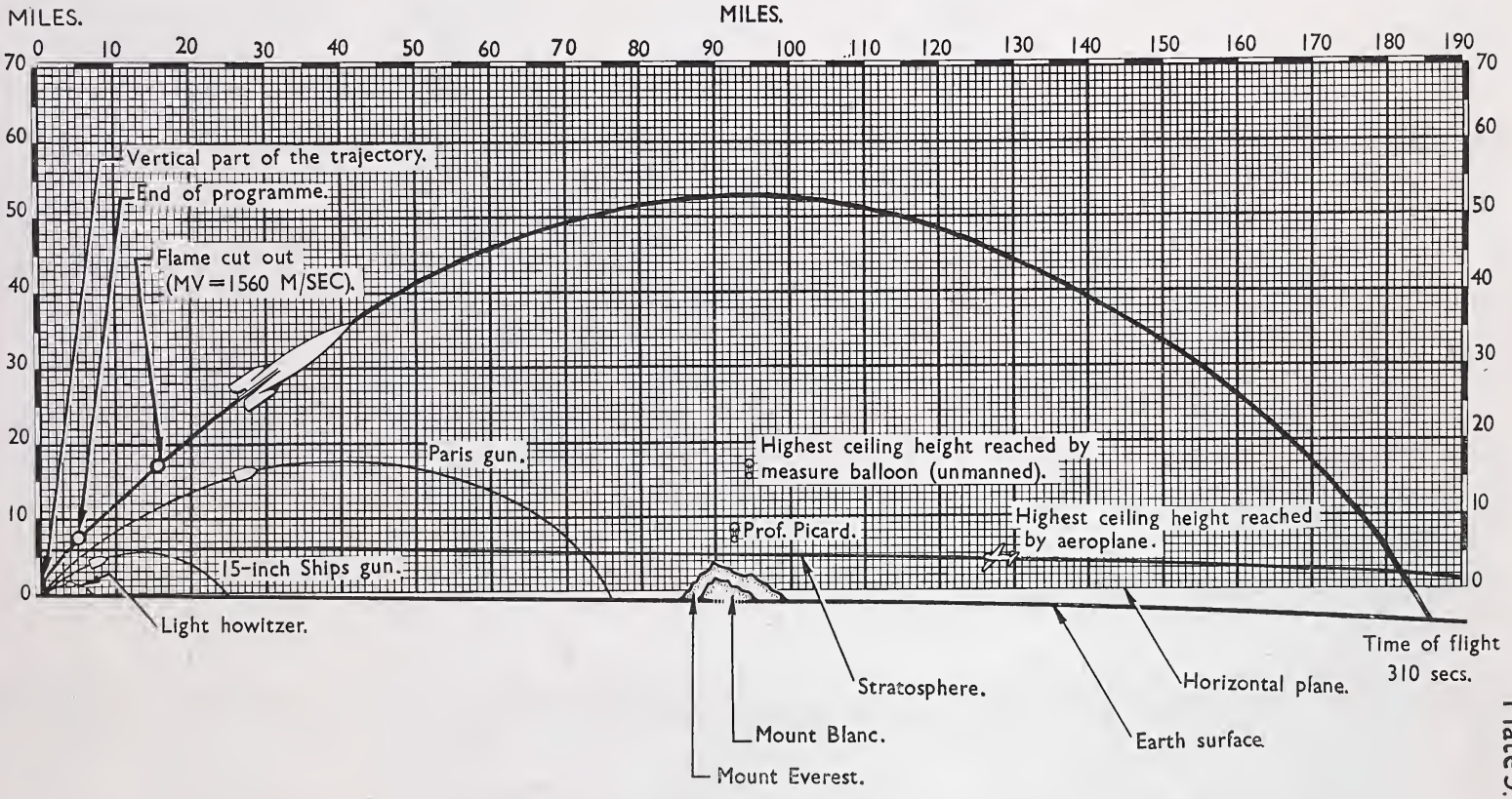


Plate 5.

ring also mates with the venturi. Sufficient clearance is provided between the ring and the venturi flange to take care of expansion, and the space between these two components is first packed with asbestos or synthetic rubber, and then filled with a mixture of magnesium oxide, talcum and waterglass to prevent flame entry. Fitment of the tail unit to the centre section is by special bolts having a minimum tensile strength of 60 kg/mm^2. Further details of the unit are given in R.A.E. Report 228/4, Para. 3-4. As the accuracy of the rocket depends to a large extent on the accurate positioning of the stabilising fins these were carefully tested before assembly as described in Section 3.

14. With regard to the speeds which the rocket attained at various points in flight, a graph showing velocity plotted against time is shown at Plate 4. On this graph "Y" represents the height above the ground. From this graph it will be seen that the rocket starting with an acceleration of Ig reaches the speed of sound after 25 seconds. The maximum velocity at fuel cut-off was 4,928 ft./sec., and at a ceiling of 46·603 miles was 3.700 ft./sec. Velocity on impact 1,740 ft./-sec. Plate 5 gives a comparison of the flight of the rocket in relation to artillery projectiles and indicates the height to which the rocket rises.

15. In order to handle a projectile of this size which had to be fuelled and fired in a vertical position under conditions which made mobility essential, special vehicles had been designed both for transport of rockets and fuels and the ancillary gear such as the firing platform, air compressor and portable cranes. For transporting the rocket by road a low level 4-wheeled trailer was used known as a Vidalwagen For the transport of the rocket to the firing site and elevating on to the firing platform a Meilerwagen is used. A brief outline of these vehicles is given in Section 5 and also in O.T.I., reports 284, 280, 277, 252, 263 and 272.

Propulsion Unit Construction . . . SECTION 1

16. The layout of the various units is shown in the schematic diagram at Plate 6, Section 1, and can be conveniently divided into the following sub-sections :—

(*a*) Initial energy to start the system.
(*b*) The fuel system including turbine driven pumps.
(*c*) The combustion chamber.
(*d*) Heater exchanger.
(*e*) The steam unit.
(*f*) Details of valves.

17. Fuel is delivered to the combustion chamber in two stages.

STAGE 1

Is operated from the ground equipment and firing panel allowing alcohol under gravity and oxygen under a pressure of 1·5 kg/cm^2 to flow to the combustion chamber where it is ignited by means of a pyrotechnic igniter. If the flame pattern at this stage is correct (Plate 7), stage 2 is brought into action. Stage 1 gives a thrust of approximately 2·5 tons.

STAGE 2

18. The electrical connections from the ground to the rocket are thrown off, causing the operation of relays in the control compartment which operate the solenoid valves of the fuel and steam unit system, thus causing superheated steam to be produced and rotate the turbine and pumps. Fuel then flows under pressure to the combustion chamber, giving sufficient thrust (25 tons) to cause the rocket to be airborne. Pipe connections 1, 2, 3, 4 and 5 (Plate 6, Section 1) to the ground equipment are made with synthetic rubber seals so that automatic disconnection occurs when the rocket leaves the firing platform.

INITIAL ENERGY TO START THE SYSTEM

19. Energy for the initial operation of the various units is in the form of compressed air. Until the rocket is airborne this energy is supplied through the ground unit via pipes 1, 2, 4 and 5. During flight air is supplied for the propulsion unit from a bank of seven air bottles, one of which is shown at Plate 8, Section 1. For the pressurisation of the alcohol tank in flight a bank of three air bottles (Plate 9, Section 1) is installed in the control compartment. The outlets are connected and a stop valve (para. 55) is fitted. Both sets of bottles are of the same size.

THE FUEL SYSTEM INCLUDING TURBINE DRIVEN PUMPS

20. The fuels are carried in light alloy gas-welded tanks housed in the centre compartment. The alcohol tank is as illustrated at Plate 10, Section 1, and is fitted at the top with a filling pipe supported by an aluminium bracket, together with a screwed connection to accommodate the pressurising valve (para. 50) and with an air connection which leads via solenoid S4H (Plate 20, Section 1, para. 51) to the set of three air bottles. The tank supports have already been described in the R.A.E. Reports, Nos. EA228/4, dated November, 1944. At the bottom of the tank are three main flange connections, and one air connection which is used for pressure tests. The 148 mm. outlet houses the alcohol tank shut-off valve (para. 52) which prevents the flow of alcohol to the pump. A spring-loaded drain valve (para. 53) is fixed to the 70 mm. connection, whilst the 107 mm. outlet is blanked-off. Further details of this tank will be found in R.A.E. Reports Nos. EA228/4, Aero. 2012, dated

November , 1944, and March, 1945. A tube leading from the seat of the alcohol tank valve passes through the oxygen tank by way of a lagged duct down to the alcohol pump inlet. A bye-pass from the main alcohol valve (para. 54) on the combustion chamber re-delivers bye-passed alcohol to the inlet side of the pump.

21. Liquid oxygen is contained in the lower tank, illustrated at Plate 11; this is of gas-welded light alloy construction and through its total length is a duct packed with glass wool, through which passes the alcohol delivery pipe. At the top end a manhole and a test connection are fitted. Three outlets at the lower end couple up to the following :—

(*a*) Outlet No. 1 carries the oxygen vent valve (para. 56). A vent pipe from this connection continues from the base of the tank up to the top where it is supported by brackets. Connections between the bottom of the tank and the flange enable air to be supplied from the ground equipment pipe No. 5 for pressurising, and also to return the gaseous oxygen from the heat exchanger.

(*b*) Outlet No. 5 is the main delivery pipe to the oxygen pump. This is tapped to provide an inlet for the oxygen topping up pipe and the filling pipe.

22. The tank supports for this tank are shown in the R.A.E. Report, No. EA 228/4, dated November, 1944, and contraction is taken care of by coppered brass concertina connections between the tank outlets and mating parts.

TURBINE PUMP UNIT

23. The assembly of this unit is shown on the drawing attached at Plate 12, Section 1, and the earlier type on the R.A.E. Drawing CD 32203. The assembly is mounted on a tubular framework in the tail of the rocket by means of feet cast on the unit casings which are bolted to supports in the framework. The alcohol pump casing and the turbine volute are bolted together and have a common shaft mounted on ball bearings carrying the pump impeller and turbine rotor.

THE OXYGEN PUMP

24. The oxygen pump is fixed on the early models by studs and spring spacers to the turbine casing on the entry side, these spring spacers being replaced by a spacing flange in the later models. The oxygen pump shaft is mounted on bronze segmental bearings of large clearance at room temperature, which are drilled to allow of the passage of oxygen from the low pressure side. On the early models this shaft was held against the turbine shaft by an internal compression rod, but in the later models the compression rod was dispensed with and the pump was adjusted for thrust by the collar on the turbine side of the impeller. The drive of the oxygen pump is by means of a flexible coupling having 12 bolts 10 mm. diameter of austenitic steel, each bolt being fitted with 7 leather washers 23·5 mm. diameter. The shaft is of mild steel splined to accommodate the impeller. Sealing is carried out by means of three cast iron seals on the turbine side, the sealing rings being in three sections held together by spring gaiters. The flexible coupling is contained in a separate housing built on to the turbine casing on one side and the seal ring housing on the other. Any leakage of oxygen through the seals and pump shaft is vented through a pipe at the bottom of this casing which is connected to the oxygen exhaust pipe. All the castings are of aluminium alloy and the impeller is of the 7 vane mixed flow type. Its delivery at 4,000 revs. is stated to be 70 kgs. at 18 kg/cm^2 per sec.

TURBINE

25. The turbine casing consists of two light alloy aluminium castings; the front casting carries the steam manifolds and nozzles, the rear casting is recessed externally to accommodate part of the housing for the flexible coupling. Both castings are machined to incorporate sealing rings round the shaft. The nozzles are of cast iron and are fitted in four groups of four to the steam manifold which is bolted to the front casting. The turbine rotor of light alloy has a riveted steel boss and carries two rows of blades which are tongued into the ring. Each row is equipped with 177 blades which are fitted in position through two slots machined in the inner side of the rotor rim. After the blades have been assembled the slots are fitted with plugs secured by pins. Located between the two sets of moving blades are four groups of 28 fixed blades which are tongued into four light alloy segments secured to the turbine casing by screws. The sealing rings on the shaft are cast iron made in three segments held by a spring gaiter. The feed manifold is of square section as opposed to the tubular section of early units.

ALCOHOL PUMP

26. The alcohol pump casing comprises two aluminium castings, one forming the volute and the other the cover. A mild steel shaft is splined to carry a light alloy impeller and is mounted on ball bearings. This shaft also carries the turbine rotor and centrifugal switch. A lug is fitted to its outer end thus enabling the unit to be turned by hand for test purposes after assembly. In order to counteract leakage of alcohol through the bearings, two synthetic seals are placed in-board of the bearings and one out-board. Drain pipes from the seal pockets are taken to the alcohol overflow pipe discharging at the tail of the rocket. As in the case of the oxygen pump the impeller is of the 7 vane mixed flow type. Its delivery at 4,000 revs. is stated to be 56 kgs. at 23 kg/cm^2 per sec.

CENTRIFUGAL SWITCH (Turbine Overspeed Trip)

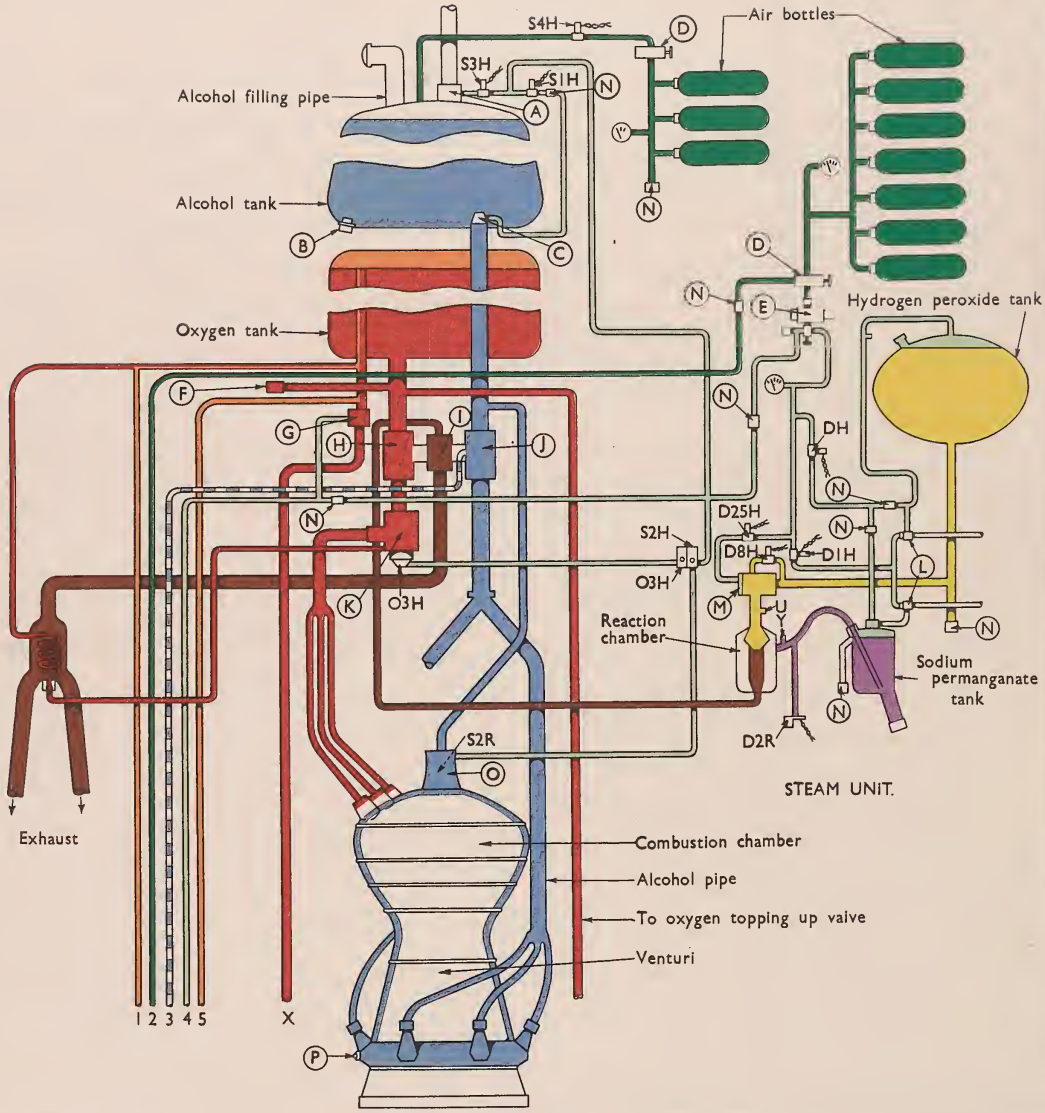
27. The centrifugal switch (Plate 13, Section 1) consists of a spring-retained eccentric ring which moves outwards against a spring. The switch is adjusted by either packing under the spring or shortening of the spring, so that at 5,000 revs. per minute centrifugal force moves the ring outwards, striking a spring-loaded plunger which trips the spring-loaded push rod. When the spring-loaded push rod

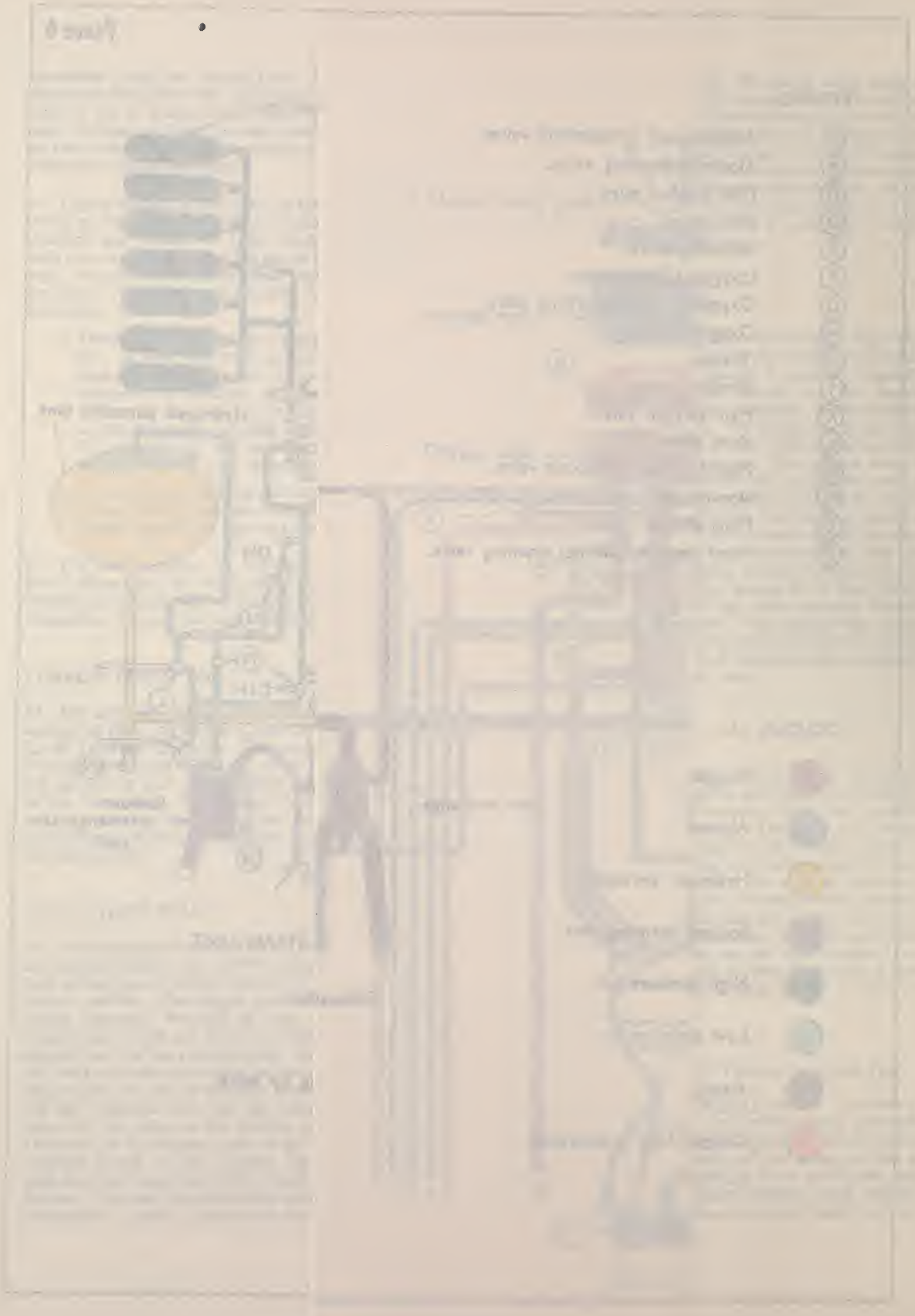
LEGEND.

- (A) Alcohol tank pressurising valve.
- (B) Alcohol defuelling valve.
- (C) First alcohol valve.
- (D) Stop valve.
- (E) Reducing valve.
- (F) Oxygen fuelling valve.
- (G) Oxygen tank pressurising valve.
- (H) Oxygen pump.
- (I) Turbine.
- (J) Alcohol pump.
- (K) Main oxygen valve.
- (L) Vent valve.
- (M) Main hydrogen peroxide valve.
- (N) Non-return valve.
- (O) Main alcohol valve.
- (P) Hand operated alcohol draining valve.

COLOUR KEY.

- Oxygen.
- Alcohol.
- Hydrogen peroxide.
- Sodium permanganate.
- High pressure air.
- Low pressure air.
- Steam.
- Oxygen tank pressurising.





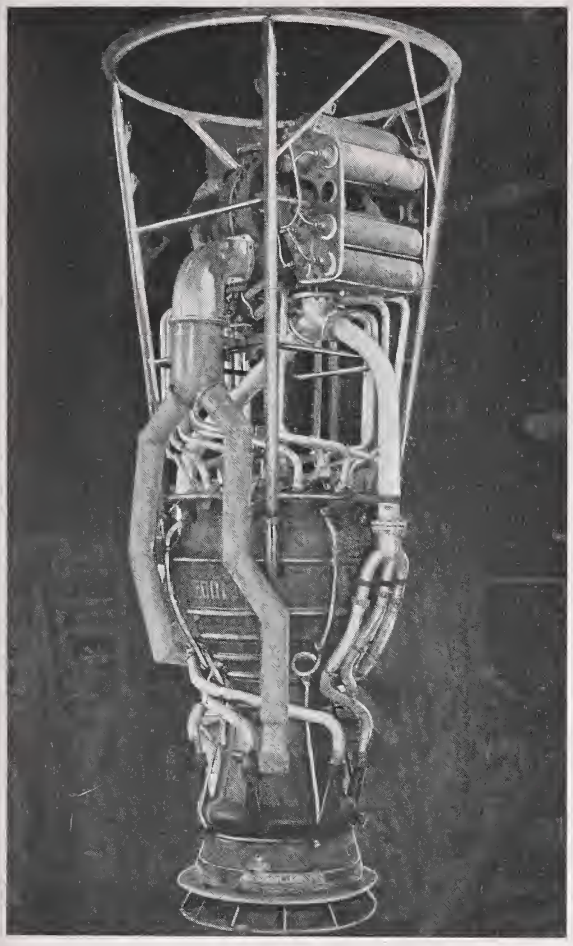


Fig. 6

is released it closes a contact switch connected to the programme switch. Re-setting is effected by pulling the external handle outwards.

MATCHING

28. Matching of the pumps to deliver the correct proportions of fuel was carried out by the fitting of flanges, bored to suit the choking effect desired on the outlets of the pump at the original manufacturers.

CONNECTIONS FROM PUMPS TO COMBUSTION CHAMBER

29. From the alcohol pump outlet fuel is delivered through a Y-piece 125 mm. dia. into two 90 mm. diameter aluminium pipes, each of which subsequently divides into three 50 mm. diameter feeds to the manifold at the bottom of the combustion chamber (Fig. 6, Section 1).

30. The oxygen pump outlet is connected to the oxygen distribution valve (para. 57) having six outlets each of 47 mm. diameter. Each of these outlets subsequently divides into three 31 mm. inside diameter pipes connected to the burner cups on the combustion chamber (Fig. 7, Section 1).

THE COMBUSTION CHAMBER (Plate 14, Section 1)

31. The combustion chamber is of prefabricated steel construction, the sections being formed from pressings.

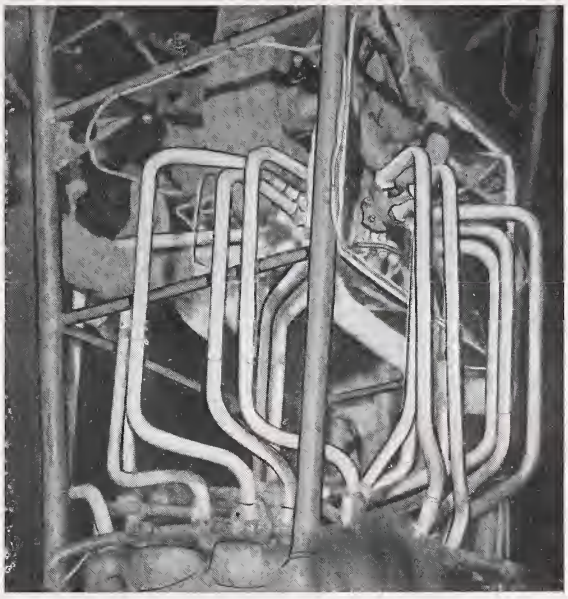


Fig. 7

OPERATION

32. Alcohol is fed to the six inlets V and from these passes through wall K to flange B in the burner-head. Alcohol passes from K through to the third skin E by way of the alcohol valve which is fitted to flange D and seats on flange B. Within the third skin E are disposed 18 forged steel cups. From E alcohol is passed to the combustion chamber by way of 44 bronze cooling nozzles (Fig. 8) and two rows of 12 feed holes. The cups are also machined to receive the brass oxygen delivery roses. Oxygen is fed to the roses by way of aluminium pipes from the oxygen distribution valve. For cooling purposes, four pipes G are connected to skin E and deliver alcohol to four annuli L. The pressure of the feed is governed by drilled plugs at the entrance of the annuli which restrict the flow pressure to 1 atmosphere above the working pressure at the zone of the annuli. From these four annuli alcohol flows into the combustion chamber through rings at L which are drilled to give the free passage of alcohol through the wall and also from the annuli into the combustion chamber.
Thirty-six jets in 12 sets of 3 are located above the throat of

PRE-STAGE INCORRECT FLAME PATTERN.

PRE-STAGE CORRECT PATTERN
UMBRELLA SHAPED AND EVEN.

Plate 7

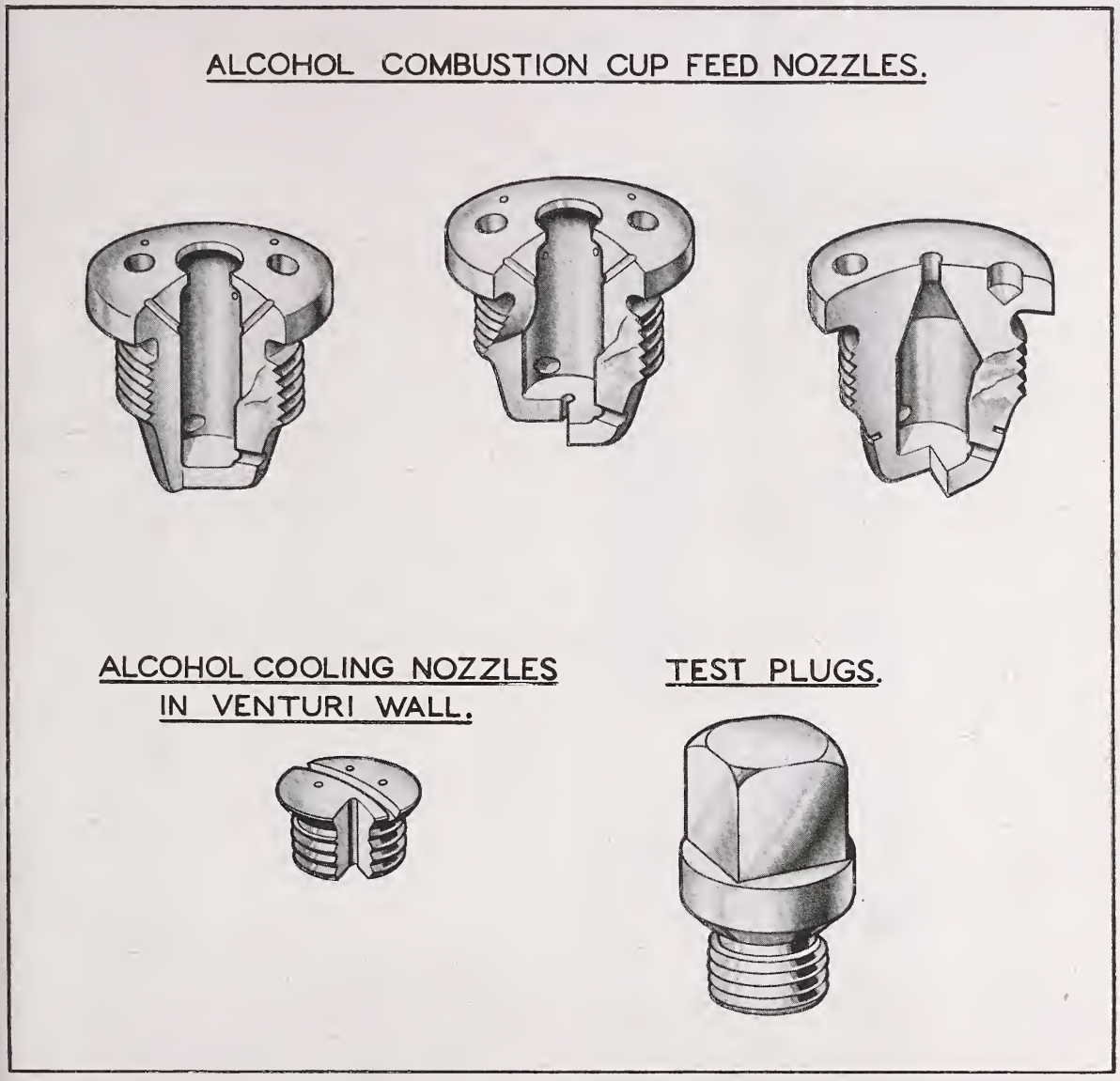


Fig. 8

the venturi and serve as balancing jets (Fig. 8). These are screwed into the inner wall and connect into the cooling jacket of the chamber. Before actual firing takes place these are plugged with a low melting point metal.
Plate 14 is marked to show the various sections built up to form the whole.

SECTION 1

33. This forms the outlet of the venturi and the interior skin is comprised of two welded pressings mounted on a machined forged steel ring, this ring being mated to the thrust ring of the tail unit.

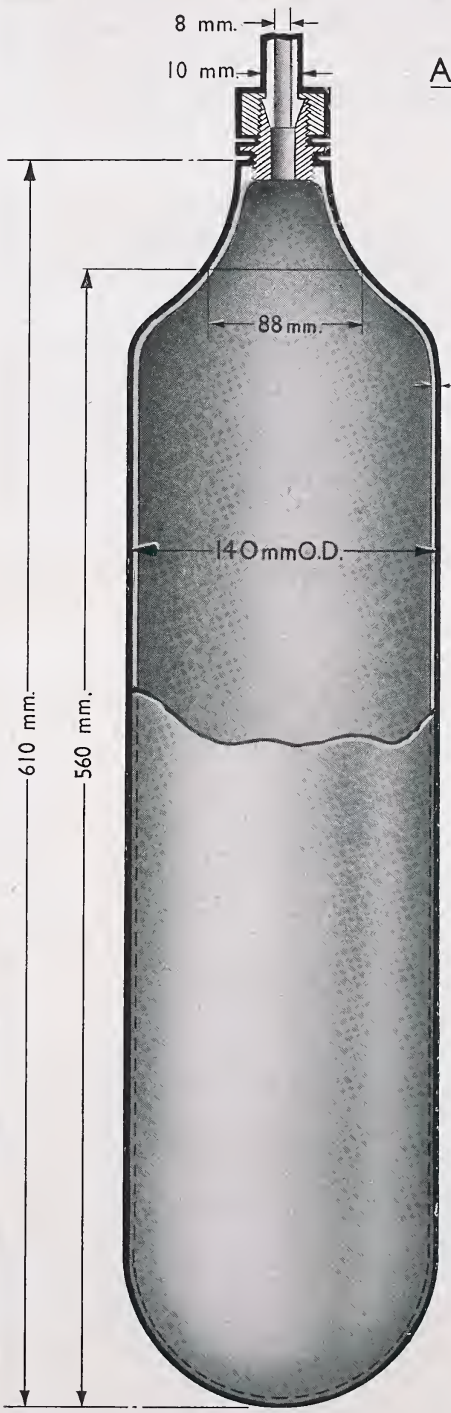
The outside of the section is insulated with glass wool retained in position by a welded plate casing. Plugs are fitted to the casing to allow for the escape of pressure and steam in heat treatment and also serve to dry the glass wool, the outlets of the plugs being closed with the venturi in a heated condition.

SECTION 2

34. This forms the venturi and carries the alcohol inlet manifold and drain plug (para. **65**). The inner skin is formed of two pressings welded into a truncated cone, the smaller diameter of which is then manipulated to form the

Plate 8

AIR STORAGE CYLINDER.



CAPACITY..... 7 LITRES
WORKING
PRESSURE.....200 ATMOSPHERES.
TEST
PRESSURE.....300 ATMOSPHERES

WEIGHT EMPTY.....6·7 K.G.

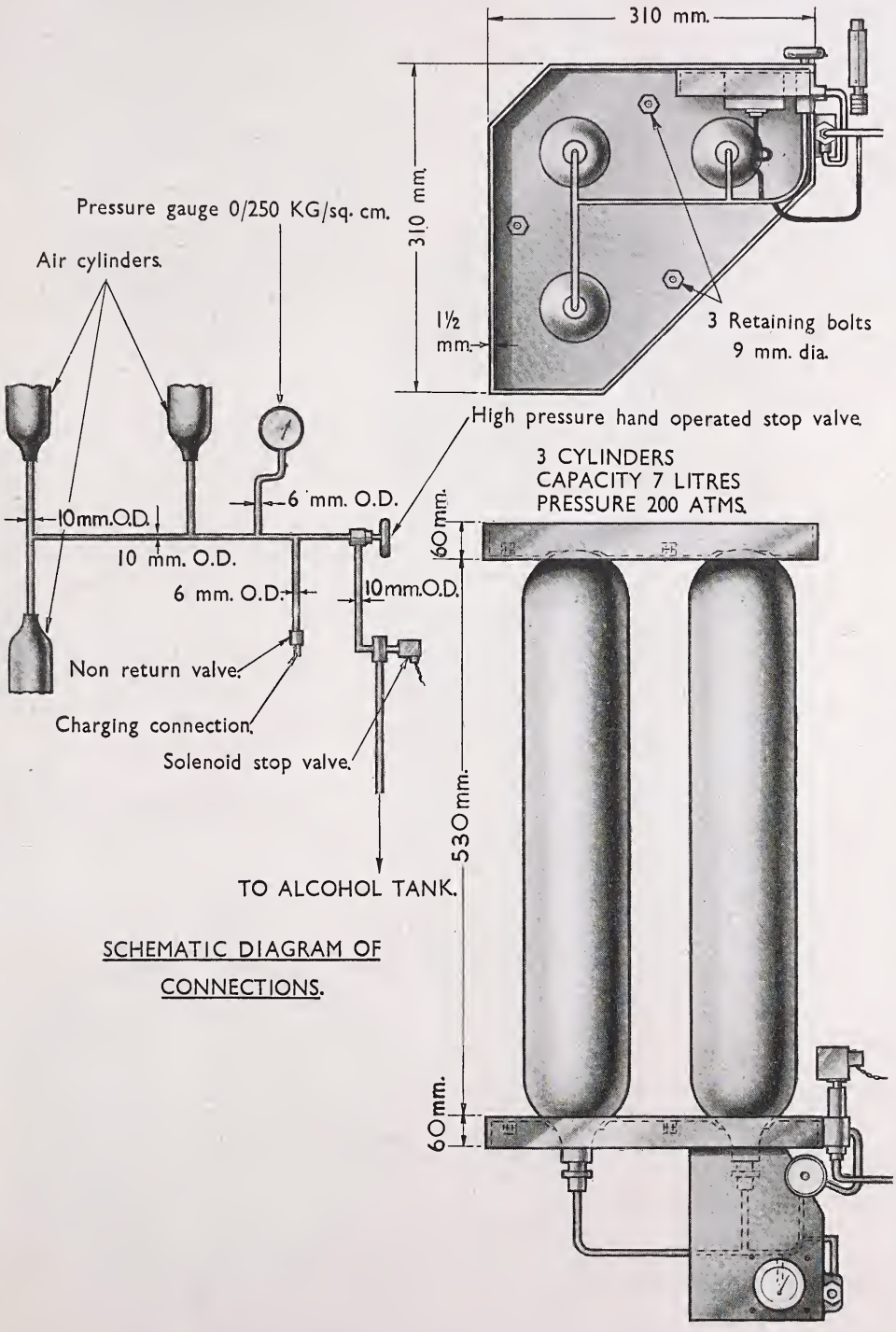
7 Cylinders in lower compartment for Steam unit and Alcohol and Oxygen valves.

3 Cylinders in forward compartment for pressurising the Alcohol tank.

NOTE.
Several cylinders were examined and the weights varied between 6·7 and 10·1 K.G. Cylinders of latest manufacture were lightest.

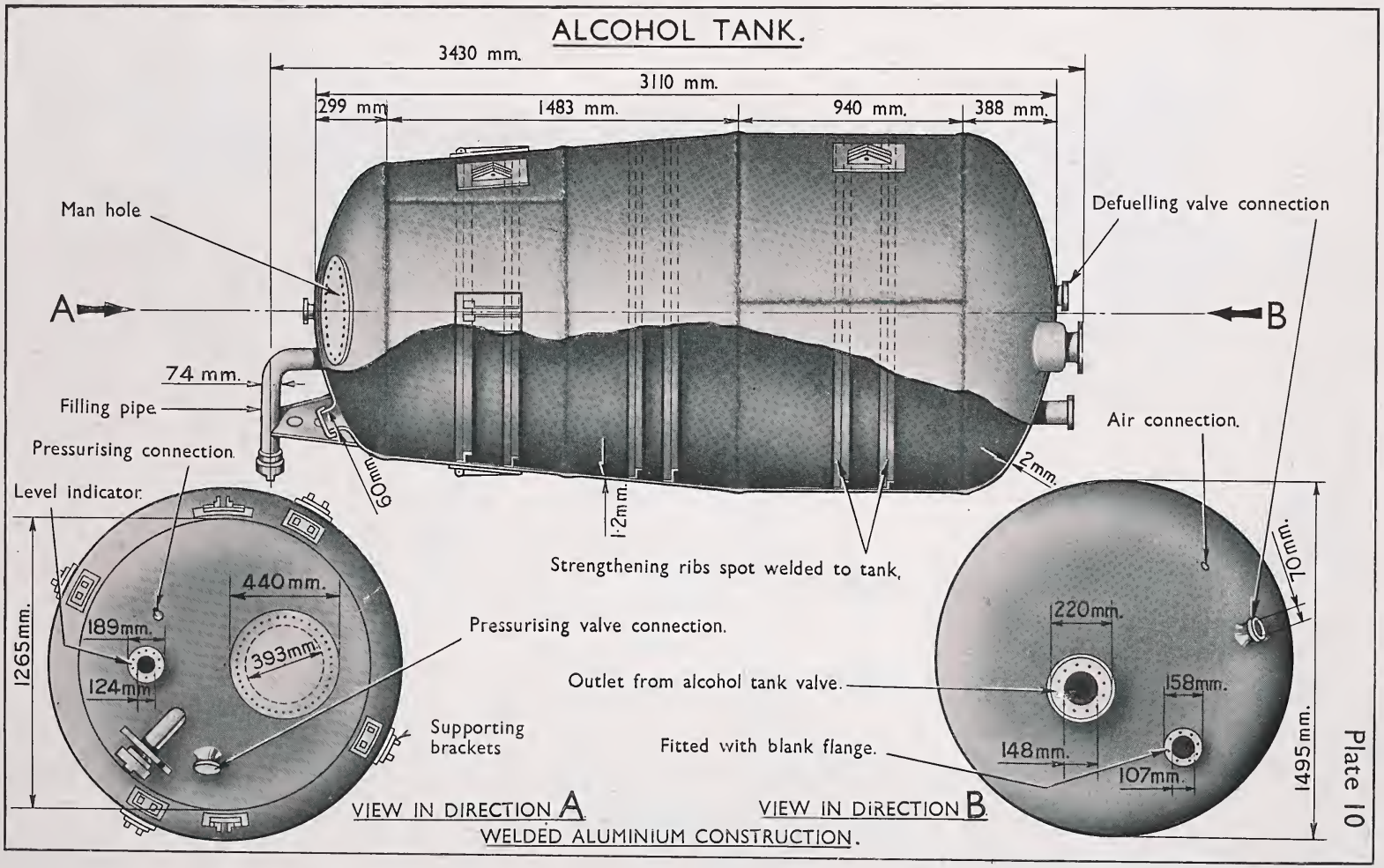
Plate 9

AIR STORAGE CYLINDERS FOR PRESSURISING ALCOHOL TANK.



SCHEMATIC DIAGRAM OF CONNECTIONS.

ALCOHOL TANK.



WELDED ALUMINIUM CONSTRUCTION.

Plate 10

throat. An expansion joint P is fitted to the outer casing equipped with plugs for test purposes and drainage. At A a strengthening ring of forged steel has been introduced since it was found on the early development that the heat generated caused the venturi to belly inwards. On this section the alcohol manifold strengthening ring and the outer casing, as far as the expansion joint P were fabricated and then pressure tested before welding the annulus for the cooling jets L_1. Sections 3, 5 and 7 are formed of machined forged steel rings drilled to permit a flow of alcohol through the jacket and also the passage of alcohol from the annuli L to the chamber.

SECTION 4

35. This section is welded with 3 and 5 and pressure-tested before being built into the remainder. It incorporates two sets of cooling rings with an expansion joint P centrally disposed.

SECTION 5

36. Two pressings are utilised for the inner wall and the outer casing of this section is the final set of plates to be fitted. Sections 7 and 8 form the combustion head, 7 being the forged steel ring previously referred to, which is built into pressings forming the inner skin K and holding the base of the mixing cups and the seat of the alcohol valve. The section is pressure-tested in this condition. The outer skin, which forms the distribution chamber for alcohol to the mixing cups, is then welded and the whole head finally tested before being made into the complete assembly.
The head carries four supports for the tubular steel frame in which is housed the pump and steam unit assembly (Section C/D, Plate 14).

SPACING RODS

37. In order to ensure that a free passage of alcohol is maintained throughout the jacket between the walls of Section 6, 12 equally dispersed spacing rods have been introduced. Similar spacers are inserted in Section 4, and 36 are placed round Section 2. The spacers are of such size as to ensure that should the outer jacket distort the minimum allowable area of flow is maintained.

COOLING CONNECTING PIPES

38. Cooling connecting pipes G coupling the third skin of the venturi to the annuli L are finally welded, four of these being disposed at 90 deg. to each other.

WELDING AND TREATMENT

39. All welds on the inner jacket are made both inside and out. The material is preheated to 300 deg. C., and finally stress relieved at 800 deg. C., being brought up to this temperature in 30 minutes and held for two hours, after which it is allowed to cool slowly. After welding and stress-relieving, the assembly is hammered to remove scale, washed through with water, drained and has hot air circulated through its ports. It is then phosphated and blanking caps fitted to all outlets.

STEELS USED

40. No physical tests or analysis of material have been carried out, but the following German specifications were confirmed :—

(1) Inner skin ST1604.
(2) The machined rings in Sections 3, 5 and 7 1 ST37/-12.
(3) The expansion joints P ST VII.
(4) 23 flanged burner cups ST4712.
(5) Alcohol valve seat and flange 37/12.
(6) Burner cup third skin U deep drawing steel.
(7) Steel cold pressed is used for main burner forgings.
(8) Alcohol inlets and manifolds U ST1604.
(9) Electrodes used SH-GEL 6 AGIL-CLAMROB.

The various pressures generated in the sections are also shown on the attached diagram.

HEAT EXCHANGER (Plate 15, Section 1)

41. Position : In the exhaust steam line from the turbine.
Duty : To vaporise liquid oxygen for the purpose of pressurising the oxygen fuel tank.

In order to give the oxygen a positive head and to ensure adequate flow in the initial stage the oxygen tank is pressurised to 1·5 kg/cm. While the rocket is still on the firing platform this is done by air. When airborne the exhaust steam from the turbine is utilised to vaporise liquid oxygen through the exchanger and pass the vapour back to the oxygen tank (Plate 6, Section 1).
Referring to Plate 15, Section 1, exhaust steam is passed from the turbine through the casing and escapes through the two legs into exhaust pipes which terminate at the base of the rocket.
Liquid oxygen is fed into adaptor A from the main oxygen valve and passes through the four coiled steel tubes to outlet B, to which the oxygen tank pressurising pipe is connected.
In order to avoid the oxygen flowing back and to retain the initial air pressure in the tank when pumps are not working a non-return valve (Plate 16, Section 1) is inserted in the line. Oxygen or air enters the body G and the pressure raises valve C against spring B. Oxygen or air then passes to heat exchanger coil through A.

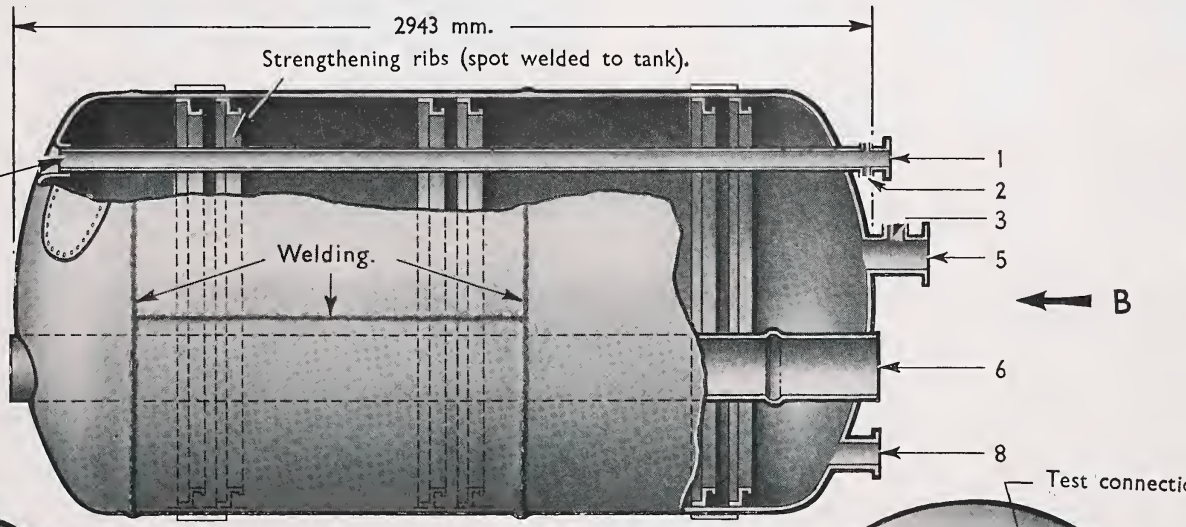
STEAM UNIT ASSEMBLY

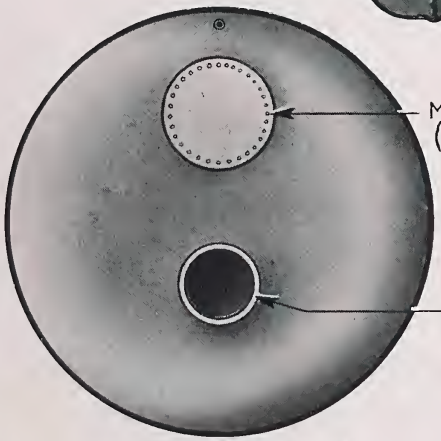
42. The steam unit assembly is mounted longitudinally on the propulsion unit frame (Fig. 9, Section 1) and located near the turbine and pump set at the end of the oxygen tank. The method used to supply steam to the main propulsion unit is by the chemical decomposition of H_2O_2 using sodium permanganate solution as a catalyst and forcing both these chemicals into the reaction chamber by means of air pressure. For this purpose the assembly used consists of the components shown in the schematic diagram, Plate 17, Section 1. The designations of the electrically operated valves match up with the wiring diagrams of the rocket shown in Section 4.

TANK : Welded construction in 4 pieces.

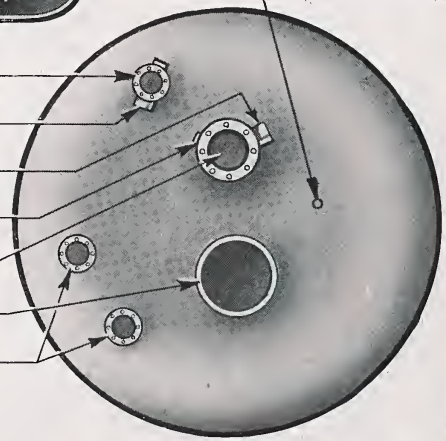
MATERIAL : Aluminium.

THICKNESS : 2 mm.





1. Vent pipe (I.D 91·5 mm).
2. Pressurising pipe (I.D 49 mm).
3. Filling pipe (I.D 66·5 mm).
4. Topping up pipe (I.D 31 mm).
5. Main delivery pipe (I.D 145 mm).
6. Alcohol duct (I.D 235 mm).
7. and 8. Blanked out (I.D 107 mm).



VIEW IN DIRECTION A.

OXYGEN TANK.

VIEW IN DIRECTION B.

Plate 11

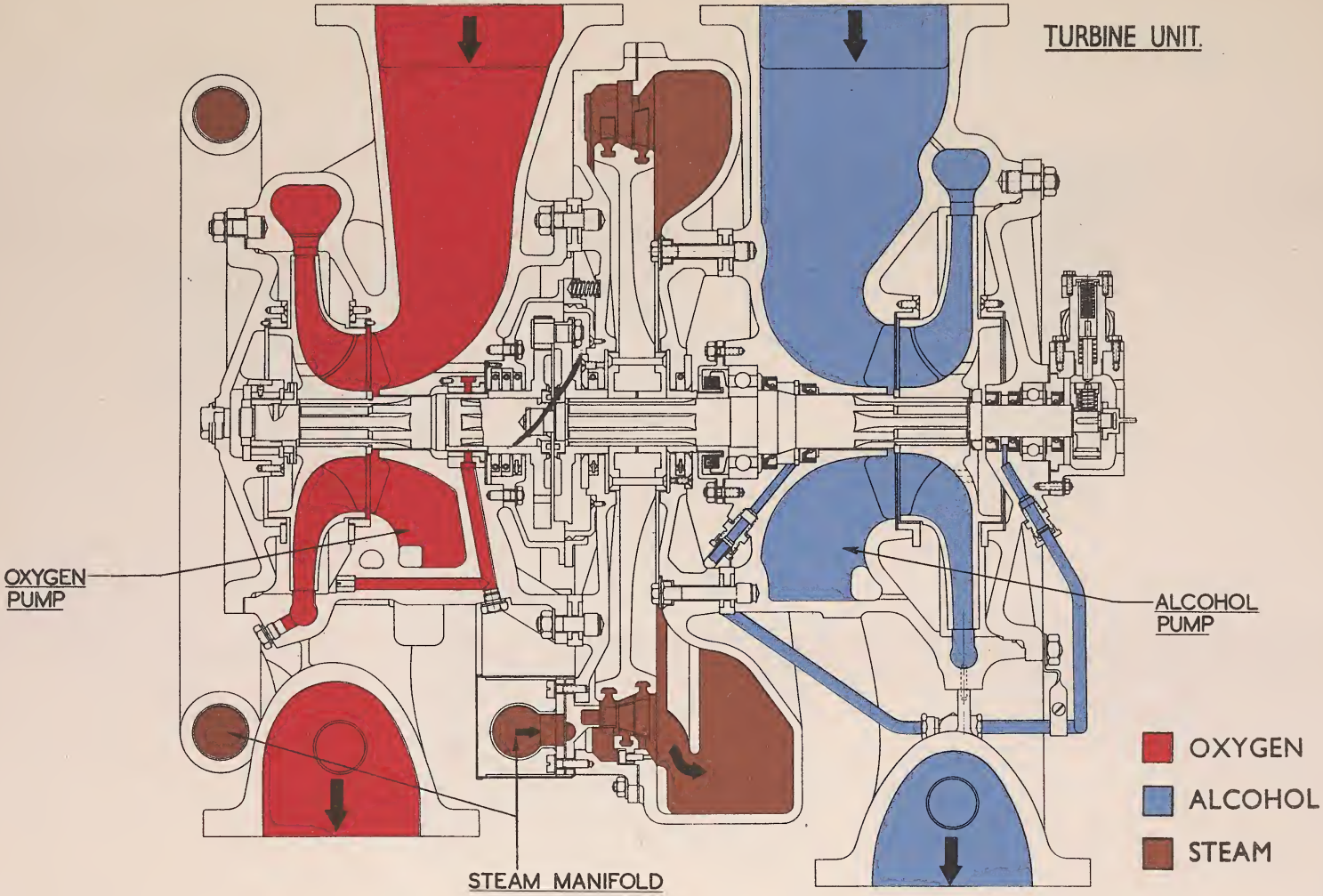

TURBINE UNIT.
OXYGEN PUMP
ALCOHOL PUMP
STEAM MANIFOLD
OXYGEN
ALCOHOL
STEAM

Plate 12.

TURBINE OVERSPEED TRIP.

(CENTRIFUGAL SWITCH.)

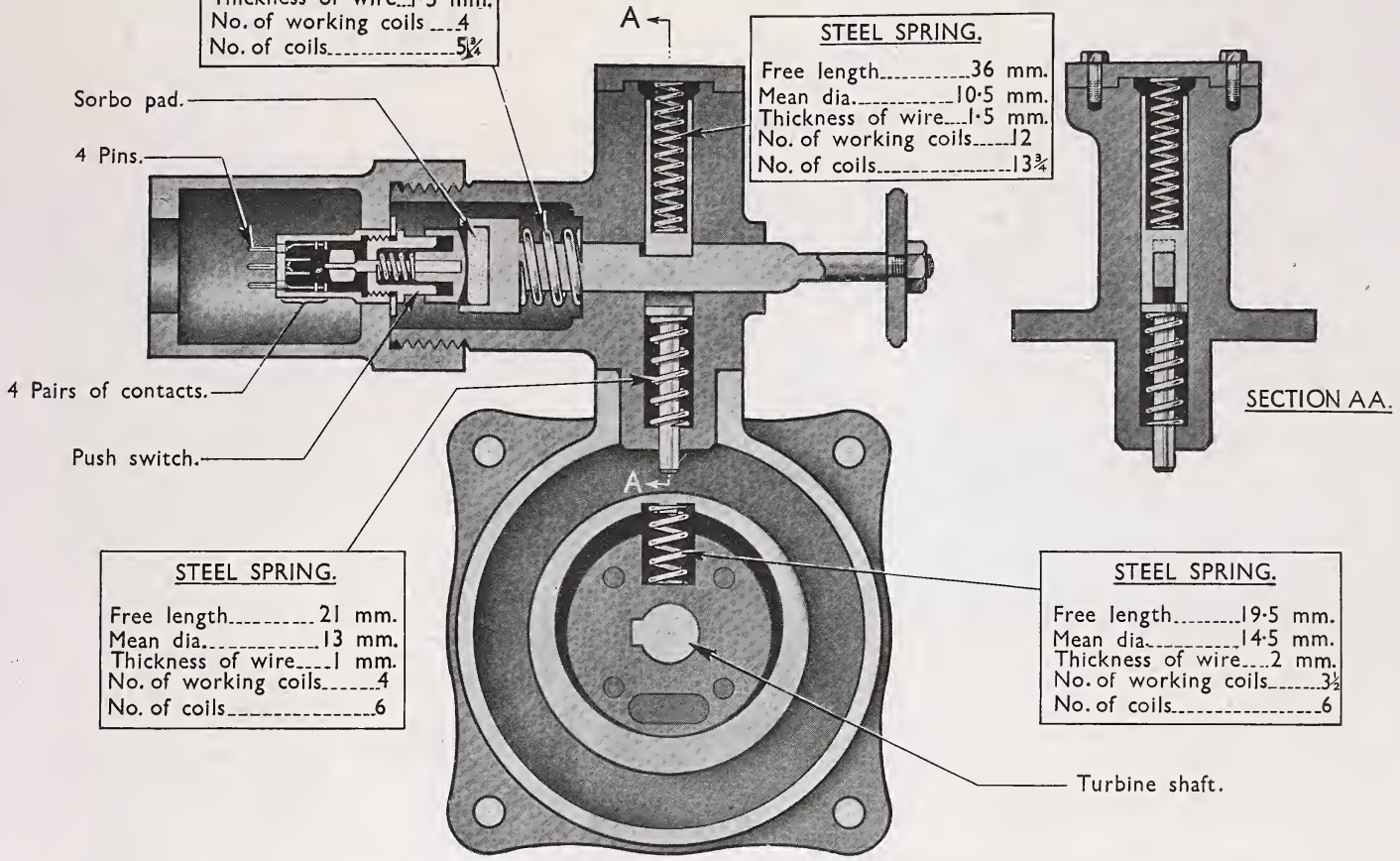
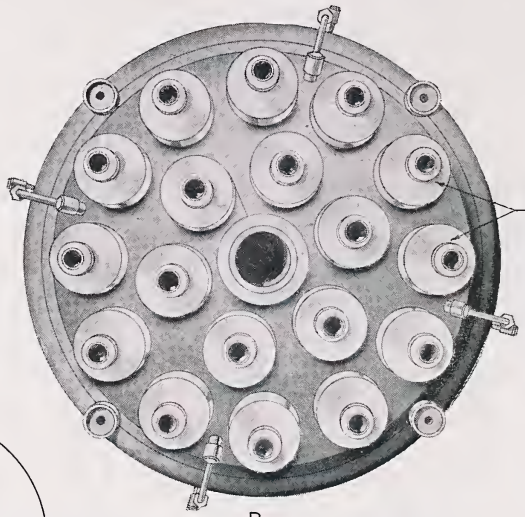
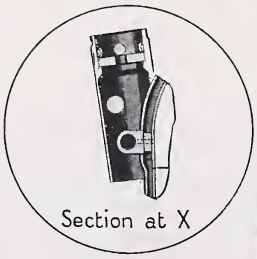


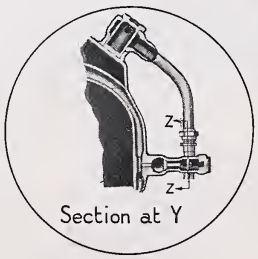
Plate 13

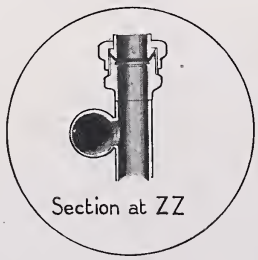
COMBUSTION CHAMBER

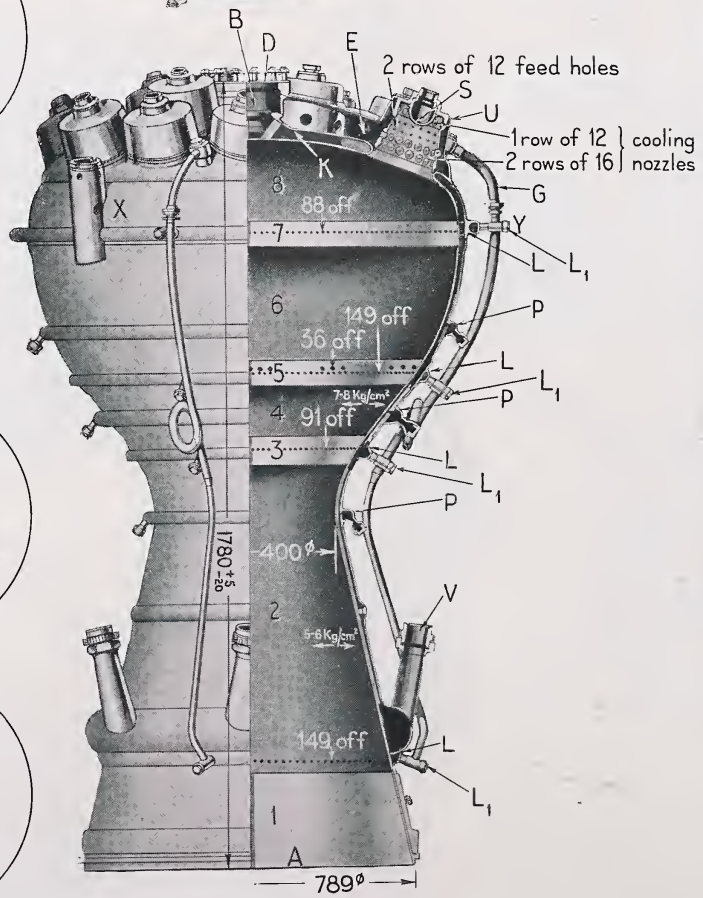
Plate 14











43. Pressure drawn from a bank of 7—7 litre air cylinders charged to 200/220 kg/cm,^{2} or, for test purposes, pressure drawn from the ground unit is fed through the hand-operated stop valve (para. 66) and ceramic filter to a reducing valve (para. 67) set to pass 31/32 kg/cm.^{2} on the low pressure side. A high pressure gauge reading from 0 to 250 kg/cm.^{2} is disposed between the hand-operated stop valve and the main air supply. Similarly, a tapping from the low pressure side of the reducing valve feeds a gauge indicating the pressure the valve is passing. This gauge reads from 0 to 60 kg/cm.^{2} and is fitted with an electric contact which completes a circuit at 30 kg/cm.^{2} pressure, thus giving an indication of its functioning to the electrical test panel. The reducing valve is fitted with a safety valve set to blow at 42 kg/cm.^{2}, a bleed valve, and a hand-operated stop valve which is used for test purposes (para. 67). One side of the low-pressure outlet is fitted with a banjo connection and a 12 mm. inside diameter copper pipe with a non-return valve inserted in its line supplies air to the pressure operated valves on the combustion unit. Two branches are taken off the other side of the low-pressure outlet, one a 15-mm. inside diameter steel pipe connected through a solenoid operated stop valve DH (para. 51) and a Y-piece to the permanganate and peroxide tanks. Check valves are fitted in these two lines to prevent back pressure. The other outlet is a 6-mm. inside diameter steel pipe which divides again. Branch 1 feeds air through 4-mm. inside diameter steel pipes via a solenoid operated stop valve D1H (para. 64) to the pistons on the vent valves (para. 69) exhausting the hydrogen peroxide and permanganate tanks. Branch 2 feeds air via the solenoid-operated valve D25H to the piston of the main peroxide valve. This completes the air system.

44. A welded steel 4·5 mm. thick ceresin lined egg-shaped tank, capacity 132 litres, is used as the H_2O_2 container (Plate 18, Section 1). This is fitted with a right-angle filling pipe 25 mm. inside diameter complete with cap and a steel outlet pipe of 25 mm. inside diameter. The outlet pipe is connected to the inlet pipe of the main peroxide valve. There are two branches off this pipe, one of 16 mm. inside diameter terminating in a non-return valve which allows for drainage and flushing to be carried out if dirt, etc., is suspected; the other branch is an 8-mm. inside diameter pipe, which connects to the bye-pass of the peroxide main valve through the solenoid operated valve D8H. From the main peroxide valve a 25-mm. inside diameter pipe feeds the peroxide to the reaction chamber through the pilot jet and main jet.

45. The permanganate tank is of welded steel 4 mm. thick (Plate 19, Section 1) and is also fitted with a non-return drain valve at the base and a filling pipe leading into the top of the tank. A syphon pipe 8 mm. inside diameter connects the sodium permanganate tank with the reaction chamber. A branch taken off this feed line is coupled to the pressure operated contact switch which operates when a pressure of 1·5 kg/cm^2 is in the line and allows valves D8H and D25H to be operated.

46. The reaction chamber consists of a circular steel welded cylinder (para. 72) which is lagged with glass wool on the outside, the glass wool being retained by means of

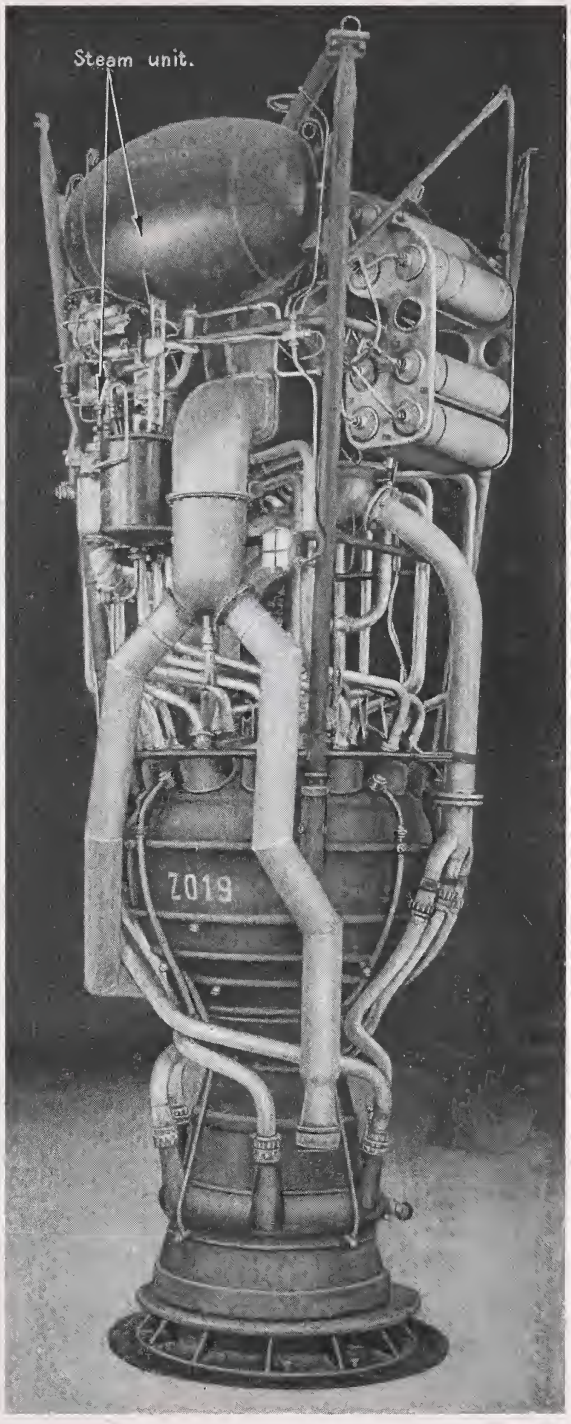


Fig. 9. Steam Unit Location.

HEAT EXCHANGER.

Lengths of coils from R.A.E. Drawing C.D.44027 are:-
104·5, 160·7, 191, 199·7 inches.

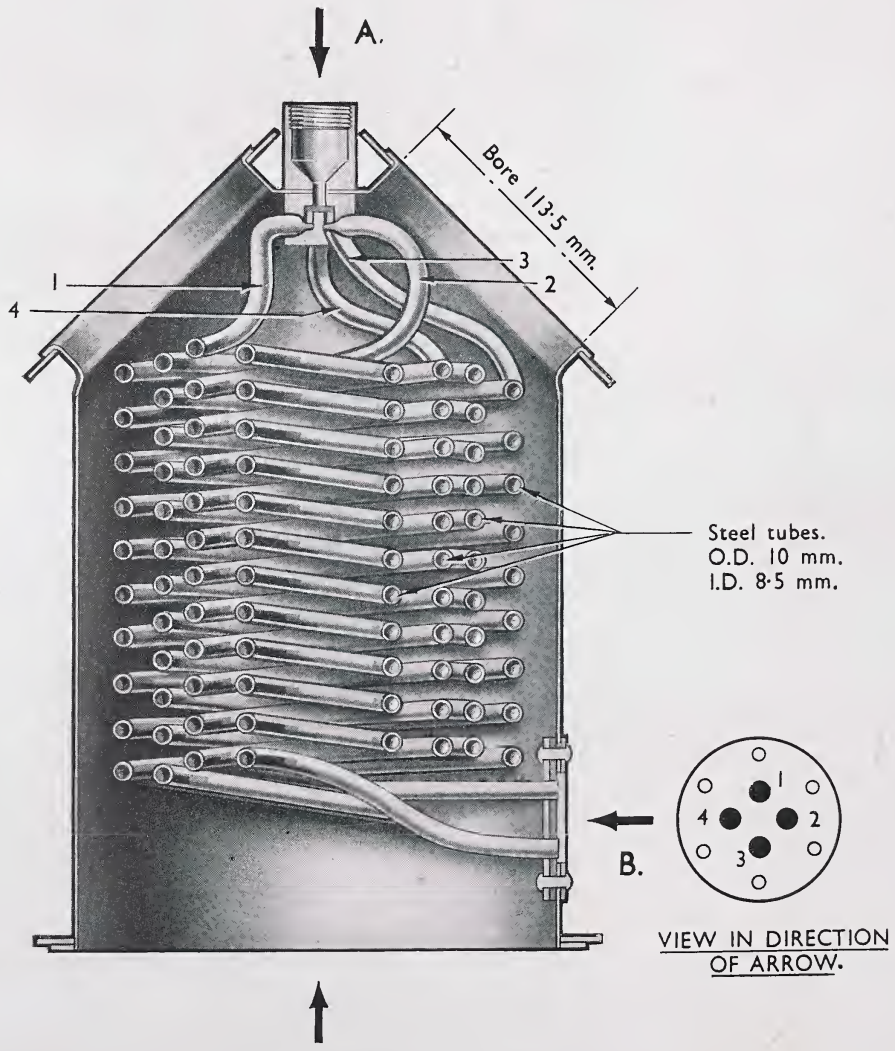
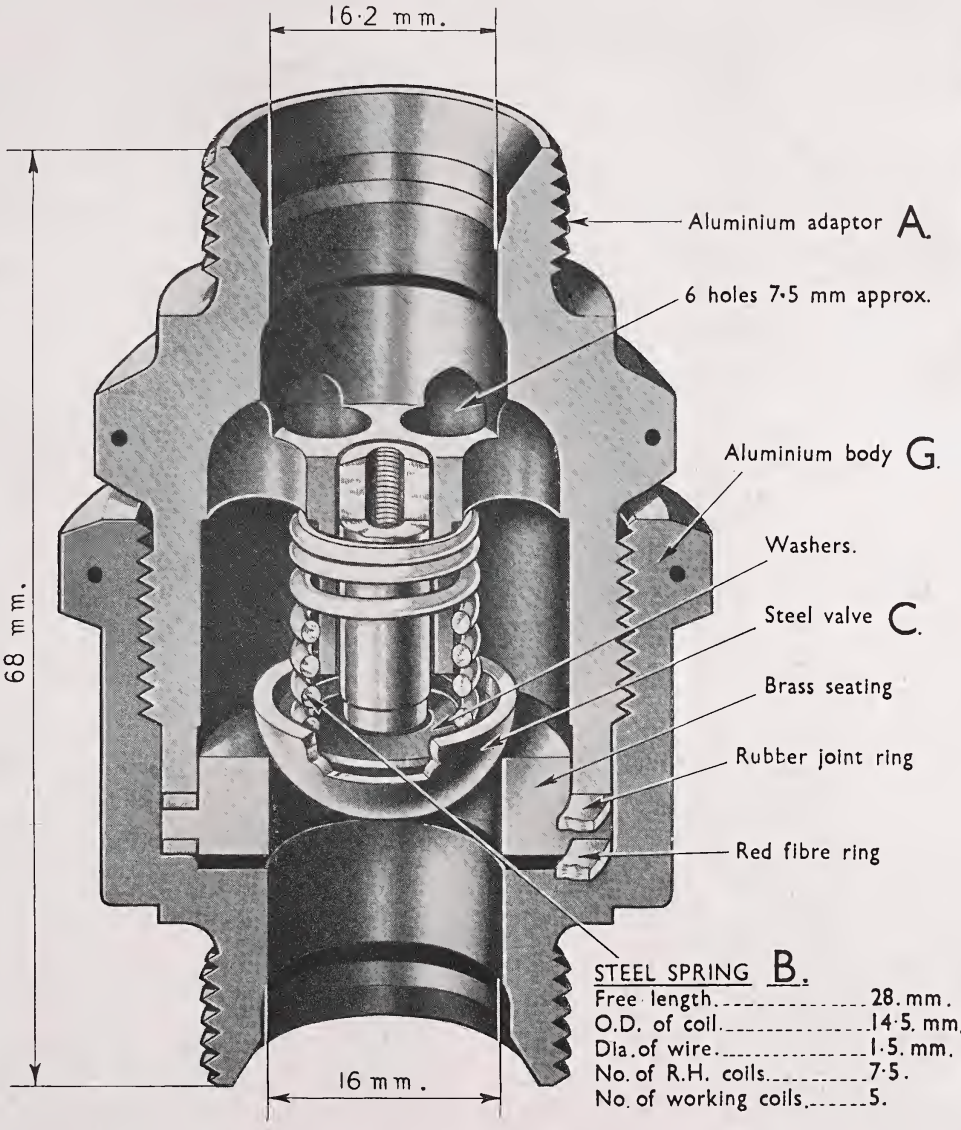


Plate 16

NON-RETURN VALVE.



STEEL SPRING B.

Free length	28. mm.
O.D. of coil	14·5. mm.
Dia. of wire	1·5. mm.
No. of R.H. coils	7·5.
No. of working coils	5.

a steel housing. It is equipped with a spring-loaded valve, which also contains a pilot jet, on the peroxide side, and a series of internal baffles. In operation both jets open simultaneously, giving a direct flow through the pilot jet and a flat cone-shaped spray from the main valve. Under full pressure the spray is increased and the peroxide covers the internal walls and baffles. The sodium permanganate inlet is located at 90deg. to the peroxide inlet and is fed through a choke in the delivery line, this choke being determined from tests at manufacturer's works. The sodium permanganate impinges on a small baffle directly under the pilot jet of the peroxide inlet. From the outlet of the reaction chamber a lagged pipe is taken to the turbine inlet.
The electrical connections on this unit are brought to a 14-pin List plug, fitted on the assembly. Electrical connections between the pressure operated contact switch D2R (para. 73) and valves D8H and D25H are made through a 6-pin List plug. Further descriptions of valves and components comprising this assembly are dealt with under valve details.

47. For test purposes two bosses are welded and tapped in the peroxide delivery line, one shown at Z and the other at U. These are used for the connection of pressure lines in the test procedure.

48. The method of operation of this assembly as used on the A-4 rocket was as follows :—

126 litres of peroxide were fed into H_2O_2 tank of concentration 82 per cent., 11 litres of sodium permanganate solution of concentration 27 per cent. were filled into the permanganate tank. Air at 200/220 kg/cm.^{2} pressure is fed to the reducing valve. This is set to give a flow pressure of 31/32 kg/cm. on the outlet side. Solenoid valve D1H is energised, and the resulting flow of pressure through the 6-mm. pipes to the pistons of the vent valves closes the vents making the system airtight. Solenoid valve DH is energised, allowing pressure to build up in the hydrogen peroxide and the sodium permanganate tanks. Pressure on the sodium permanganate tank forces the solution to the reaction chamber and through the branch connection to the diaphragm contact switch. When a pressure of 1·5 kg/cm.^{2} has been attained this switch closes and operates solenoid valves D8H and D25H. The operation of D8H allows the bye-pass on the main peroxide valve to operate and feed peroxide into the reaction chamber. The energising of D25H allows air to force open the main peroxide valve and full flow is established. The contact switch ensures that sodium permanganate must enter the reaction chamber first. When starting up this unit on the rocket, the delay between the operation of the bye-pass D8H and the main peroxide valve is purely the time lag taken by the pressure released through Valve D25H operating the piston in the main peroxide valve.
On the rockets built for Operation " BACKFIRE " at the end of the specified time of operation of the steam unit both valves D25H and D8H were switched off simultaneously. The operation of the valves separately was confined to those rockets to which radio control was fitted.

49. A noticeable feature in the construction of the unit was the use of brass in place of aluminium for valves on the sodium permanganate system. All non-ferrous pipes were treated with stove enamel finish on external surfaces.

VALVES

50. ALCOHOL TANK PRESSURISING VALVE

Position: Immediately above the alcohol tank and inserted between the tank and the pressurising pipe connected to the warhead of the rocket. A Section of this valve is shown in Fig. 10, Section 1, which shows this valve in its normal position. It will thus be seen that normally the valve forms the vent for the alcohol tank.
After the rocket has been in flight for 40 seconds, air is applied through adaptor B via the solenoid valve (S3H), which forces piston E in a downward direction. This operation also forces down the valve casing A until a seating is made. On the release of air pressure the spring returns the valve case in A and free passage of air from the tank to the atmosphere is allowed.

51. SOLENOID OPERATED HIGH PRESSURE STOP VALVE (Plate 20, Section 1)

Position: In the pipe line between hand-operated stop valve and alcohol tank. Also used in steam unit as valve DH (Plate 17, Section 1).

Duty: To discharge the air from the air storage cylinders, in the control compartment of the rocket, into the alcohol tank. This takes place after 65 seconds flight and serves to pressurise the tank. When used in steam unit it releases air pressure to the hydrogen peroxide and permanganate tanks.

Sequence of Operation :

(*a*) The valve is normally closed as shown.

(*b*) Air enters through adaptor A and flows round valve B through duct C and through port D to the top side of valve B. The air pressure on the top side of this valve and the spring retains it on seating E.

(*c*) At the correct time in the programme solenoid coil F is energised and core G thrust downwards under the influence of magnetic flux. The core pushes valve H down on to duct C against spring J. Thus duct C is sealed but port K opened, cutting off the pressure to the top of the valve B and allowing the pressure to be released through vents L. In this condition high pressure on the underside as against low pressure on the top side ensures that valve B is raised off seating E, allowing the air to flow to the tanks via adaptor M.

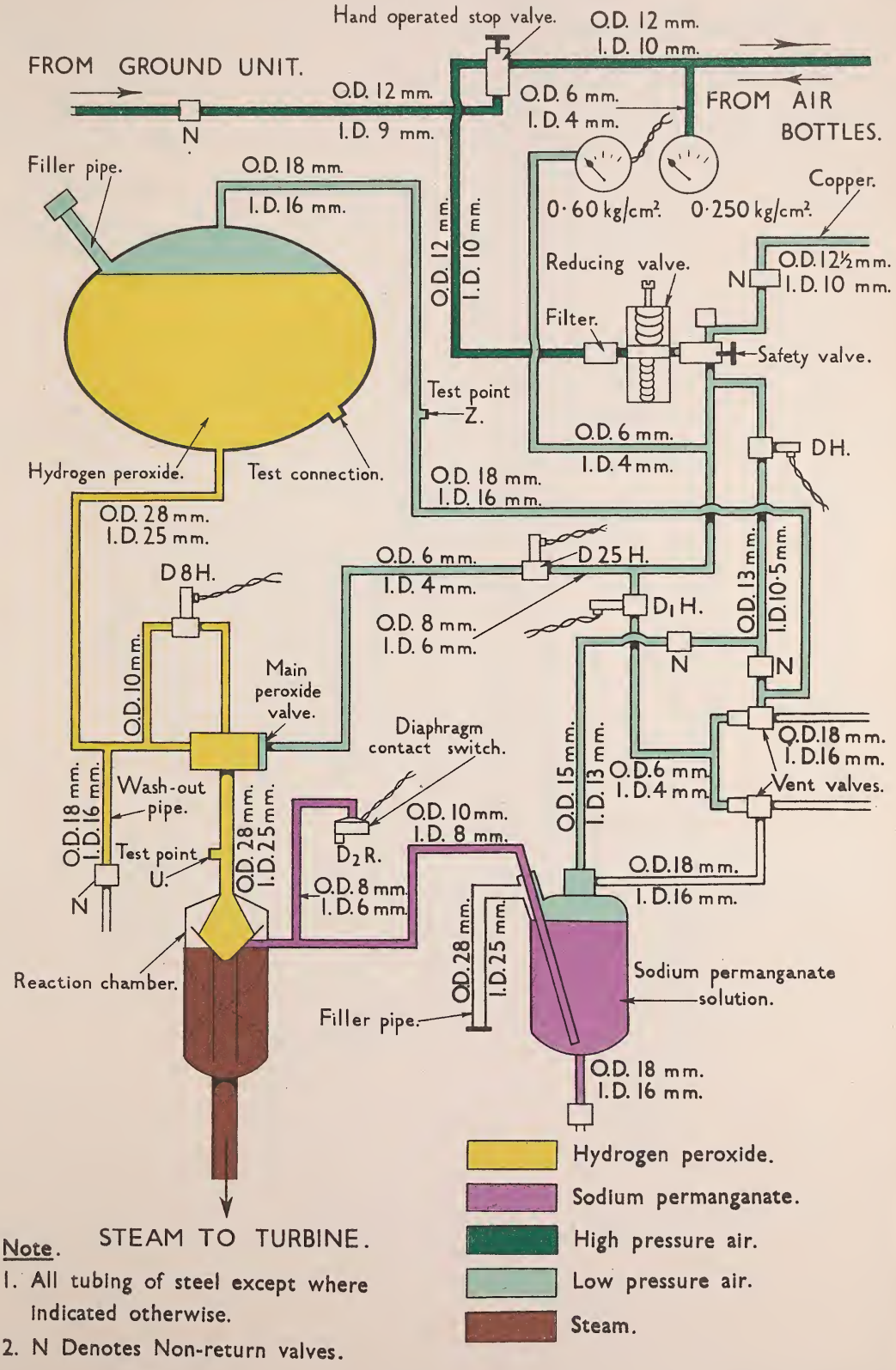
52. ALCOHOL VALVE IN FUEL TANK (Plates 21 and 22, Section 1)

Position: The valve is located at the bottom of the alcohol tank where the lower flange is bolted to a seating inside the tank by six studs. Three connections are brought from the valve (2 air and 1 electrical) and the lower flange has three portions cut away to clear the coupling points where they are served from the external services. The valve is controlled through the application of air via solenoid S1H (para. 63).

Duty: This valve allows the alcohol tank to be filled and isolates the alcohol system from the duct through the oxygen tank to the pump and thence to the main alcohol valve in the venturi. An

STEAM UNIT.

Plate 17.



Note.

1. All tubing of steel except where indicated otherwise.
2. N Denotes Non-return valves.

electrical switch is incorporated which closes an open circuit when the valve is fully open. The switch is used when testing to give an indication on the test desk of the position of the valve.

Operation :

The valve is operated by an air pressure through adaptor C of from 31 to 35 kg/cm². and its maximum travel is 80 mm. The gland P serves to prevent the access of alcohol into the air chamber and seals Q are held in position by large type circlips which are blued but not plated as those used on the oxygen valve. These seals are also supported internally with moulded plastic rings R, which in other valves have been in steel. Its main components are of aluminium alloy, but such items as the stem G springs and circlips are made of steel.

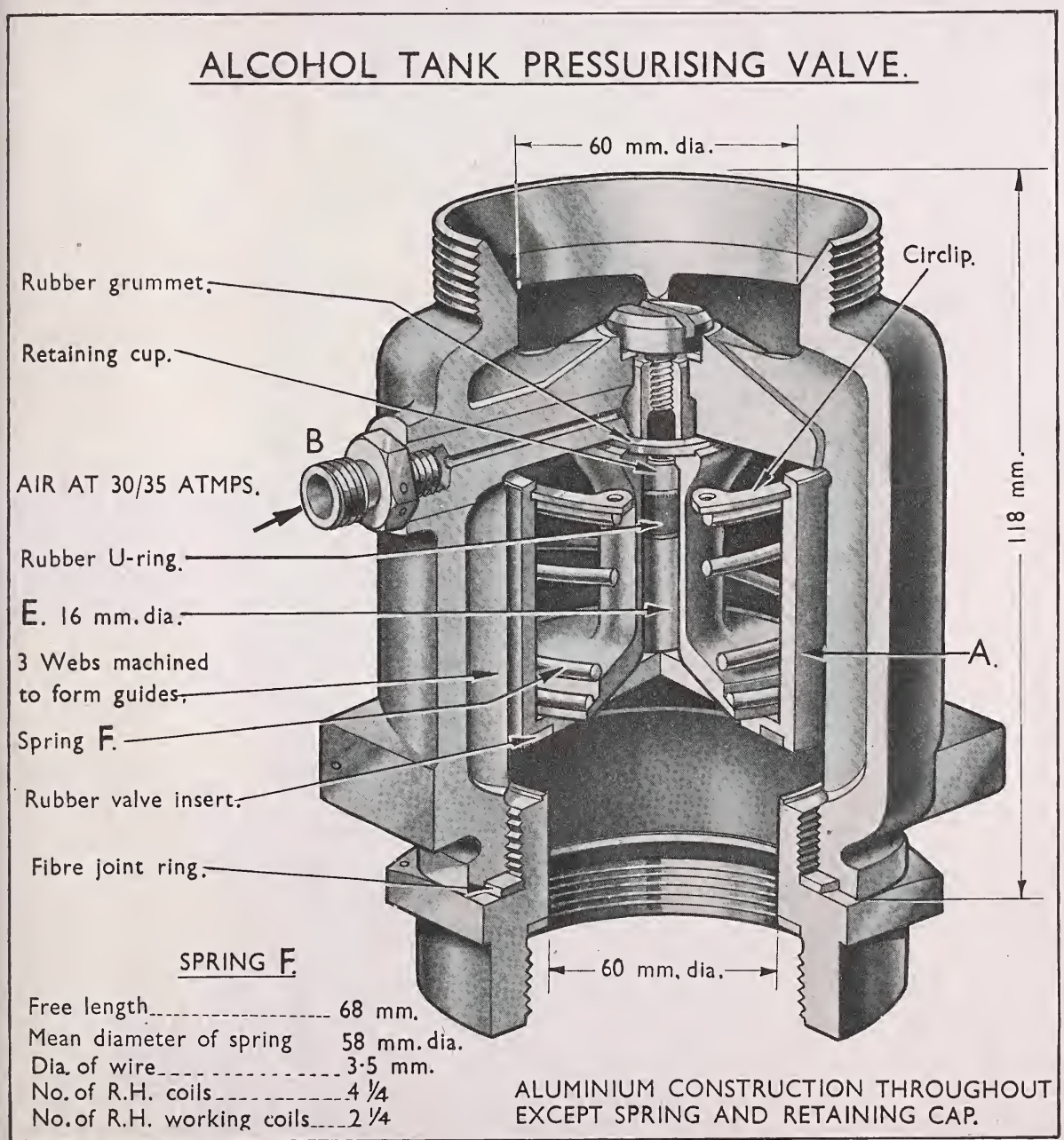
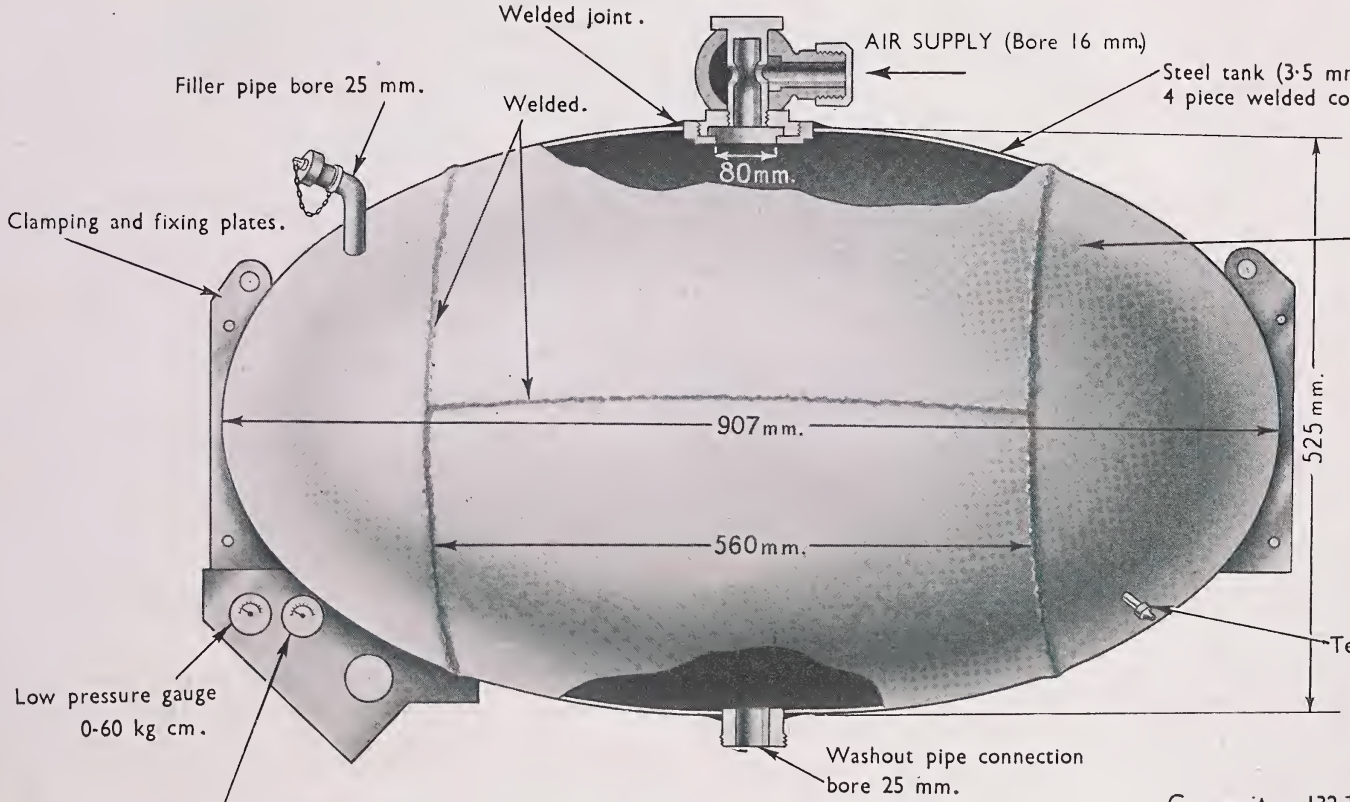


Fig. 10

HYDROGEN PEROXIDE TANK.



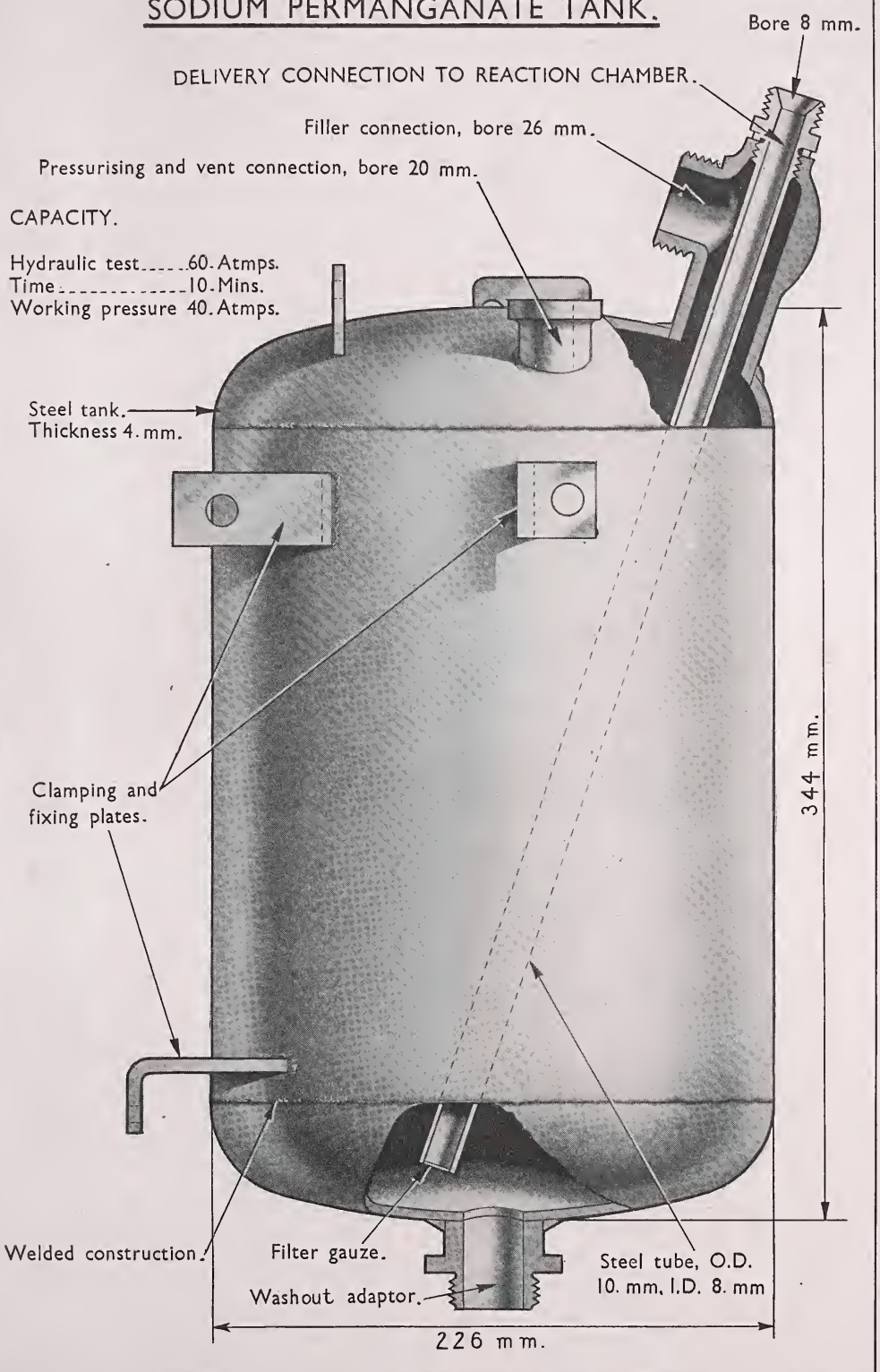
External surface painted black.

Capacity 132 ± 1·5 Litres.
Hydraulic test 60 atmps
Time ..... 10 mins.

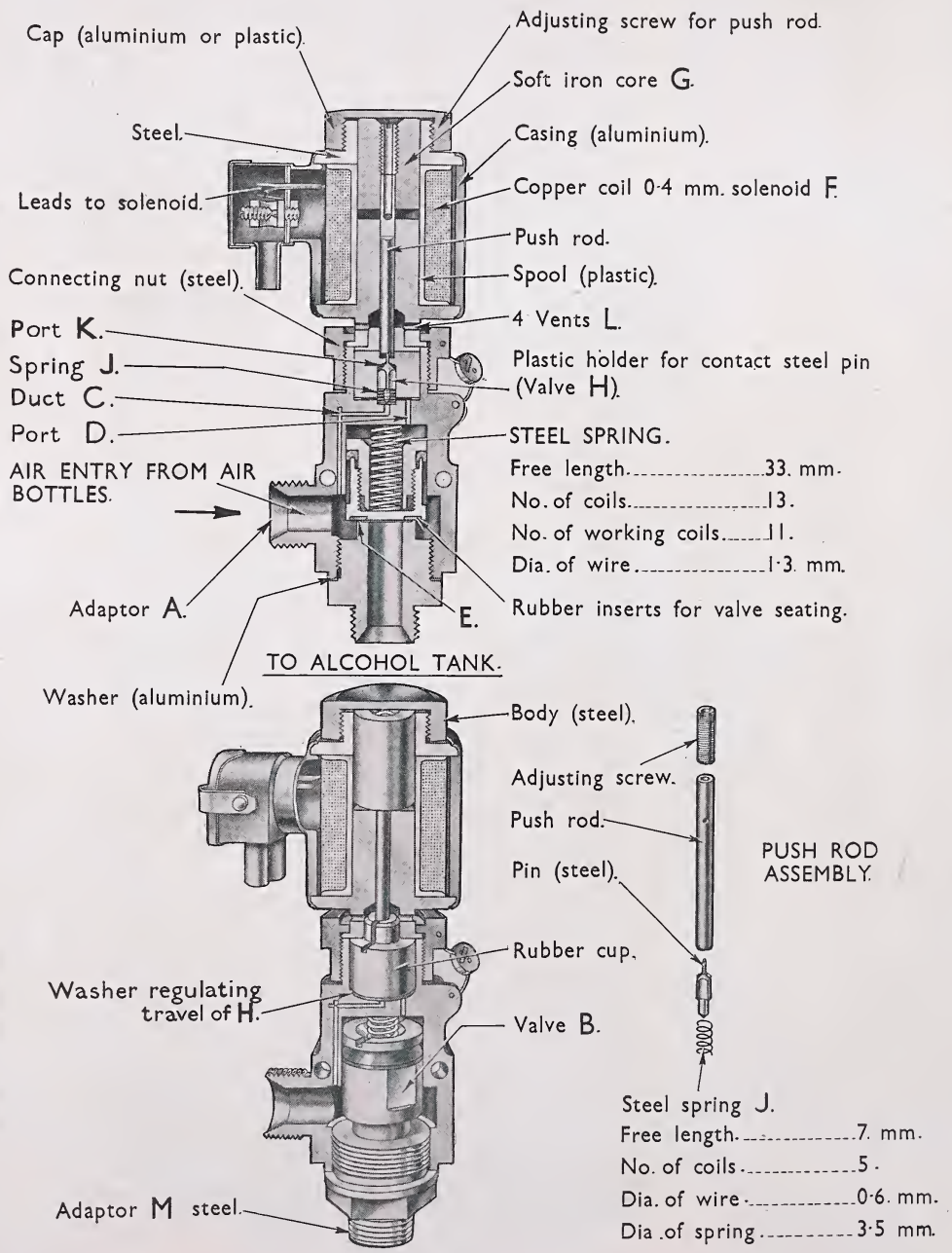
Plate 18

Plate 19

SODIUM PERMANGANATE TANK.



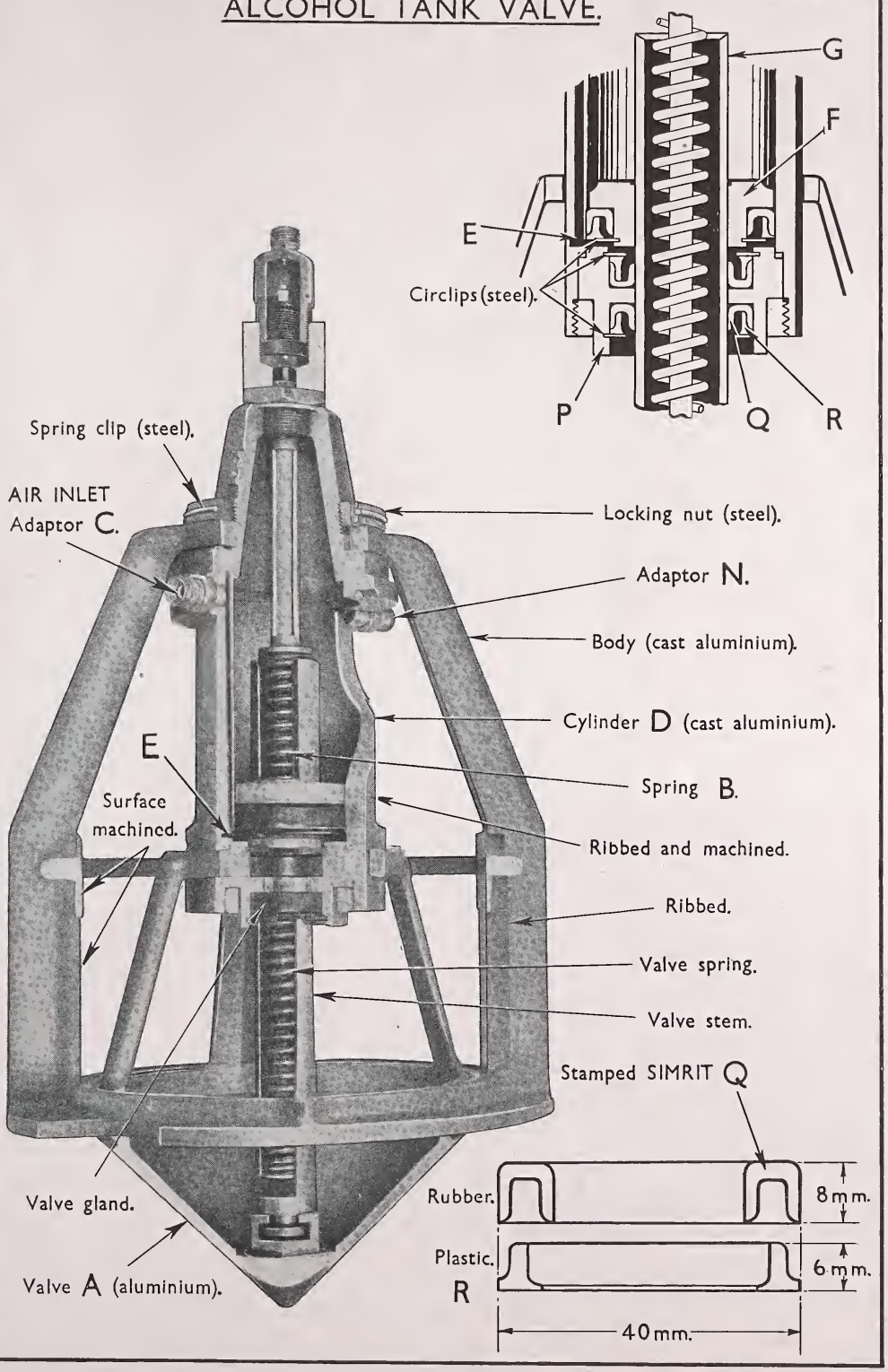
SOLENOID OPERATED HIGH PRESSURE STOP VALVE.



VIEW SHOWING HALF BODY REMOVED.

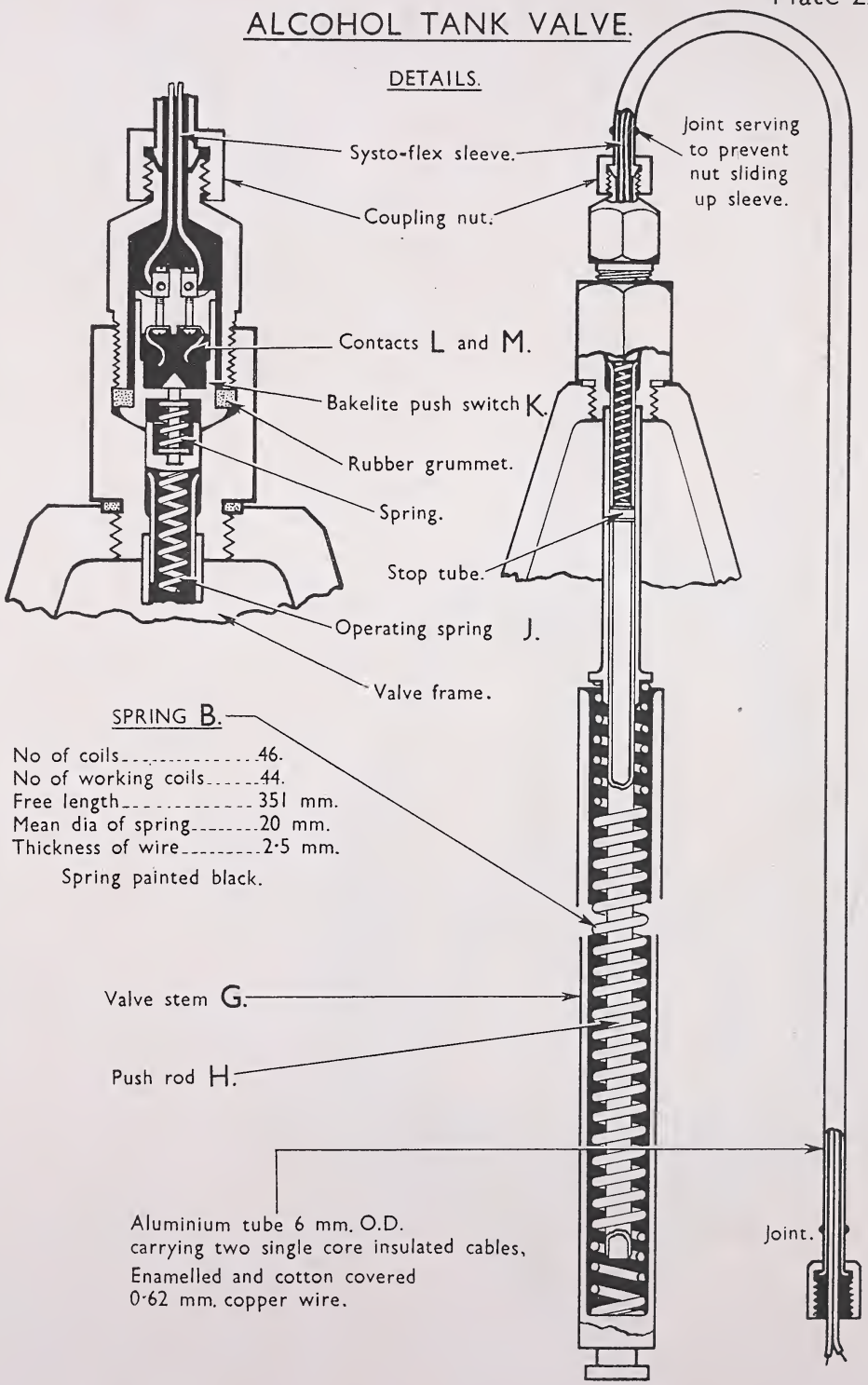
Plate 21

ALCOHOL TANK VALVE.



ALCOHOL TANK VALVE.

DETAILS.



In its normal condition the valve is closed under the influence of spring B. When air is supplied to adaptor C it is fed via the duct in the wall of cylinder D and the port E to the underside of piston F which is rigidly attached to stem G. Through this A is raised against spring B and permits passage of alcohol through the system. When valve A is near the end of its stroke the bottom of stem G forces the push rod H against the spring J operating switch K and bridges contacts L and M.
When piston F is pushed upwards the air in the reverse side of the system escapes via adaptor N, which is connected to atmosphere.

53. ALCOHOL DEFUELLING VALVE (Fig. 11, Section 1)

Position: In the bottom of the alcohol tank.
Duty: To enable the alcohol tank to be emptied should defuelling of the rocket be necessary.
Operation :
Referring to the drawing Fig. 11, the spring D is close-coiled and secured to sleeve B by the eye-bolt E and to the port F by pin G. Any upward movement of the sleeve B puts D in tension. Normally valve C is closed as shown. When defuelling the cap A is removed and a coupling on the hose from the alcohol vehicle is connected. As the coupling is screwed home sleeve B is pushed upwards against spring D, valve C is lifted off its seating, thus allowing alcohol to flow over the seating and through to ports in sleeve B to the hose. Similarly when the hose is uncoupled the valve automatically closes.

54. MAIN ALCOHOL VALVE (Plate 23, Section 1)

Position: In the centre of the head of the combustion chamber held to its seating by 12 studs.
Duty: To supply the main alcohol feed to the burners, cups and combustion chamber cooling system.
Control : In the initial stages is by air applied through adaptor C. This source is taken from the ground equipment before filling and from the battery of air cylinders in the rocket at fuel cut-off.
Sequence of operation :
The valves A and B are normally opened by 8 mm. and 25 mm. respectively. When air is applied through adaptor C at 30/36 kg/cm.^{2} stem D is forced down against spring E until valve A is seated. This isolates the burner cups and the cooling pipes of the combustion chamber, but allows alcohol to flow through the outer skin into the first skin of the combustion head (Plate 14K, Section 1).
When the air supply is cut-off from C, valve A is opened to its original position under the influence of spring E; alcohol can now flow to the burners and cooling pipes.
When the turbine driven pump has generated sufficient pressure valve A is completely opened to 33 mm. against spring E while valve B is closed by the seating on the top side of valve A, thus shutting off the bye-pass system.
The operation of this valve in the rocket is governed through the solenoid pressure operated valves, para. 58, and the system is connected to the switch in the main oxygen distributing valve giving a time lag of ·8 second between the opening of the main oxygen valve and the main alcohol valve. The purpose of this is to make sure that oxygen is present in the combustion chamber before the admittance of alcohol. In the early stages of development it was found that local explosions took place in the burner cups if alcohol was present before oxygen.
A further feature in the operation of this valve is the use made of the spring E. When working under air pressure the lower end of the spring is held by a collar on the central stem and compression takes place by the movement of stem D, the top securing cap of which forms an abutment picking up on the top of spring E. When the valve is working in the reverse direction under pressure of liquid from the pump a ring on the inside of stem D carries the spring the rear end of which is held against the shoulder on the centre tube.

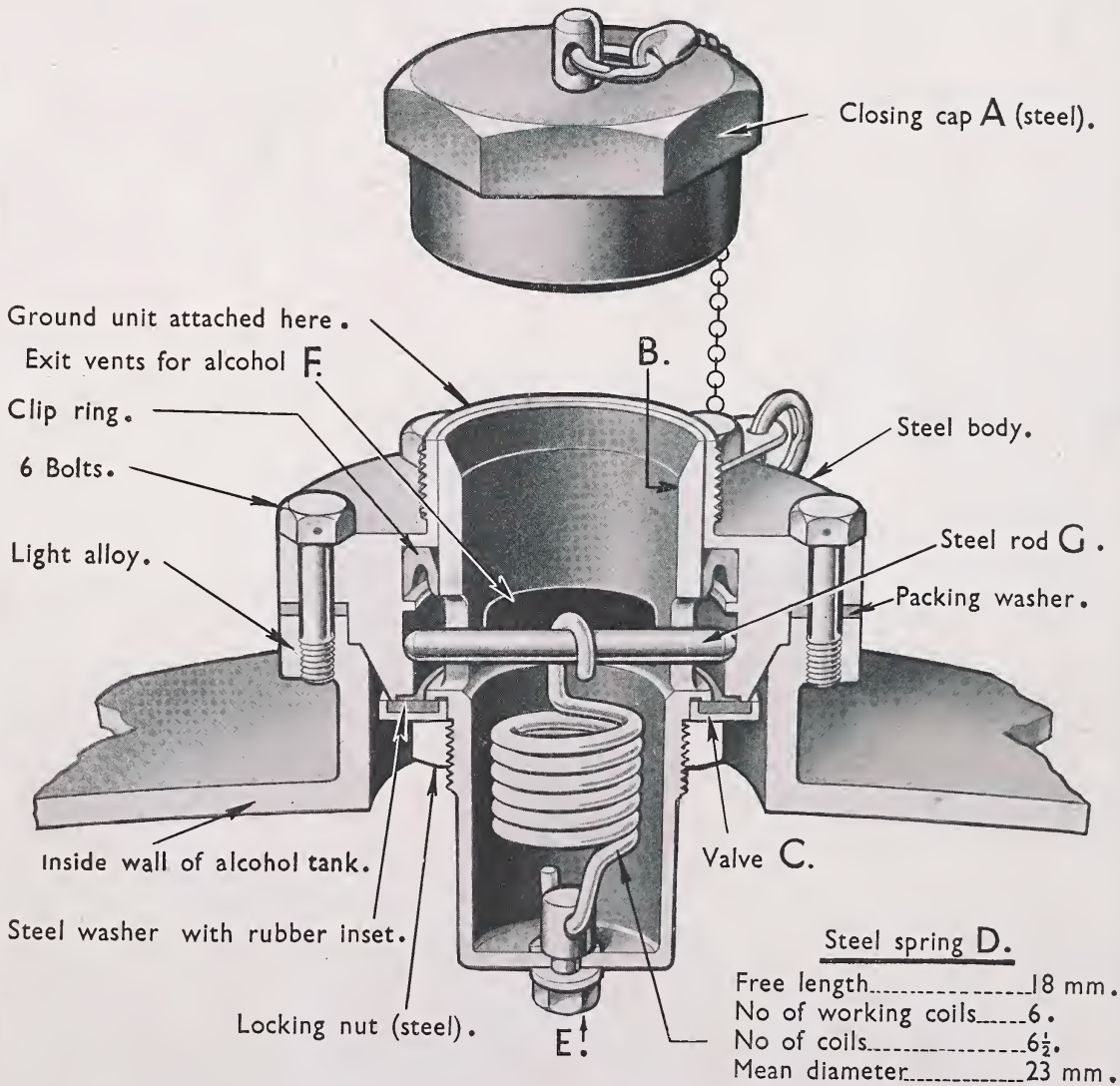
55. HAND OPERATED STOP VALVE (Fig. 12, Section 1)

Position: In the air supply line from the air reservoir in the control compartment as shown in Plate 9, Section 1.
Duty : For the isolation of the air supply in the control compartment from the alcohol tank pressurising system.
Operation :
The valve A is normally closed as shown isolating the alcohol tank system and allowing the air bottle to be charged to 200 kg/cm.^{2}. When this has been accomplished valve A is lifted off its seat by turning the handwheel B anti-clockwise. This withdraws spindle C through cap D, and since C is coupled to the stem of valve A the latter is raised off its seating against the rubber sleeve E.
This valve was not designed for the rocket, but is a German standard. A number of the valves used have a tapped boss on the body plugged by a small tap bolt, indicating that for some applications two outlets were utilised.

56. OXYGEN TANK VENT VALVE (Fig. 13, Section 1)

Position: In the oxygen vent pipe immediately below the oxygen tank.
Duty: To act as a vent valve when air operated from the ground equipment during filling and as a safety valve during the operation of the rocket; venting when the pressure in the oxygen tank exceeds 1·1 kg/cm.^{2}.
Operation :
In its normal position the valve is closed, being retained on its seats by spring C.
To use the valve as a vent during filling, air at a pressure of 31/35 kg/cm.^{2} is admitted from the ground equipment via pipe 4 (Plate 6, Section 1) through adapter A. Passing through the valve body to the inner chamber air acts on the plastic piston which is driven downwards, thus forcing the double seated valve open against the pressure of spring C.
In its normal role no air is supplied to the piston and the spring is adjusted on test so that the valve opens when the pressure in the oxygen tank exceeds 1·1 kg/cm. in flight.
Both the seats on this valve are of leather and interrogation disclosed that this was not entirely satisfactory since the coldness of the oxygen caused brittleness. A number of valves had been manufactured with synthetic rubber seatings, but were not available for Operation "BACKFIRE."

ALCOHOL DEFUELLING VALVE.



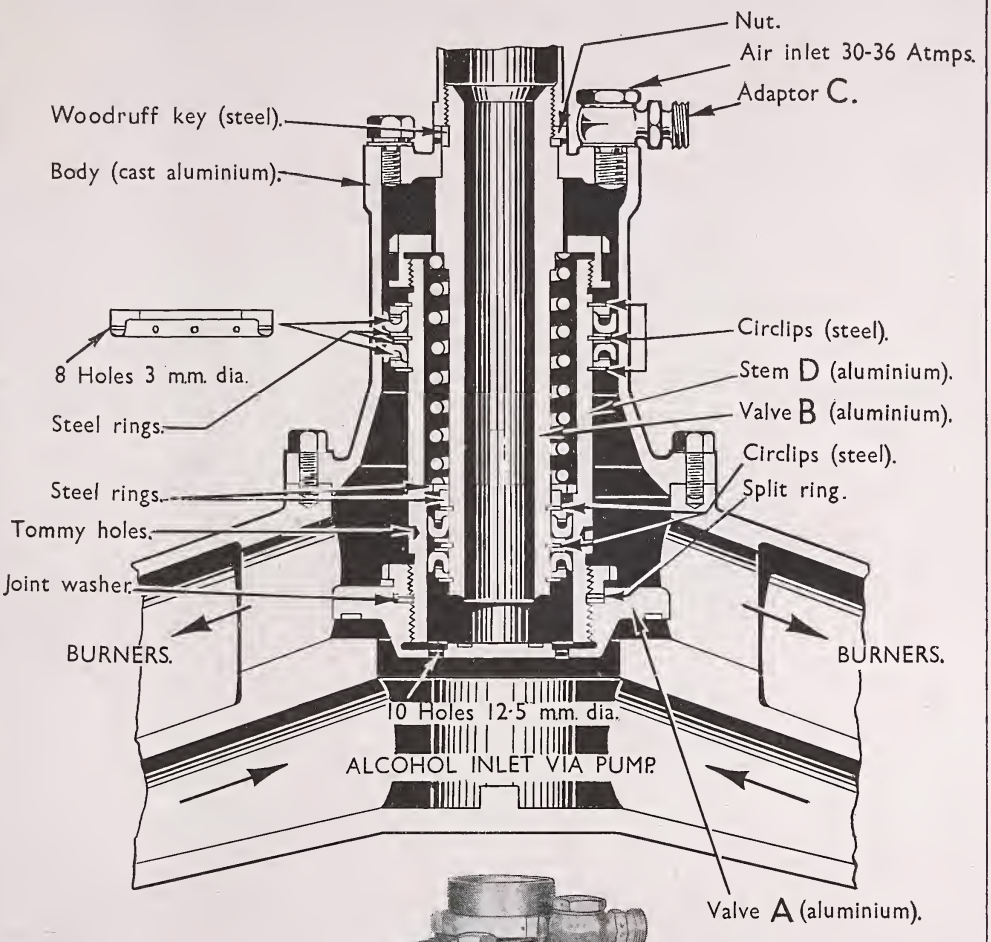
Steel spring D.

Free length	18 mm.
No of working coils	6.
No of coils	6½.
Mean diameter	23 mm.
Thickness of wire	3 mm.

Fig. 11

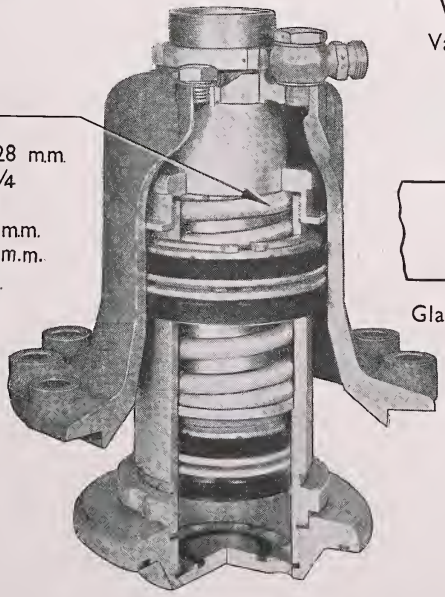
MAIN ALCOHOL VALVE.

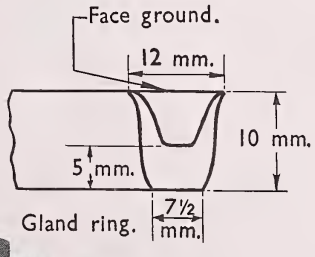
Plate 23



SPRING E.

Free length ---------- 128 m.m.
No. of coils ---------- 7 ¼
No. of working coils ------ 5
Thickness of wire ---------- 9 m.m.
Mean dia. of spring ------- 69 m.m.
Material : Galvanised steel.





Material :
Rubber composition.

HAND OPERATED (HIGH-PRESSURE) STOP VALVE.

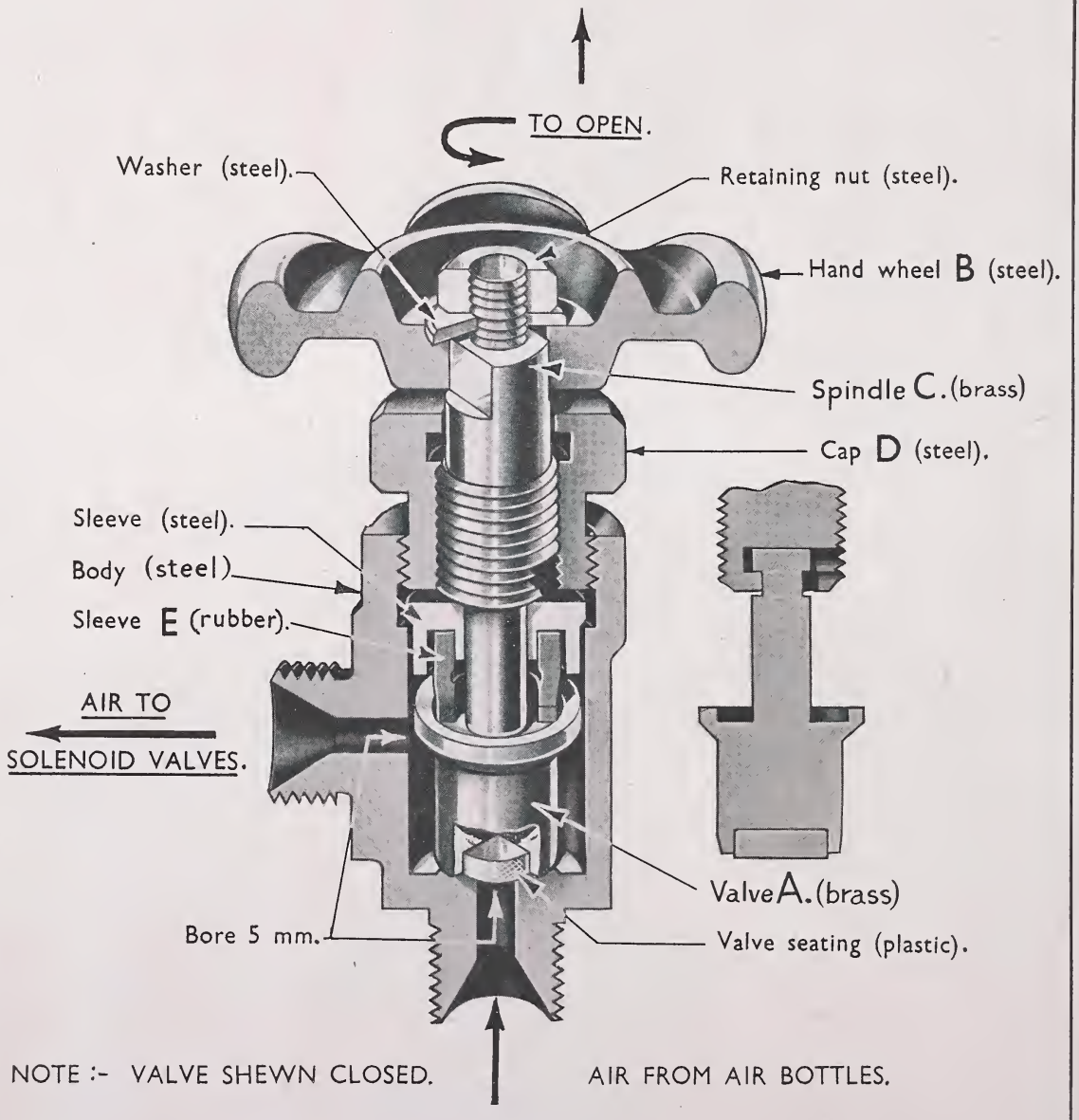


Fig. 12

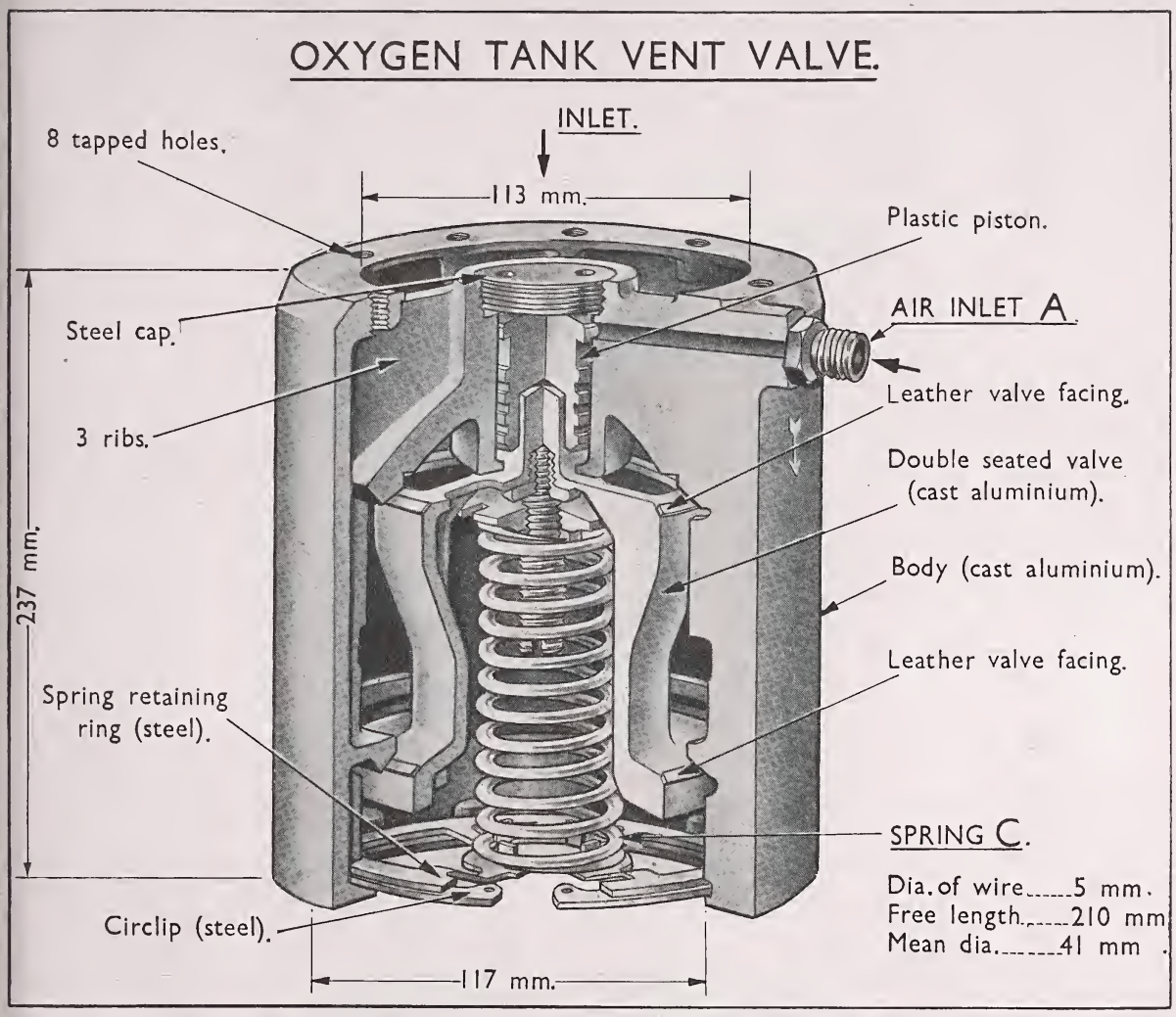


Fig. 13

57. OXYGEN DISTRIBUTION VALVE (Plates 24, 25 and 26, Section 1)

Position: Mounted on the outlet of the oxygen pump.

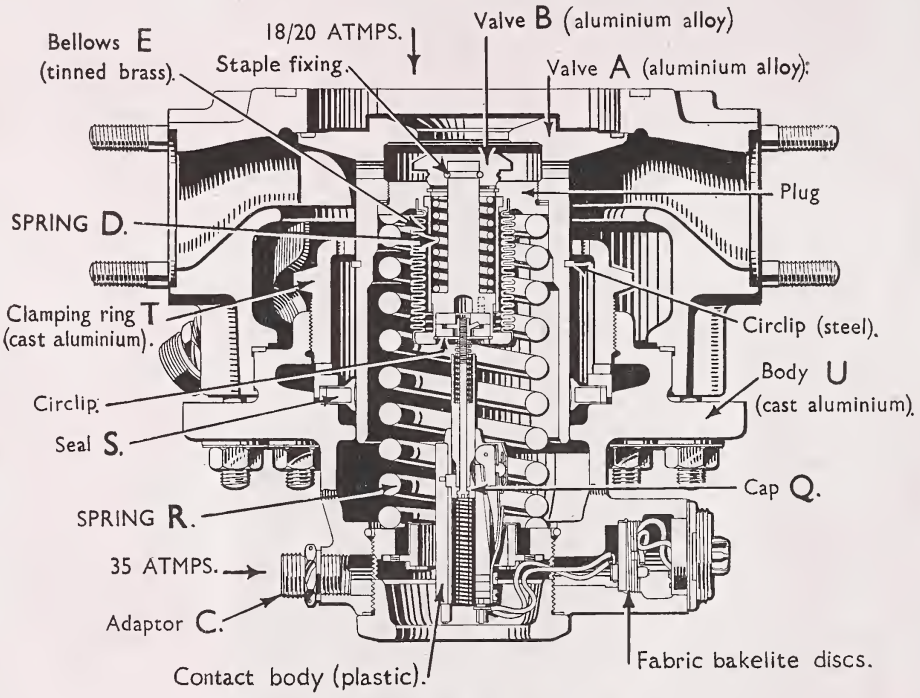
Duty: To deliver liquid oxygen to the burner cups for the preliminary and main combustion stages and to supply liquid oxygen to the heat exchanger. A switch incorporated in the base coupled mechanically to the pilot valve governs the opening of the main alcohol valve.

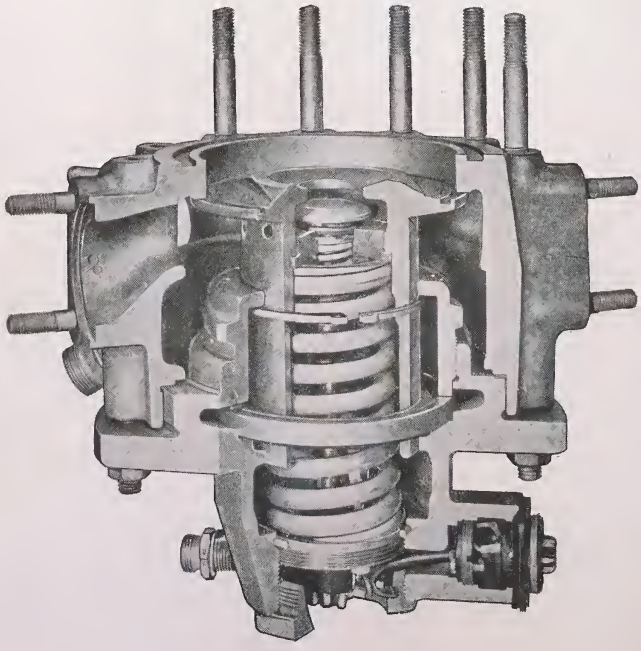
Operation :

The valve consists of a main body having six outlets, and fitted with a main valve A and a pilot valve B. The main valve is operated by liquid pressure from the pump against the spring R. The pilot is centrally disposed in the main valve and is air operated from the ground equipment, air being supplied through adaptor C and acting on the bellows E against spring D. The pilot valve is double-seated so that in its open position it prevents gaseous oxygen entering the bellows. An extension on the pilot valve stem is shaped to operate an electrical switch the circuit of which is broken when the pilot closes. Originally a potentiometer was fitted as well as the switch, and when connected to the ground test panel gave an indication of the movement of the pilot valve, this was subsequently discontinued as an unnecessary refinement. Two wires from the switch are connected with a relay which operates the alcohol valve air supply, and until the pilot valve is operated alcohol cannot flow to the burner cups. The relay gives a delay of ·8 seconds between the pilot opening and the main alcohol valve opening.

It will be noticed that the clamping ring T has 16 holes 2·5 mm. diameter drilled through the top flange; these were used originally for the circulation of hot air admitted through a plug in U via the holes in T and valve B. This

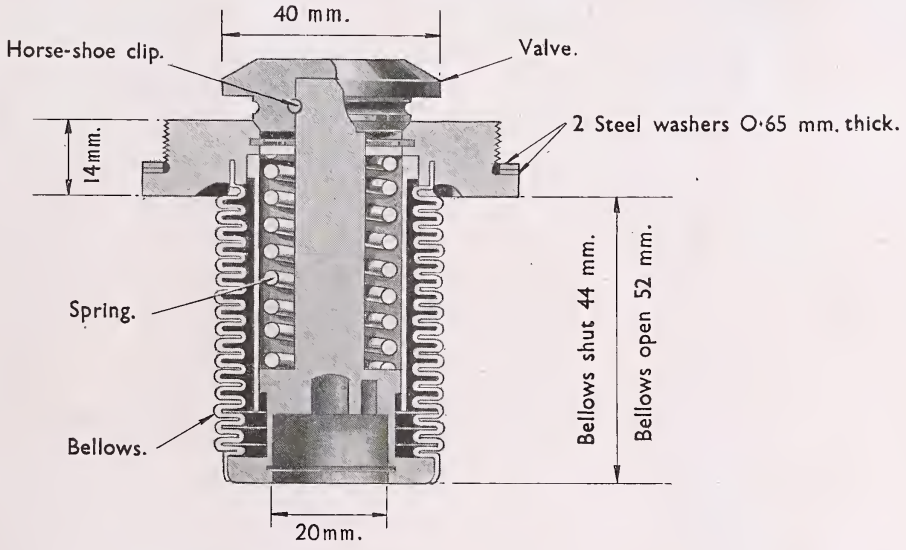
OXYGEN DISTRIBUTION VALVE. Plate 24



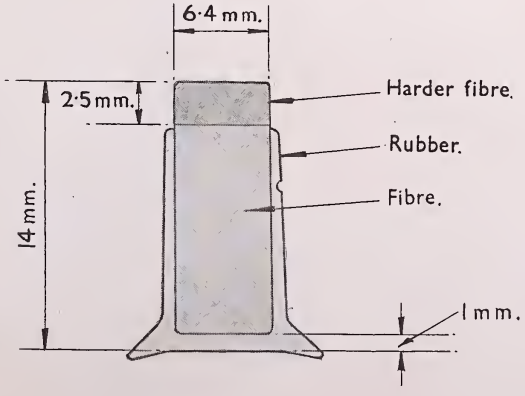


OXYGEN DISTRIBUTION VALVE.

BELLOWS AND VALVE.



SECTION THROUGH GLAND RING



OXYGEN DISTRIBUTION VALVE. Plate 26

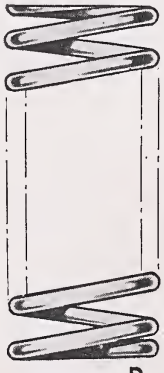
DETAIL.

SPRING D

DETAILS OF SPRING D.

Free length	46 mm.
No of working coils	7.
No of coils	8¾.
Thickness of wire	3 mm.
Mean diameter of spring	22 mm.

Material : Galvanized steel wire.

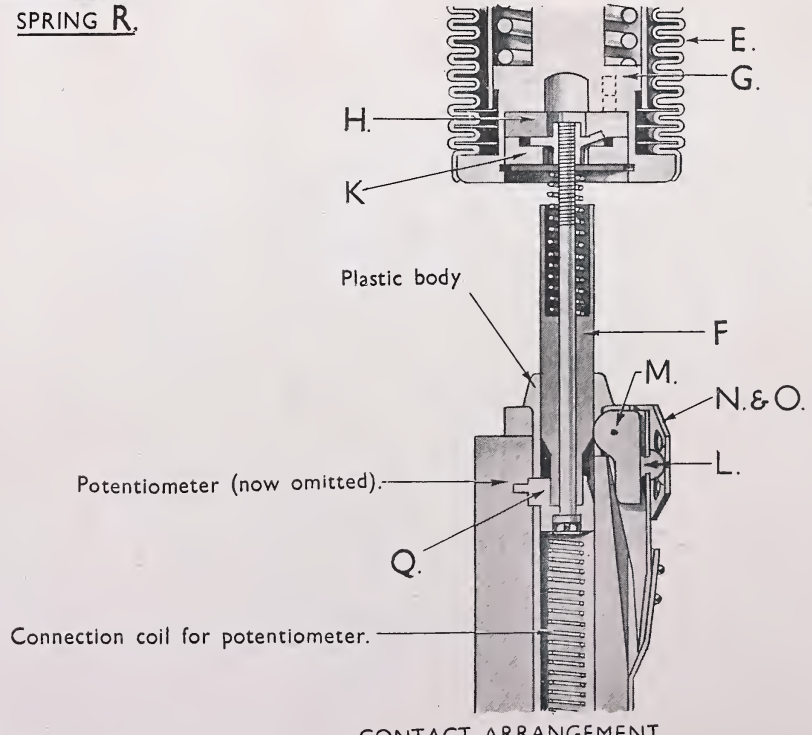


SPRING R.

DETAILS OF SPRING R.

Free length	182 mm.
No of working coils	8.
No of coils	10¼.
Thickness of wire	8·5 mm.
Mean diameter of spring	66 mm.

Material : Galvanized steel wire.



CONTACT ARRANGEMENT.

was to dry out the valve after final tests to evaporate any liquid which might be present and would freeze when oxygen was flowing thereby causing the valve to stick. The movement of the valves is B =3·5 mm., A = 28 mm.

Sequence of Operation :

The main valve A is normally closed under spring R and the pilot valve B normally opened under spring D.
Air is supplied through adaptor C from the ground unit and the bellows E are compressed against spring D and the pilot valve B is therefore closed.
The push rod F, which is insulated from the valve rod G and the bellows E by the insulating pieces H and K, has a cap Q which operates the contact L through the plastic arm M. The closing of contacts N and O complete an open circuit which is coupled to the indicating lamp on the test panel for preliminary tests. The circuit is also coupled to the pressure operated relay for alcohol valve to ensure that oxygen flows first.
With valve B closed under air pressure the oxygen is shut off from the combustion chamber.
With the release of air pressure valve B opens under the influence of spring D and permits oxygen to flow under gravity to the heat exchanger and through the six ports to the oxygen nozzles in the combustion chamber. This intermediate position allows the tests of the flame pattern to be checked.
When the valve B is opened the under face seats on the plug F and prevents oxygen being trapped in the bellows and becoming gaseous.
When the turbine driven pumps are in action valve A remains closed until the delivery pressure has been built up sufficiently to overcome spring R. When this has been accomplished oxygen flows through the ports to the combustion chamber under pressure.
Should any part of the programme be defective the valve can be instantly closed by air pressure supplied via the relay operated valve.
At the end of the programme, i.e., fuel cut-off, the relay valve admits air to the adaptor C and shuts off the oxygen valve. The air pressure supplied to this valve is 35 kg/cm.^{2}.

58. SOLENOID OPERATED PRESSURISING VALVES, TYPE B (Plate 27, Section 1)

Position: On the main tubular framework of the rocket near the heat exchanger.

Duty: To apply air to the main alcohol valve and the oxygen distributing valve by remote control, i.e., from the operating switches on the test panel of the ground equipment or from sequence switch in the rocket. The valve is in two identical units, one serving the main alcohol valve and the other the oxygen distribution valve. For the purpose of description only one unit will be taken. A common air duct D serves to bolt the two units together and supply air at 30/35 kg/cm.^{2}; a locating pin in the base of the unit prevents them turning about D.

The main body of aluminium can be divided in two sections, one incorporating a solenoid actuated valve in the operating ports and the other a double-seated valve regulating the air supply to the oxygen and alcohol main valves.
The solenoid is operated by a current of 18/27 volts at ·8 to 1·2 amps. The coils examined were stamped 24 volts 53 watts. All joint rings are of soft aluminium, whereas in type A these were of synthetic rubber.

Whilst there are fewer components in this B type valve the production cost is higher than type A or the bakelite case version. The body is machined from the solid instead of being die cast. The advantages over the other type is that the body has not the same tendency to porosity, it does not depend on springs for its operation and the bellows are more reliable at low temperatures than the synthetic seals.

Sequence of Operation :

Valve A is normally open, valve B normally closed, while valve C is seated in the lower position.
Air is supplied through duct D and passes via ports E, F and G to both valve cylinders.
Air flows through A around the solenoid coil H through port G to the bellows J and lifts valve C on to its upper seating closing port K.
Air is now free to pass through port F and the flutes in stem L to the air adaptor P and thus to the fuel valves.
To vent air from the fuel valves and shut down air supply the solenoid H is energised by power supplied from the ground unit or rocket control unit and core N is held up under the influence of magnetic flux. Valve B is now opened and the pressure inside the bellows exhausted to atmosphere. The bellows thus contract and valve C is returned to its lower seating preventing air flow to adaptor F and opening port K to exhaust the pressurised valve control lines.
Spring R serves to return valve A when the power supply is cut.
Spring S enables the solenoid coil to be retained in its correct position.

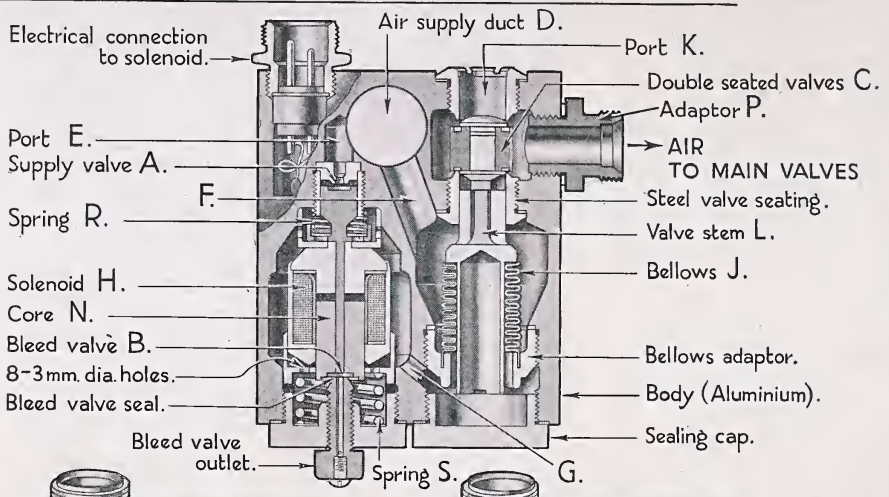
59. SOLENOID OPERATED PRESSURISING VALVE, TYPE A (Now obsolete) (Plates 28 and 29, Section 1)

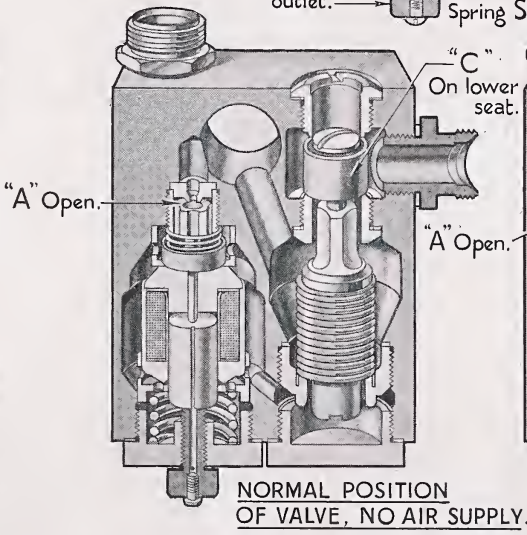
This valve was the alternative put forward to type B but for the reasons outlined in paragraph 58 was discontinued. It is situated in the same manner as type B and performs the same duties.

Sequence of Operation :

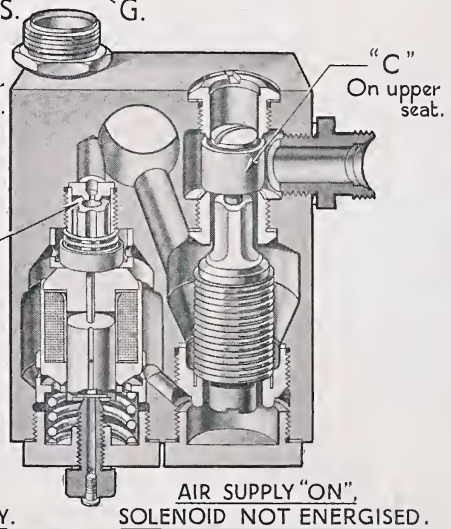
Valve A is normally open while valves B and C are normally closed.
Air is supplied through duct D and passes via ports E, F and G to both valve cylinders.
Air flows through valve A around the solenoid coil H through port G and distance piece J to the underside of piston K.
Air also flows via port E to the upper side of piston K.
With the assistance of springs M, N and O and the pressure on the underside of piston K the downward force is overcome and valve C is closed.
Valve B is closed by the down pressure on core Q.
Air is now free to flow from the underside of valve C through adaptor P to the fuel supply valves.
To close the valve the solenoid H is energised by current supplied from the ground unit or rocket control unit and core Q is drawn and held up under the influence of the magnetic flux. Valve B is thus opened and A closed.

SOLENOID OPERATED PRESSURISING VALVES-TYPE B.

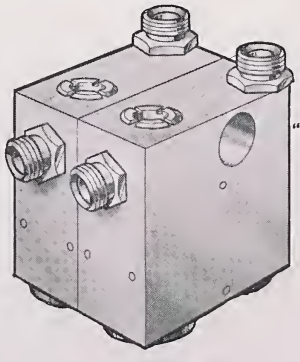




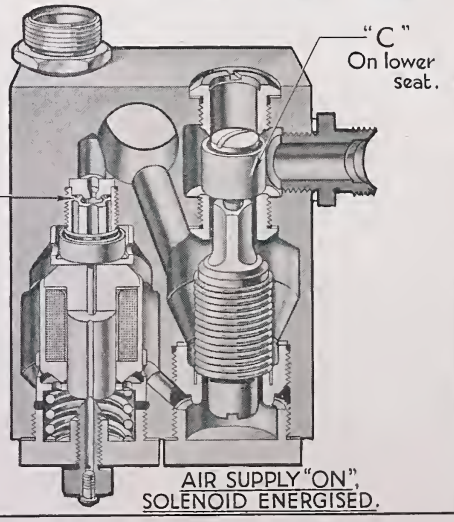
NORMAL POSITION OF VALVE, NO AIR SUPPLY.



AIR SUPPLY "ON", SOLENOID NOT ENERGISED.



BLOCK MOUNTING.



AIR SUPPLY "ON", SOLENOID ENERGISED.

No air can flow through port G to the underside of piston K which is thrust down against springs M, N and O. The underside of valve C is seated and closed.
The valves coupled to adaptor P are depressurised and the air allowed to escape through port R.
Valve B acts as a bleeder and depressurises the underside of piston K.
Spring S serves to return valve A to its off or normal position.

60. OXYGEN FUELLING VALVE (Fig. 14, Section 1)

Position: At the end of the branch pipe leading from the bottom of the oxygen tank towards the perimeter.
Duty: The valve is of the spring loaded non-return type fitted at the inlet end with a hose coupling thread. A screwed cap closes the inlet when disconnected from the fuelling hose. Its duty is to enable liquid oxygen to be filled into the tank when the rocket is in the vertical position on the firing platform.
Operation: The valve is normally closed.
Oxygen is pumped from the oxygen vehicle via a special light hose and the pressure forces valve A down against spring B and the liquid is then free to flow through the ports in the valve to the tank. When the tank is filled and pumping is stopped the head of oxygen and the spring returns the valve A on to its metal seating.

61. OXYGEN TOPPING UP VALVE (Plate 30, Section 1)

Position: Attached to the tail unit between two fins. When the tail unit is assembled on to the rocket a union nut, from a pipe leading to the oxygen tank outlet, is coupled on to adaptor F.
Duty: To replenish oxygen if after filling there is a delay before firing.
Operation : The closing cap A is removed and the supply hose connected in its place. As this hose is screwed home a central pin in the hose connection contacts the central pin of the valve forcing it downwards. This carries the valve seating B past the ports in the inner sleeve allowing liquid to flow. Spring D returns the valve to the closed position as the hose is disconnected.

62. CHECK-VALVE—NON-RETURN VALVE (Fig. 15, Section 1)

Position: On 4 mm. air line, i.e., charging line to air bottles in control compartment (Plate 9).
Duty: To enable the cylinders to be charged with air at 200 atmospheres from the ground unit and to hold this pressure when the supply is cut off. A valve of the same construction but with a bleed hole incorporated is used on the alcohol tank valve pressurising line (Plate 31, Section 1).
Function: An air supply is connected to adaptor A which lifts valve B off seating C and allows air to flow through adaptor D to the air cylinders.
When air supply is disconnected the air pressure in the system returns valve B on to seating C with the aid of spring E. No air can now return through adaptor A and the system is sealed.

63. SOLENOID OPERATED AIR VALVE ASSEMBLY (Plate 31, Section 1)

Operating pressure 30/35 kg./cm.^{2}.
Serving : (1) Alcohol tank valve (S1H).
(2) Alcohol pressurising valve (S3H).
Position: At the top of the alcohol tank.
Duty: To apply air pressure and exhaust the alcohol tank valve. To apply air pressure to the alcohol pressurising valve.

Sequence of Operation

The valves are normally closed, as shown in the attached sketch.
Air is applied via adaptor A from the ground unit during the preparations for firing, and from the air storage cylinders on the main driving assembly during flight.
Normally valve B is held on its seating by spring C and air pressure.
At the desirable point in the programme coil D is energised and core E drawn downwards under the influence of magnetic flux, and push rod F thrusts valve K on to its seating. At the same time pin G pushes valve B against spring C off its seating and allows the air to flow through the valve via choke H to the alcohol tank valve.
A similar action is taken to feed air to the alcohol pressurising valve, but both valves are not operated at the same moment since it is desirable to pressurise the alcohol tank later in the programme.
When the solenoid is de-energised the valves return to their normal positions and the alcohol tank valve is vented through choke H which allows air to pass through its small orifice to be exhausted to atmosphere through port J.
NOTE.—The choke valve H under direct pressure is raised off its seating M and bye-passes air through adaptor P. When air tends to be exhausted back through adaptor P choke H is returned to its seating M, allowing a limited flow to exhaust through the small orifice to ports J.
No choking of the line to the alcohol pressurising valve is incorporated.

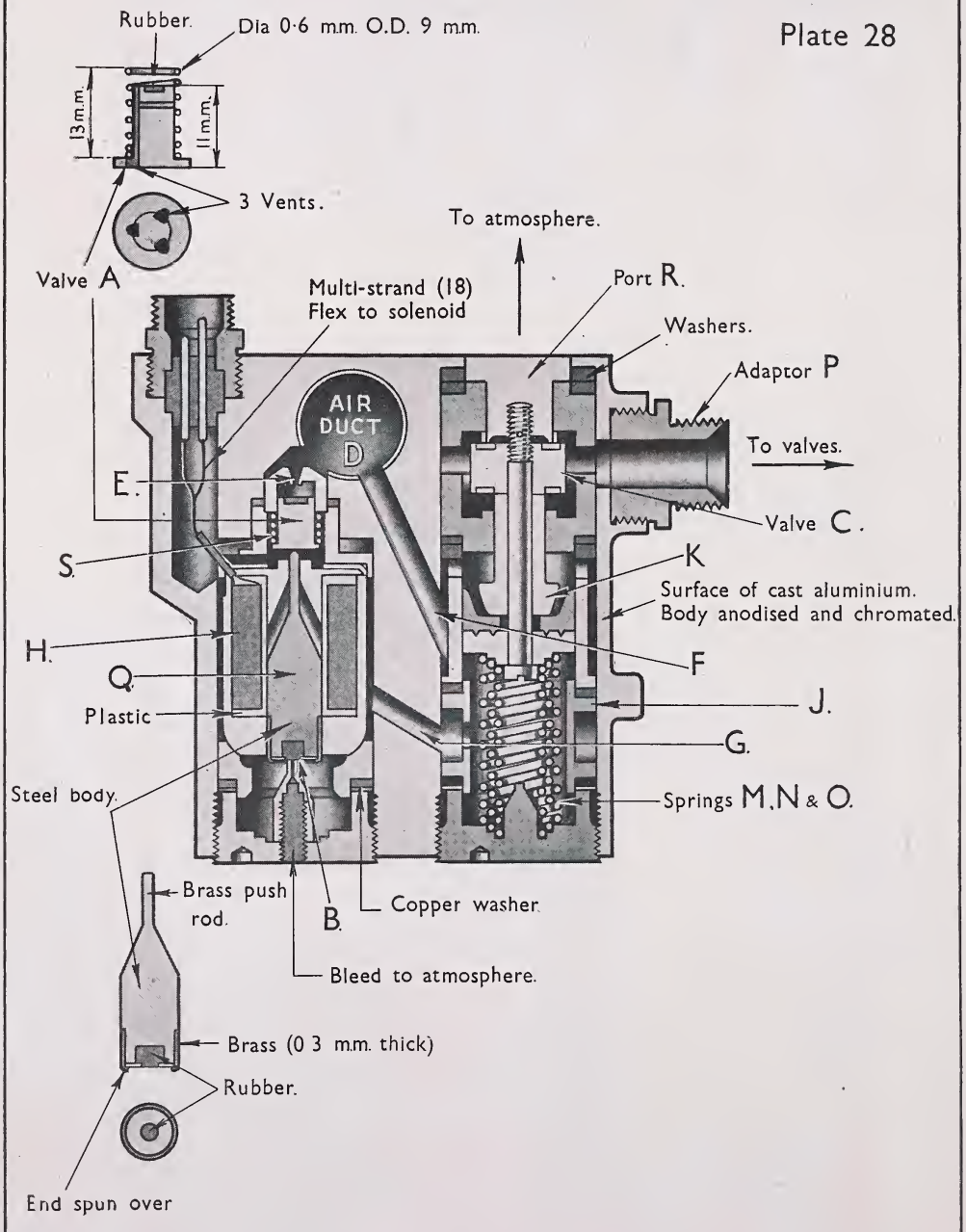
64. SOLENOID OPERATED AIR VALVES (Plate 31, Section 1)

Position: In steam unit air system. Valves numbers D25H and D1H (Plate 6, Section 1).
Duty: D25H. To apply air pressure to the piston of the main hydrogen peroxide valve, thus opening the valve and allowing hydrogen peroxide to flow to the reaction chamber (Plate 6, Section 1).
D1H. To apply air pressure to the pistons of the hydrogen peroxide tank vent valve and sodium permanganate tank vent valve. (Plate 6, Section 1.)
These valves are of the same construction as described in paragraph 63, and operate against the same air pressure.
In the normal position air is unable to pass through the valve owing to valve B being held against its seating by spring C and air pressure.
When the solenoid is energised the push rod is forced downwards, carrying with it valve K, which in turn pushes valve B off its seat. Valve

SOLENOID OPERATED PRESSURISING VALVE.

TYPE A.

Plate 28



K closes on to the upper seating and air is free to flow through the adaptor P.

When the solenoid is de-energised spring C causes valve B to reseat and lifts valve K, thus exhausting the pressure in the lines through ports J.

65. HAND OPERATED ALCOHOL DRAIN VALVE (Fig. 16, Section 1)

Position: On the external wall of the venturi on the lowest point in the alcohol supply system.

Duty: To drain the alcohol system after defuelling the tank.

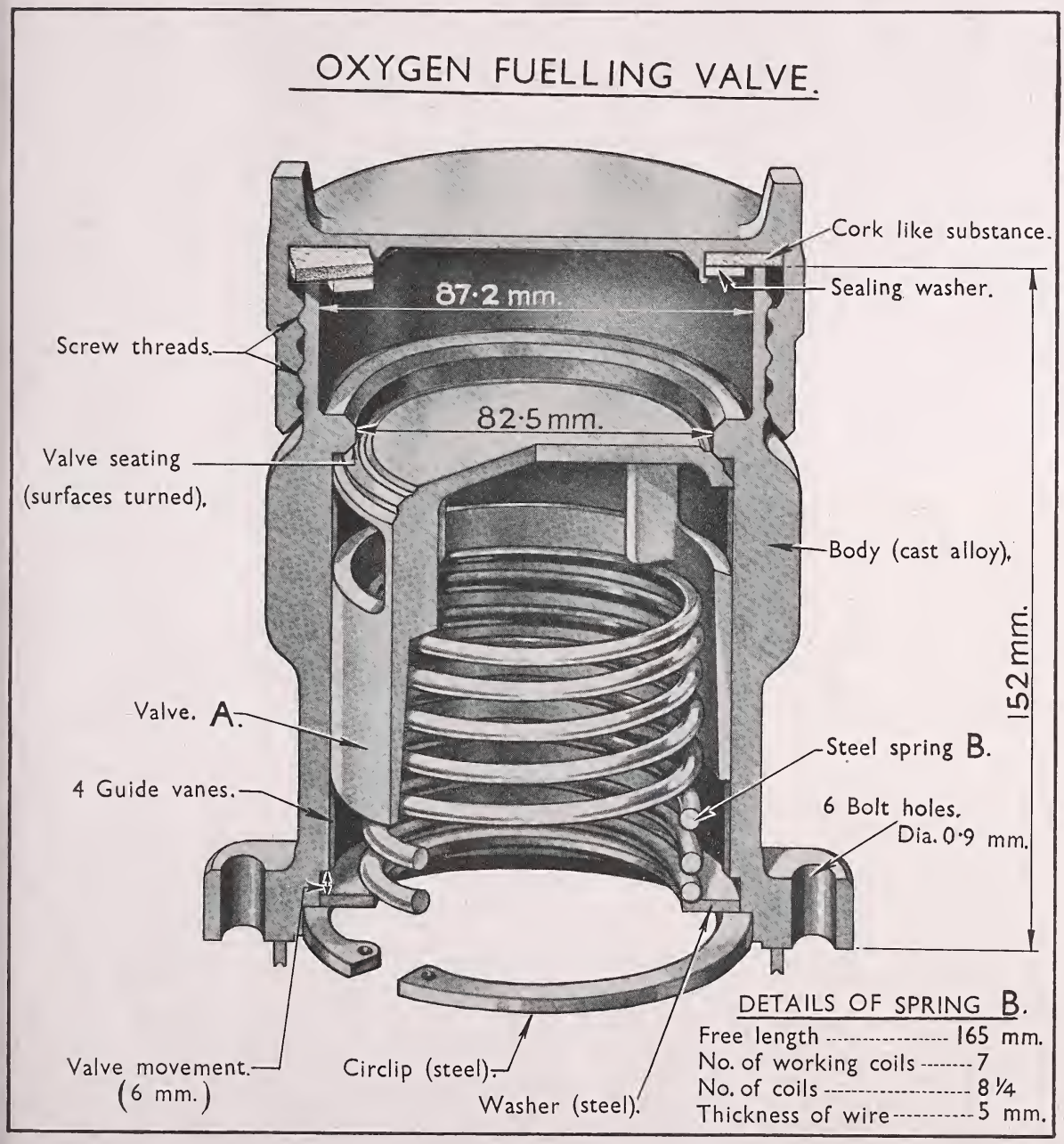
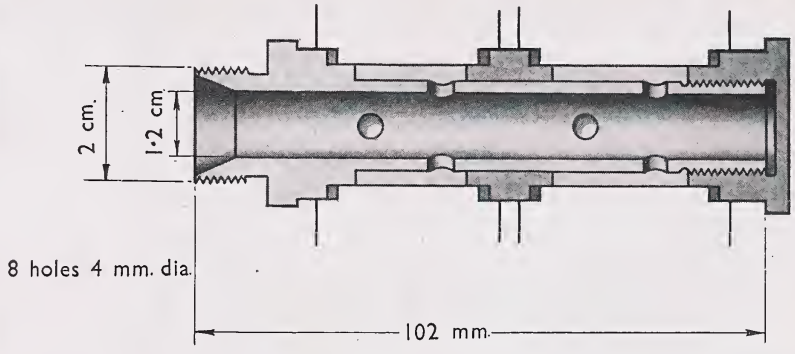


Fig. 14

SOLENOID OPERATED PRESSURISING VALVE.

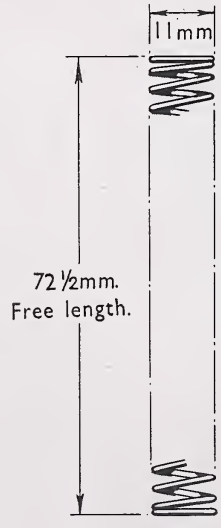
TYPE A.

Plate 29



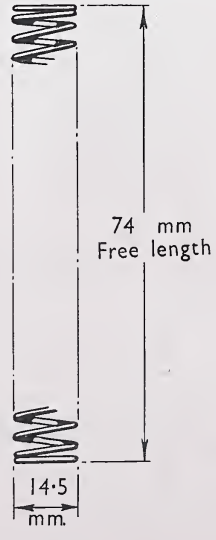
D

Dia of wire ---------- 1 mm.
No of coils ---------- 24¼
No of working R.H. coils ----- 21



M

Dia of wire ---------- 1·5 mm.
No of coils ---------- 18 ¾
No of working L.H. coils ---- 16



N

Dia of wire ---------- 1·7 mm.
No of coils ---------- 13 ¾
No of working R.H. coils ----- 11

O

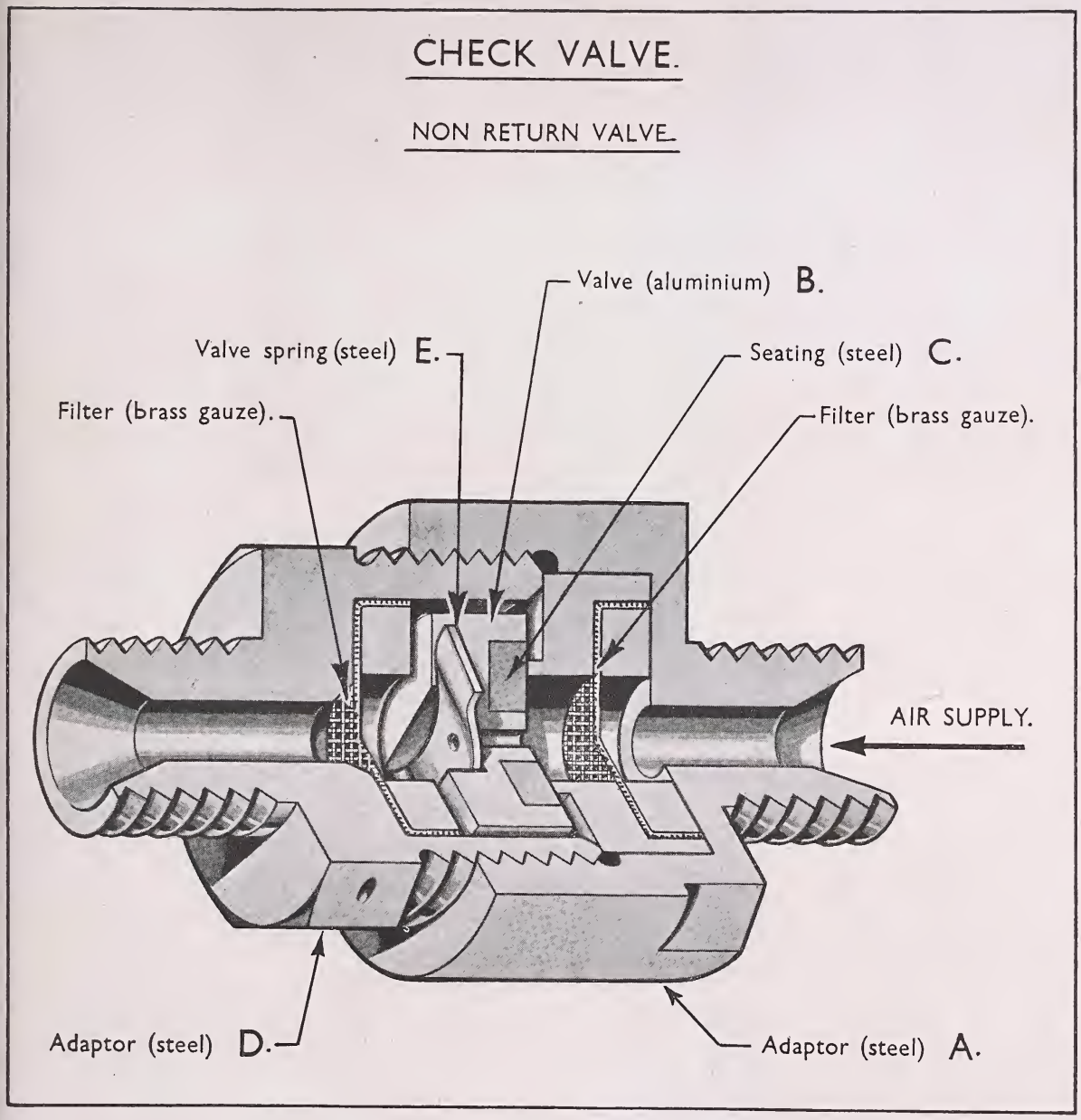


Fig. 15

Operation: Valve A is normally closed as shown in the sketch. By turning handwheel B in a clockwise direction it advances into the screw thread of the valve body. Since valve A is prevented from rotating with the handwheel by pin C it moves upwards through the internal thread of the handwheel and is raised off its seating. The alcohol is now free to pass over the valve seating, through the slots D and out via the hollow stem of valve A.

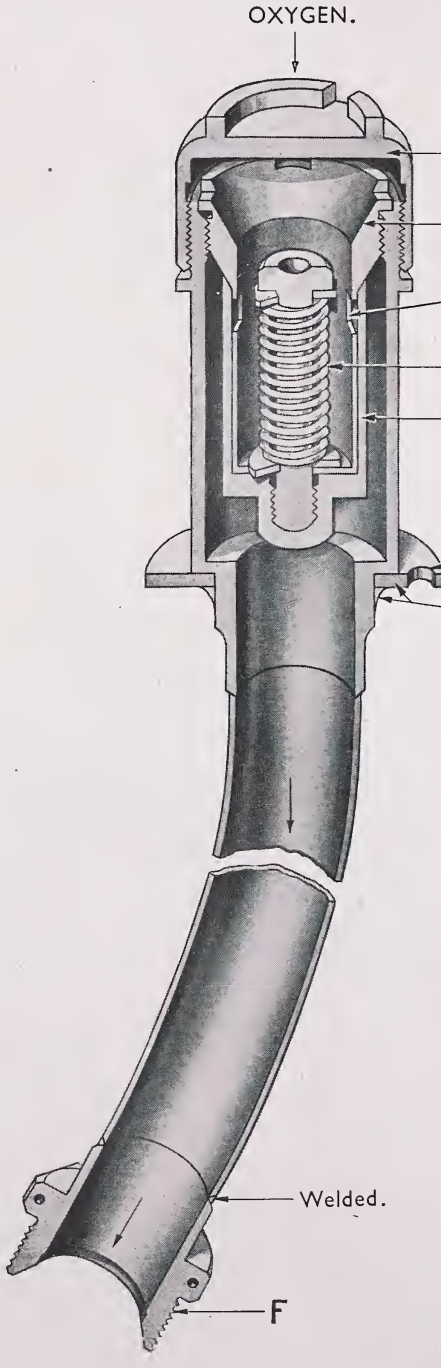
66. HAND OPERATED HIGH PRESSURE AIR VALVE (Fig. 17, Section 1).

Position: On the steam unit near the hydrogen peroxide tank.

Duty: To allow the air storage cylinders to be charged with air at 220 atmospheres .

Plate 30

OXYGEN TOPPING - UP VALVE.



NOTE
All components of light aluminium alloy anodised and stained.

Valve may also be used for draining purposes.

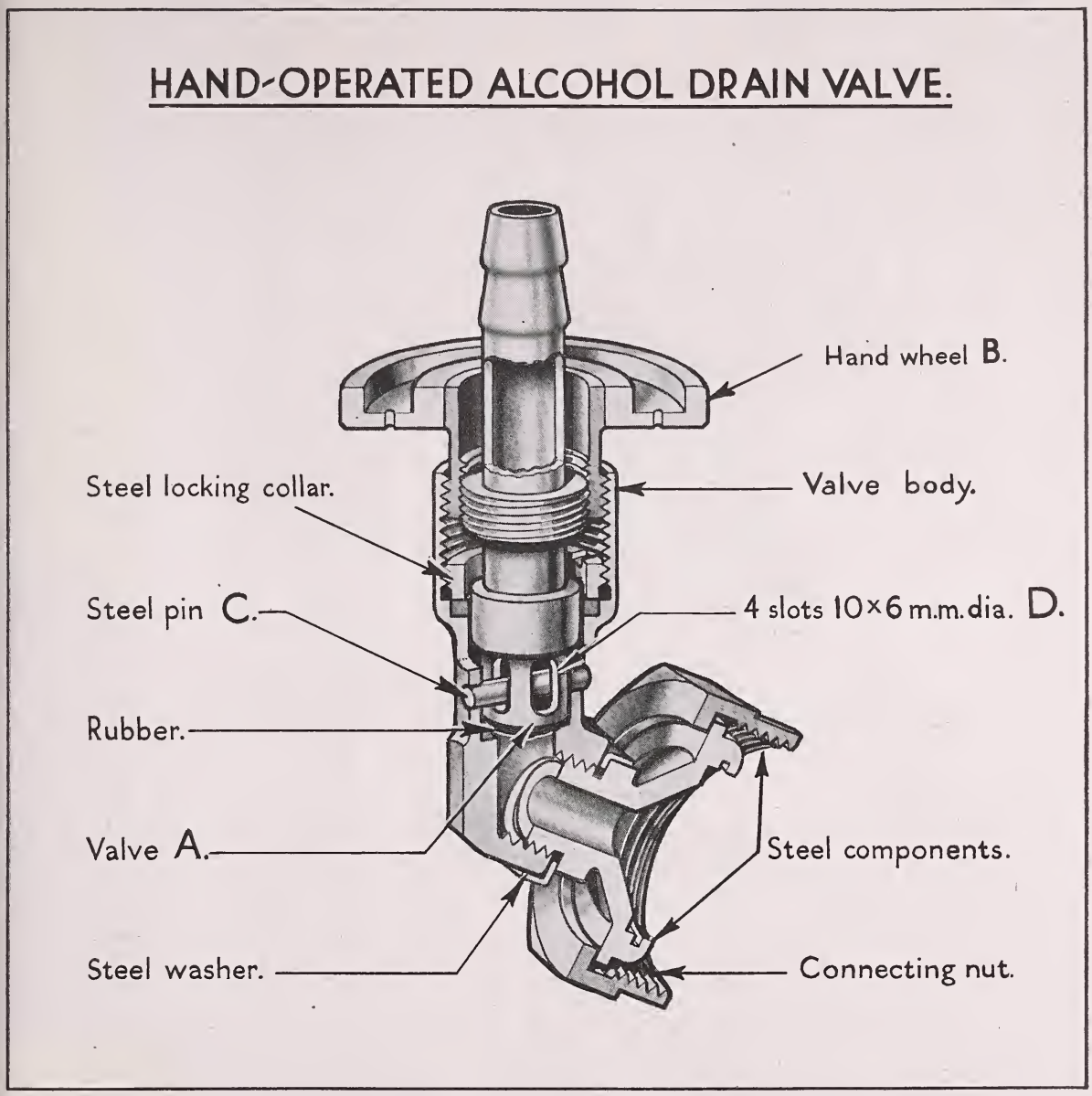


Fig. 16

SEQUENCE OF OPERATION:

The valve is normally closed as shown in the sketch.
Before firing the rocket the air supply from the ground unit is supplied, via a copper pipe terminating at the tail unit, to adaptor A and valve E is opened by turning hand-wheel F anticlockwise.
When the air is switched on from the ground unit, valve B is opened against spring D and air is free to flow to the storage cylinders via outlet H and to the reducing valve via outlet G.

Before firing the valve E is closed and air bottles topped up, the air supply from the ground unit is then cut off and valve B is returned to its seating under the influence of spring D and the air pressure from the storage bottles. The air supply to the steam unit and various oxygen and alcohol valves is now drawn from the storage cylinders.

STEAM UNIT

67. REDUCING VALVE AND HEATER (Plate 32, Section 1).

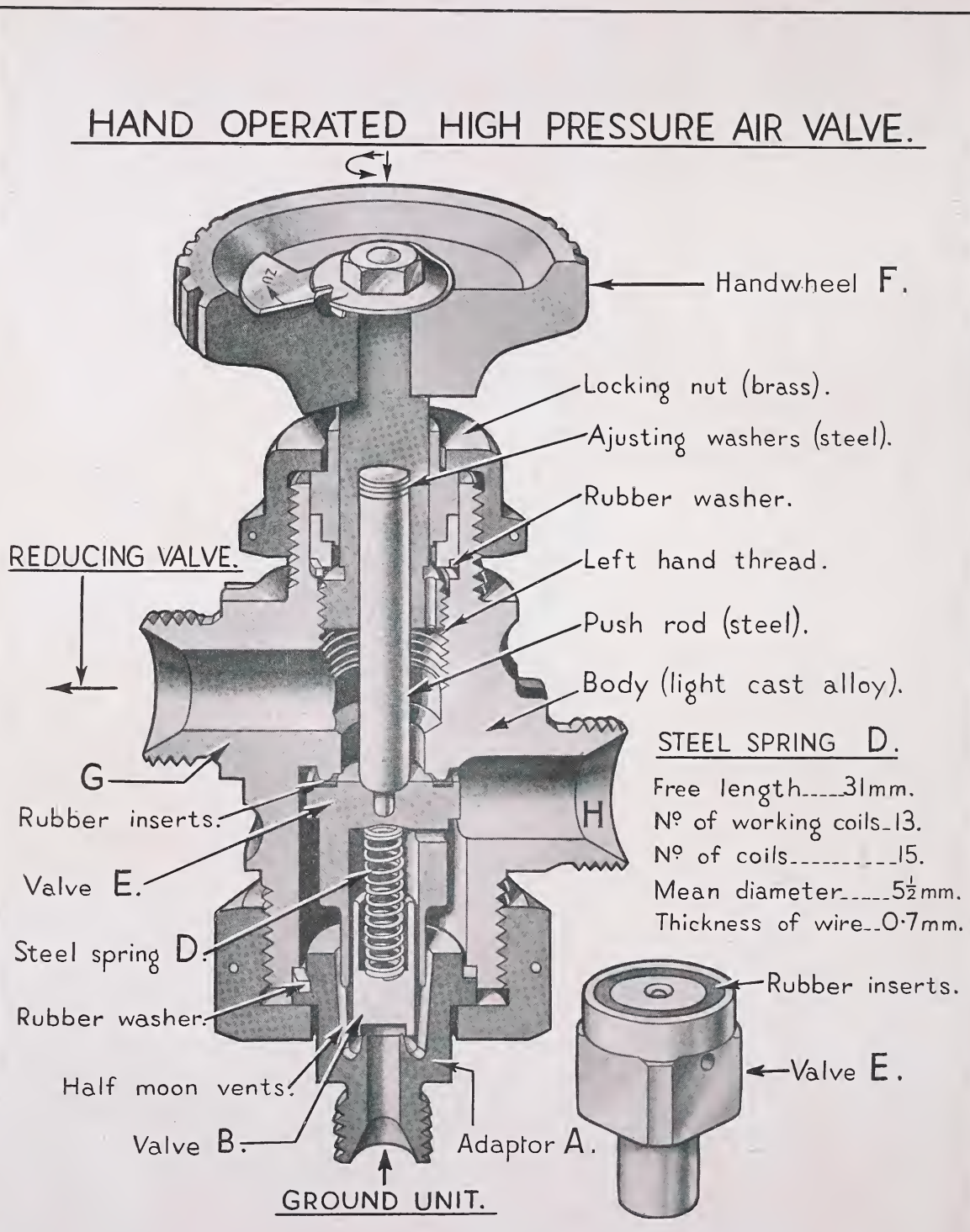

HAND OPERATED HIGH PRESSURE AIR VALVE.
Handwheel F.
Locking nut (brass).
Ajusting washers (steel).
Rubber washer.
REDUCING VALVE.
Left hand thread.
Push rod (steel).
Body (light cast alloy).
STEEL SPRING D.
Free length____31mm.
Nº of working coils_13.
Nº of coils_____15.
Mean diameter_____5½mm.
Thickness of wire__0·7mm.
G
Rubber inserts.
H
Valve E.
Steel spring D.
Rubber washer.
Half moon vents.
Valve B.
Adaptor A.
GROUND UNIT.
Rubber inserts.
Valve E.

Fig. 17

Position: Below the hydrogen peroxide tank and connected to the air storage cylinders housed in the tubular framework of the rocket.

Duty: To reduce the air supply from the storage cylinders from 220 kg./cm.^{2} to 32/35 kg./cm.^{2}. The air at 32/35 atmospheres is used to pressurise the hydrogen peroxide tank, permanganate tank, alcohol and oxygen valves, and various valves in the steam unit.
The heater serves to prevent freezing up due to pressure reduction and proximity of the oxygen lines.

Operation: The valve A is normally open as shown. Air at 220 kg/cm.^{2} pressure is supplied to adaptor B from an air filter, and passes down ports C through the valve via ports D, and pressurises the outlet side of the valve to 32/35 atmospheres. Should the pressure of air in the outlet chamber rise above the set requirement, piston G is forced upwards against spring E and valve A is slightly closed under the influence of spring F and increases air pressure in the lower chamber from port H, until the pressure is restored to 32/35 atmospheres.

NOTE : A universal joint J is incorporated between the valve rod and piston G, and is intended to cancel any mal-alignment which may result from the downward thrust spring E.

ELECTRICAL HEATER

The heater has a capacity of 100 watts and is connected to a 27 volt supply and serves to keep the valve at a normal operating temperature throughout the programme. The element is enclosed in a coiled steel tube and the complete valve and heater is lagged with glass-wool.

68. HIGH PRESSURE REDUCING VALVE FITTINGS (Plate 33, Section 1)

1. FILTER

Position: On the inlet connection to the reducing valve.

Duty: To extract dust and moisture from the air before it passes into the valve.

Operation : Air enters body A and passes through the three legs of the plastic grid B to the external walls of the ceramic filter C. After passing through the filter the air flows through adaptor D to the reducing valve.

2. SAFETY VALVE

Position: On the outlet of the reducing valve.

Duty: To blow off and relieve any excess air pressure on the system should the reducing valve fail to do its duty.

Operation: The valve is normally as shown in the sketch. Air is fed to the inlet E from the reducing valve and flows through to the alcohol and oxygen air valves via the banjo outlet F, through outlet G to the solenoid valves controlling the pressurising of the hydrogen peroxide and permanganate tanks and the various air operated valves in the pipe lines. Should the air in the system rise to 42 atmospheres valve H is raised off its double seating against spring K and air escapes through ports J and over the valve seats to exhaust through the spring chamber.

When the air pressure in the system is restored spring K returns valve H to its normal position.

3. BLEED VALVE

Position: On the side of the safety valve.

Duty: Test cock for use during the initial tests on the steam unit.

Operation : The valve is normally closed as shown. By turning handwheel anticlockwise the valve is raised off its seating allowing air to escape via port N.

4. BLOW-DOWN VALVE

Position: Screwed on the side of the safety valve by boss T.

Duty: For blowing down the system during tests, etc.

Operation: This is a typical shut off valve of the needle seating type, and is normally closed as shown in Plates 32 and 33, Section 1.
By turning the handwheel Q the plastic valve S is forced off its seating by air pressure and air is exhausted through outlet T to atmosphere.

69. VENT VALVE FITTED ON HYDROGEN PEROXIDE OR PERMANGANATE TANKS (Fig. 18, Section 1)

Position: Connected to the pressurising lines to the tanks.

Duty: To enable air to be vented from the tanks during the filling.

Sequence of Operation: The valve is normally open under the influence of spring F as shown and the upper face of valve C is held on the seating on body A.
When the tank is being filled the displaced air is vented through the valve as indicated.
After filling the tanks, air at 32/35 kg./cm.^{2} pressure is applied to adaptor E acting on the piston B, and valve C is forced down against spring F on to seating G and the valve is closed.
It should be noted that although the construction of the valve is the same for both tanks the materials used differ. Valve C, ring D and body A are of aluminium for the hydrogen peroxide tank and of brass for the permanganate tank.

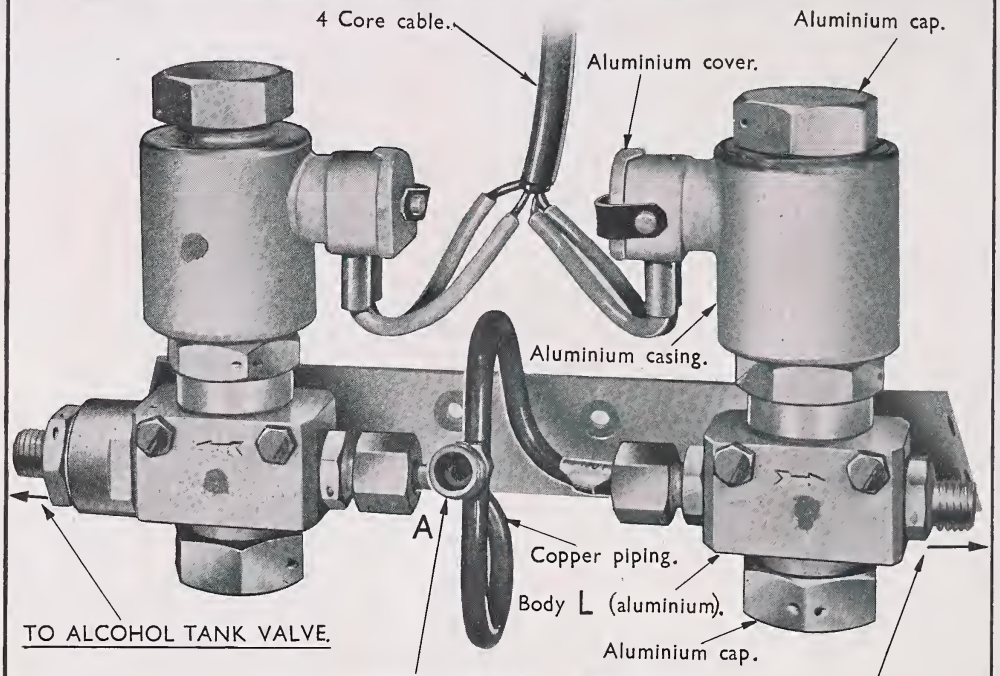
70. SOLENOID OPERATED VALVE IN HYDROGEN PEROXIDE LINE D8H (Plate 34, Section 1)

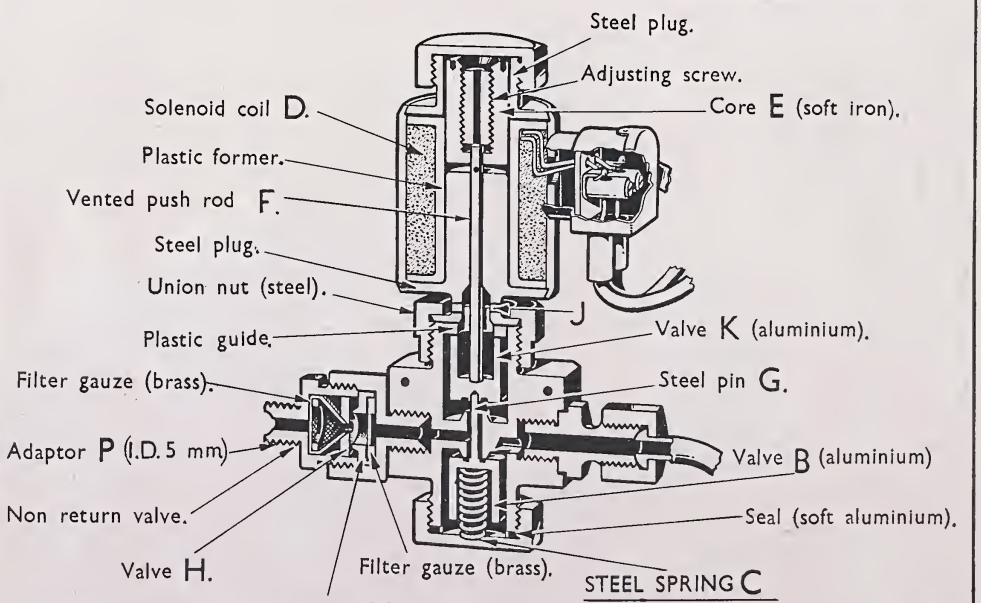
Position: Situated on the peroxide bye-pass line to control the flow via the bye-pass, through the main peroxide valve.

Operation: The normal position of the valve is as shown, closed. The piston of valve C is a sliding fit in its housing and when liquid is flowing under pressure through adaptor F the clearance enables the liquid to be forced between the piston and cylinder and to the underside of valve A. Thus the pressure on the inlet side assists the spring M to keep the valve closed. The push rod H of the solenoid when de-energised rests on the top of the pilot valve A. When the solenoid is energised, the push rod forces valve A downwards for 1 mm., thereby allowing the pressure of liquid to escape through the outlet. When the release valve A has been pushed down 1 mm. it contacts the spring ring, and valve C is opened against spring thus allowing free passage of liquid from F to E.

SOLENOID OPERATED AIR VALVE ASSEMBLY.

Plate 31



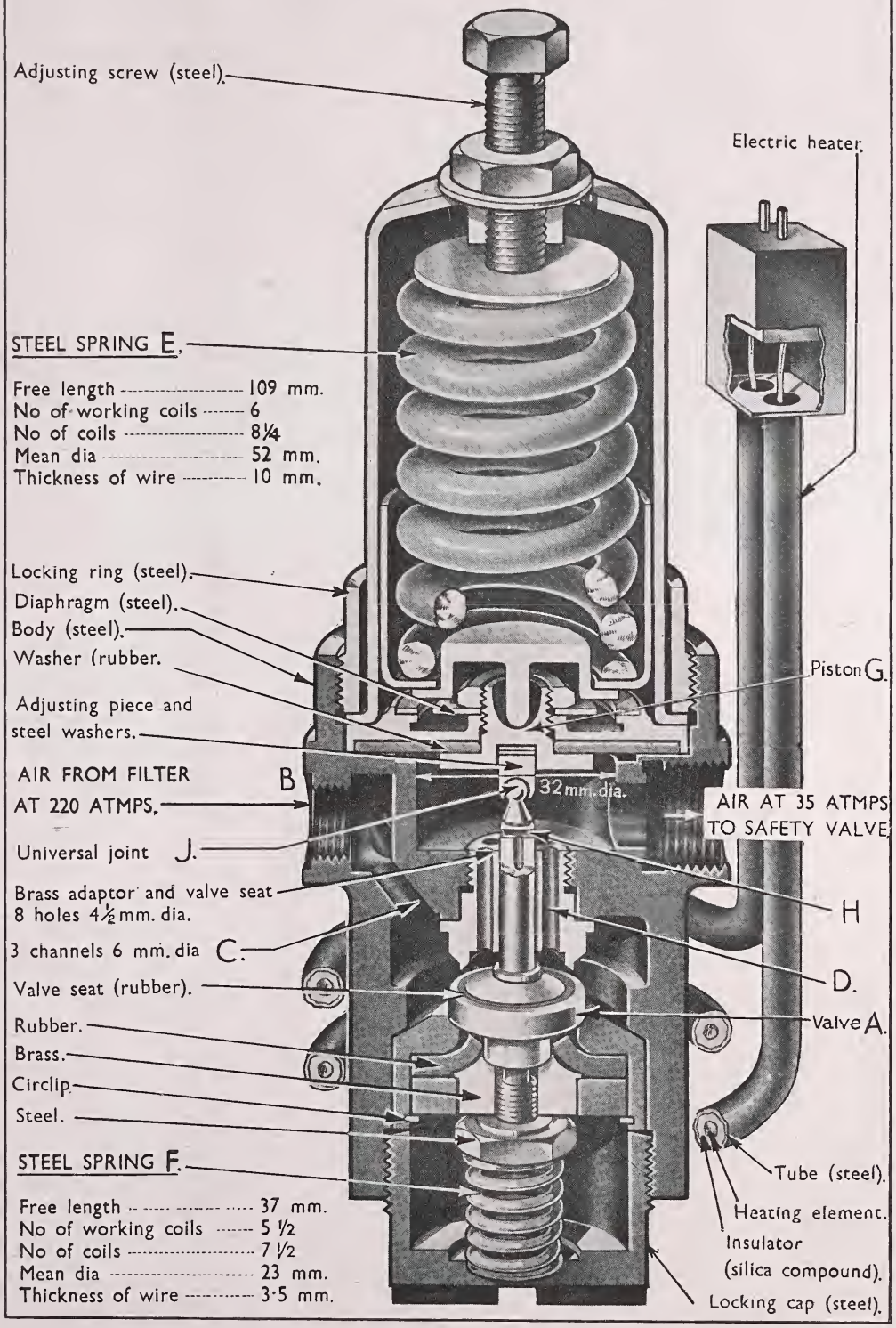


STEEL SPRING C

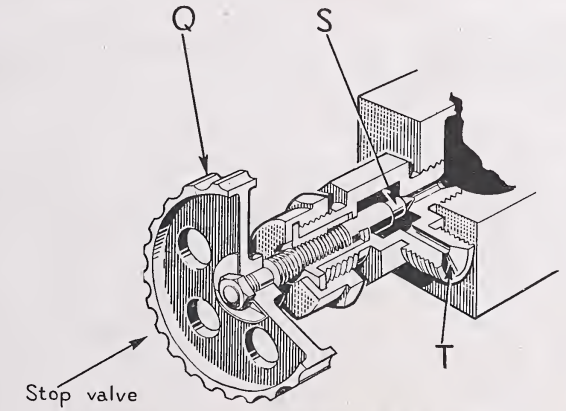
Free length	23 m.m.
Dia of wire	1 m.m.
No of R.H. coils	11¾.
No of R.H. working coils	9.
O.D. of coils	11·5 mm.

REDUCING VALVE AND HEATER.

Plate 32



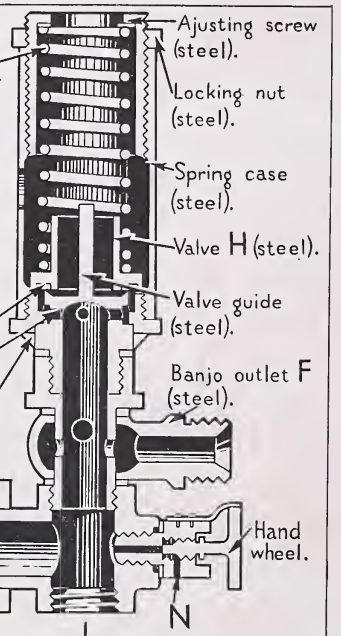
HIGH PRESSURE REDUCING VALVE FITTINGS 220/30·35 ATMOSPHERES.

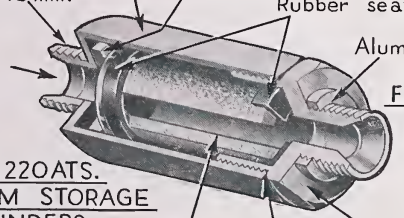


BLOW-DOWN VALVE.

SPRING STEEL K.

Free length 88mm.
Dia. of wire 3·5mm.
Nº R.H. coils 13¼.
Nº working coils 11.
O.D. of coils 25mm.





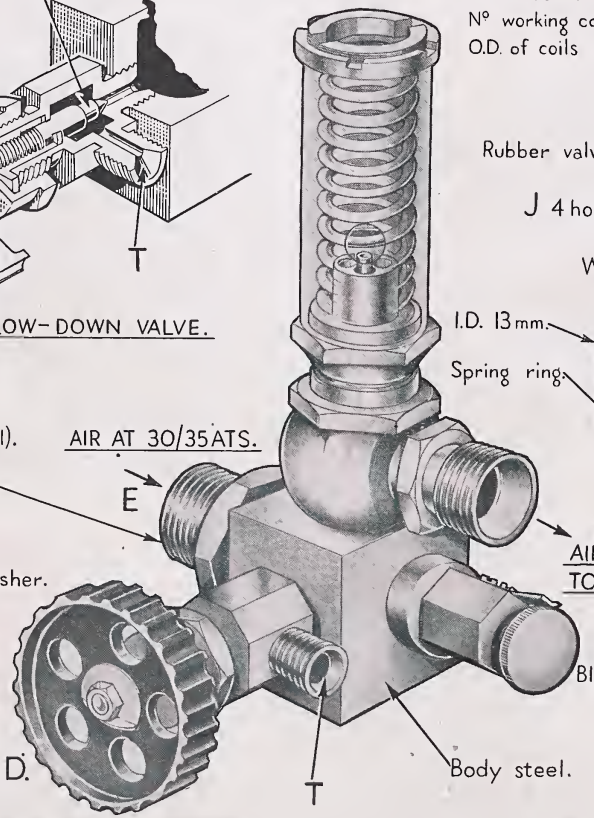


Plate 33

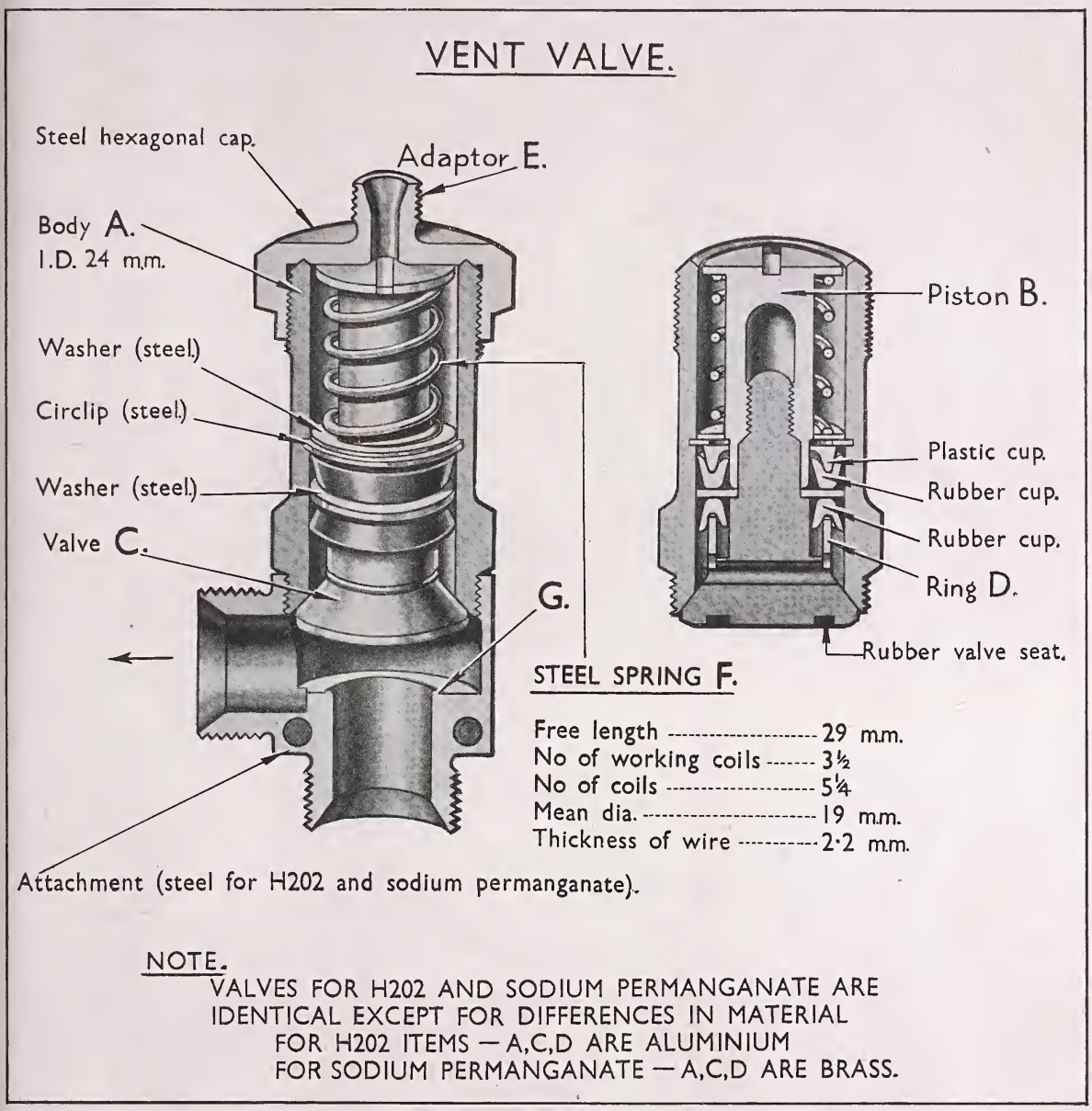


Fig. 18

71, HYDROGEN PEROXIDE FEED VALVE (Plate 35, Section 1)

Position: In the pipe line between the hydrogen peroxide tank and the reaction chamber.

Duty: To feed hydrogen peroxide into the reaction chamber.

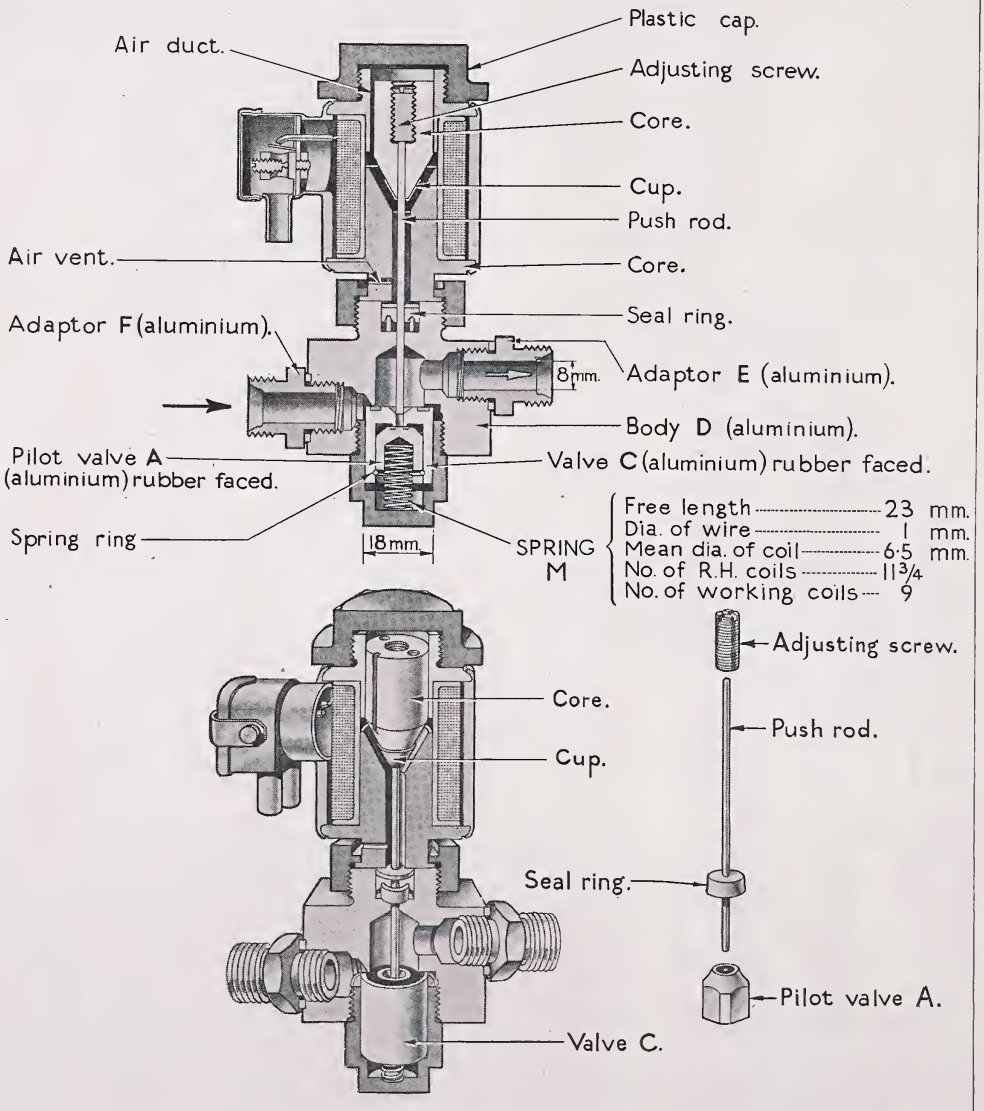
Operation: The valve A is normally closed as shown, and is retained so by spring F.

To open the valve A, air is supplied at 32/35 atmospheres via a solenoid valve to adaptor E. The air pressure pushes piston G downwards against spring F which in turn moves valve A off its seating and allows the hydrogen peroxide to flow through outlet D to the reaction chamber. A small bye-pass is brought from the pipe connected to the pipe feeding inlet B up to boss C with the solenoid operated valve described in para. 20.

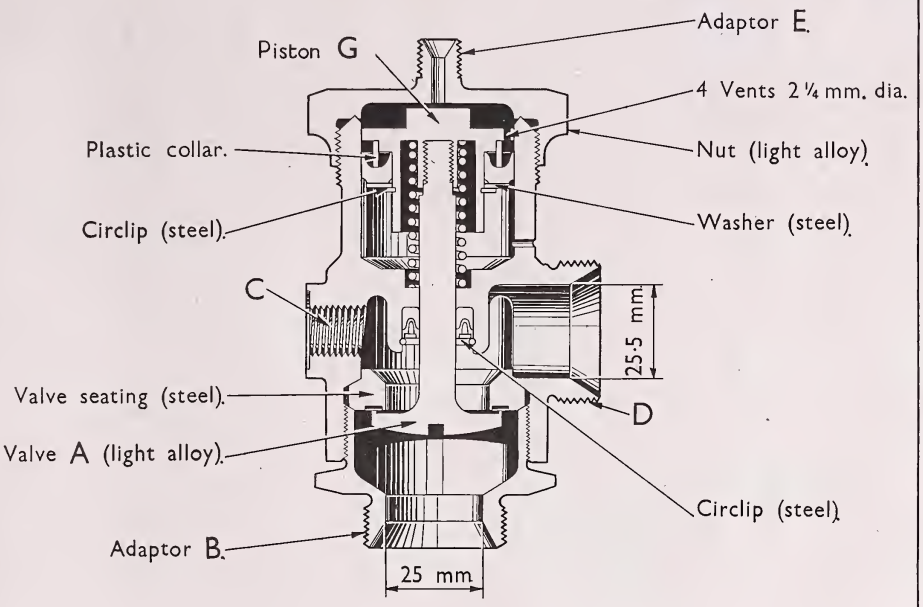
72. REACTION CHAMBER (Plate 36, Section 1)

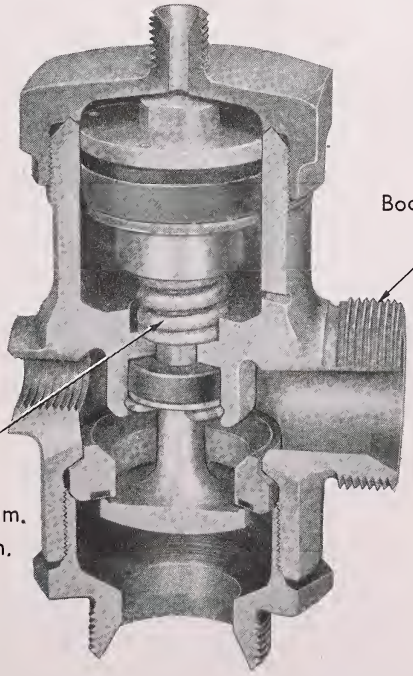
Duty: To produce high pressure steam from the reaction of hydrogen peroxide and sodium permanganate, the steam generated being fed to the turbine and driving the pumps.

SOLENOID OPERATED HYDROGEN PEROXIDE VALVE.



HYDROGEN PEROXIDE FEED VALVE.

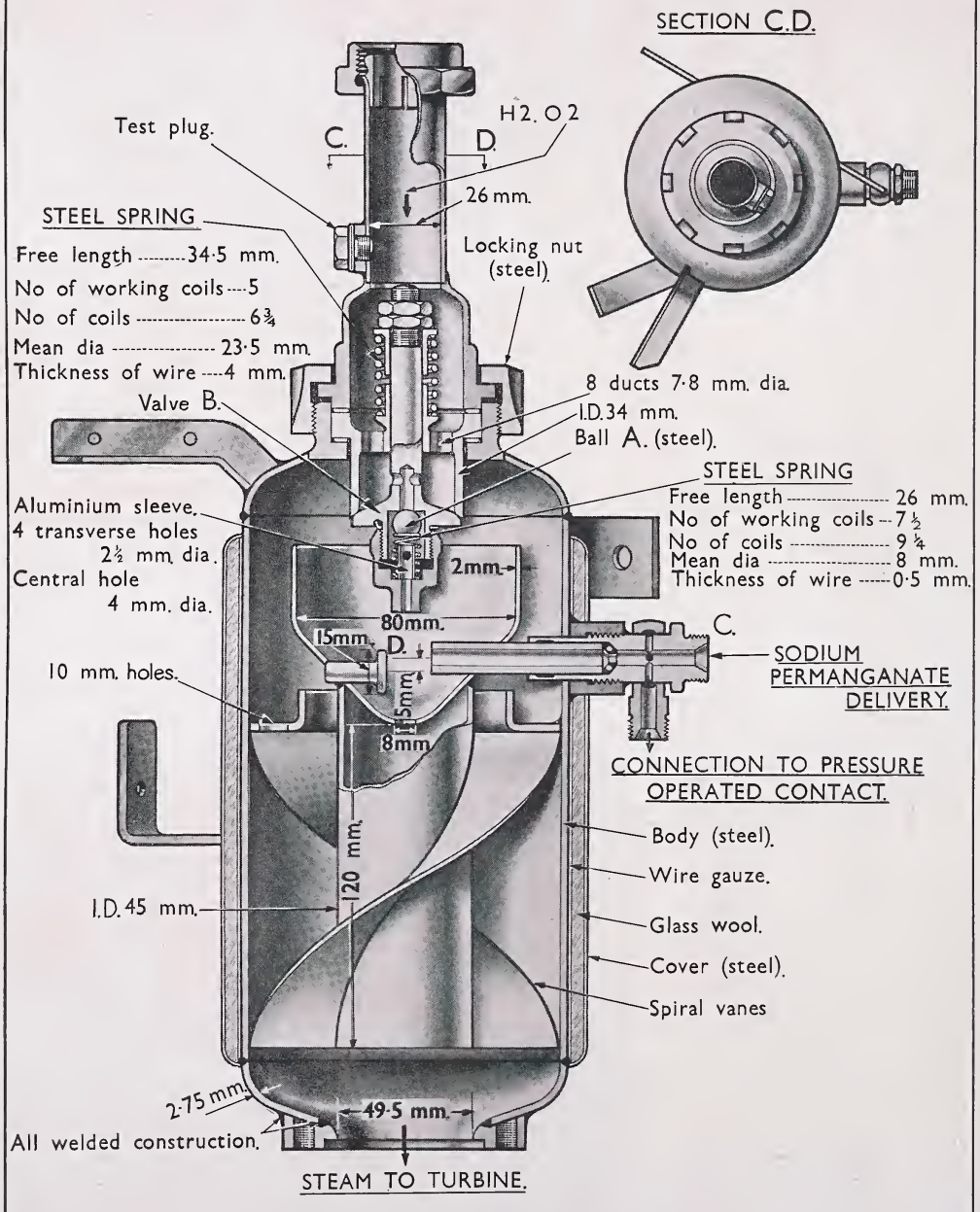




STEEL SPRING F.

Free length	47·5 mm.
Mean dia.	19 mm.
No. of coils	10 ¼.
No. of working coils	8.
Thickness of wire	3 mm.

STEAM UNIT REACTION CHAMBER.



Operation: Ball valve A and mushroom valve B on the hydrogen peroxide side are normally closed. Sodium permanganate is forced through adaptor C via a choke and impinges on baffle D. The sodium permanganate is then sprayed upwards from the cup and over into the baffles. The main hydrogen peroxide valve comprises a mushroom valve B and a ball seated valve A. In operation both of these valves open at the same pressure and hydrogen peroxide is fed firstly from the jet through the cup and also sprayed from valve B into the baffles. The reason for this duplex feed is that by taking a jet through the cup the inner section is heated, thereby assisting the disintegration of the H_2O_2. The body of the chamber is lagged with glass-wool to reduce heat losses.

73. DIAPHRAGM OPERATED CONTACT SWITCH D2R (Fig. 19, Section 1)

Duty: This switch is incorporated into the steam unit system in order that peroxide shall not be fed into the reaction chamber until sodium permanganate solution is present. In order, however, to guard against flooding, the switch operates at 1·5 atmospheres, although the feed pressure on the permanganate is 30 kg./cm.^{2}

Sequence of Operation: Pressure is applied to adaptor A from the permanganate delivery pipe, and when it has reached 1·5 kg./cm. the copper diaphragm B forces piston C down against spring D. Pin E engages lever F which in turn moves switch G down to make contacts H and J. Thus, the external circuit connected to this plug K is closed to energise the solenoid valve. Adjustment is carried out by means of the screw L which alters the tension of the spring D.

74. NON-RETURN VALVE FOR HYDROGEN PEROXIDE AND SODIUM PERMANGANATE TANK PRESSURISING LINES (Plate 37, Section 1)

Position: In the air pressurising lines to the tanks.

Operation: The valve is normally closed as indicated and is held on its seat by the spring B which is an integral part of the valve.

When air at 32/38 atmospheres is applied to adaptor D the valve is raised off its seating and air passes through body A to pressurise the tanks.

On test it was found that the valve will not lift until a pressure of 1·5 kg./cms. is applied.

As is usual the valve on the permanganate side of the system is made of brass and that for the hydrogen peroxide of light alloy.

75. NON-RETURN FOR VALVE DRAINAGE AND WASHING FITTED TO H_2O_2 AND SODIUM PERMANGANATE TANKS (Fig. 20, Section 1)

Position: At the end of the drain pipes from both the above-mentioned valves.

Description: Referring to Fig. 20, the valve is normally closed under the pressure of the spring B. The adaptor D is screwed on to the drainage pipe on the outlet of each tank.

Operation: A coupling is screwed on to body C, which is so designed as to mechanically lift valve A off its seating against the pressure of spring B.

76. FIVE-WAY COUPLING (Plate 38, Section 1)

Position: On the tail unit between two fins, and is the coupling piece to which pipes 1 to 5 (Plate 6, Section 1), fit when the tail unit is positioned over the propulsion unit.

Operation: The five-way coupling is actually part of the tail unit assembly and when the rocket is mounted on the firing platform the coupling mates with its opposite number. Jointing between the ground and rocket couplings is carried out by means of synthetic rubber seals which are located in the ground coupling, the pipes on the rocket connection passing through the inside orifice.

Plate 38 shows the services fed to the coupling.

77. FUNCTIONING OF PROPULSION UNIT (Plate 6, Section 1)

After the rocket has been set up on the firing platform prior to fuelling, the five-way coupling is connected to the ground equipment coupling, the pipes of which are served from a valve box fitted to the platform. The oxygen topping up connection is linked up with its counterpart on the firing platform at the same time. The final pressurising tests are then made (described in Section 3).

Within the valve box is a safety device consisting of pressure operated contacts which prevents the pressure in the oxygen tank exceeding 1·5 atmospheres. This device is operated by the pressure fed back through pipe 1 from the oxygen tank when it is being supplied by air through pipe 5.

78. During fuelling the pipes 1 to 5 and the oxygen topping up pipe are left connected. Air is supplied through pipe 2 and charges up the air bottle reservoir to 220 kg./cm.^{2} the stop valve being closed. Through a reducing valve in the valve box a pressure of 31/35 kg./cm.^{2} is applied through pipe 4 which feeds this pressure to the oxygen vent valve, and via O3H and S2H to the oxygen distribution valve and main alcohol valve. The alcohol tank valve line is pressurised up to the solenoid valve S1H. In these circumstances the positions of the main valves are :—

(*a*) Oxygen vent valve open.
(*b*) Ports to atmosphere in O3H and S2H closed therefore.
(*c*) Pressure on oxygen distribution valve pilot closes valve.
(*d*) Pressure on alcohol main valve piston closes valve.
(*e*) Remaining valves are in normal position.

79. The rocket is now fuelled, the alcohol tank being filled first and a preliminary amount of liquid oxygen pumped into the tank to cool it before it is filled. Whilst the liquid oxygen is being pumped in, the permanganate and hydrogen peroxide tanks are filled. With fuelling complete the air supply to pipe 4 on the five-way coupling is shut off and the air to the oxygen vent valve exhausts to atmosphere through the valve box. The vent valve closes, but the other valves remain as in para. 78 since the non-return valve in pipe 4 holds pressure in the line. The stop valve on the air bottle reservoir is now opened allowing pressure from the bottles to flow into those lines served from pipe 4.

DIAPHRAGM OPERATED CONTACT SWITCH.

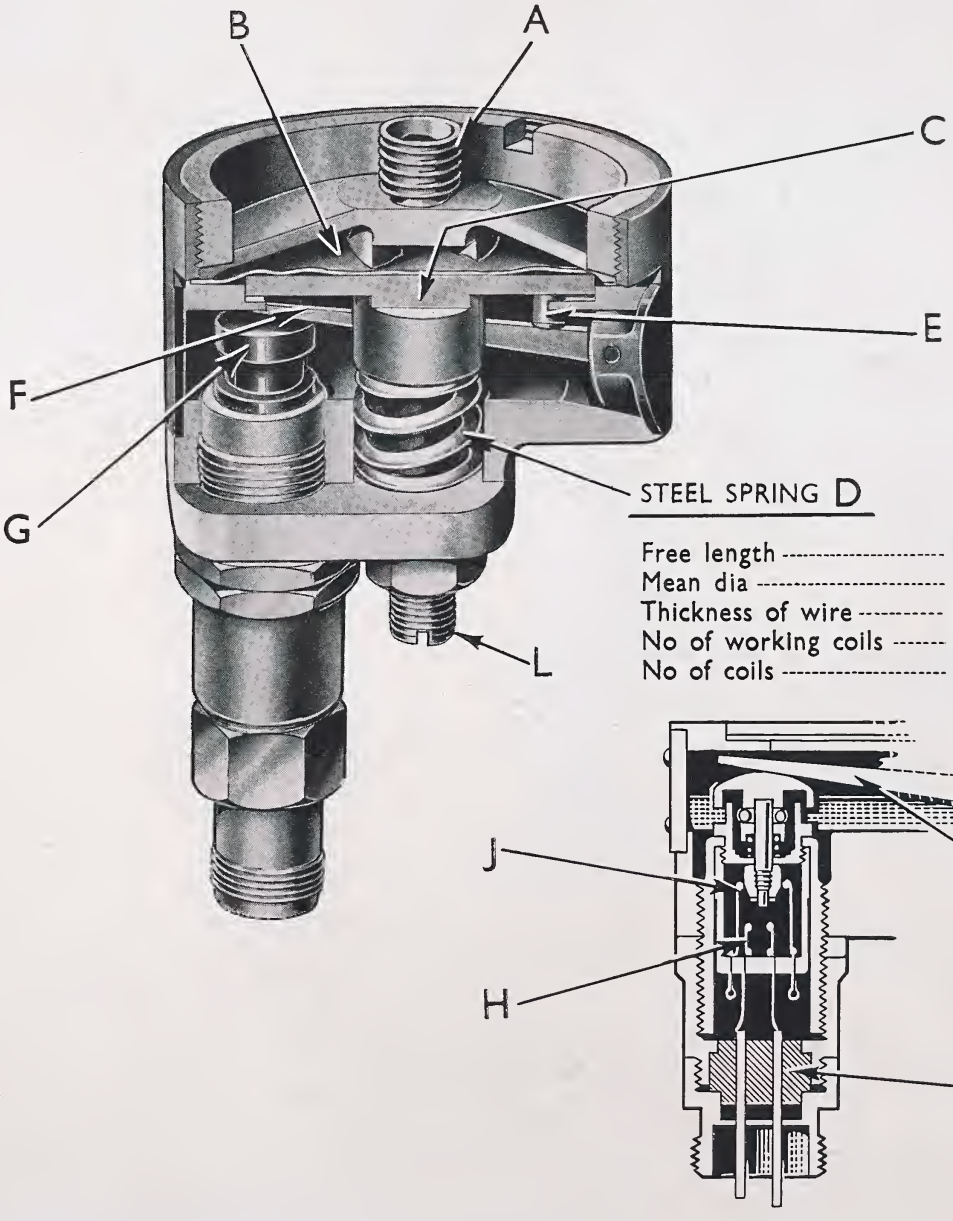


Fig. 19

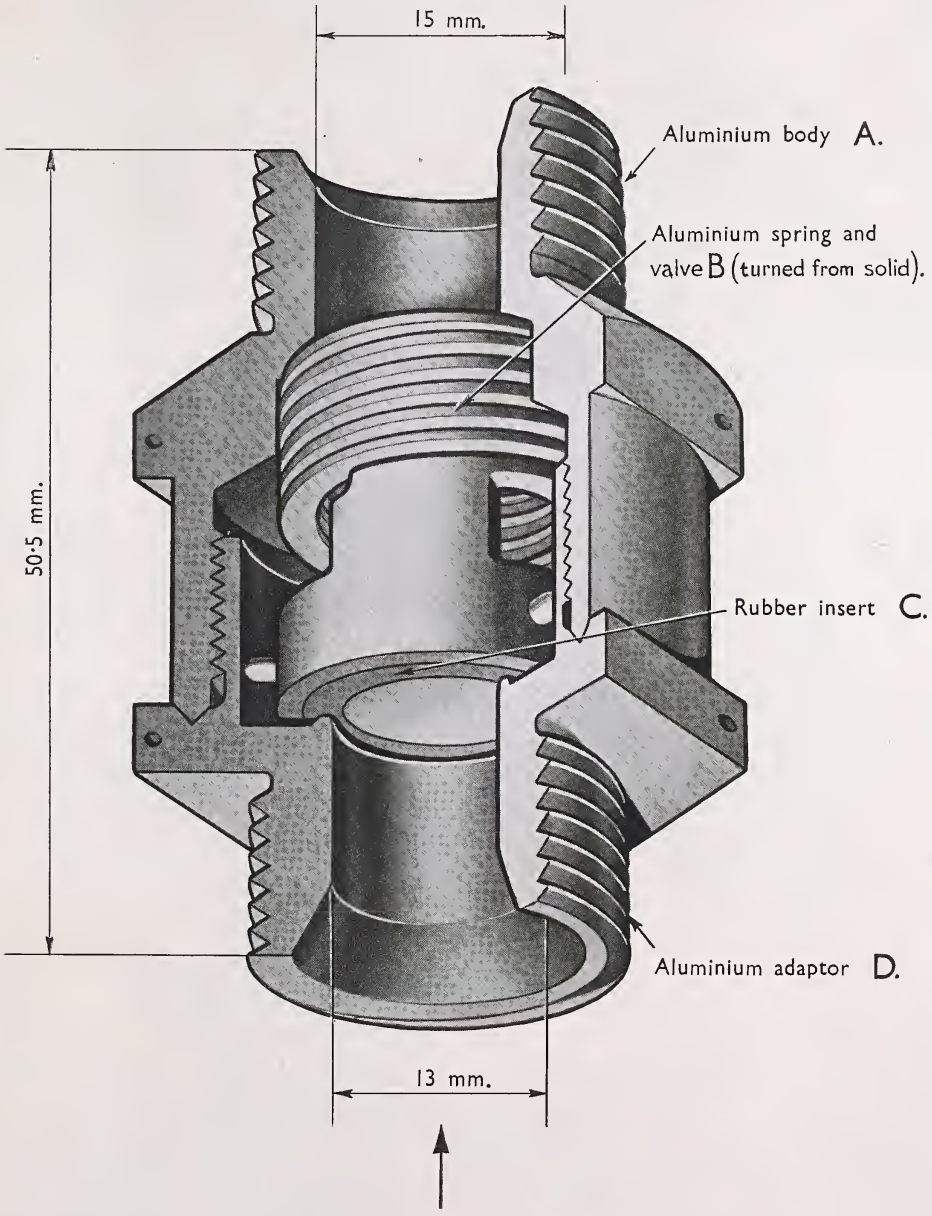
NON RETURN VALVE FOR H_2O_2.

Plate 37

(AS DRAWN).

NON RETURN VALVE FOR SODIUM PERMANGANATE.

(AS DRAWN BUT ALL COMPONENTS OF BRASS).



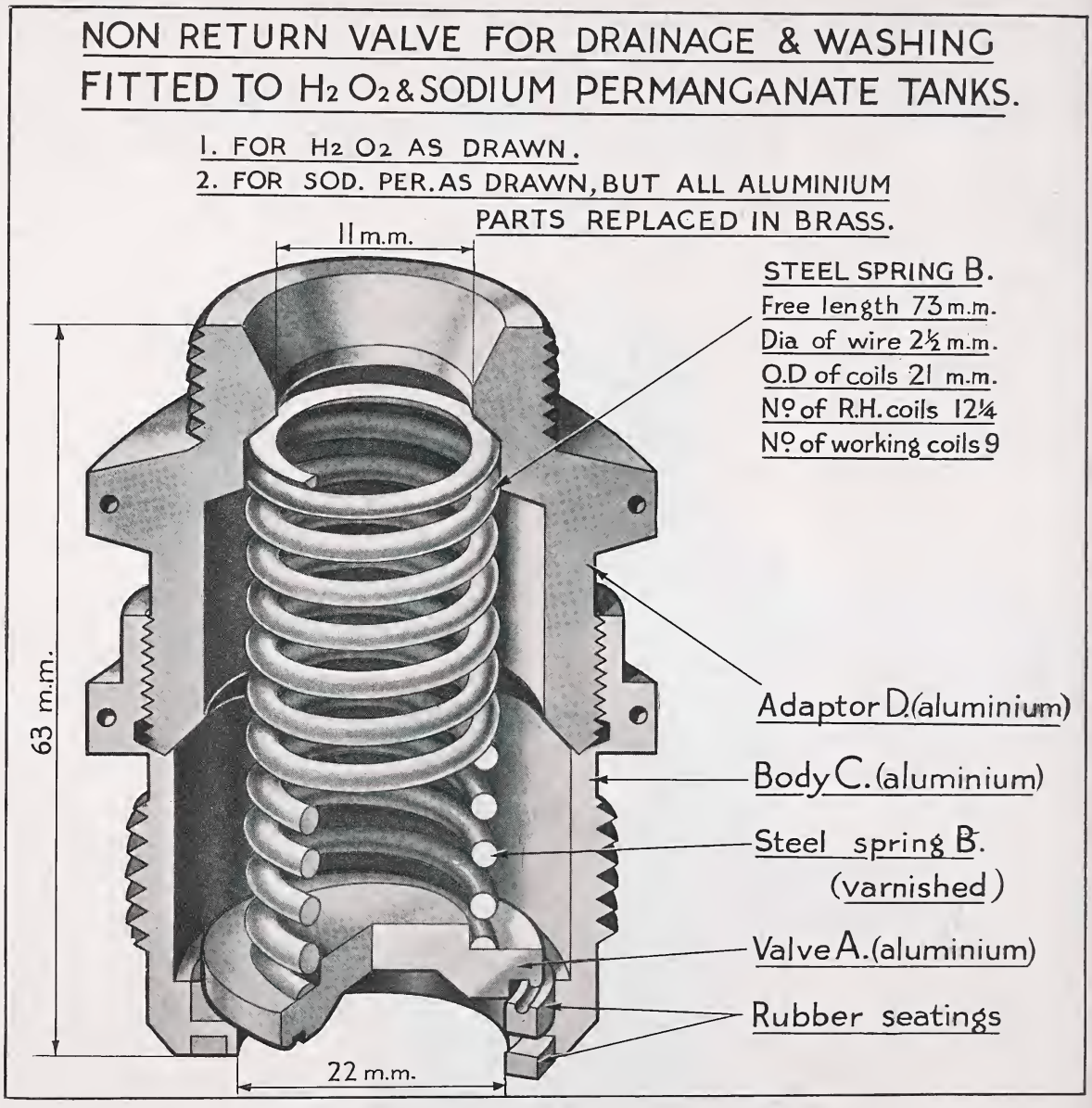


Fig. 20

80. The oxygen tank is pressurised by way of pipe 5, the pressure being automatically controlled through pipe 1 and the ground valve box. At the same time solenoid D1H is energised allowing air to flow to the pistons of the steam unit vent valves, and close them. The igniter is inserted into the venturi and the power supply is changed from the external generators to the lead acid and nickel cadmium batteries fitted in the rocket.

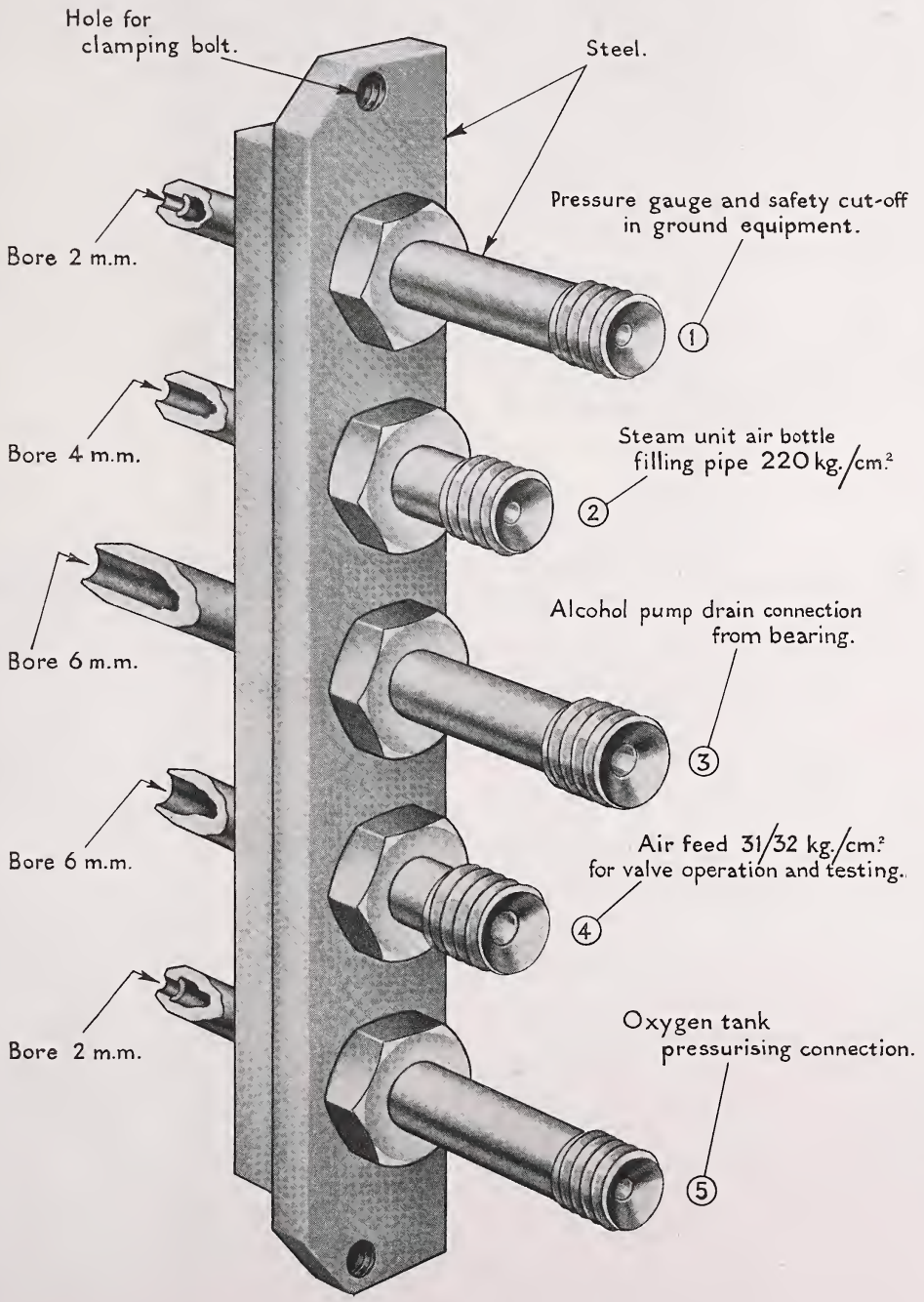
In order to prevent a premature mixing of the oxygen and alcohol which would cause local explosions on ignition or freezing, the oxygen roses are covered with paper caps.

81. The firing site is now cleared of all personnel and vehicles, control of the rocket being operated from the firing bunker.

From the test board the circuit to the igniter is closed, simultaneously solenoid S1H is energised, admitting compressed air to the alcohol tank valve, which opens, allowing alcohol to flow under gravity into the combustion chamber as far as the main alcohol valve. The displaced air is driven through the bye-pass pipe on the main valve. To ensure that the alcohol system is flooded before switching to the preliminary firing stage, there is a lag of 10

Plate 38

5-WAY COUPLING FOR GROUND UNIT.



seconds between the time the igniter switch is pressed to the actual ignition of the pyrotechnics.

82. With the ignition of the pyrotechnics the preliminary stage commences since solenoid O3H is energised, opening the pilot of the oxygen distribution valve. When this is open valve S2H is energised after a ·8 second delay and the alcohol main valve opens, thus allowing alcohol under gravity and oxygen at 1·5 kg./cm² pressure to flow into the venturi. The thrust generated in this preliminary stage is approximately 2·5 tons.
In this condition the positions of the valves are :—

(*a*) Oxygen vent valve closed.
(*b*) Ports to atmosphere on O3H and S3H open therefore.
(*c*) Oxygen distribution valve open to normal position.
(*d*) Alcohol main valve open to normal position.
(*e*) Alcohol tank valve open.
(*f*) Steam unit vent valves closed.

83. MAINSTAGE

Press the mainstage button on the firing desk and when it is released the ground connecting sockets are thrown off, valve DH on the steam unit opens and the compressed air drives the hydrogen peroxide up to the main peroxide valve and bye-pass, and the sodium permanganate to the reaction chamber. When the pressure in the sodium permanganate line reaches 1·5 kg/cm. the content switch D2R closes and operates D8H and D25H, allowing the peroxide to flow to the reaction chamber. Steam is then generated and flows to the turbine, causing the pumps to rotate. The oxygen and alcohol valves open into the full flow position by the fluid pressure from the pumps.

84. FINAL STAGE

At take-off the contact switch in the tail is opened and starts the sequence switch. Oxygen is vaporised in the heat exchanger and fed back into the oxygen tank, maintaining a preliminary pressure of ·9 atmosphere in the tank during flight. After four seconds the sequence switch starts the programme motor on the horizontal gyro. At forty seconds the solenoid valve S3H opens, and the pressurising valve on the alcohol tank is closed. At sixty-five seconds flame cut-off occurs and solenoid valve S4H is operated, releasing the air from the three air bottles in the control compartment to the alcohol tank. At the same time the steam unit is closed down by de-energising the solenoids, the main oxygen and alcohol valves are closed, and propulsion ceases.

The Assembly of A-4 Rockets . . . SECTION 2

85. SHOP LAYOUT (Plate 39, Section 2)

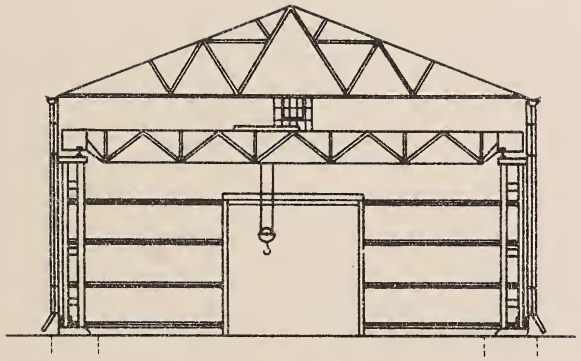
The main assembly was carried out in a shop 50 ft. by 200 ft., having an overhead clearance of 17 ft. A 10-ton lift travelling crane was installed running the full length of the shop. This was operated from a platform on the gantry since operation from the ground by chains would have interfered with the assembly and movement of the rockets.
Sliding doors were fitted at each end of the shop giving openings of 14 ft.
Two sets of decauville rails were laid as indicated in Plate 39 to accommodate the special bogies on which the assembly took place. In addition to the plant shown the usual portable drills, grinding machines and vacuum cleaners were installed together with air line delivering air at 3,500 lb./sq. in. This was broken down by reducing valves and fed to a common air line down the length of the shop. To reduce failures in the rocket mechanism due to condensation and to dry the tanks after cleaning three portable hot air dryers were supplied ; the capacities of these were (*a*) 1 cub. metre per min. 60 deg. C, and (*b*) 3 cub. metres per min. 100 deg. C.
From interrogation as to why vacuum cleaners and hot air dryers were necessary, it was found that failures had occurred where dirt had been left in components. Valves stuck owing to the presence of moisture, causing them to freeze. Throughout the assembly line it was therefore necessary to ensure cleanliness and dryness.

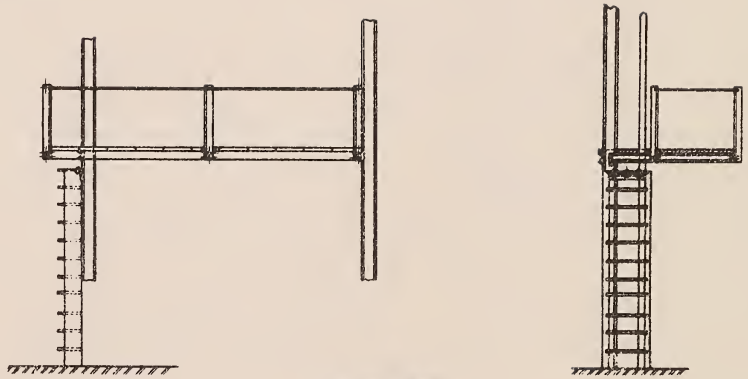
86. Adjoining the main shop a small sub-assembly and component test shop was arranged. Attached to this was a small brick-built test house for the proving of the steam unit assembly. In the sub-assembly shop the control compartment and thrust rings were assembled and tested.

87. For the manufacture of small simple brackets and bushes a light machine shop was set up. No attempt was made to manufacture new components other than brackets, since the facilities were not suitable, such new parts and test equipment needed being manufactured where more suitable plant was available.

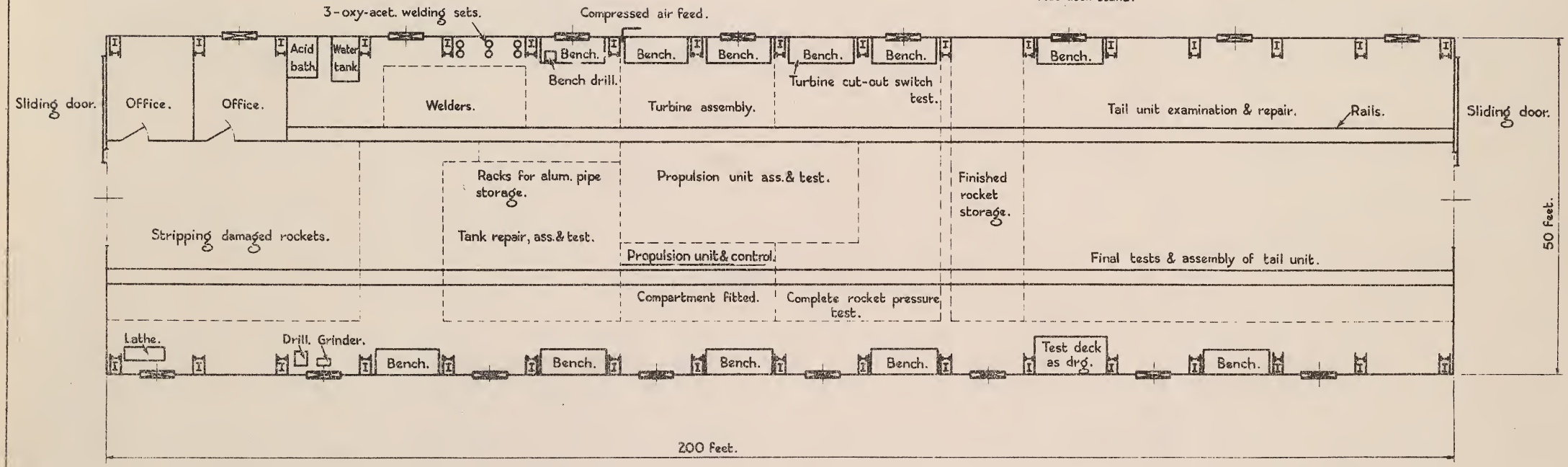
88. The location of the gyros in the control compartment and final testing was carried out in a purposly built proof tower (Plate 40 and Figs. 21 and 22, Section 2). Platforms installed at the positions shown enabled test rigs to be installed at various levels and the examination and test of assemblies to be carried out through the inspection doors

SHOP LAYOUT.
MAIN ASSEMBLY HALL.





Test deck stand.



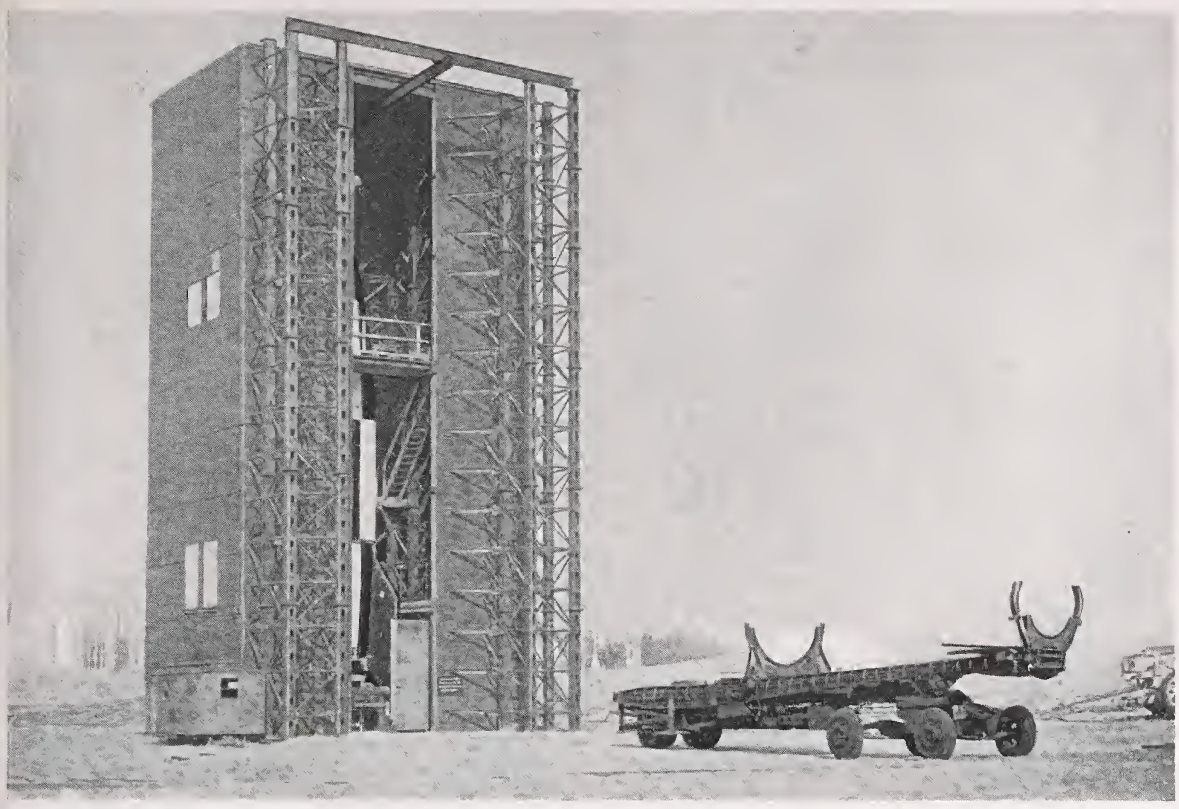


Fig. 21

of the rocket. Details of these tests are described in Sections 3 and 4.

89. TRANSPORT OF ASSEMBLIES DURING MANUFACTURE

In addition to the standard lifting tackle such as slings, etc., special tackle has been developed for the movement of the various assembled units and the transport of the final assembly.

The assembly proper was carried out on special bogies, a description of which is given with the lifting tackle in the following paragraphs.

90. THRUST RING LIFTING GEAR (Plate 41, Section 2)

Two channel sections are welded as shown and fitted with 4 cleats which serve to hold the wire rope slings and act as locating points on the inner diameter of the thrust ring.

91. TAIL UNIT LIFTING BARS (Plate 42, Section 2)

Bar A is used alone to transport the tail unit in the vertical position or to raise it from the horizontal. Built up of channel section it is bolted on to the larger diameter of the tail and gives a central point of lift. When lifting a tail without its thrust ring, bar B is used in conjunction with A. This fits over the smaller diameter and is bolted on, utilising the thrust ring bolt holes. Slings are then taken from both lifting eyes.

To lift a tail unit complete with its thrust ring A is used in conjunction with C the flanges of which mate up with the flange on the inside diameter of the rings.

92. PROPULSION ASSEMBLY TACKLE (Figs. 23 and 24)

Two types of tackle are used for this assembly, the first being for a lift in the vertical position and the second in the horizontal position, as when fitting the propulsion assembly to the centre section.

For the first case the top ring is removed and a bar having a central lifting shackle is bolted diagonally across two of the uprights (Fig. 23).

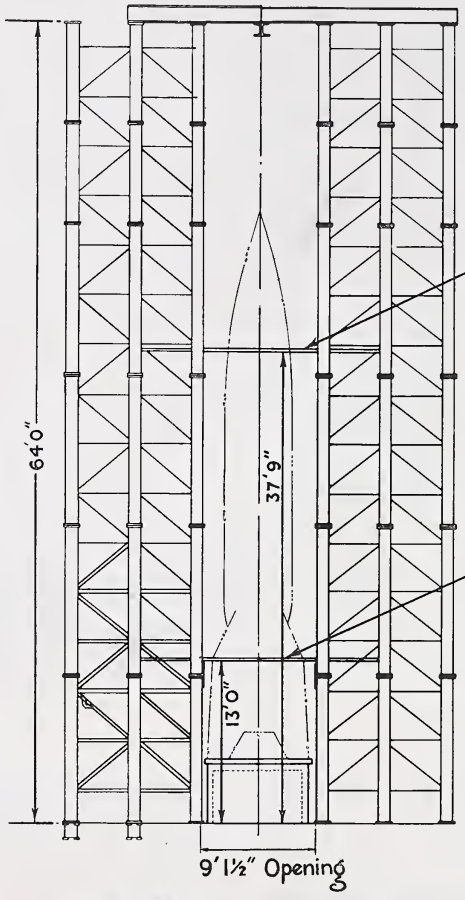
Fig. 24 illustrates the tackle for horizontal lift. In this case two mild steel rectangular section bars are fitted with clamps, one 80 mm. i/d and 2-55 mm. i/d. The 80 mm. clamp is fitted with two studs 10 mm. diameter, which position the bars in relation to the tubular framework of the propulsion unit. These large clamps fit round the sockets on the combustion chamber, whilst the other 2-55 mm. clamps bolt round the tubular framework. The whole is carried on wire ropes which extend from the clamp bars to a cross bar, having a central lifting point.

93. TANK LIFTING GEAR (Fig. 25, Section 2)

This tackle takes the form of a bar with a wire rope sling along its length and at the extremities slings fitted with

PROOF TOWER.

Plate 40



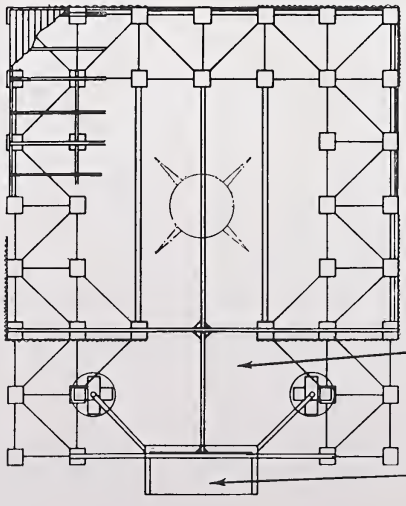
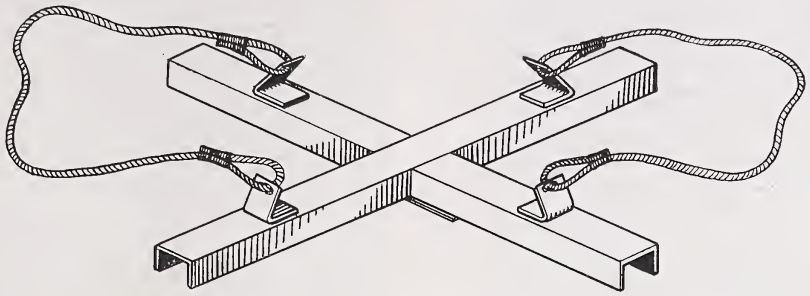
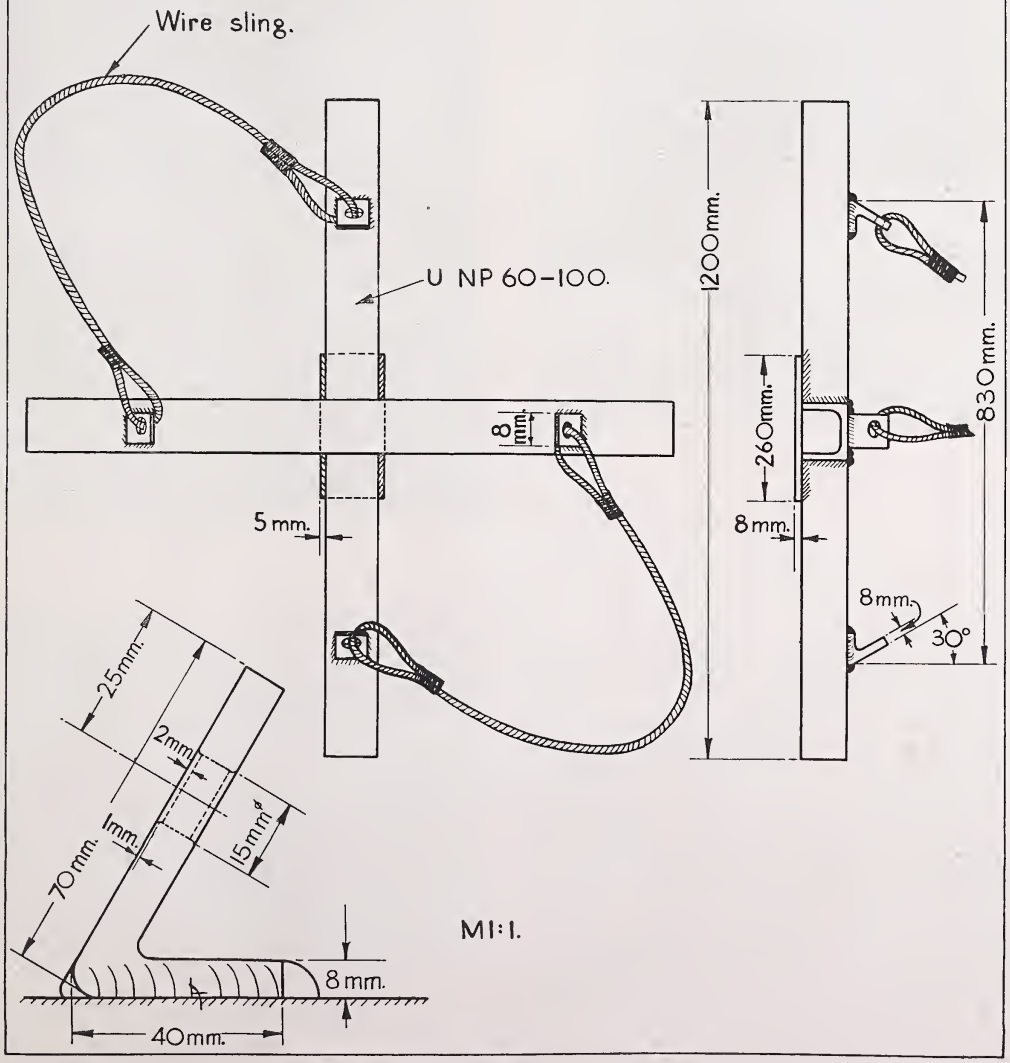


Plate 41

LIFTING GEAR FOR THRUST RING.





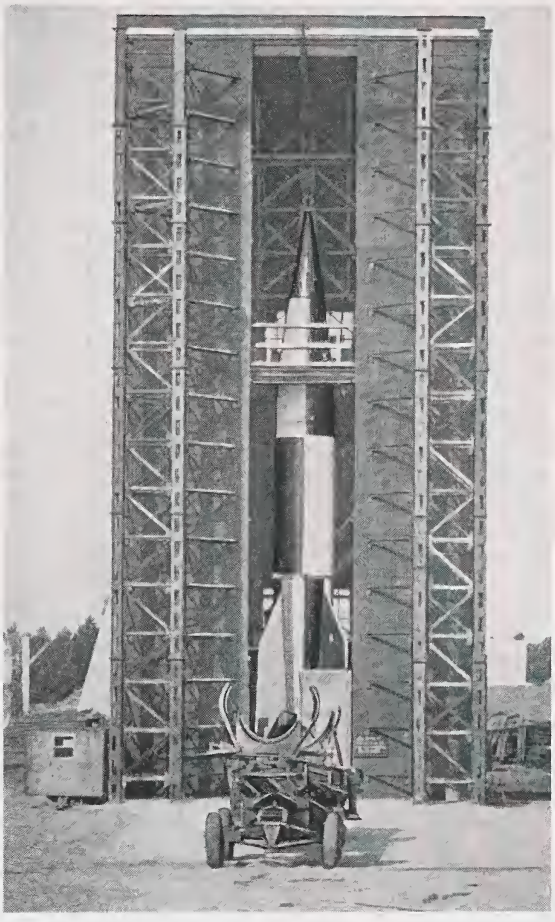


Fig. 22
Proof Tower

shackles which pick up on the supporting plates on the tanks.

94. LIFTING OF THE ASSEMBLED ROCKET
(Plate 43 and Figs. 26, 27 and 28)

Felt-lined clamps are placed round the rocket in two places, viz., on the centre section behind the control compartment and at the junction of the centre section and the tail unit. The first-named is positioned by means of bolts into screwed bosses in the shell and held snugly to the shell by the clamping bolts. Lifting bosses on the centre line carry the lifting eyes. The rear clamp has projections on the inside which fit into the space left by the special bolts at the junction of the sections. These act as location stops. On the centre line a pair of trunnions are fitted diametrically opposed and carrying a slotted locking tongue These fit into the cradles of the Meilerwagen and road transport vehicle. Above the trunnions a pair of lifting eyes are situated.

Plate 43 illustrates these clamps in position and also the lifting bar, the shackles of which couple up to the lifting eyes on the clamps.

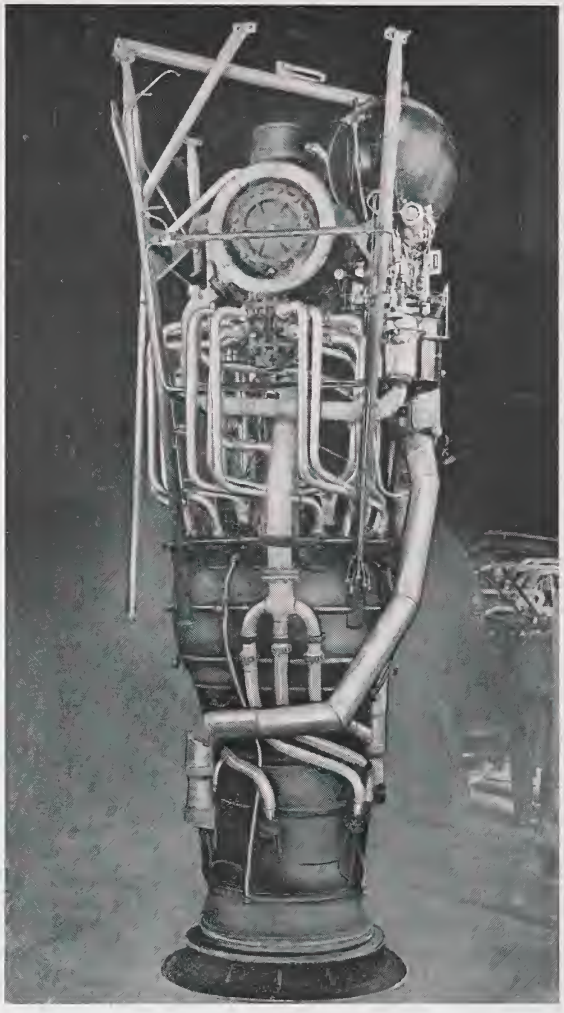


Fig. 23
Propulsion Assembly Tackle

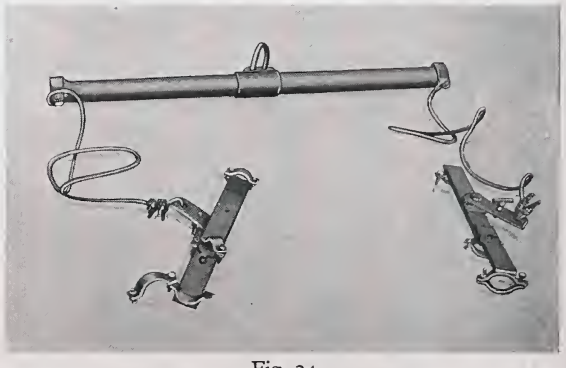
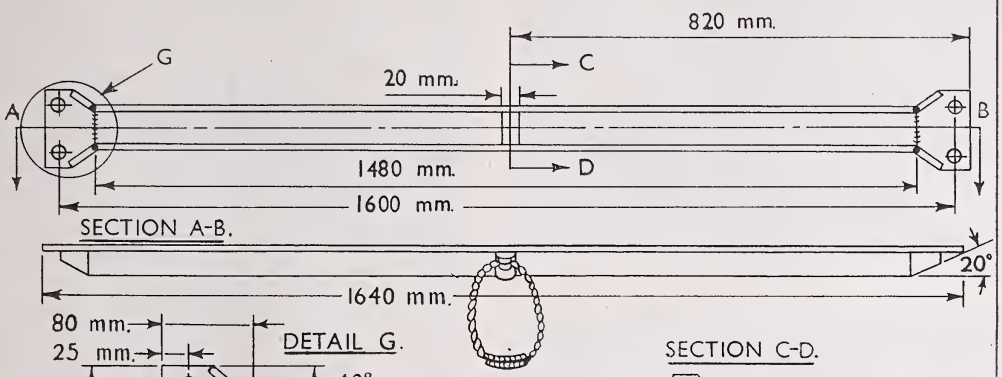


Fig. 24
Propulsion Assembly Tackle

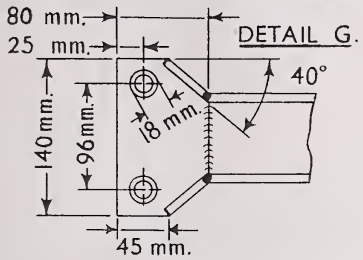
TAIL UNIT LIFTING BARS.

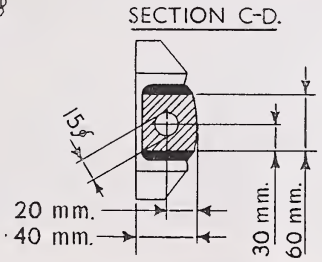
Plate 42

A.

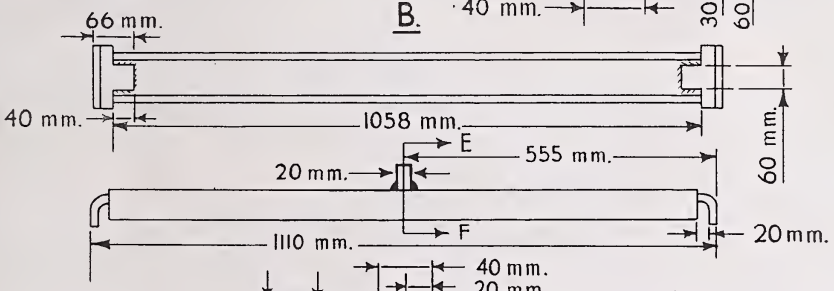


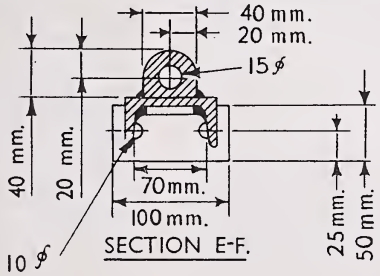
SECTION A-B.

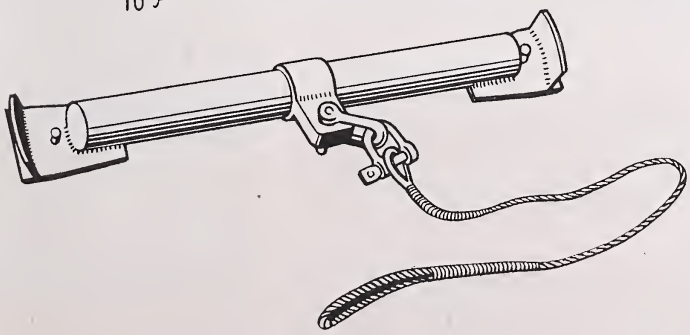




B.







It will be noticed that on the extension to the lifting bar a weight is carried, the purpose of which, in conjunction with alternative lifting holes, is to balance the load when a warhead is fitted.

95. ASSEMBLY BOGIES (Figs. 29, 30 and 31, Section 2)

The bogies for the centre section are of the 4-wheel type having a pressed steel fabricated chassis. Centrally disposed and on a swivel pin is a top carriage. In the case of the bogie for the rear of the central section, this carriage is lined with rubber blocks, but for the forward bogie, the carriage is equipped with a separate roller carriage giving self-alignment. When used to transport completed rockets, these bogies are connected by a tee bar as shown in Fig. 29.

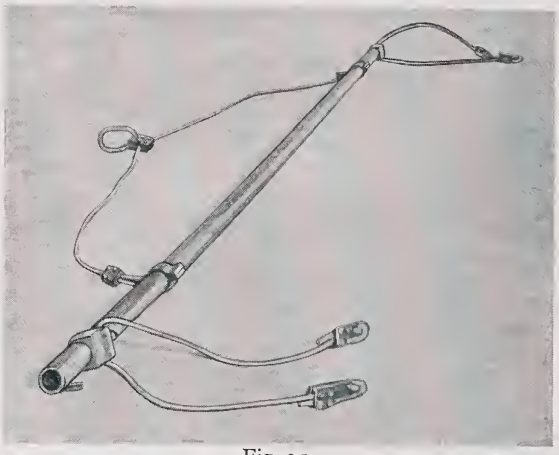


Fig. 25

Fig. 26

The tail unit bogie is of different construction, its main member being a channel section carrying a pair of wheels at either end. A V-shaped carriage fitted with an adjustable leather carrying strap takes the load of the larger diameter. The other end is carried on the adjustable block, a close-up of which is seen at C. These adjustments allow the tail unit and centre sections to be lined up before being bolted together.

96. AIR SUPPLY

In order to supply the pressure necessary for various tests a 4-stage air compressor delivering 1·9 cub. metres per min. of free air compressed to 230 kg./cm.^{2} was installed in an external building. An air reservoir consisting of air bottles was fitted and two silica-gel filters inserted in the lines to the assembly and sub-assembly bays for the purpose of drying.

97. MATERIAL AVAILABLE FOR ASSEMBLY

Since adequate workshop facilities were not available nor the necessary jigs and fixtures, no new assemblies could be made and the final rockets were made up from salvaged equipment or components which had been gathered from various German manufacturers. Among the complete units obtained in this manner were the steam units (Plate 44, Section 2), pump units (Plate 45, Section 2), and combustion chambers. A good quantity of the various valves and pipes, etc., were available, so that replacements could be made. Skeletons of the control compartment and outer shells, together with a number of tail units, were also available for the replacement of damaged parts.

It is interesting to note that although components and assemblies carried the mark of the German inspection authorities as passed tests, it was found necessary to strip and examine units before putting them in the rocket.

Little attention had been paid to preservation, and where grease had been applied it was of such poor quality as to be useless.

In practice it was found that on Operation "BACKFIRE" 36 per cent. of the valves failed due to corrosion and needed replacement.

98. The plan of operation for the assembly of the rocket

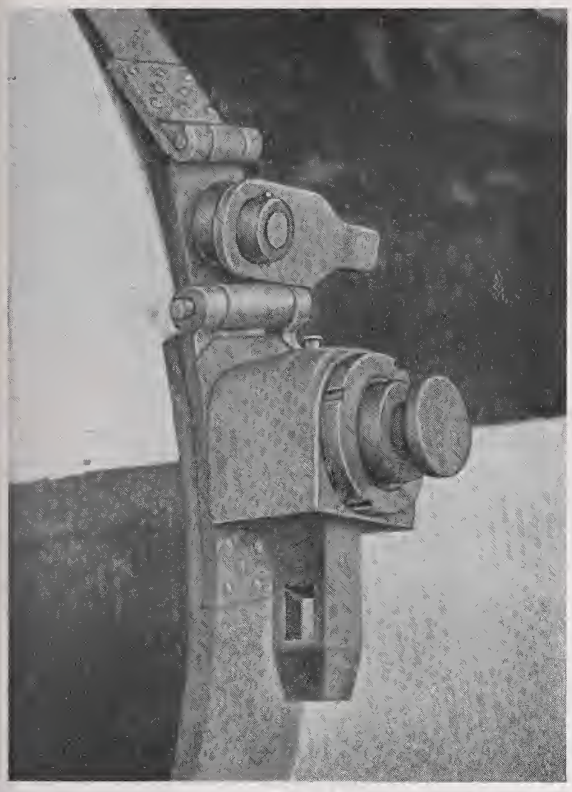


Fig. 27

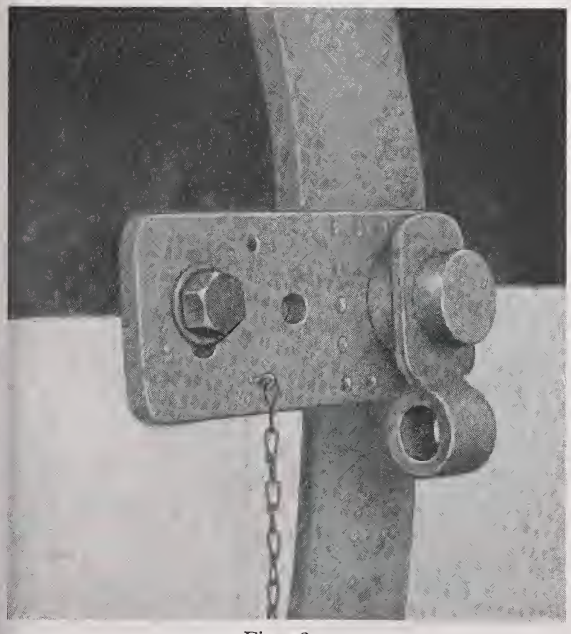


Fig. 28

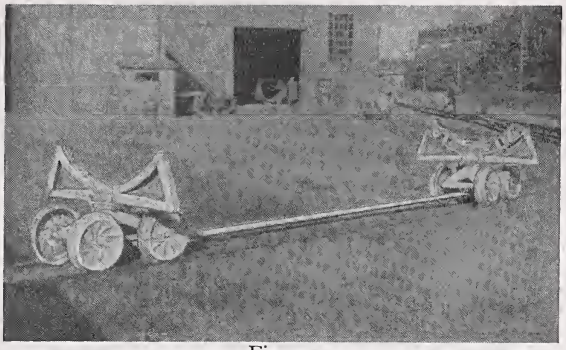


Fig. 29

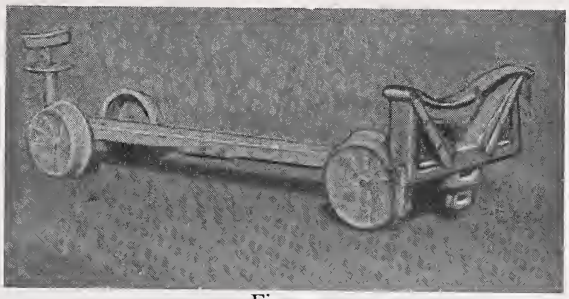


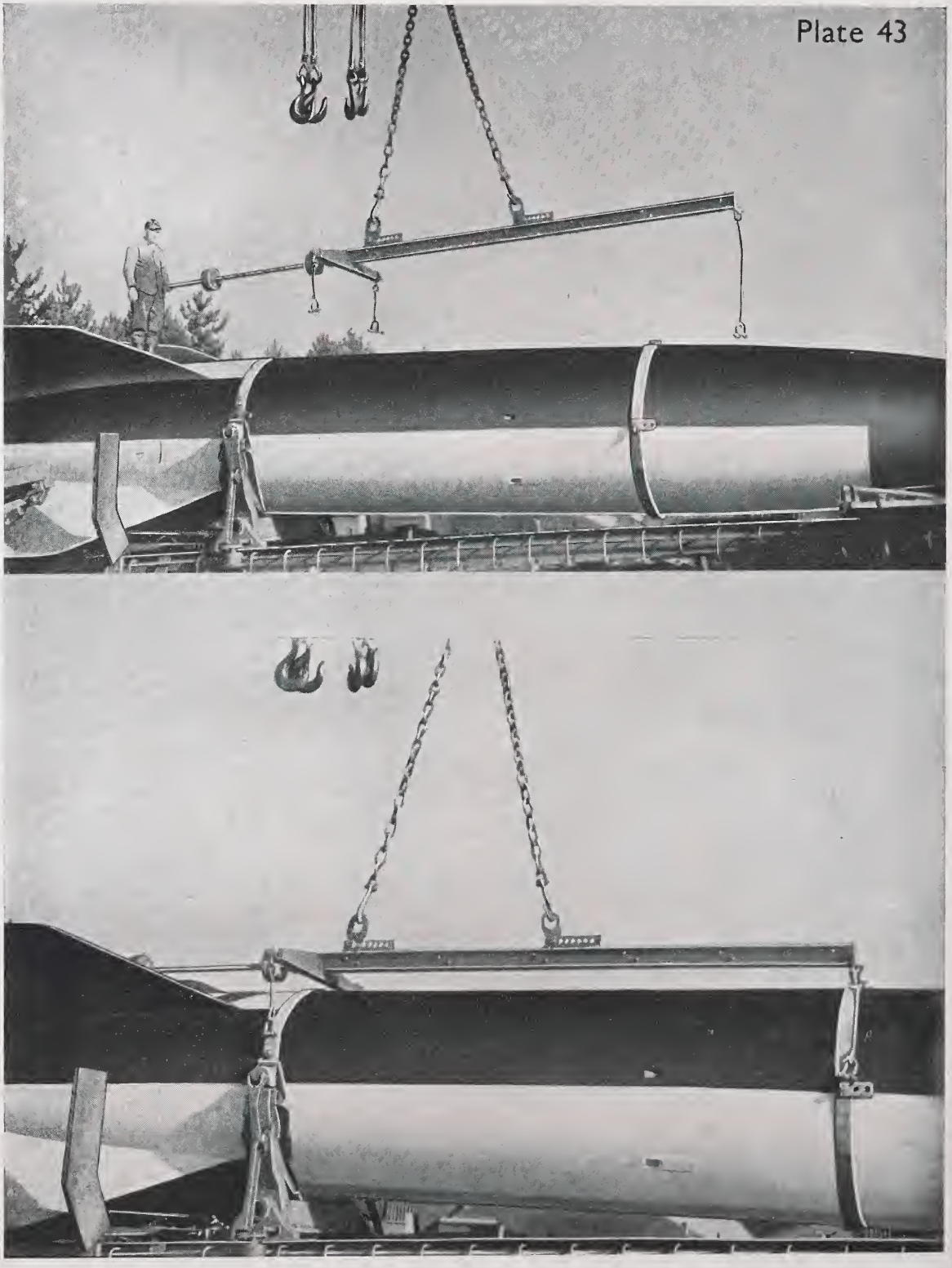
Fig. 30

Fig. 31

is shown in Fig. 32, and was divided into two sections viz., mechanical and electrical. The sub-assemblies and components in the control compartment were not dealt with in the assembly or sub-assembly hall, the work being carried out in the electrical workshops.

99. After examination and stripping of the damaged rockets the salvaged components and replacements from the stores were sent to their respective sections for test and overhaul. Details of the tests are shown in Section 3 on the mechanical side, and Section 4 on the electrical. In order to give continuity on the assembly line the work was split into following sections :—

Plate 43



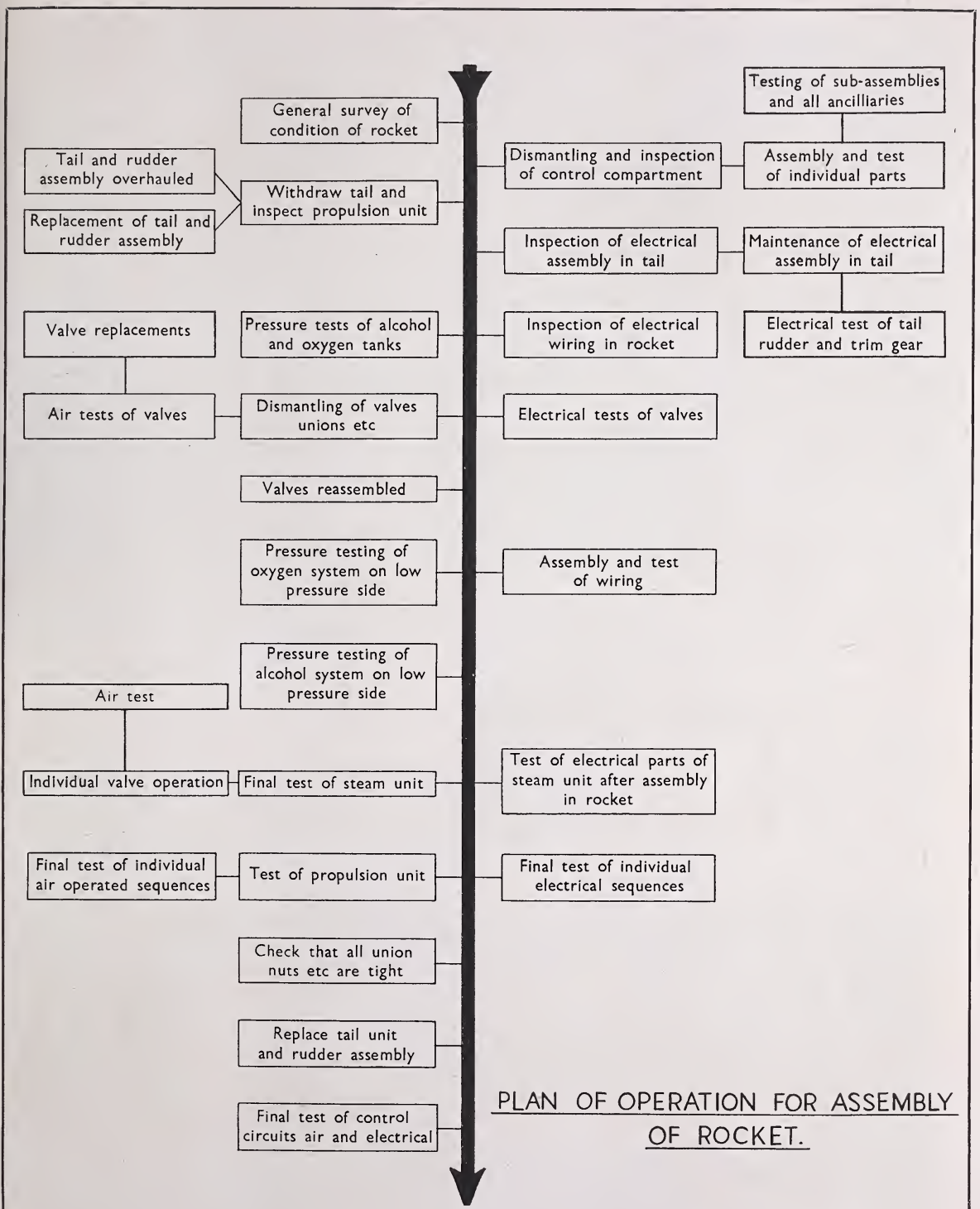
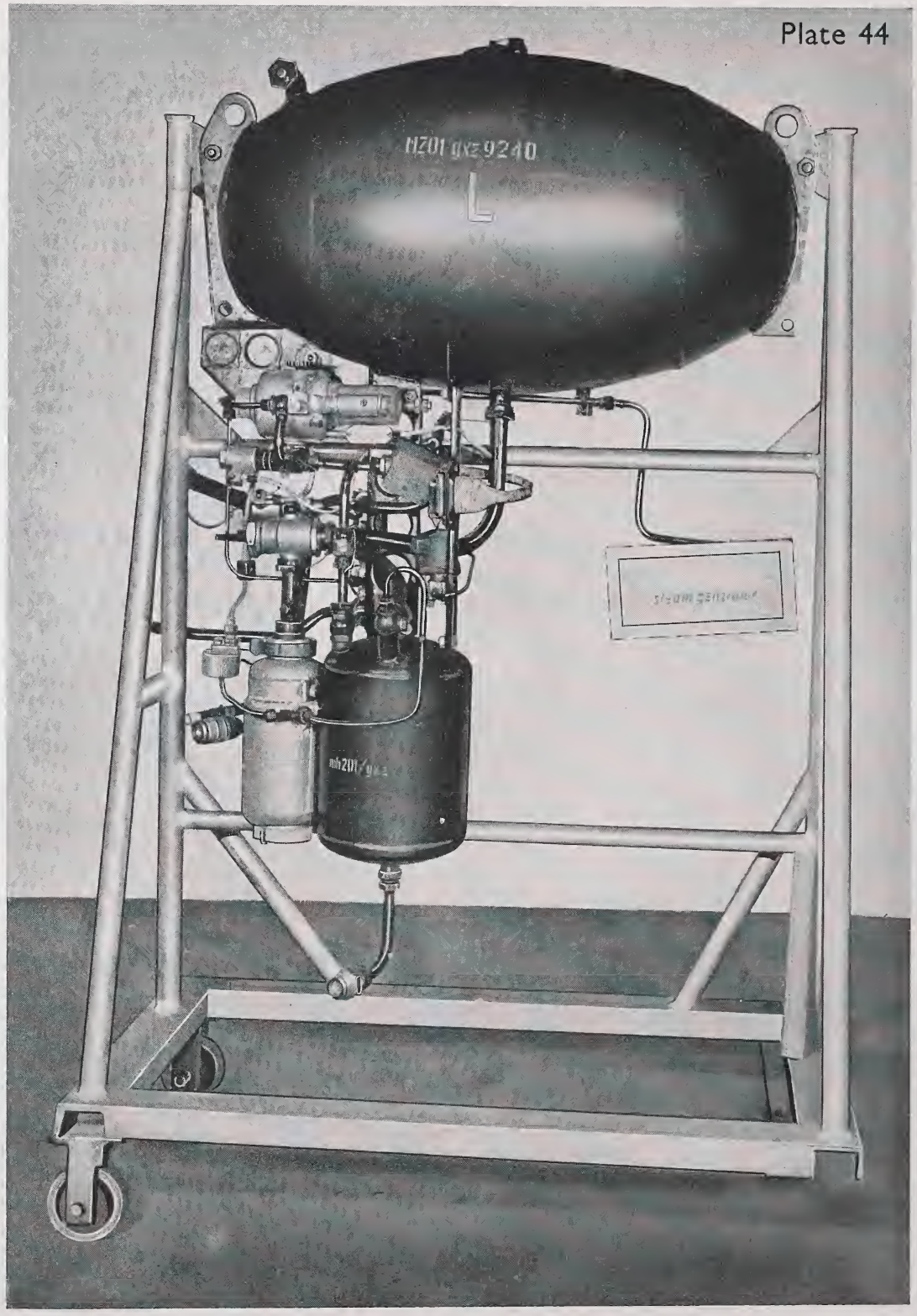

General survey of condition of rocket
Tail and rudder assembly overhauled
Withdraw tail and inspect propulsion unit
Replacement of tail and rudder assembly
Valve replacements
Pressure tests of alcohol and oxygen tanks
Air tests of valves
Dismantling of valves unions etc
Valves reassembled
Pressure testing of oxygen system on low pressure side
Pressure testing of alcohol system on low pressure side
Air test
Individual valve operation
Final test of steam unit
Final test of individual air operated sequences
Test of propulsion unit
Check that all union nuts etc are tight
Replace tail unit and rudder assembly
Final test of control circuits air and electrical
Testing of sub-assemblies and all ancilliaries
Dismantling and inspection of control compartment
Assembly and test of individual parts
Inspection of electrical assembly in tail
Maintenance of electrical assembly in tail
Inspection of electrical wiring in rocket
Electrical test of tail rudder and trim gear
Electrical tests of valves
Assembly and test of wiring
Test of electrical parts of steam unit after assembly in rocket
Final test of individual electrical sequences
PLAN OF OPERATION FOR ASSEMBLY OF ROCKET.

Fig. 32.

Plate 44



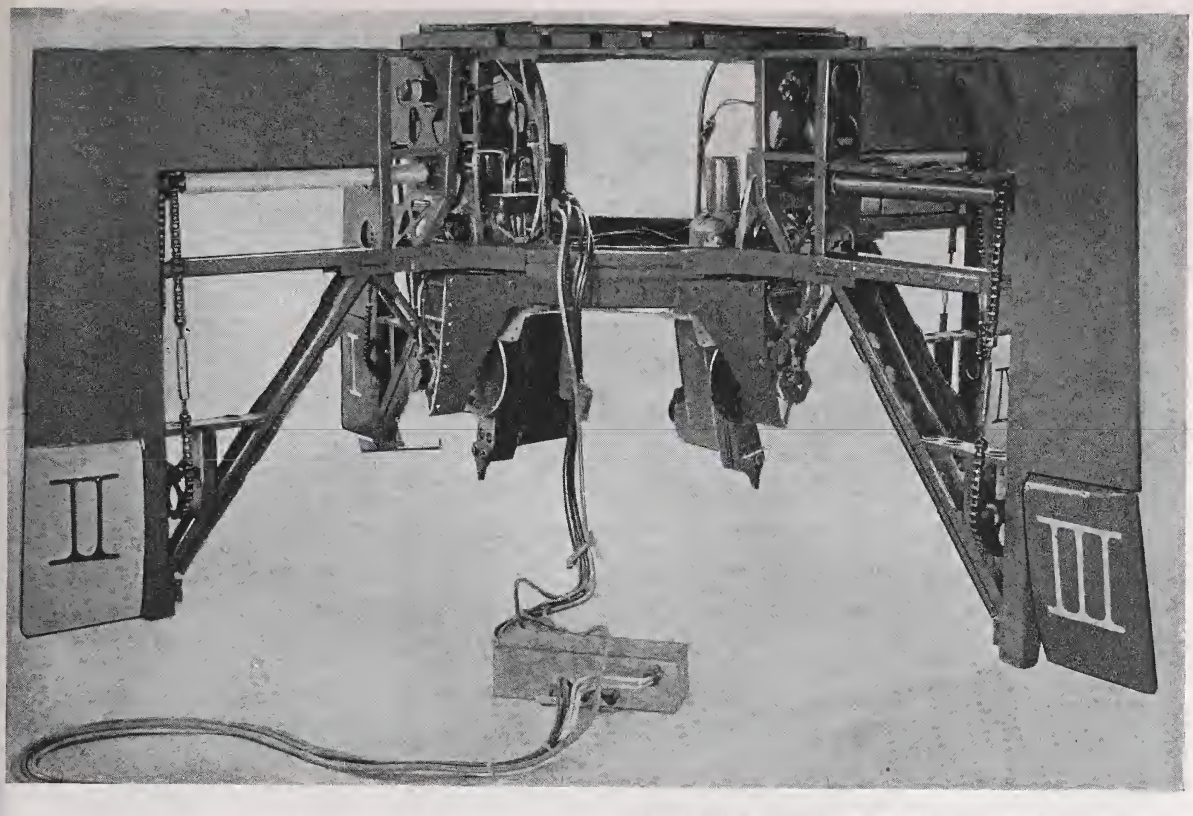


Fig. 33

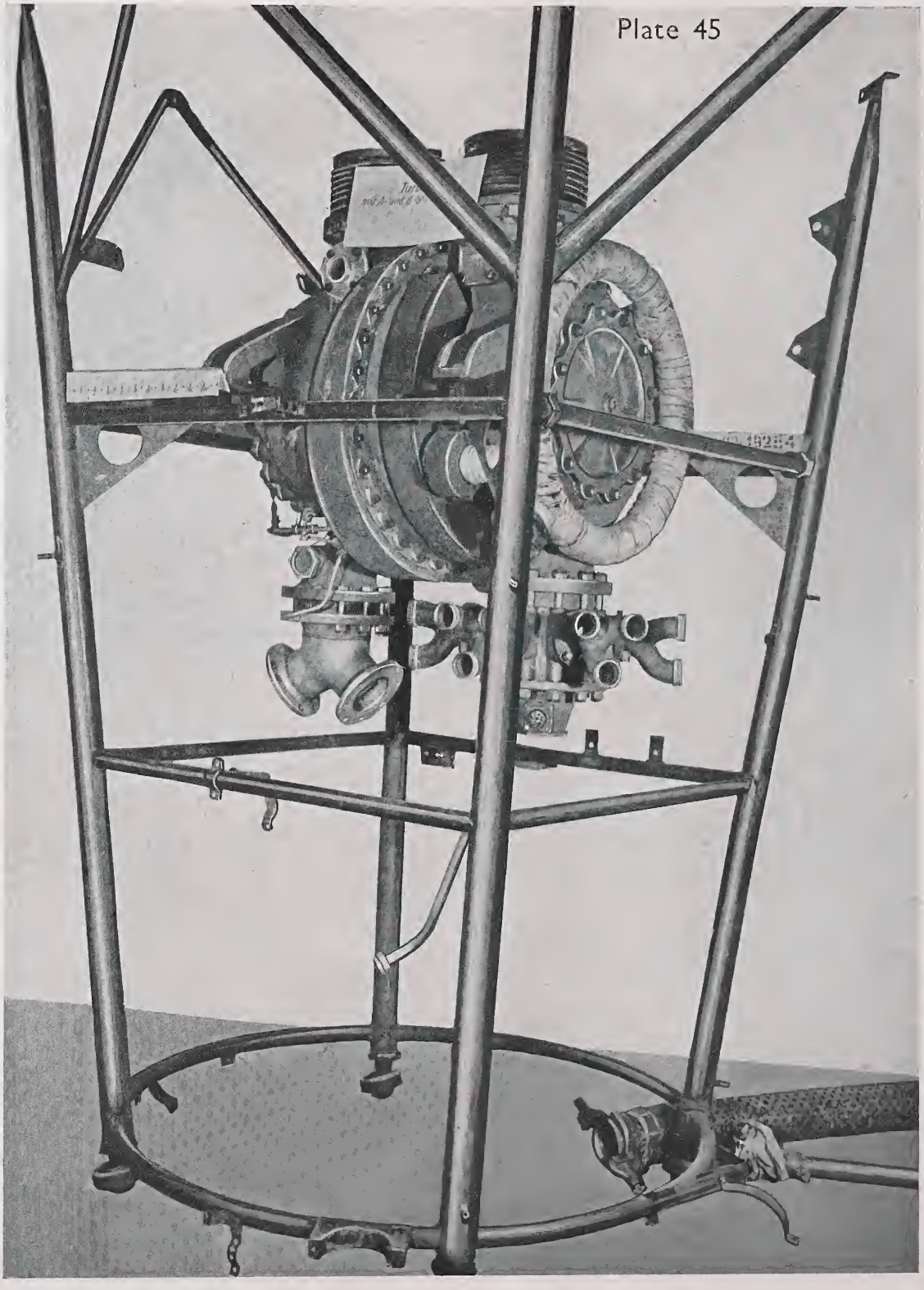
Fig. 34

Assembly Section 1. Stripping and examination.
Assembly Section 2. Tail Unit.
Assembly Section 3. Tail Unit Thrust Ring.
Assembly Section 4. Propulsion Unit.
Assembly Section 5. AssemblyofControl Compartment.
Assembly Section 6. Assembly of Centre Section.
Assembly Section 7. Complete Assembly.

100. ASSEMBLY SECTION 2. TAIL UNIT

(*a*) By means of survey instruments measure the unit and check fins for alignment.
(*b*) Check damage to main shell or platework.
(*c*) Examine and overhaul chain cases (Fig. 33, Section 2).
(*d*) Replace damaged external control surfaces, assemble torsion bars and adjust chain mechanism (Fig. 34).
(*e*) Install the tail unit thrust ring.
(*f*) Fit flanges carrying the carbon rudders.
(*g*) Bolt in the two trim motors and adjust their mechanism (Fig. 35).
(*h*) Attach the five-way coupling unit and oxygen topping-up valve.
(*j*) Clear, by tapping, all the threads for taking the bolts holding the inspection covers, etc.
(*k*) Carefully fit chain casings, cowlings, inspection covers and fuelling panels. Care must be taken to see that these are bedded down properly so that air cannot get under them when the rocket is in flight and cause cleavage of the skin.
(*m*) Clip the cable form from the thrust ring assembly in position.
(*n*) Test and adjust control surfaces.
Transfer to main assembly line.

Plate 45



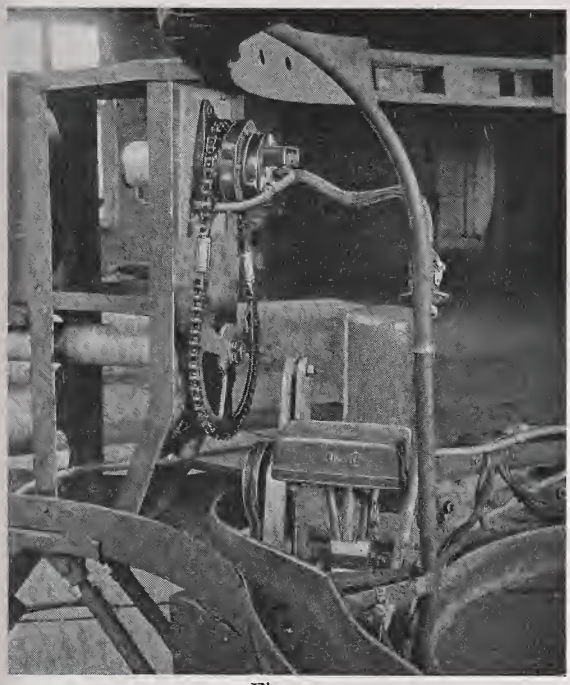


Fig. 35

101. ASSEMBLY SECTION 3. THRUST RING (Fig. 36, Section 2)

(*a*) Fit the 4 brackets carrying the carbon rudder mechanism.
(*b*) Install the servo units and mechanism (Plate 46, Section 2).
(*c*) Attach potentiometers and vane adjusting box.
(*d*) Connect cable forms.
(*e*) Test and adjust servo units and subject to a load test.

102. ASSEMBLY SECTION 4. PROPULSION UNIT (Fig. 37, Section 2).

(*a*) Clean, test and dry combustion chamber (Fig. 38, Section 2).
(*b*) Check joint seatings and reseat if necessary.
(*c*) Fit blanking caps on oxygen outlets of the combustion chamber.
(*d*) Fit blind plugs to row of balancing jets in the combustion chamber.
(*e*) Level combustion chamber on lining up rig (Fig. 39, Section 2).
(*f*) Mount tubular framework for carrying the pump unit, etc., and adjust for alignment. Remove unit to rotating assembly platform.
(*g*) Install the pump unit (Plate 45, Section 2) with blank flanges between the outlets of the pump and the oxygen distribution valve, and between the alcohol pump outlet and the Y piece. Blank flanges are fitted for test purposes.
(*h*) Fit 3-way branches to the oxygen distribution valve outlets.
(*j*) Connect oxygen delivery pipes from 3-way outlets to combustion chamber (Fig. 40).
(*k*) Install main alcohol valve and blank off bye-pass outlet.
(*m*) Make connections on alcohol side between 2-way and 3-way branches.
(*n*) Make connections on alcohol side between 3-way branch and inlet manifold on combustion chamber (Fig. 41, Section 2).
(*o*) Fit air bottle assembly.
(*p*) Bolt steam unit assembly in position and install steam delivery piping.
(*q*) Fit steam exhaust and heat exchanger.
(*r*) Position oxygen exhaust pipe.
(*s*) Couple heat exchange with oxygen distribution valve.
(*t*) Pipe up air system and ground service pipes.
(*u*) Test. See Section 3.
(*v*) Remove blind flanges on the pump outlets and fit restricting throats.
(*w*) Remove blanking pipe from alcohol bye-pass outlet and fit bye-pass pipe.
(*x*) Stress relieve aluminium pipework by heating with a blowlamp.
(*y*) Wire nuts, and secure locking plates on the oxygen and alcohol pipes.
(*z*) Remove top ring and attach lifting gear for transporting in horizontal position.

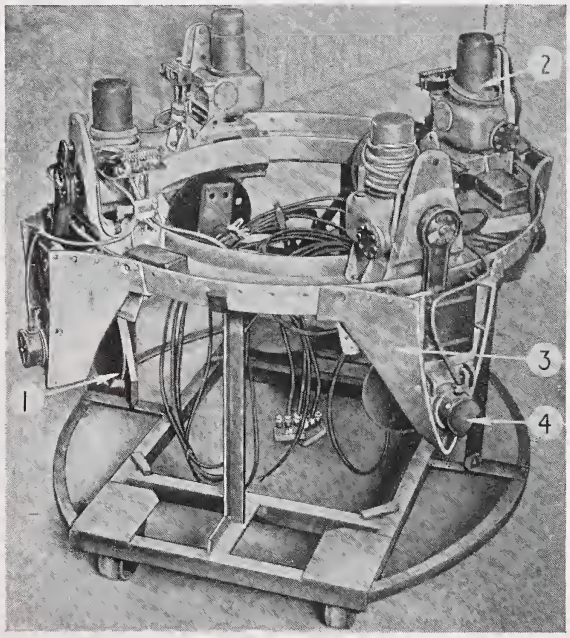
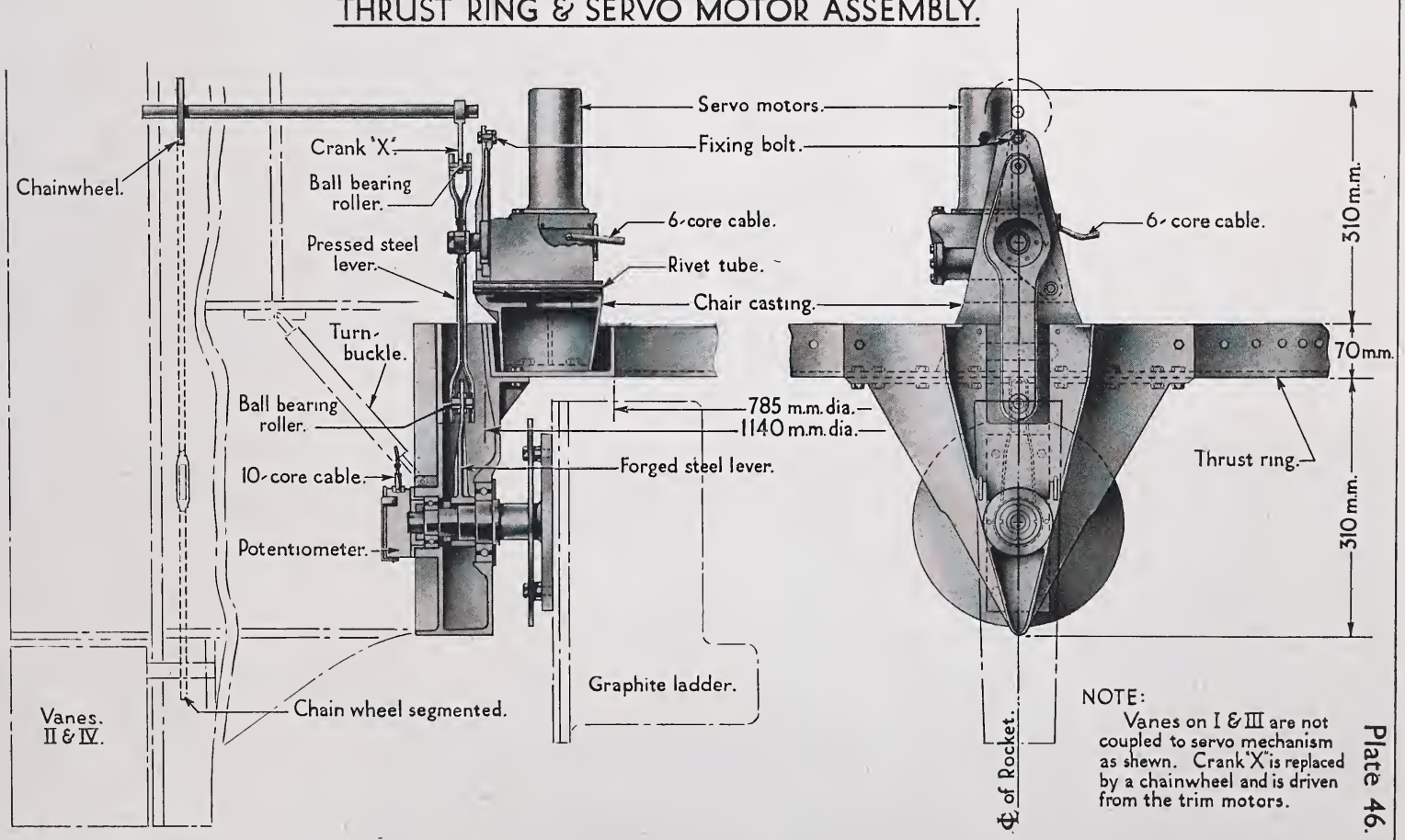


Fig. 36
1. Carbon Rudder Flanges 2. Hydraulic Servo and Motor
3. Brackets 4. Potentiometer

103. ASSEMBLY SECTION 5. CONTROL COMPARTMENT (Figs. 42 and 43, Section 2)

(*a*) Install and secure the wooden centre piece.
(*b*) Fit the electrical distribution box.
(*c*) Attach pressurising pipe.
(*d*) Install electric sequence switch.
(*e*) Build in alternators and regulators.
(*f*) Fit gyro locating plate.

THRUST RING & SERVO MOTOR ASSEMBLY.



NOTE:
Vanes on I & III are not coupled to servo mechanism as shewn. Crank 'X' is replaced by a chainwheel and is driven from the trim motors.

Plate 46.

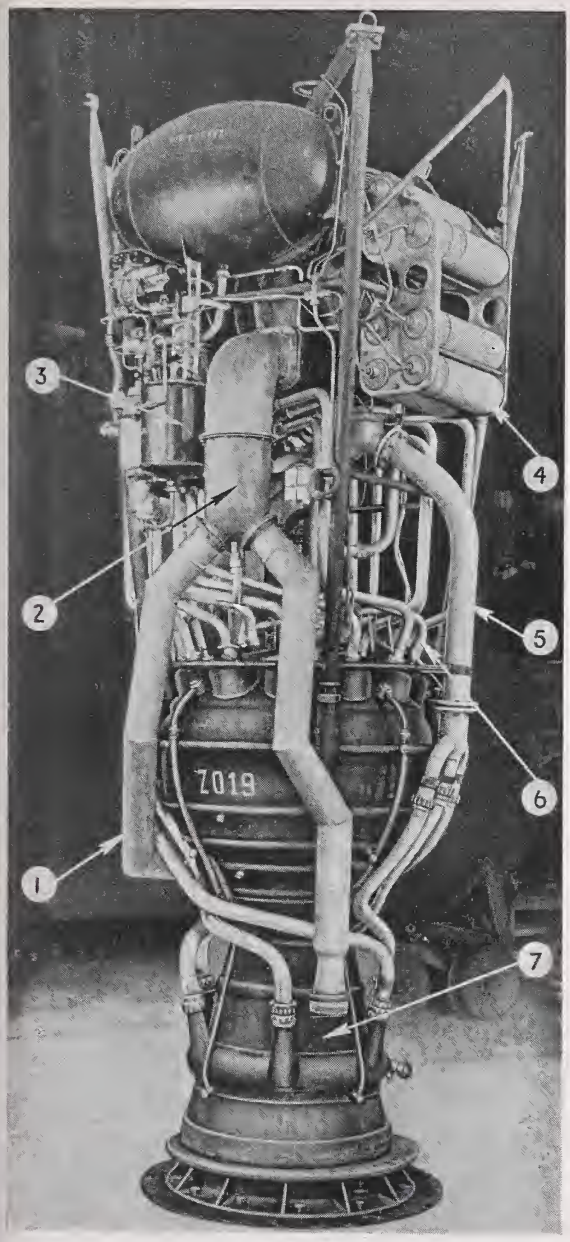


Fig. 37

1. Steam Exhaust
2. Heat Exchanger
3. Steam Unit
4. Air Bottles
5. Alcohol Pipes
6. Oxygen Pipes
7. Combustion Chamber

(*g*) Install control amplifier and battery brackets.
(*h*) Bolt up alcohol tank air bottle battery.
(*j*) Install cable forms.
(*k*) Install emergency cut-off box.
(*m*) Fit panels and doors.
(*n*) Test.

104. ASSEMBLY SECTION 6. CENTRE SECTION (Figs. 44 and 45, Section 2)

(*a*) Survey, measure and adjust the shell sections (Figs. 46 and 47, Section 2).
(*b*) Install wooden chocks.
(*c*) Clip in cable form.
(*d*) Fit air lines.
(*e*) Pack with glass wool and wire in position.
At this stage the bottom section is lifted to the main assembly trolley.

Fig. 38

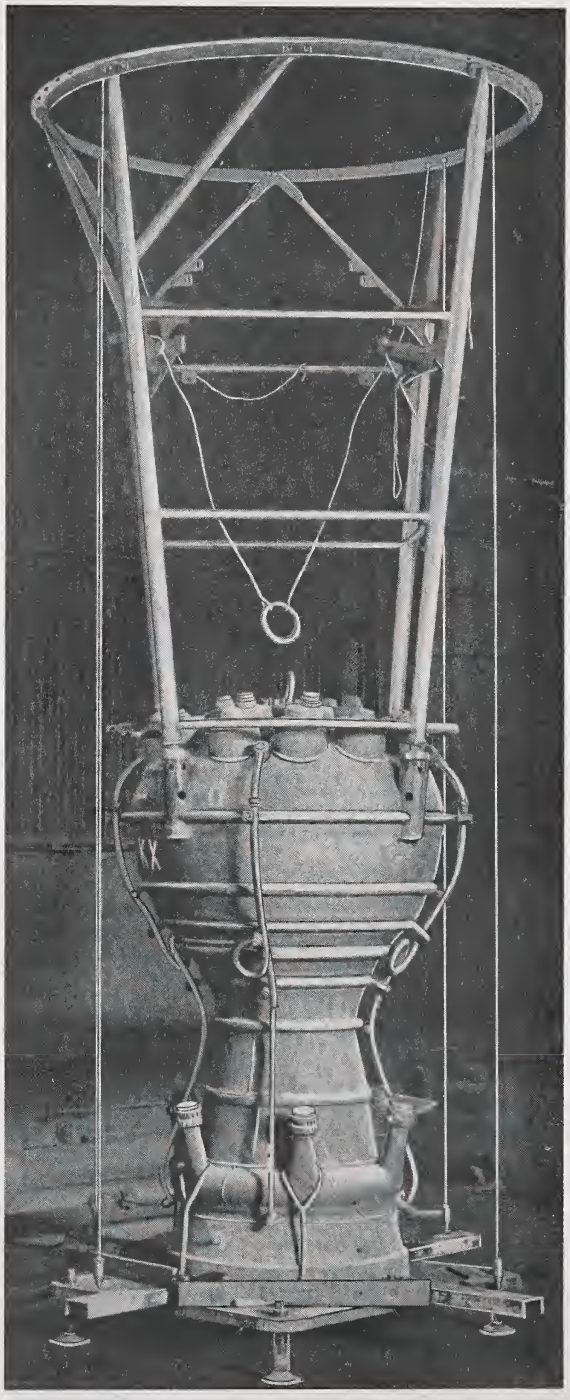


Fig. 39

Combustion Unit on Alignment Rig

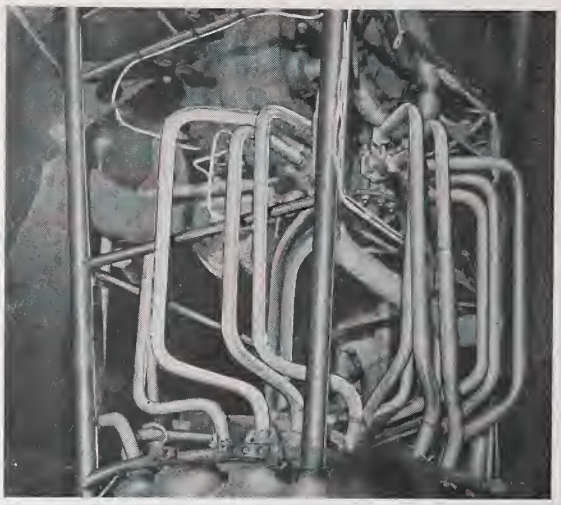


Fig. 40

Oxygen Delivery Pipes

105. OXYGEN TANK (Figs. 48 and 49, Section 2)

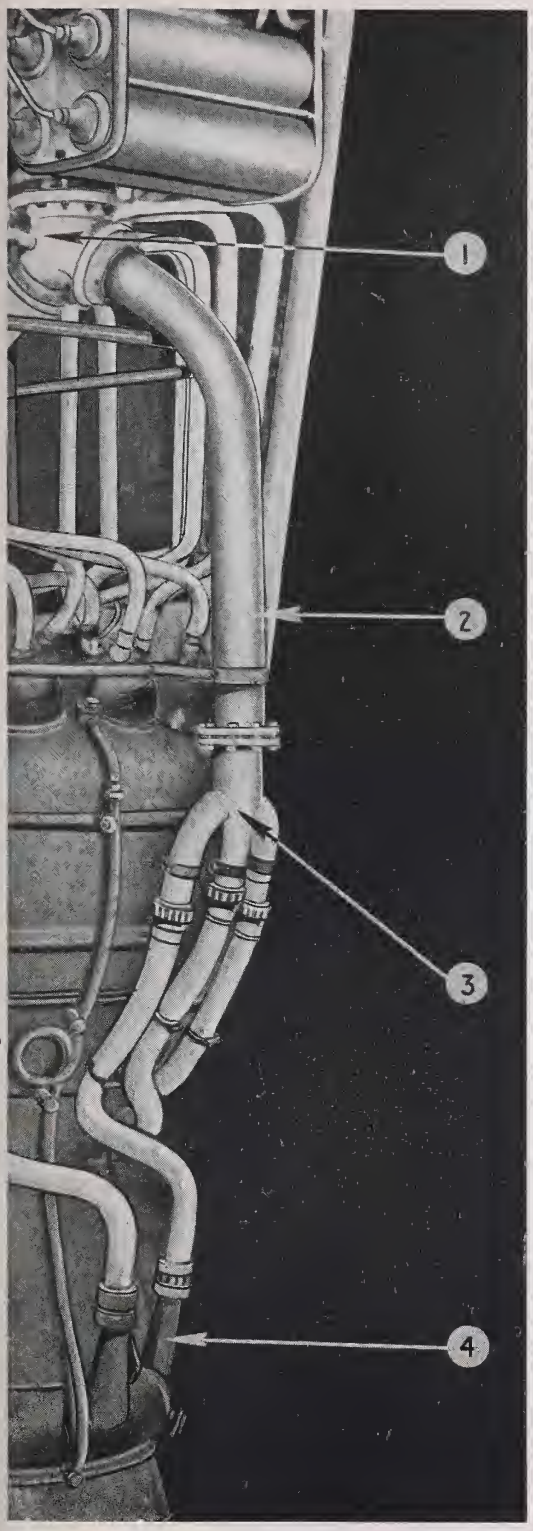
(*a*) Fit struts and fishplates for holding the tank in the shell.
(*b*) Clean the tank inside and dry by circulation of hot air.
(*c*) Pressure test, and close outlets with dummy flanges.

106. ALCOHOL TANK (Fig. 50, Section 2)

(*a*) Install supports and brackets for holding in position in the shell.
(*b*) Fit alcohol tank valve.
(*c*) Fit pressurising valve.
(*d*) Fit bracket holding solenoid air valves.
(*e*) Clean the inside and dry by circulation of hot air.
(*f*) Test.
(*g*) Clean and lay alcohol delivery pipe through the oxygen tank.

107. ASSEMBLY SECTION 7. COMPLETE ASSEMBLY

(*a*) Lift oxygen and alcohol tanks into position in the half section prepared on the assembly bogie (Figs. 51 and 52, Section 2)
(*b*) Fit alcohol delivery pipe and expansion bellows.
(*c*) Pressure test both tanks.
(*d*) Line up tanks and position locating stays.
(*e*) Place top half in position and bolt up (Fig. 53, Section 2).
(*f*) Fit propulsion unit ring and tank supports (Fig. 54, Section 2).
(*g*) Pack ends with glass wool and retain by wire netting.
(*h*) Fit dividing bulkhead (Fig. 54, Section 2).
(*j*) Bolt sealing plates along the joints of the half sections.
(*k*) Secure centre distribution box (Fig. 54, Section 2).
(*m*) Fit oxygen vent valve.
(*n*) Install oxygen filling pipe and brackets.
(*o*) Move to propulsion fitting bay.
(*p*) Fit propulsion unit to centre section (Fig. 55, Section 2).



(*q*) Connect air lines to alcohol pressurising valve and tank valve.
(*r*) Pressure test for leakage.
(*s*) Pressure test for functioning of propulsion unit.
(*t*) Check electrical connections.
(*u*) Remove the blind plugs in the venturi and replace with standard plugs and roses.
(*v*) Fit control compartment (Fig. 56, Section 2).
(*w*) Test electrical circuits.
(*x*) Fit tail unit (Fig. 58, Section 2).
(*y*) Test and adjust.
(*z*) Attach warhead (Fig. 57, Section 2).

108. Plate 47, Section 2, illustrates the various methods of attaching the main assemblies to form the whole, together with the relative positions on the tail of the exhausts and five-way coupling to the ground connections.

109. The time study of the assembly of the A-4 rocket in the following paragraphs is not meant to be a complete schedule for assembly under manufacturing conditions. It was compiled from the building of one rocket for Operation BACKFIRE, and is considered to be representative of the whole.

Fig. 41
Alcohol Delivery Pipes

1. Y Piece from Alcohol Pump
2. Aluminium Pipes
3. 3-way Branch
4. Alcohol manifold on Combustion Chamber

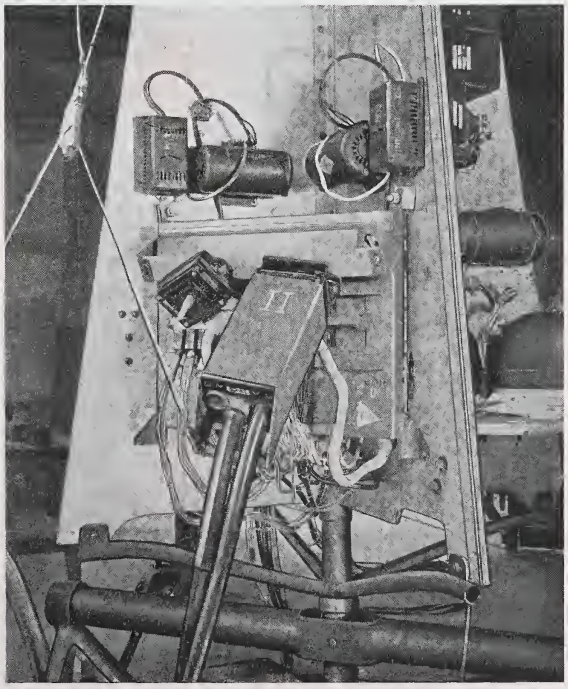


Fig. 42
View less Outer Shell

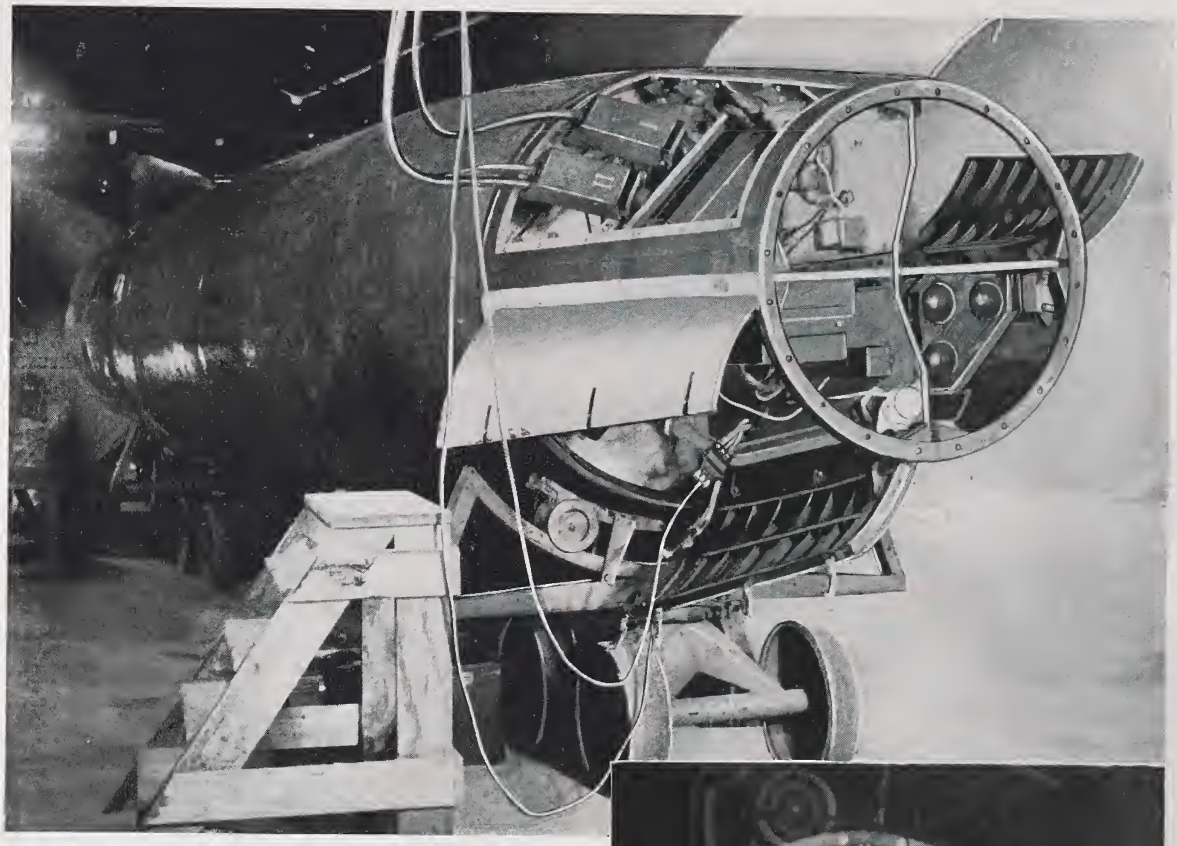


Fig. 43
Control Compartment

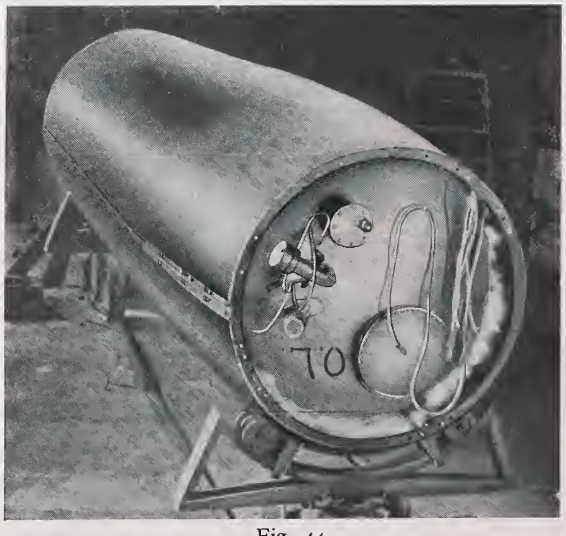


Fig. 44
Centre Section looking on Alcohol Tank

Fig. 45
Centre Section looking on Oxygen Tank

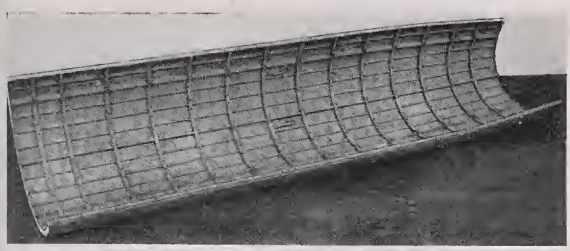


Fig. 46. Half Shell with Ports

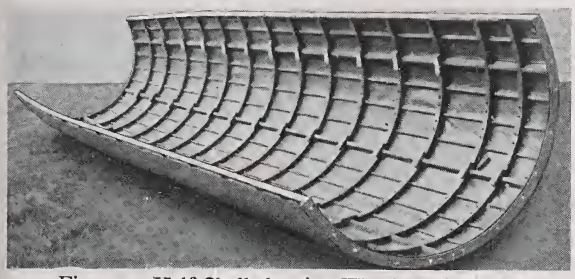


Fig. 47. Half Shell showing Wood Tank Chock

Fig. 50. Alcohol Tank

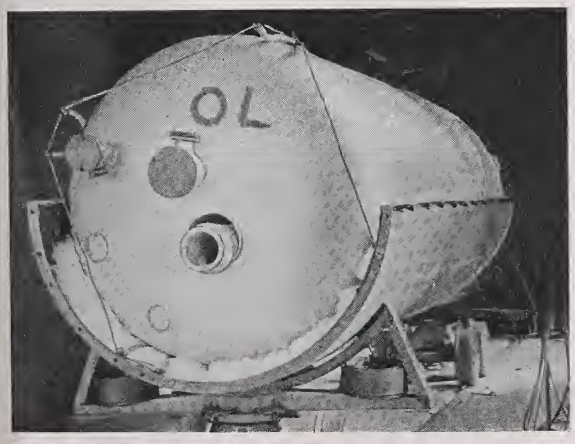


Fig. 51
View of Tanks in Position, from Oxygen Tank Side

Fig. 48. Oxygen Tank

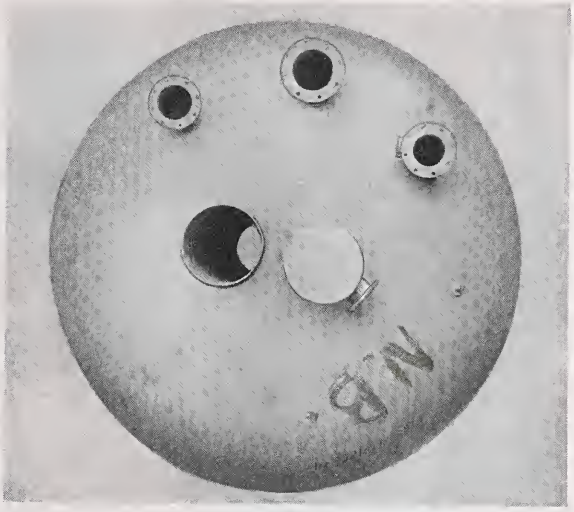


Fig. 49
View of Oxygen Tank from Combustion Chamber End

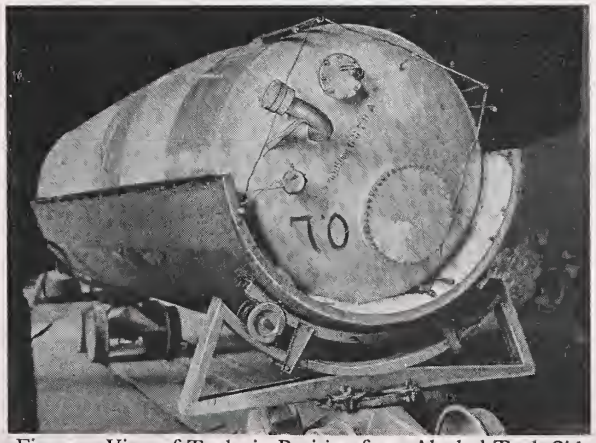


Fig. 52. View of Tanks in Position from Alcohol Tank Side

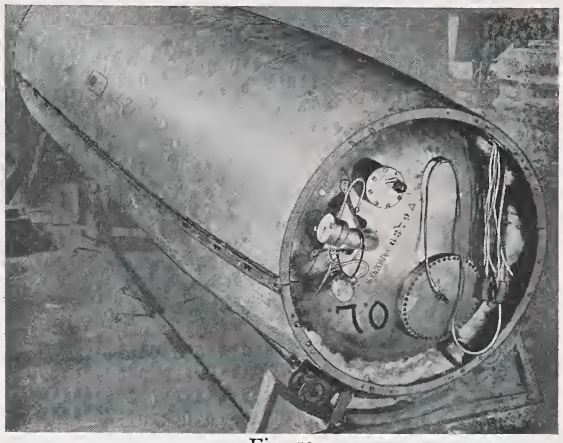


Fig. 53
Top of Centre Section Fitted

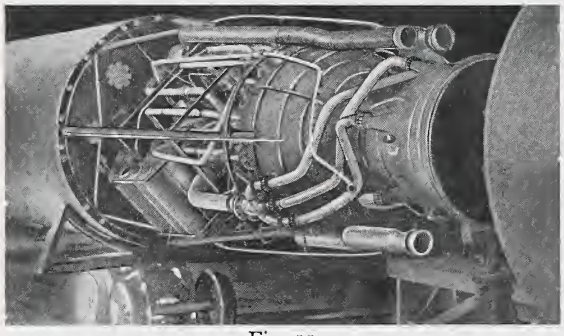


Fig. 55
Propulsion Ring Fitted

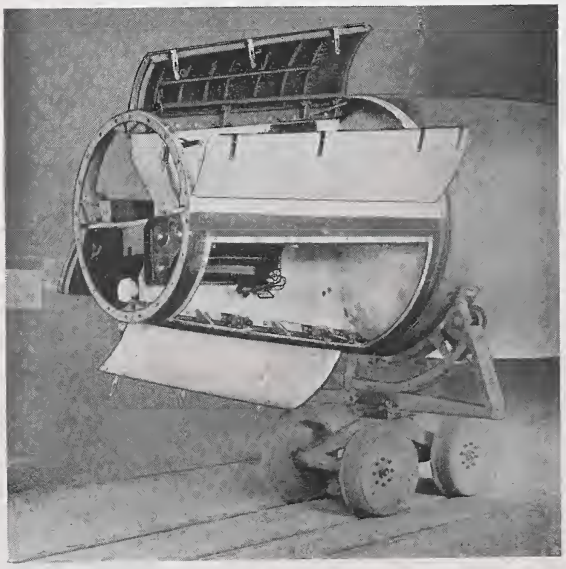


Fig. 56
Control Compartment Fitted

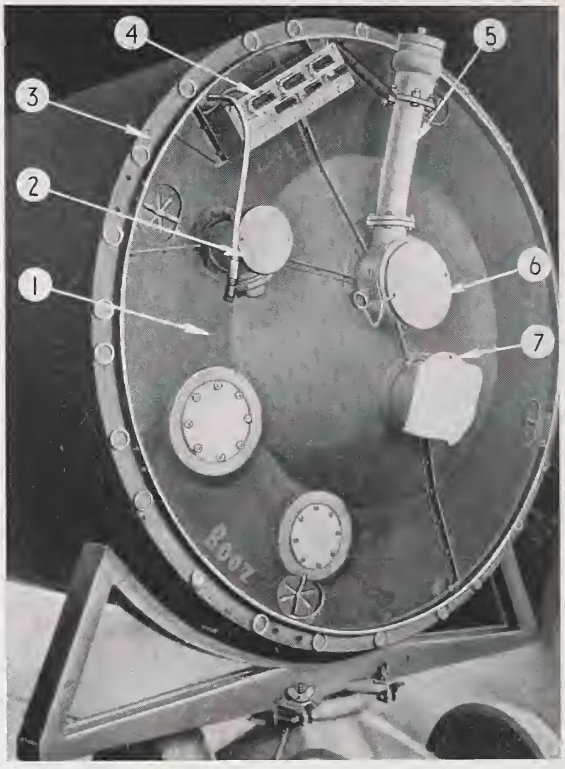
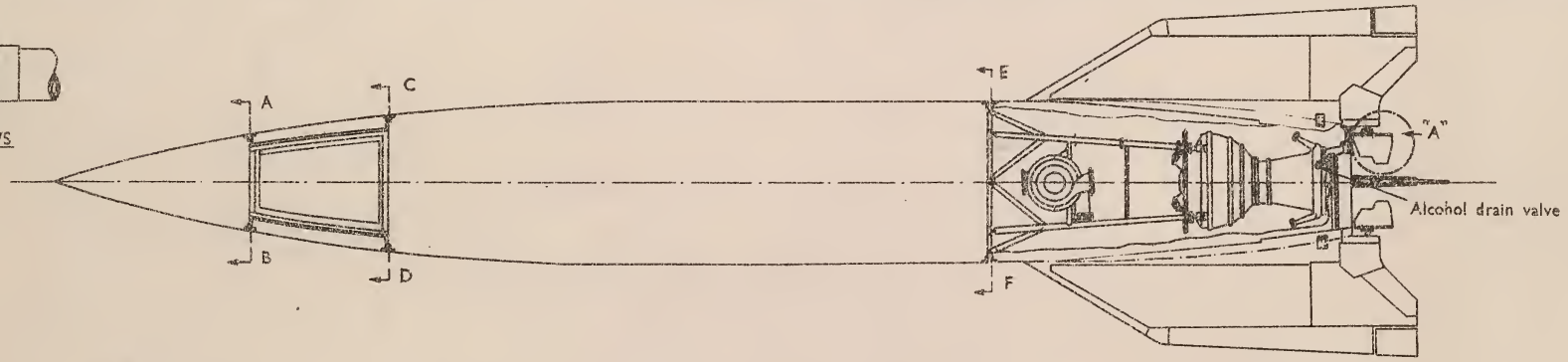


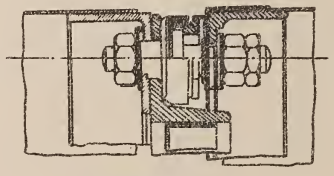
Fig. 54
Bulkhead Ring

1. Dividing Bulkhead
2. Oxygen Vent Valve Flange
3. Propulsion Unit Ring
4. Central Electrical Distribution Box
5. Oxygen Filling Pipe
6. Oxygen Delivery to Pump
7. Alcohol Delivery Pipe

Fig. 57
Warhead Attached

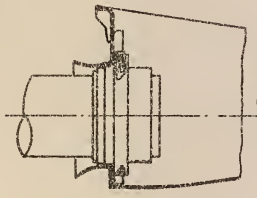
EXPANSION BELLOWS (TYPICAL).





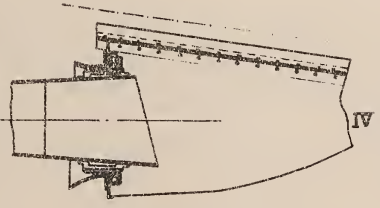
SECTION X-Y.

SECTION GI-HL



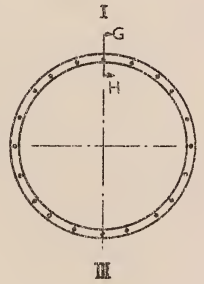
OXYGEN EXHAUST PIPE FITTING TO COWLING.

SECTION JI-KL

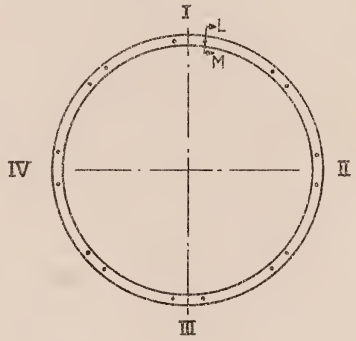


STEAM EXHAUST PIPE FITTING TO COWLING.

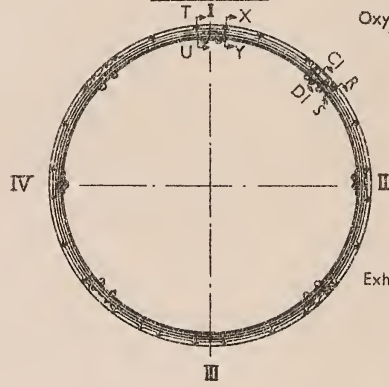
SECTION A-B.

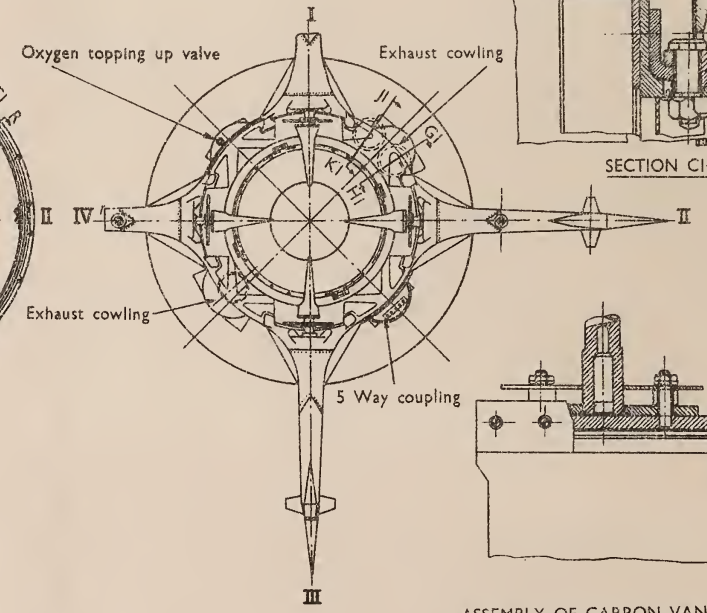


SECTION C-D.

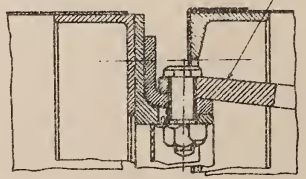


SECTION E-F.

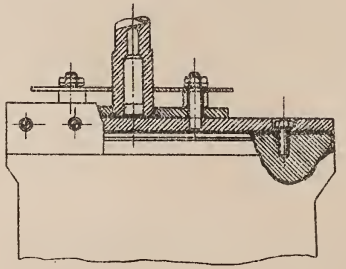




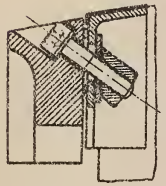
Combustion unit frame main support



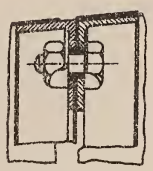
SECTION CI-DI.



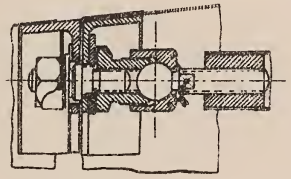
ASSEMBLY OF CARBON VANE FLANGES. (SEE DETAIL 'A')



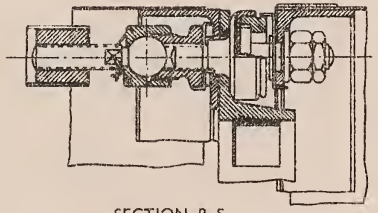
SECTION G-H. WARHEAD JOINT



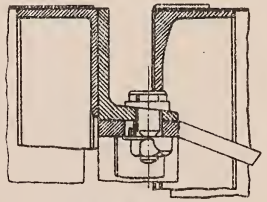
SECTION L-M. CONTROL COMPARTMENT JOINT.



SECTION N-O. ALCOHOL TANK SUPPORTS.

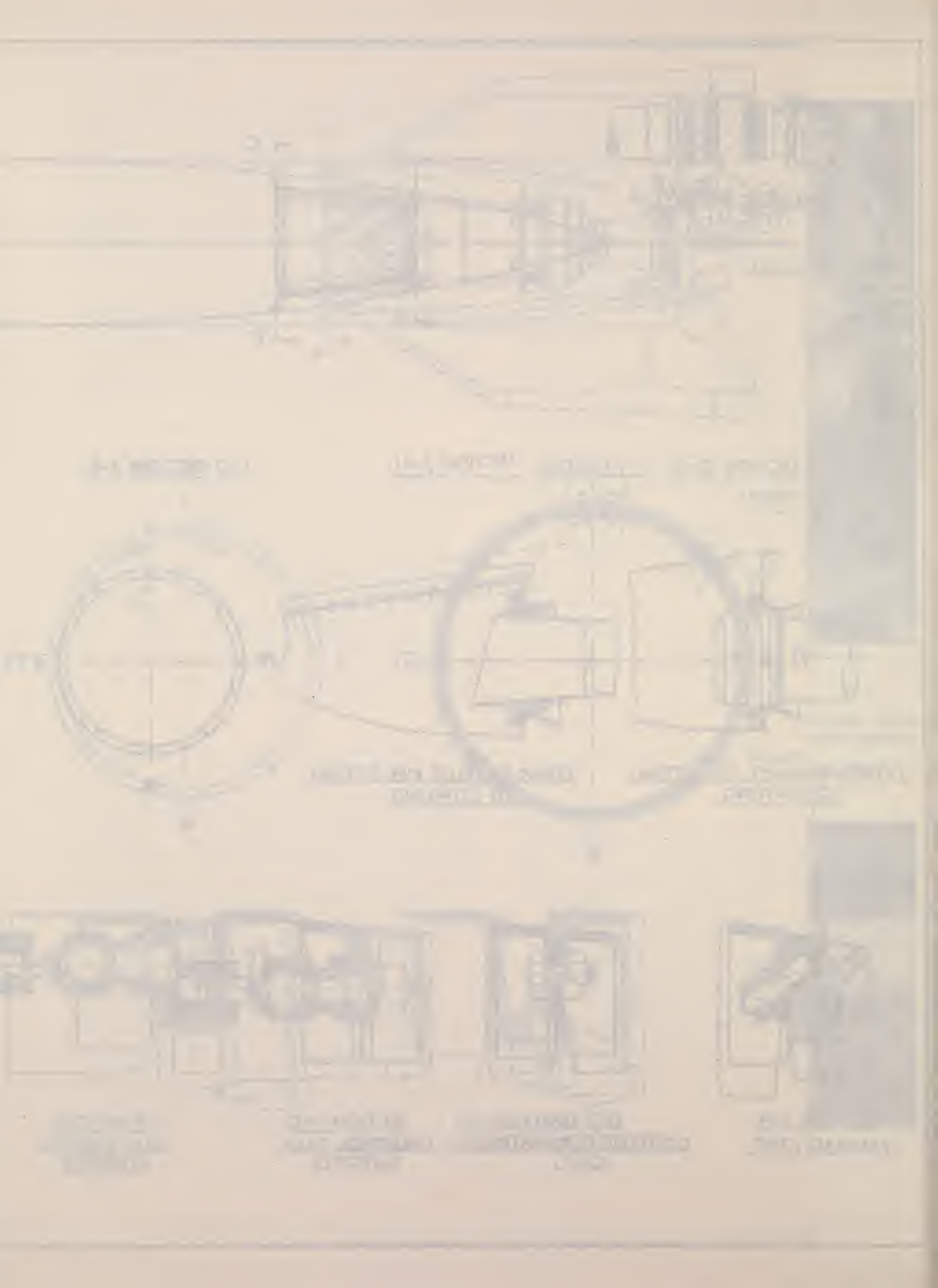


SECTION R-S. OXYGEN TANK SUPPORTS.



SECTION T-U. COMBUSTION UNIT STAY SUPPORTS

SHELL JOINT DETAILS.



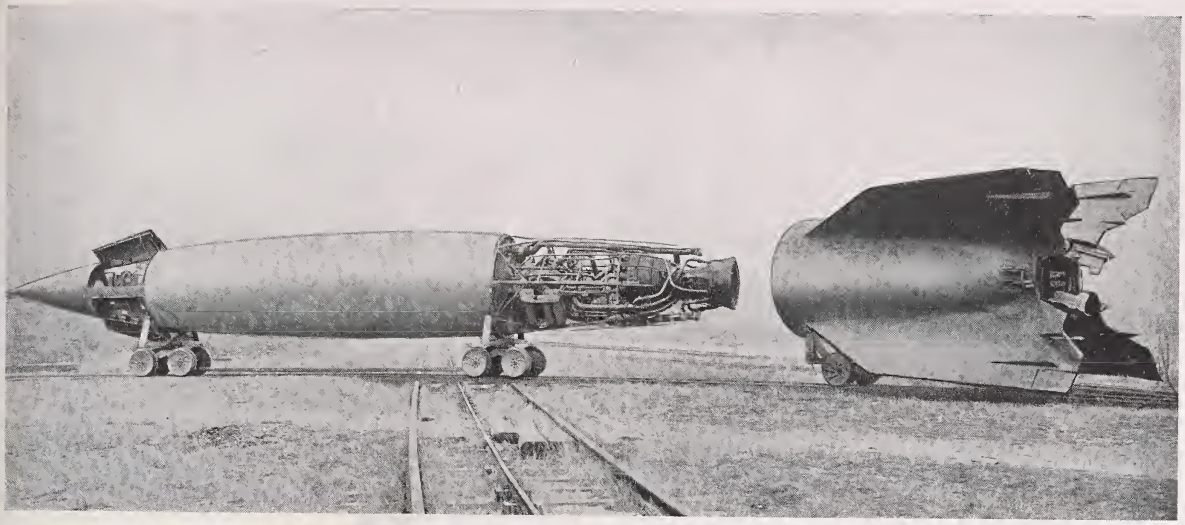


Fig. 58. Tail Unit ready to be Fitted

TIME STUDY OF ASSEMBLY OF A-4 ROCKET

1. ASSEMBLY TAIL UNIT

	MEN	HOURS	TOTAL MAN HOURS
(*a*) Assembly thrust ring			
Fit brackets	2	3	6
Install hydraulic servos	2	3	6
Fit potentiometers	2	1	2
Fit carbon rudder adjustment box	2	1	2
Connect cable forms	2	3	6
Connect hydraulic servos	2	2	4
Load test of hydraulic servos	2	6	12
Total			38
(*b*) Tail Unit			
Measure tail unit	2	12	24
Overhaul outer cover	4	24	96
Overhaul chain case	4	8	32
Assemble torsion bars and simplex chains	2	4	8
Install thrust ring	4	2	8
Fit flanges to carbon rudder	4	16	64
Install coupling for supplementary fuelling and five branch pipe coupling	1	2	2
Final tapping of threads (approx. 500)	4	16	64
Install Trim motors	1	4	4
Fix chain cases, rudder flaps, cowlings and fuelling doors	4	8	32
Install cable form	1	4	4
Adjust fins of tail unit	4	2	8
Tests	6	8	48
Total			394

2. PROPULSION UNIT

	MEN	HOURS	TOTAL MAN HOURS
Clean, rinse and dry combustion chamber	3	3	9
Check joint seatings and renew if necessary	1	1	1
Fit blanking caps	1	1	1
Fit blind plugs	1	1	1
Test	2	8	16
Install on alignment rig	2	·5	1
Mount and line up tubular framework	2	2	4
Remove to rotating assembly platform	2	·5	1
Fit turbine unit	2	·5	1
Fitting pipes	3	9	27
Fit air bottles	2	·5	1
Install steam unit	2	1	2
Fit steam exhaust and heat exchanger	1	·5	1
Pipe up air supply lines	1	6	6
Test	2	6	12
Fit restricting shorts or pump outlets	3	3	9
Stress relieve aluminium pipes	2	3	6
Wire nuts and adjust locking plates	2	2	4
Remove top ring	1	·5	·5
Total			103.5

3. ASSEMBLY OF CENTRE SECTION

	MEN	HOURS	TOTAL MAN HOURS
(*a*) Half Sections			
Survey, measure, adjust and prepare half sections	2	4	8
Install wooden chocks	1	1	1
Install cable form	1	1	1
Install air pipes	1	1	1
Put in glass wool and secure with wire netting	2	4	8
Total			19
(*b*) Assembly of oxygen container	4	1	4
Fit struts and fish plates for fixing of container	1	1	1
Clean container	1	1	1
Pressure test of container	2	2	4
Fit dummy flanges	1	1	1
Total			11
(*c*) Assembly of alcohol container	4	1	4
Install supports and brackets	1	1	1
Fix pressurising valve, and fix regulator valves	1	2	2
Install alcohol tank valve	1	1	1
Clean container and close manhole cover	1	1·5	1·5
Pressure test of container	2	1·5	3
Total			12·5
Insulate suction pipe with glass wool string	3	2	6
(*d*) Assembly of oxygen and alcohol container in the lower half sections	3	1	3
Fix suction pipe on to alcohol container	2	0·5	1
Total	2	0·5	10

3. ASSEMBLY OF CENTRE SECTION—(*continued*)

	MEN	HOURS	TOTAL MAN HOURS
(*e*) Laying on of upper half sections	3	0·5	1·5
Connecting (screwing) of both half sections	4	1·5	6
Install frame work ring and screw in bracket appliances	2	1·5	3
Fit sealing strips along shell joint	4	2	8
Fill in oxygen front with glass wool and fit dividing wall	2	2	4
Secure centre distribution box	1	0·5	0·5
Fix oxygen vent valve	1	0·5	0·5
Install oxygen filler pipe with valve and fix brackets	1	1	1
Install tank brackets alcohol side	1	4	4
Fill in alcohol tank end with glass wool and secure with wire netting	1	1·5	1·5
Total			30·0

4. CONTROL COMPARTMENT

Installing wooden sections	2	3	6
Fit electrical distribution box	2	1	2
Attach pressurising pipe	2	·5	1
Install sequence switch	2	·5	1
Install alternators and regulators	2	1.5	3
Install gyro mountings	2	1	2
Install control amplifier	2	2	4
Build in air bottles	2	1.5	3
Install cable forms	2	2	4
Fit emergency cut off hose	1	·5	·5
Fit doors and panels	1	2.5	2.5
Test	2	11	22
Total			51

5. COMPLETE ASSEMBLY

(*a*) Fitting of control compartment on to the centre section	2	4	8
(*b*) Fitting of propulsion unit to the centre section	10	5	20
(*c*) Pressure test	2	9	18
(*d*) Electrical test	4	2	8
(*e*) Joining of tail unit			
Adjust tail unit	4	1	4
Tighten junction screws	4	1	4
Screw exhaust pipes and oxygen drain valve	1	2	2
Fix supplementary fuelling pipes to coupling for supplementary fuelling	1	0·5	0·5
Joining of five branch way coupling	1	1	1
Install counter brackets, and fix asbestos-string	1	6	6
Test of steering	3	0·5	0·5
Final test	4	1	4
Close flaps and cowlings	2	3	6
Total			82

6. JOINING OF WAR-HEAD

Preparation of war-head including weighing	4	1	4
Joining of war-head	2	2	4
Joining of expansion flange to war-head	1	0·5	0·5
Total			8·5
Grand Total			721 MAN HOURS

Inspection and Tests of Rocket as Assembled at KRUPPS . . . SECTION 3

110. Inspection in detail, except for a few minor items, made locally as replacements, etc., was impossible owing to the complete absence of specifications and scarcity of drawings. An overall supervision of the work done in assembling the rocket was undertaken in conjunction with as many tests as could be devised and carried out with the strictly limited facilities available.

111. Tests had to be devised based on whatever test gear was available or could be made on the spot, and this fact together with the additional fact that in many cases reliance had to be placed on the memory of individual Germans—often conflicting—must be borne in mind when considering the scope of the work done. The subsequent accurate matching of assemblies which should have followed was impossible owing to lack of sufficient information.

112. All the components used had been tested and passed at works, but subsequent storage had been under very bad conditions which made it imperative to test and inspect every item as far as possible before taking into use on the assembly line. No attempt had been made at preservation, and, moreover, several of the valve packings were of the flimsiest character, indicating that the parts were to be worked for a minimum number of times.

113. The programme of work was split up as follows :—
(1) Visual examination.
(2) Tests on individual components.
(3) Tests on sub-assemblies.
(4) Tests of rocket in horizontal position.
(5) Tests of rocket in vertical position.

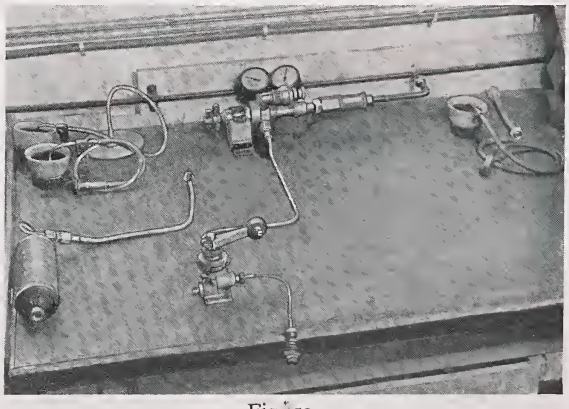


Fig. 59

114. For the purpose of this report this Section is divided into the following sub-sections :—

Sub-section (1) Tests on valves.
Sub-section (2) Tests on sub-assemblies.
Sub-section (3) Tests on main assembly in the horizontal position.
Sub-section (4) Tests on assembly in the vertical position.

115. The following tests are for mechanical performance only, and details of electrical tests follow in Section 4.

Sub-Section 1

(Typical Test Bench at Figs. 59 and 60, Section 3)

116. OXYGEN DISTRIBUTION VALVE (Plate 48, Section 3)

The test rig consists of a main pressure supply of 3,000 lb. per sq. in., fed to the reducing valve, which for test (1) reduces the pressure to 500 lb. per sq. in., and in test (2) to 200 lb. per sq. in., this pressure being fed to the oxygen distribution valve through a three-way cock. In addition to this standard electrical test, panel was used. The tests break down into two sections (*a*) Mechanical, (*b*) Electrical.

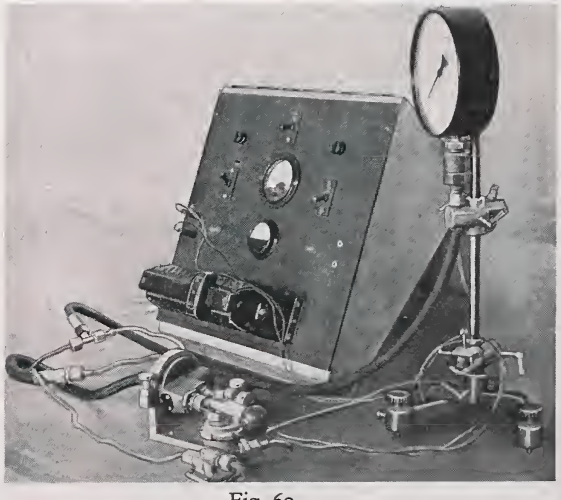
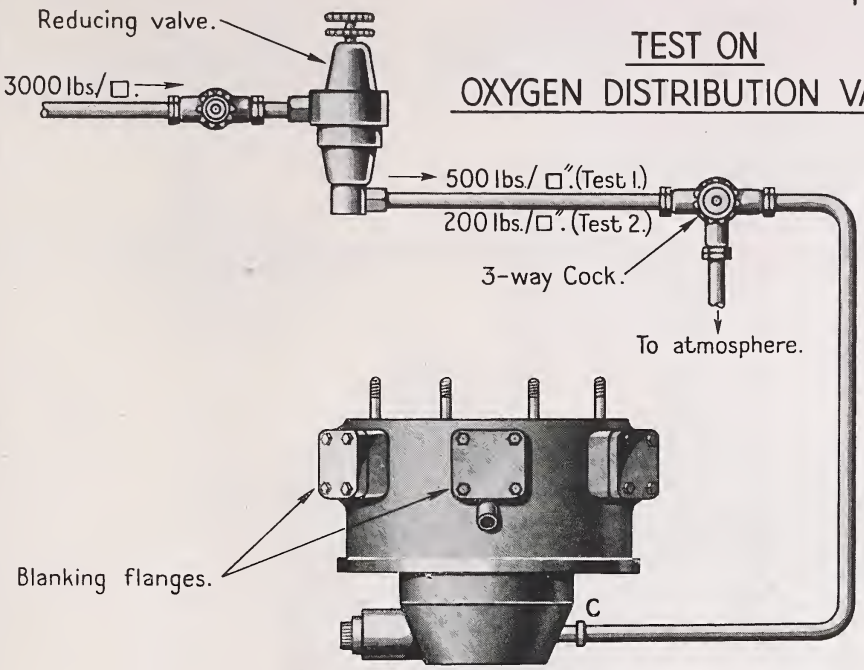
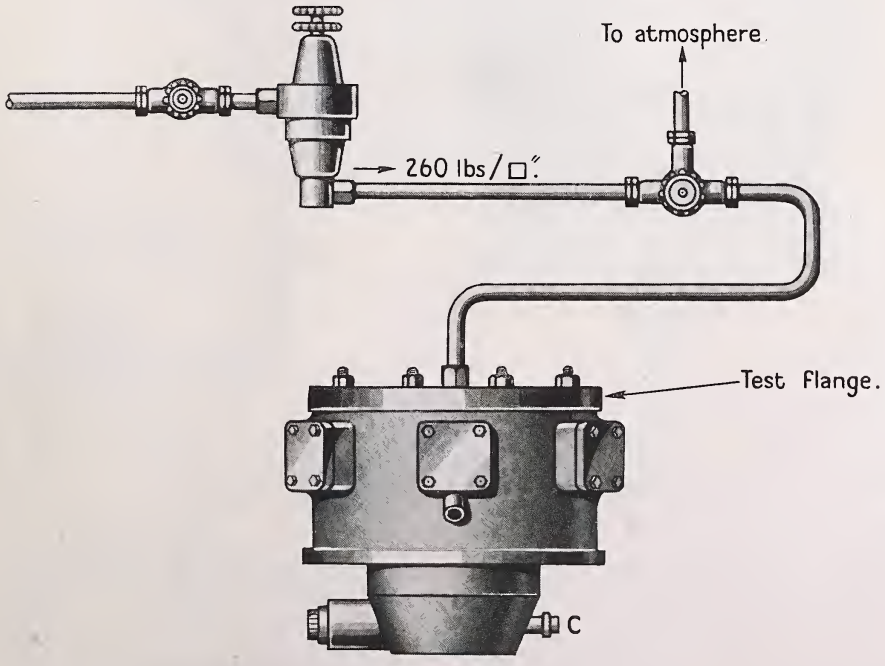


Fig. 60

TEST ON OXYGEN DISTRIBUTION VALVE.



TEST 1 & 2.



TEST 3 & 4.

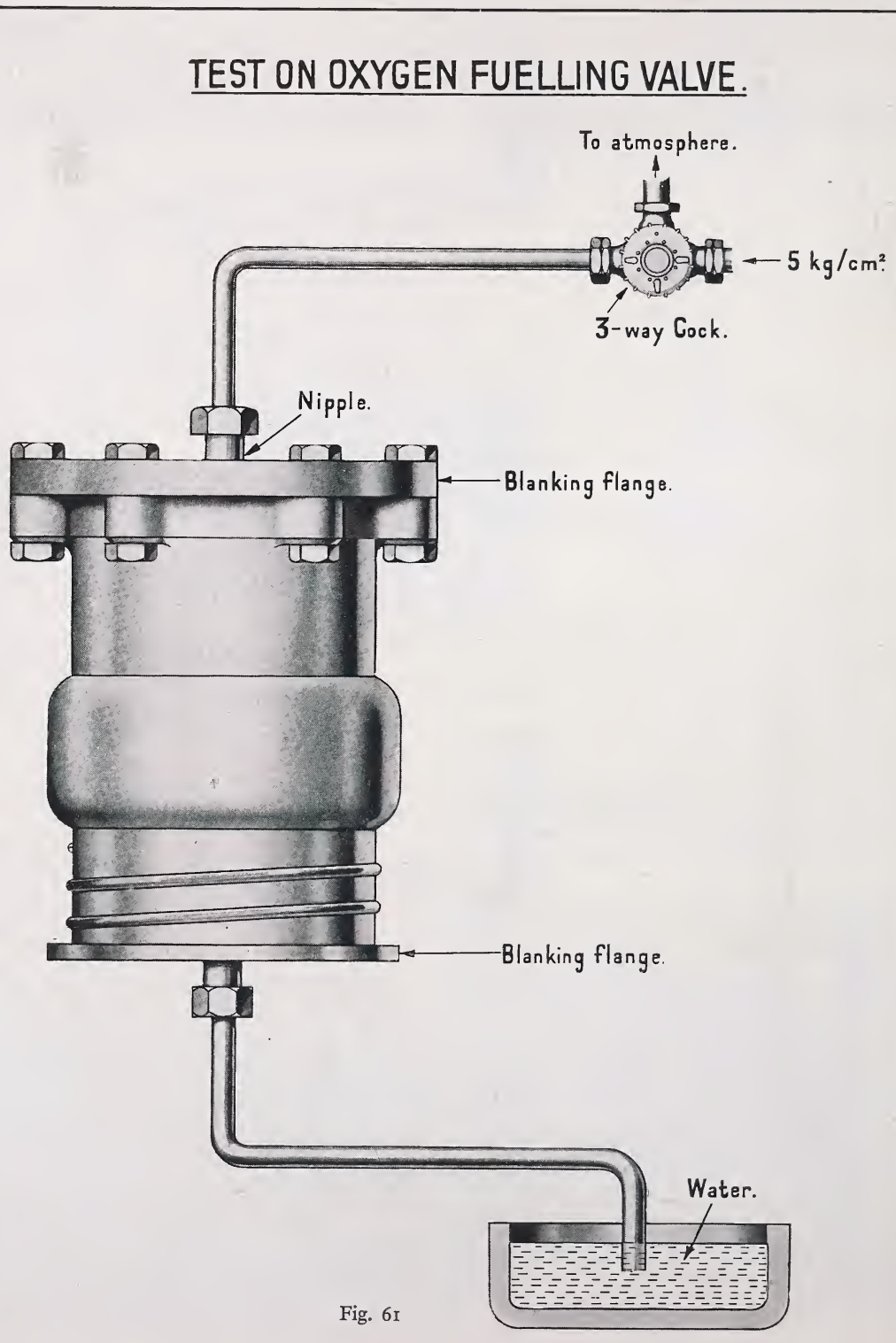

TEST ON OXYGEN FUELLING VALVE.
To atmosphere.
5 kg/cm².
3-way Cock.
Nipple.
Blanking flange.
Blanking flange.
Water.

Fig. 61

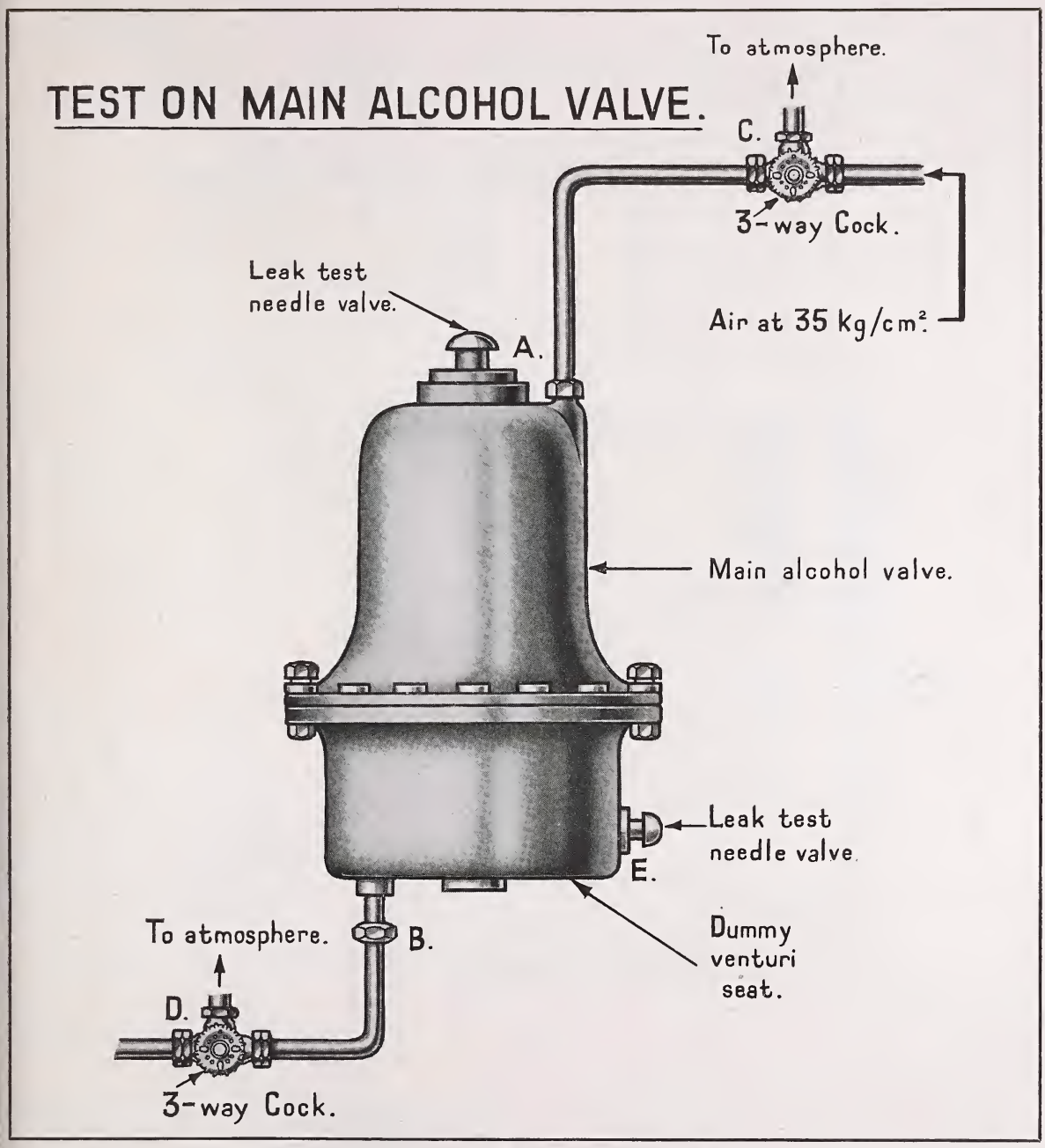


Fig. 62

117. A—TEST 1

Blank off distributing outlets. Couple the air connection from the reducing valve set to 500 lb. per sq. in. to adaptor C on the oxygen distribution valve. Apply pressure through the three-way cock. The pilot valve should close and hold pressure when the cock is turned to the off position. Check leaks through the pilot valve by connecting the bubble test apparatus to the test boss on the side of the oxygen distribution valve body.

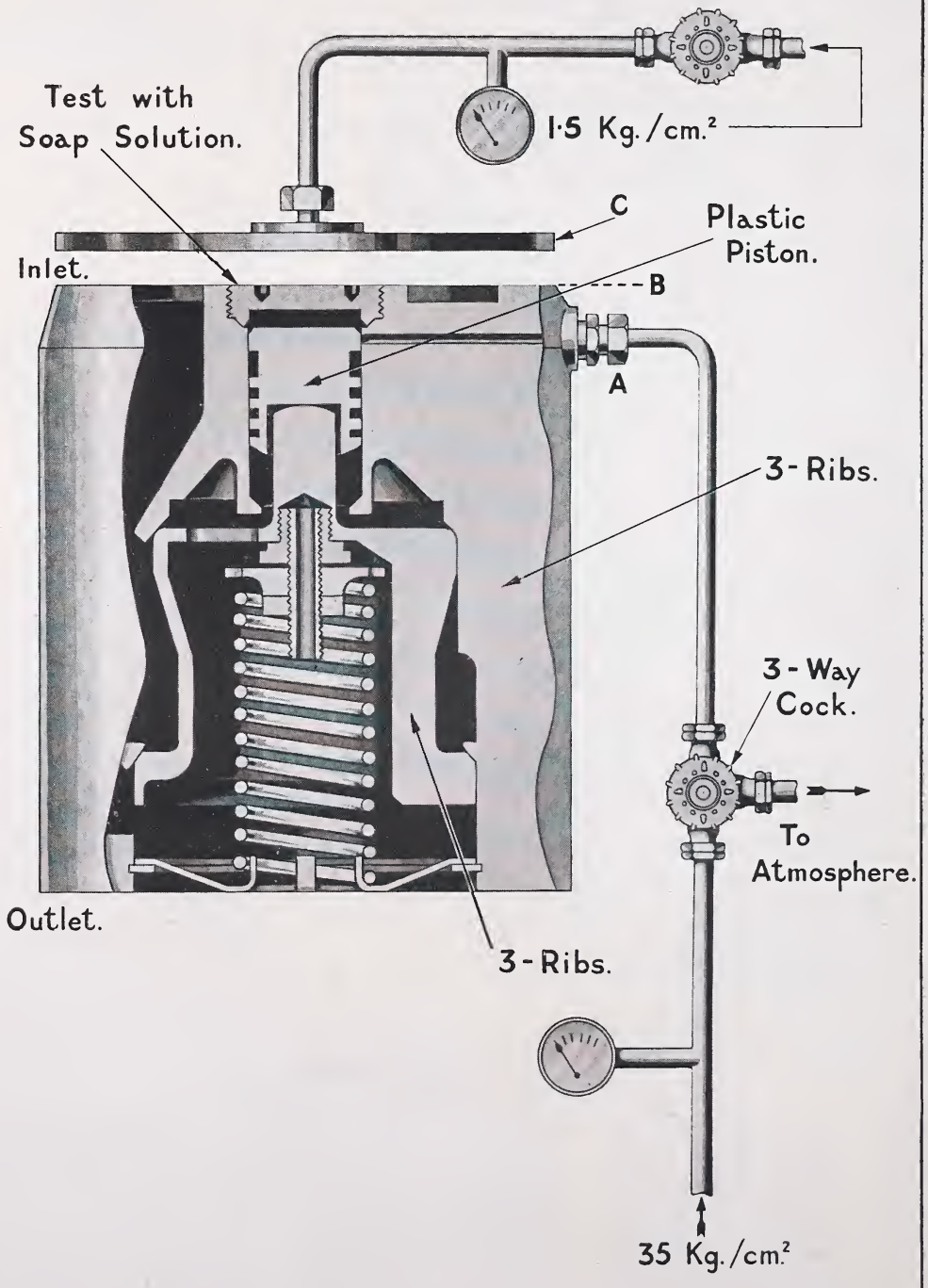
118. TEST 2

Exhaust the air on the pilot valve bellows to atmosphere through the three-way cock and measure the movement of pilot valve from the closed position to where the contact in the switch is opened and the valve is on its reverse seating. This distance should be 3·5 mm.

119. TEST 3

Disconnect the 500 lb. air supply from adaptor C. Bolt the test flange over the pump inlet connection and

TEST ON OXYGEN VENT VALVE.



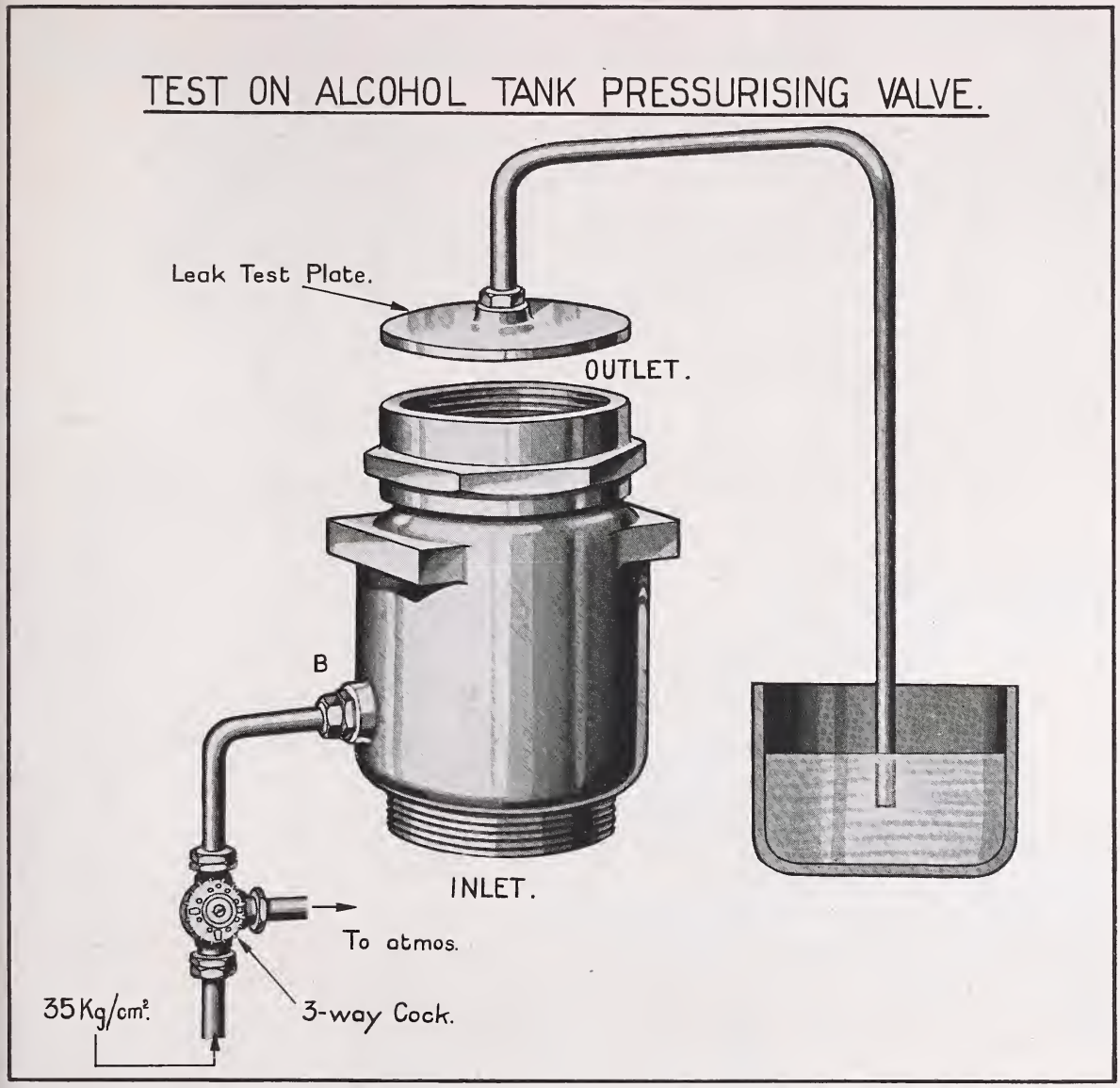


Fig. 63

through the air connection on the test flange apply pressure of 200 lb. per sq. in. This should open the main valve; at the same time the main valve closes down over the pilot.

120. TEST 4
With pressure still connected as for the previous test, apply the leak test nipple to adaptor C of the oxygen distribution valve. No leaks are permitted.

121. B ELECTRICAL TESTS
TEST 1
Check the insulation of the switch and contacts from the main body.

122. OXYGEN FUELLING VALVE (Fig. 61, Section 3)
(*a*) Examine seat of valve for damage.
(*b*) Check easy movement of spring loading manually.
(*c*) Blank off outlet side and through flange apply pressure of 5 kg/cm.
(*d*) Apply test leak plate to inlet and observe whether leakage occurs through the seating.

123. OXYGEN VENT VALVE (Plate 49, Section 3)
(*a*) Examine valve seats for damage.
(*b*) Apply a pressure of 35 kg/cm.^{2} through connection A which in turn applies pressure to the piston which opens the valve. Taking the top flange B as the datum

line, measure the travel of the piston. This should be 12 to 23 mm.
(*c*) Apply soap solution to the flange of the piston chamber, care being taken not to put it inside, and test for leakage.
(*d*) Release pressure from A through the three-way cock and fit flange C. Apply pressure at 1·5 kg/cm.^{2}, which is then increased slowly up to 2 to 2·1 kg/cm. The valve should lift at this pressure and vent. Repeat at least twice.
At the factory an air flowmeter was fitted in the test rig to check the rate of discharge.

124. MAIN ALCOHOL VALVE (Fig. 62, Section 3)
An attachment known as a dummy venturi seat is bolted to the flange of the valve and is designed so that in the normal position the valve seat is in the same relative position as it is when fitted to the venturi proper. A blanking cap fitted with a needle valve is fitted to the bye-pass outlet. A further needle valve is fitted in the side of the dummy venturi seat.

(*a*) With the valve D open to atmosphere apply air pressure to inner piston through C at 35 kg/cm.^{2} (500 lb. per sq. in.). Valve should close on dummy venturi seat.

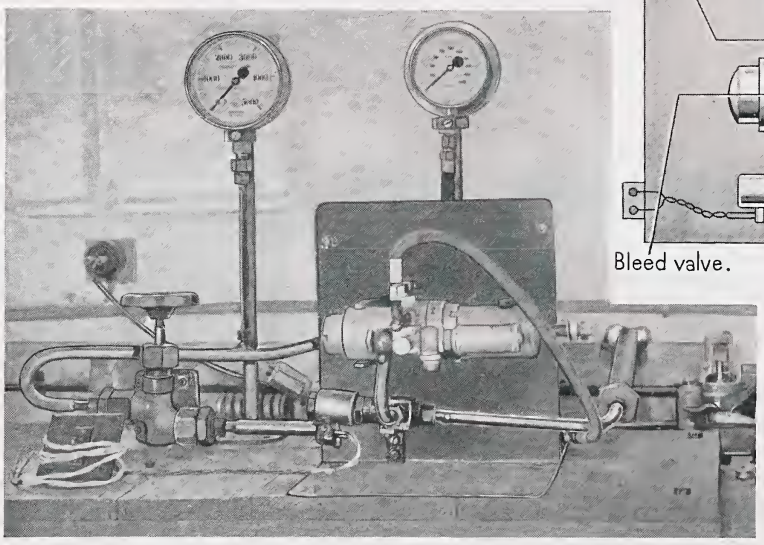


Fig. 64
Reducing Valve Test Rig

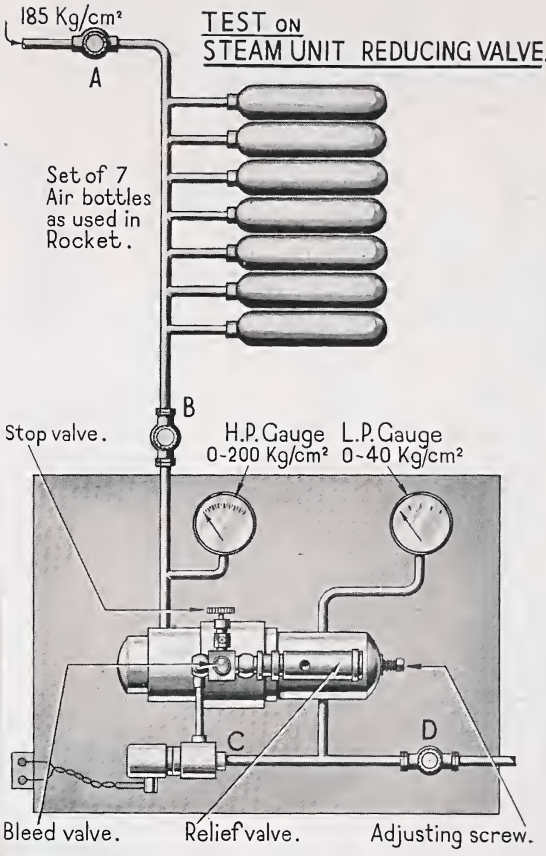


Fig. 65

(*b*) Test dummy venturi seat by means of bubble test for tightness of valve seat both at D and B.
(*c*) Exhaust air through three-way cock C from piston.
(*d*) Admit air at 18 atmospheres through D to main valve. This should close the valve against the bye-pass seat.
(*e*) Check length of travel from static position to bye-pass seating which should be 5·5 mm.
(*f*) Attach leak tester to needle valve E with 17 kg/cm.^{2} on dummy venturi seat to check tightness of bye-pass seating and at A to check packings.

125. ALCOHOL TANK VALVE (Plate 50, Section 3)
(*a*) Connect the electric cable to the test board.
(*b*) Connect air supply to the adaptor on valve at pressure of 35 kg/cm.^{2} (500 lb. per sq. in.).
(*c*) Open up air supply slowly. The valve seat should retract smoothly and electric circuit should be completed at end of stroke. Exhaust valve body through three-way cock and repeat operation smartly several times. Again check circuit operation.
On assembly to the alcohol tank and coupling, valve is again tested for pressure tight seating.

126. ALCOHOL TANK PRESSURISING VALVE (Fig. 63, Section 3)

TEST 1
Valve is examined visually for damage.

TEST 2
Air connection is coupled through the three-way cock and reducing valve to the air inlet B and a pressure of 35 kg/cm.^{2} is applied. This causes the valve to close, any

TEST ON ALCOHOL TANK VALVE.

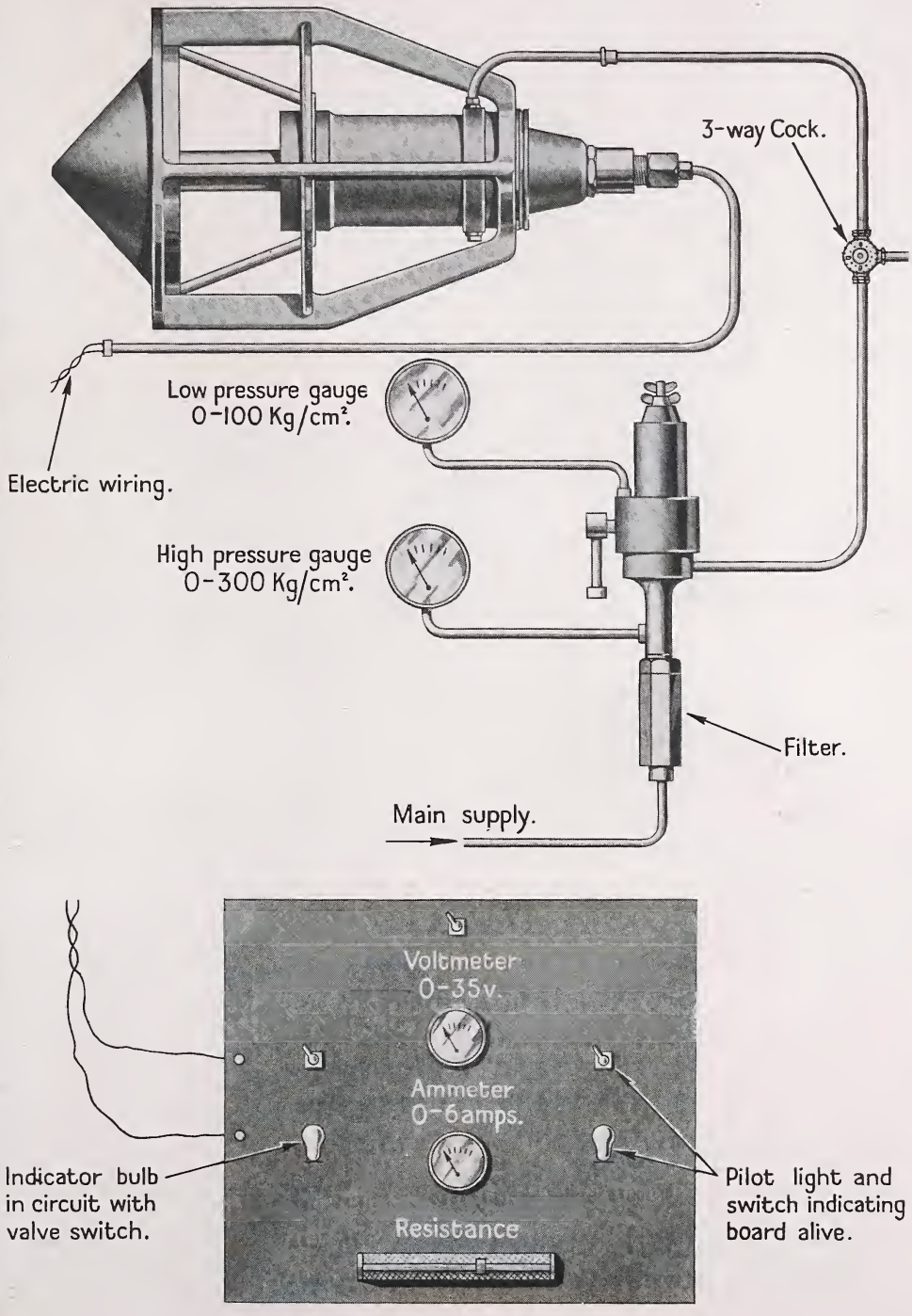
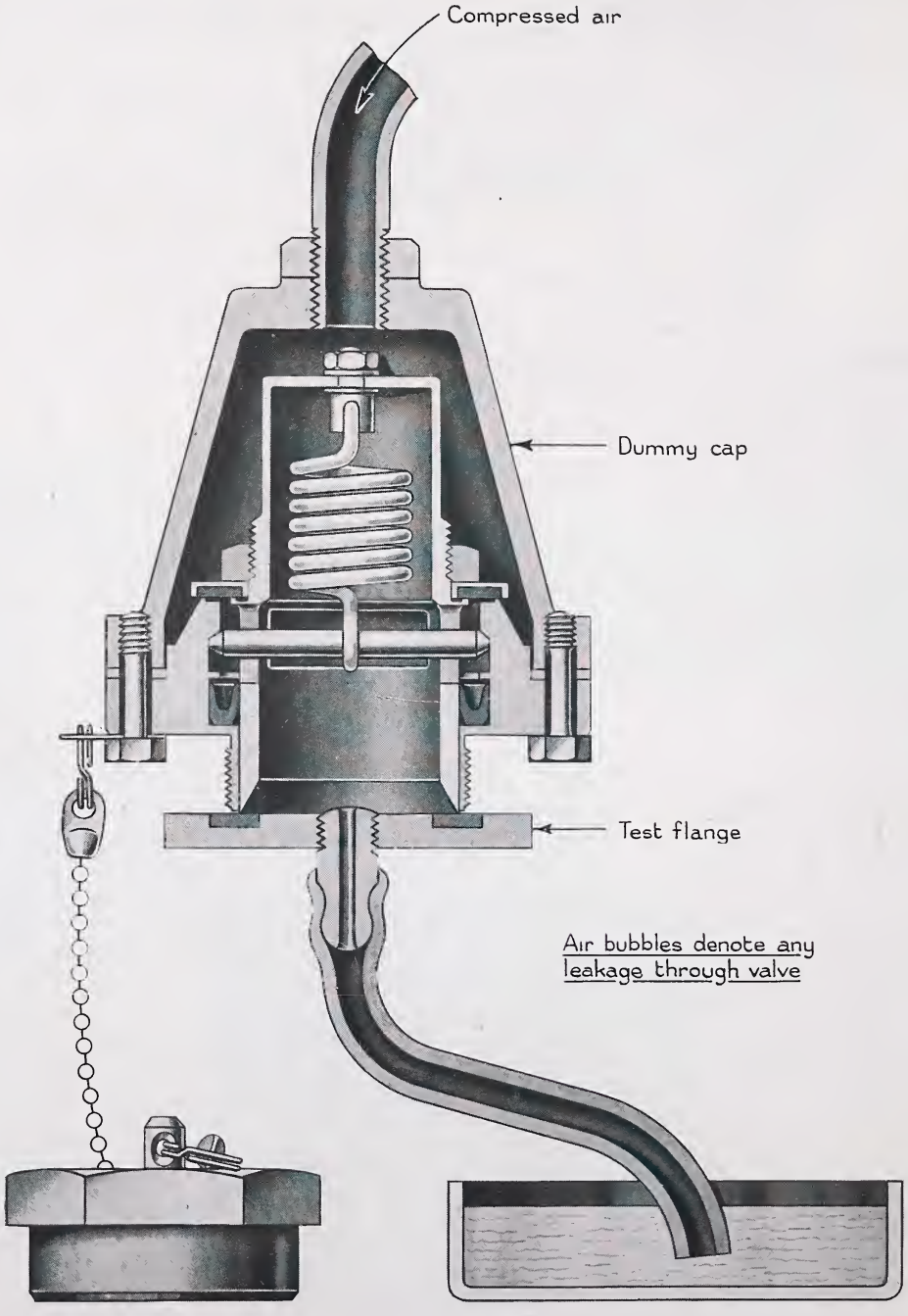


Plate 51

TEST ON ALCOHOL DRAIN VALVE



leaks from the pressure inlet side being checked by means of a bubble test on the outlet side.

TEST 3

Releasing the pressure through the three-way cock, check travel of the valve, which should be 15 mm. With a pressure at 35 kg/cm.^{2} on the inner piston, thus closing the valve, apply on the inlet side a test pressure to 1·5 to 1·8 kg/cm. The leak test plate is then placed over the outlet side, and by means of the pipe under water any leakage can be observed from the rate of flow of bubbles.

127. ALCOHOL DRAIN VALVE (Plate 51, Section 3)

A special adaptor is fitted over the valve to represent the alcohol tank. This adaptor is fitted with a normal air adaptor and air is supplied at 0·7 kg/cm.

The valve seating is tested for leaks by means of a blanking plate with the test nipple, tube and the usual bubble apparatus.

The valve is then lifted manually off its seating three or four times and re-tested.

128. PRESSURE OPERATED CONTACT ON STEAM UNIT (Plate 52, Section 3)

The pressure operated contact switch is held in the test rig as illustrated. The adjusting screw on the test rig is manipulated so that the tongued end of the screw fits into the slot of a corresponding adjusting screw of the pressure operated contact switch. The graduated collar on the test rig screw is set to zero. An airline passing pressure at 1·5 kg/cm. is coupled with a gauge to the pressure inlet of the contact switch, and from the electric socket wires are taken to the standard test panel. A three-way cock on the airline is opened and when the pressure gauge reads 1·5 kg/cm. the pressure is held while the rig adjusting screw is tightened (or slackened) until the lamp on the test panel lights up.

The full working pressure employed in the system, viz., 32 ats., is then applied to the switch, released and applied again 5 times. The valve is then re-tested at 1·5 ats. and the lamp should light up. If it fails to light up the pressure will be increased until a light is obtained. If this pressure is over 2 ats. the switch is rejected. In practice it is often found necessary to readjust switches after the testing of the steam unit assembly.

129. STEAM UNIT REDUCING VALVE (Figs. 64 and 65, Section 3)

Using the apparatus shown schematically, the following procedure was adopted :—

(*a*) Charge bottle reservoir through valve A to 185 kg/cm. (2,650 lb. per sq. in.).

(*b*) Shut off stop valve which is normally used on assembly tests and open valve B, thus allowing pressure to be applied through the filter and to the high pressure side of the valve.

(*c*) Open stop valve and check that air is present on the low pressure side.

(*d*) Close stop valve and check operation of bleed valve.

(*e*) Loosen off adjusting screw and shut bleed valve and stop valve.

(*f*) Energise the solenoid valve C and allow air to pass through the valve to the pressure gauge on the low pressure side, the valve D closed.

(*g*) Screw up adjusting screw until gauge pressure on the low pressure side reads 35 kg/cm.^{2} (500 lb. per sq. in.). Open bleed valve and recheck gauge reading after closing.

(4) Close valve A and open up valve D, thus exhausting the air bottle reservoir to atmosphere. The low pressure drop should not fall below 31·5 kg/cm. (450 lb. per sq. in.) and in 70 seconds the high pressure drop should be from 185 kg/cm. (2,650 lb. per sq. in.) to 70 kg/cm. (1,000 lb. per sq. in.).

130. TO TEST THE RELIEF VALVE

Remove the outer cap, slacken off adjusting screw and couple the reducing valve to the testing rig as indicated in para. 129 (f) adjusting screw on the relief valve to blow at 500 lb. per sq. in. to prove functioning. Finally set the relief valve to blow at 42 kg/cm.

After carrying out the above test the main adjusting screw is slackened off to relieve the tension on the main spring.

131. SOLENOID OPERATED VALVES (Plate 53, Section 3)

TEST 1

Connect solenoid to electrical test panel.

TEST 2

Remove top plate of solenoid and measure the distance of the plunger from the top face.

TEST 3

Check the electrical test panel to give a voltage of 25 volts and that the bulb indicator contact is functioning.

TEST 4

Operate switch on test panel, closing the circuit to the solenoid and energising the coil. Measure the movement of the plunger. This should be from 1 to ·5 mm. according to the flow required. At the same time check voltage and amps. Adjust plunger travel if necessary. Readings taken at this test were 25 volts, 1 amp. on the test panel.

TEST 5

Couple air-line from the three-way cock to inlet side of the valve and apply a pressure of 30 kg/cm. Check the voltage applied by means of the variable resistance on the test-board to 18 volts. Check outlet for leakage. Close the circuit on the test panel operating the solenoid which lifts the valve from its seat. Check clear flow of air and that the valve opens smartly.

Repeat at least three times.

132. AIR CHARGING AND STOP VALVE (Fig. 66, Section 3)

Diagram of Valve and Schematic Diagram of Test Rig.

TEST 1

Examine the valve components for corrosion and check seatings.

TEST 2

Reassemble and connect outlet A to air reservoir.

Connect inlet B to pressure pipe line and pass air at 10 kg/cm. through to the reservoir.

Release pressure through the three-way cock to atmosphere

CONTACT SWITCH TEST AND SETTING RIG.

(JIG MADE FROM STEEL.)

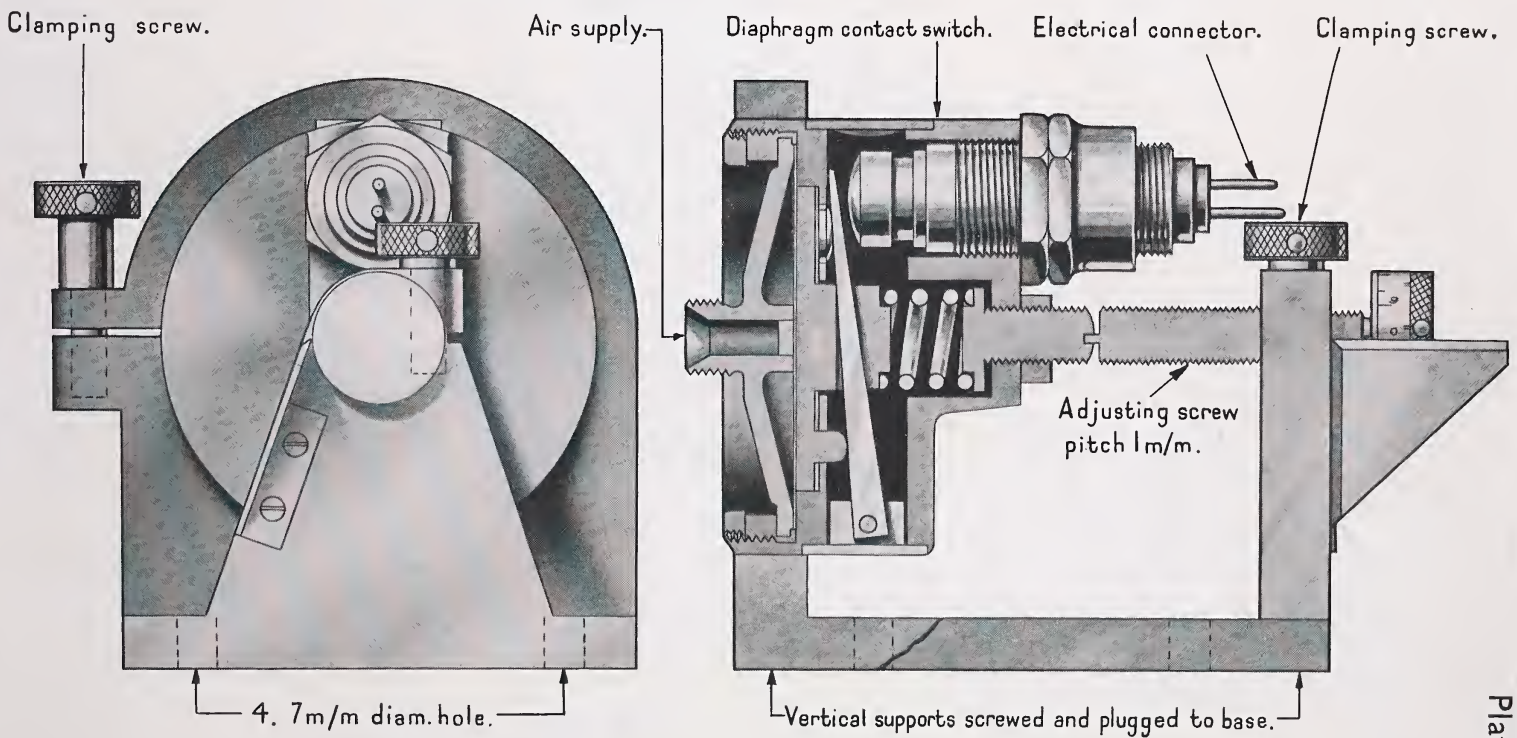
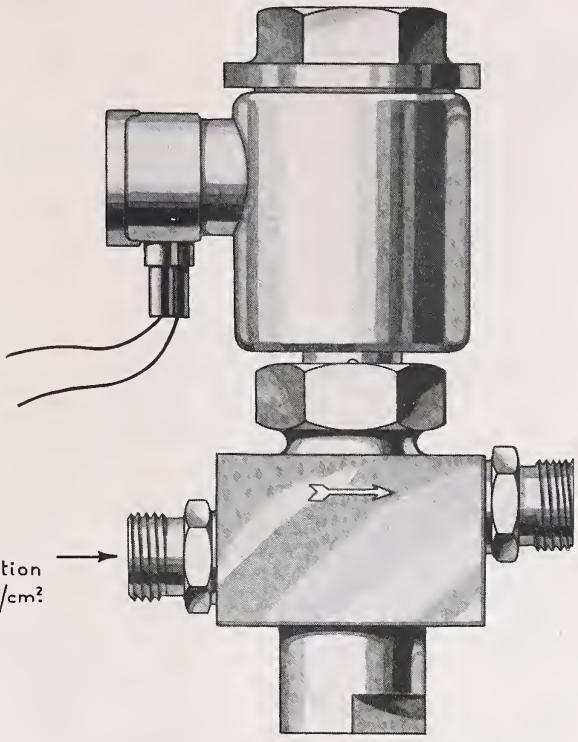
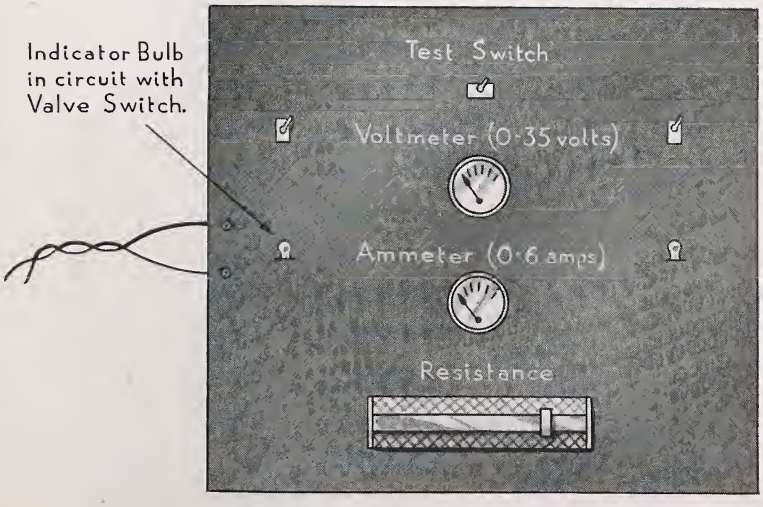


Plate 52

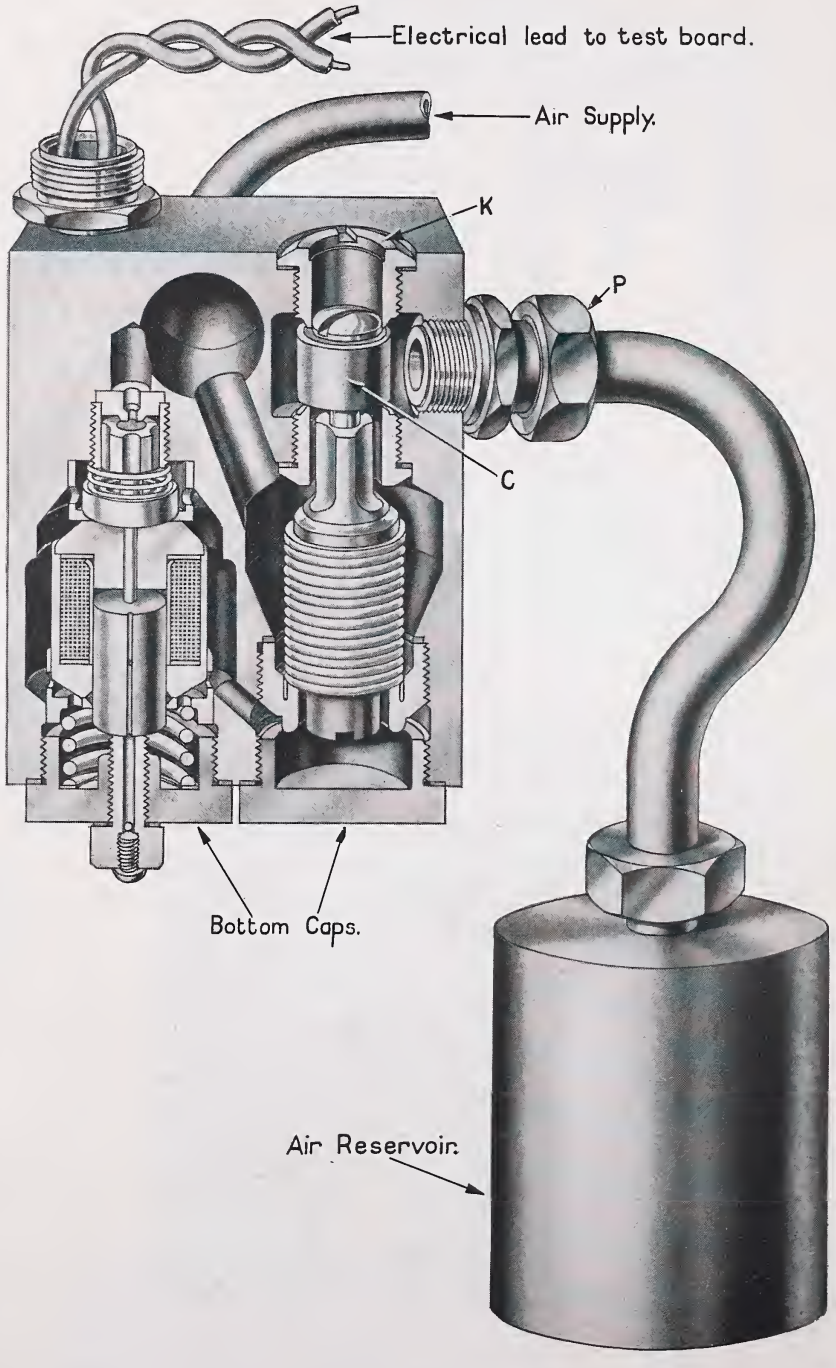
TEST ON SOLENOID OPERATED VALVES.





TEST ON PRESSURE OPERATED RELAY VALVE.

(AIR ON POSITION.)



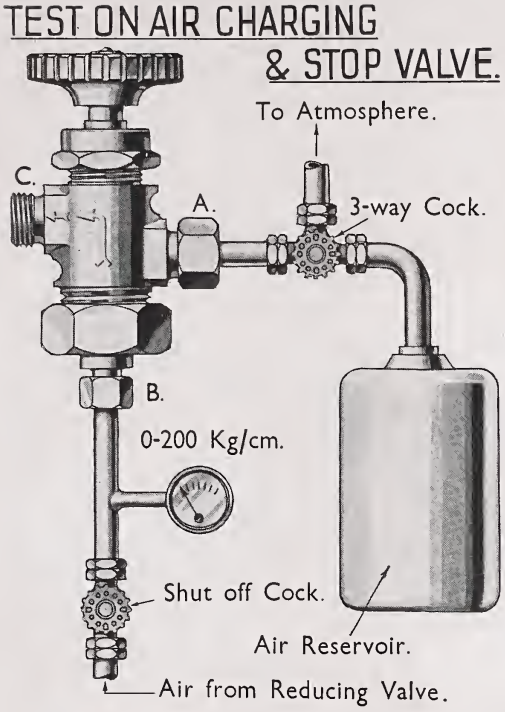


Fig. 66

and recharge to prove that air is passing through to the reservoir. Check joints on reservoir line for leakage.

TEST 3
Readjust main pressure reducing valve to give 35 kg/cm. and pressurise the reservoir.
Remove supply line from B.
By means of the bubble test apparatus test nipples B and C for leakage.
Open valve and check that a free passage of air flows from the air reservoir through C.
Repeat tests a minimum of twice.

133. PRESSURE OPERATED RELAY VALVE (Plate 54, Section 3)
(*a*) The outlet P is connected to an air reservoir.
(*b*) The inlet is connected to an air supply of 35 ats.
(*c*) The solenoid is connected electrically through the test panel, the variable resistance of which is set to give an 18-volt supply.
(*d*) Air is applied through the inlet and passes into the air reservoir.
(*e*) Outlet K is then tested for leakage.
(*f*) Solenoid circuit is then completed and at voltage of 18 volts valve C must operate instantly, releasing pressure to atmosphere through K.
(*g*) This test should be carried out at least three times.
(*h*) Test for airtightness of bottom caps.
(*i*) Disconnect air pipes and test the electrical connections for insulation by means of test prongs using the electrical test panel.

Sub-Section 2

134. OXYGEN TANK
(*a*) Visual examination.
(*b*) Blank off all orifices.
(*c*) Apply pressure for 1 minute over range of 0·3 to 1·5 atmospheres. Repeat successively for 5 reversals.
(*d*) Apply pressure of 1·5 atmospheres. Shut off and hold for 20 minutes. Pressure must be maintained.
Leaks at welds or joints should be looked for with a soap solution.
In the actual manufacture of these tanks a hydraulic test of 2·3 kg/cm.^{2} was applied followed by an air test of 2·3 kg/cm. with a 20 minute holding time.

135. Alcohol Tank
(*a*) Visual examination.
(*b*) Blank off all orifices.
(*c*) Apply pressure of 0·9 atmospheres.
(*d*) This pressure must be maintained for 15 minutes, meanwhile leaks at welds or joints should be looked for with soap solution. Manufacturing tests called for a hydraulic test at 1·5 kg/cm.^{2} followed by an air test of 1·1 kg/cm.^{2}

136. PUMP UNIT TESTS
This is a preliminary test which is made on the unit after assembly in order to check for any leaks in the system. Unit assembly comprises the oxygen and alcohol pumps and turbine.
Owing to lack of adequate facilities no actual running test can be carried out.

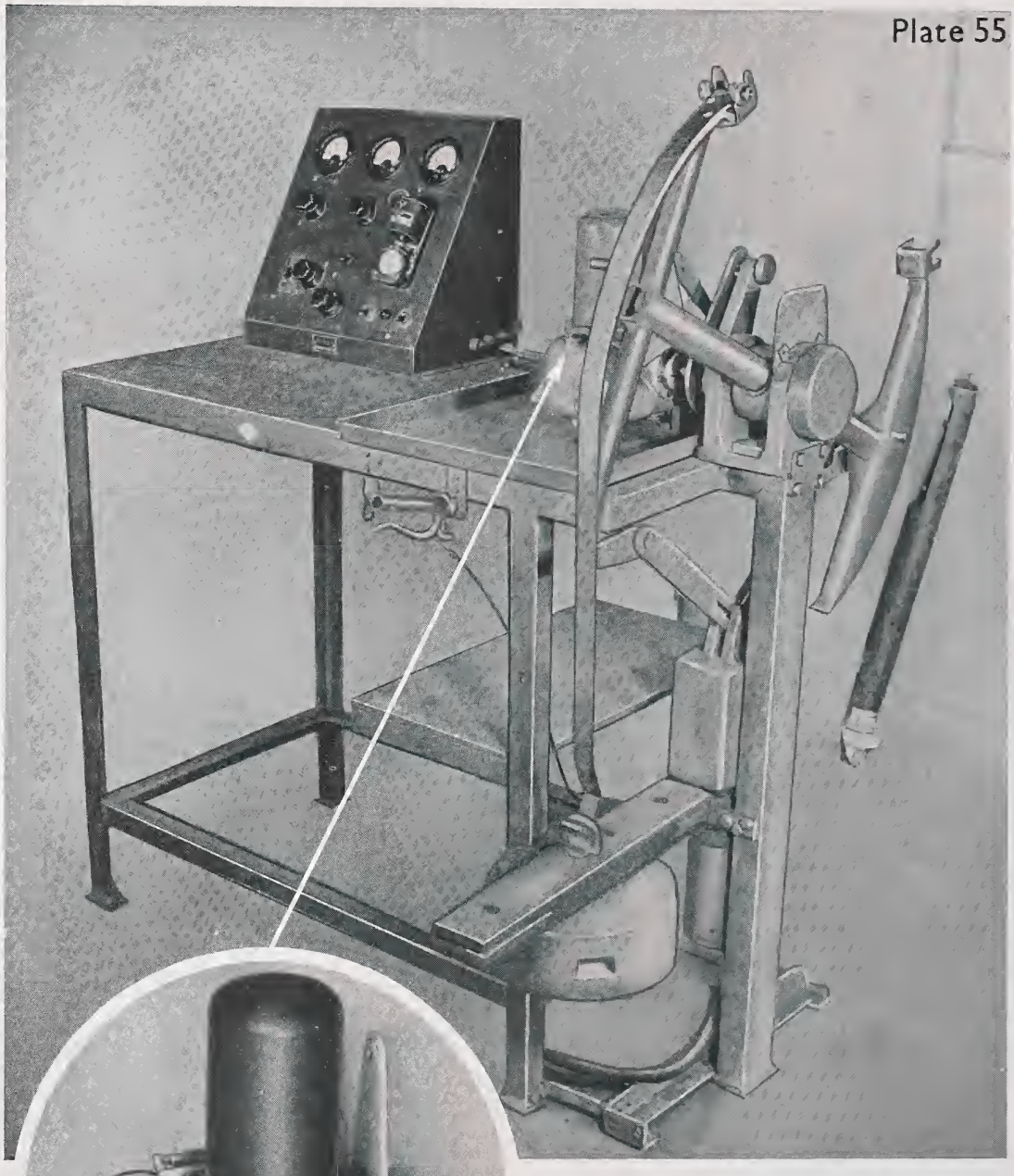
137. PREPARATION
Revolve the driving shaft by hand to check turning load.
The outlet and inlet connections of both pumps are blanked off with blind flanges, one fitted with two air line adaptors.

138. TEST 1
OXYGEN PUMP
Connect one air line from the pressure test panel with its reducing valve set to deliver 1·5 kg/cm. to inlet flange of pump; from the other adaptor on the test flange, connect pipe line to the pressure gauge on the pressure test panel, having a capacity of 2·5 kg/cm. Pressurise the system to 1·5 kg/cm. Observe the gauge for 60 seconds. Owing to the construction of the bearings of the pump, some leakage is inevitable, but the tolerance laid down is that the pressure drop should not exceed 1 kg/cm. in 50 seconds. Meanwhile all joints are tested with soap solution.

139. TEST 2
ALCOHOL PUMP TEST
Pressure air-lines are connected in the same way as for the oxygen pump test, but the reducing valve on the pressure test panel is set to give 2 kg/cm. instead of 1·5 kg/cm. The system is pressurised and held for 2 minutes whilst all joints are tested with soap solution. No leaks are allowed.

Should either pump fail to pass the tests outlined above it is necessary to strip the assembly and replace gaskets and seals.

Plate 55



140. SERVO UNIT (Plate 55, Section 3)

This test is carried out in a fixture having a moveable arm on which varying weights can be placed and which is used in conjunction with an electric test panel, so arranged as to give the desired control and allow of the necessary recording.

(*a*) Normal electrical insulation test—2 megohms.

(*b*) TIME TEST for full travel of motor arm with no load.

(*c*) LOAD TEST (*a*) WITH 1 METRE KG.

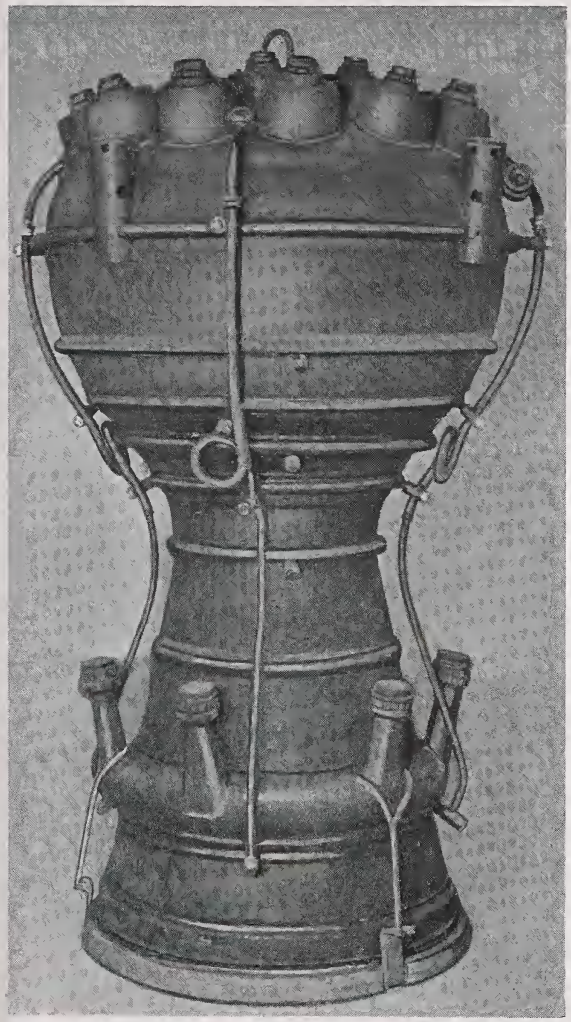


Fig. 67

The current necessary on the control relay to just move the load should be 2 mA in either direction. A maximum of 4 mA is allowed.

(*d*) LOAD TEST (*b*) WITH 30 METRE KG.

Current applied to control relay is 30 mA. Time taken for full travel of motor arm in either direction = 6·5 secs. max. It was stated that if the difference in time between each direction is more than 35 per cent. approximately of the higher time, the unit is rejected.

(*e*) ZEROING

Run the motor back and forth a number of times and test for zero position.

NOTE: Current to electric motor is 15 amps full load, voltage 30 volts.

No effort was made to adjust pump valves of any unit failing on tests (*c*) or (*d*) owing to lack of necessary facilities.

141. COMBUSTION CHAMBER

(Plates 56 and Fig. 67, Section 3)

Tests on combustion chambers which had been salvaged from either damaged rockets or from factories were as follows:—

(*a*) Hot air was circulated through the combustion chamber system in order to dry and loosen scale etc.

(*b*) WASHOUT

Connect a water pump to the aperture D at the top of the combustion chamber after blanking off cooling jet annuli with blind plugs. The alcohol inlets are left open and water is pumped through at 140/150 lb. per square inch, thus assisting to clear scale and foreign matter from the system. During this operation the combustion chamber is hammered lightly with a wooden mallet to assist in the loosening of scale and foreign matter.

(*c*) COOLING JACKET

Blank off the oxygen roses and aperture B, thus isolating the burner cups and the third skin of the combustion chamber head and alcohol inlet. The cooling jet annuli are still isolated by means of blind plugs and the alcohol outlets are fitted with blanking caps. Hoses are connected to the plugs on the expansion joints and a hydraulic pressure of 420 lb. per square inch is applied. This checks for leaks and faults in welding.

(*d*) COMBUSTION HEAD, THIRD SKIN

After draining liquid from the combustion chamber and removing blanking plate from aperture B replace this by a blanking plate at D. The mouth of the combustion chamber is blanked off by means of a plate fitted with an inserted joint ring. This plate is retained in position by means of four tie bars fitted with turnbuckles, one end being attached to the plate and the other anchored to the attachments which normally connect to the power unit frame. Blind plugs in the alcohol cooling annuli are also replaced by the standard chokes. Air is applied at 15 lb. per square inch to the combustion chamber and leaks in the third skin E and cooling pipes G can be located by means of soap solution.

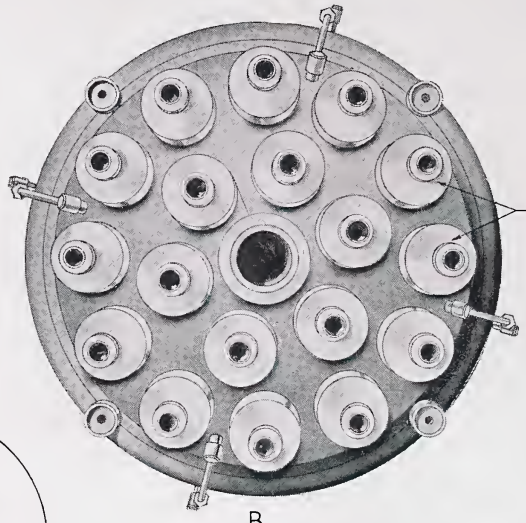
(*e*) AIR TEST OF CONNECTIONS

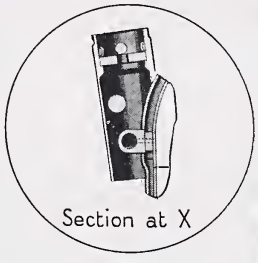
(i) The combustion chamber is now assembled to the frame and pump unit pipes, the whole being located on a rotating assembly table. The alcohol valve is installed and the bye-pass pipe on it is removed and a blanking plug inserted. From a plug in the second skin or cooling space in the combustion chamber a connection is made to a 0-15 kg/cm. pressure gauge. An air connection delivering 35 kg/cm. is made to the alcohol valve and pressure applied, thus keeping the valve closed. Blind flanges fitted with test pressure nipples are fitted over the outlets of both pumps in place of the standard orifice flanges and a connection is made to an external air supply of 8 kg/cm. This pressure is held for 15 minutes in the assembly and all joints are examined by means of soap solution on the alcohol side.

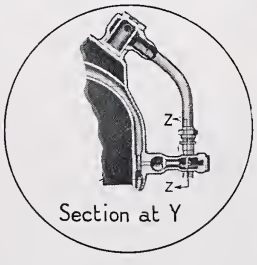
(ii) With regard to the testing of the oxygen pipes, pressure is applied through the oxygen distribution valve and blind

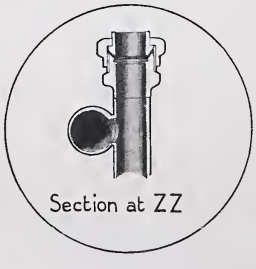
COMBUSTION CHAMBER

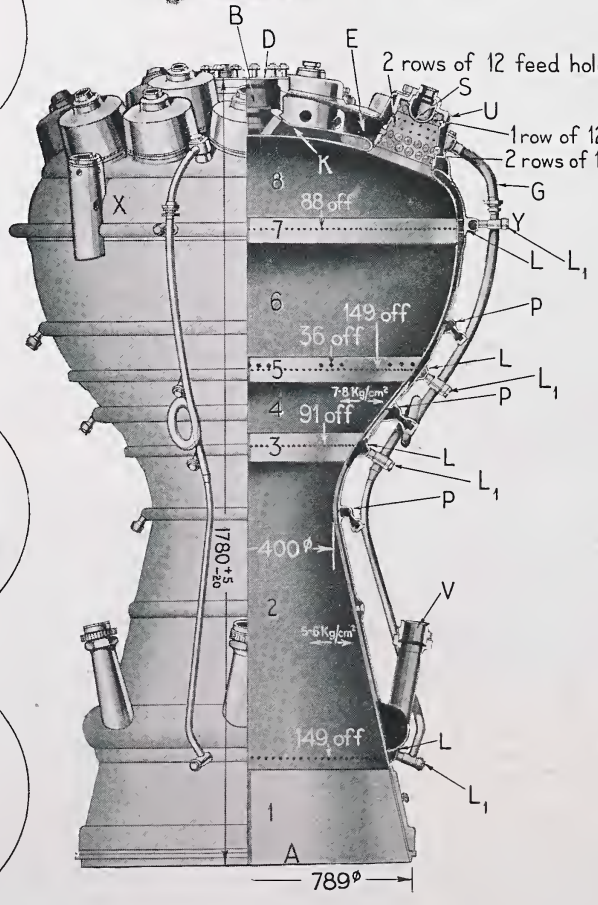
Plate 56











covers are inserted over the oxygen roses in the combustion chamber. Air pressure of 8 kg/cm. is again applied and joints examined with a soapy solution, the pressure gauge in this case being connected to the nipple on the oxygen side blanking plate.

(*f*) NOTE : The above tests are stated by German personnel to be the same as were carried out in the initial production with the following exceptions :—

(i) The burner assembly was tested after the first jacket K was welded. The test was 300 lb. per square inch hydraulic, followed by an air test.

(ii) After welding of a third skin, a blanking plate was affixed to the base of the head and aperture D blanked off. A hydraulic test of 300 lb. per square inch was applied, followed by an air test at the same pressure.

(*g*) No alterations to nozzles were made after proof fire tests and failures on the test outlined above caused the rejection of the combustion chamber which was returned to the factory.

142. NOTE FOR MATCHING PROCEDURE

The characteristics of each combustion chamber were calibrated by assembling the combustion chamber with oxygen and alcohol valves and coupling these to a water supply under pressure from air or gas bottles. Frictional losses were then measured and by means of comparator charts fuel flow characteristics were obtained. This data formed one of the variables on the nomographs and was passed to the establishment for static firing trials where alcohol and oxygen, under pressure, were used for the final calibration.

143. ALIGNMENT TEST ON COMBUSTION UNIT

(Fig. 68, Section 3)

The combustion chamber is located on a rig, comprising a levelling plate fitted with a spigot, registering the outside periphery of the combustion chamber, and with 4 channel sections disposed at 90 deg. These channel sections are scribed with dimensions from the centre of the locating jig, corresponding to the outside diameter of the angle iron ring at the end of the combustion unit frame.

The frame with the pump unit in position is attached to the special ball socket attachments on the combustion chamber and four plumb lines are dropped from the top flange of the angle iron ring. By adjusting the ball socket eccentrics on the combustion chamber, correct alignment is attained when the plumb lines are over the scribed marks of the channel sections. In order to check the horizontal axis, the distance from the underside of the angle iron ring is checked with end of combustion chamber. The distance between these sections is maintained at 3,065 mm.

144. STEAM UNIT ASSEMBLY TEST

(Plate 57 and Figs. 69 and 70, Section 3)

(*a*) Set reducing valve to pass 20 kg/cm.

(*b*) Close switches A and B. A supplying the current and B energising solenoid for pressurising the relief valves, thus closing the vents to the peroxide and permanganate tanks.

(*c*) Close switch C pressurising system to 20 kg/cm. Check for leakage after closing valve K.

(*d*) Open valve K and reset reducing valve at 33 kg/cm. Test by opening bleed valve and top up main supply to 185 kg/cm.

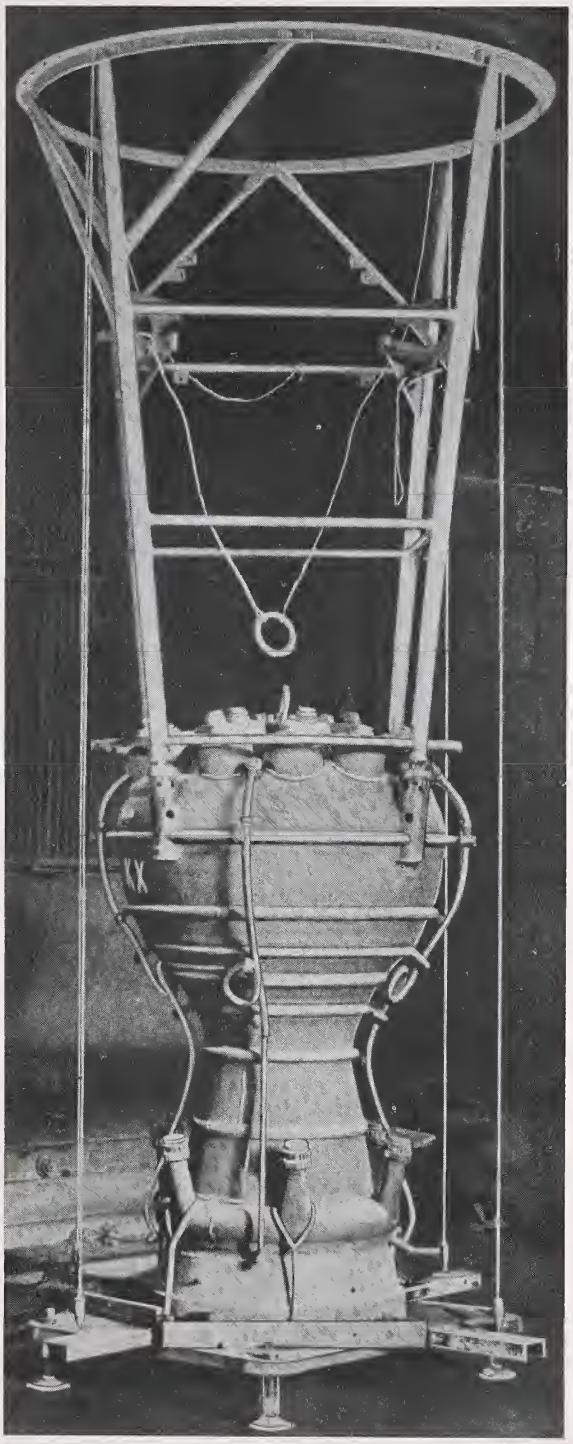


Fig. 68

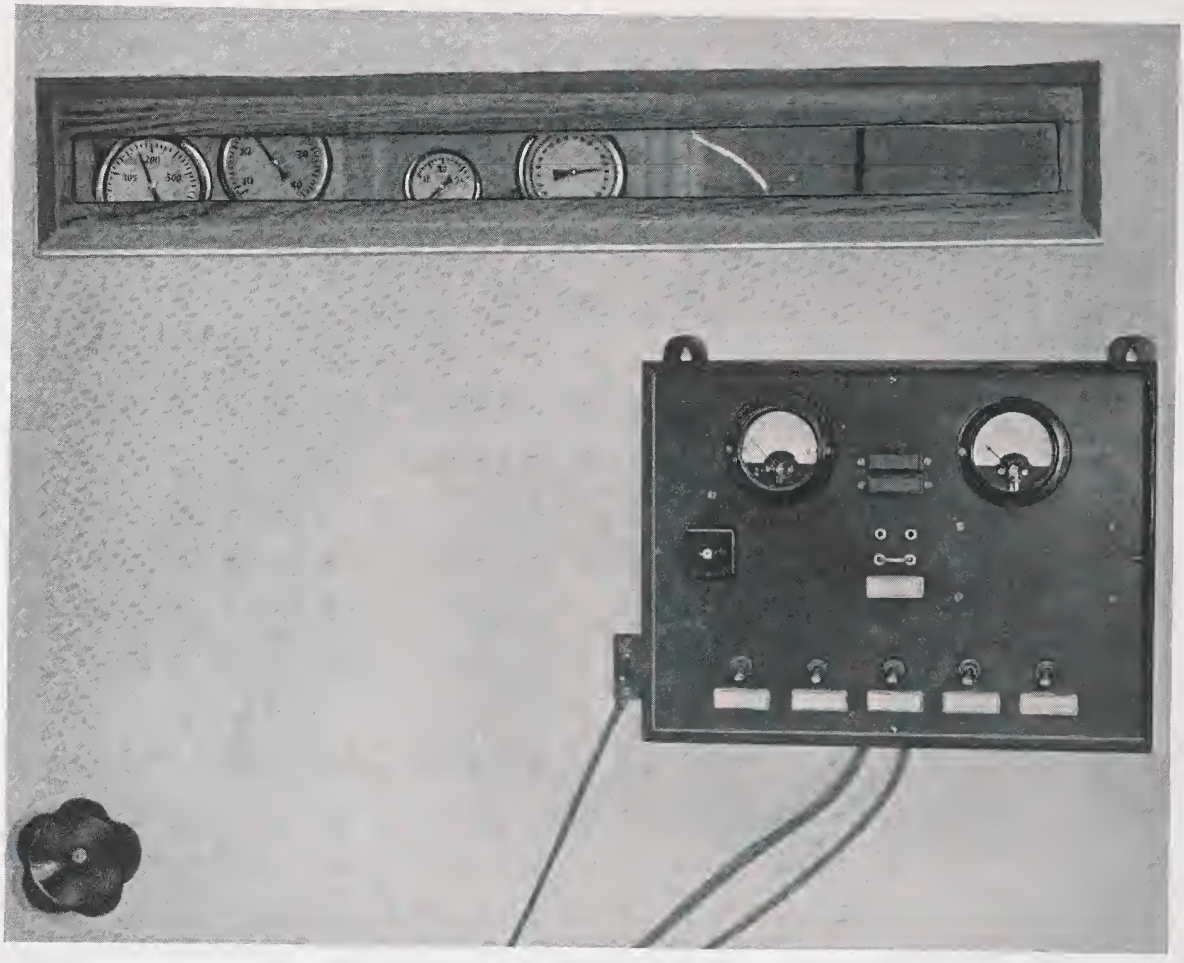


Fig. 69
Observation Slot to Steam Unit Test House with Remote Control Operating Board

(*e*) Open switch C and pressurise system to 33 kg/cm.
(*f*) Top up air cylinders to 193 kg/cm. approximately, and close main valve M.

145. RUNNING TEST NOW STARTS

(*a*) Close switches D, E and G, opening valves on peroxide line and combustion chamber exhaust.
(*b*) With stop watch time pressure drop on gauge No. 4 (main supply) between 180-80 kg/cm., this should be of the order of 70 secs. Remaining gauges should hold steady at 30 kg/cm.
(*c*) Open switch E, which closes peroxide main flow valve, and observe fall on No. 1 gauge, which will vary with setting of peroxide jet.
(*d*) Open switch D, closing peroxide bye pass valve and observe further small fall on gauge No. 1. This also depends on size of permanganate jet.
(*e*) Open switch C, closing off low pressure air supply to system and note gauge No. 2 to ensure that reducing valve maintains its set pressure.
(*f*) Open switch B, opening relief valves, and the system is exhausted.
(*g*) Open switch C, operating and opening the solenoid valve fitted for this test to the outlet of combustion chamber.
(*h*) Open switch A.
(*i*) Release tension on reducing valve.
(*j*) Dry out with warm air.
(*k*) Plug.

Unit will be retested for pressure tightness and resetting of reducing valve on final assembly.
For the tests outlined above a choke of 8 mm. diameter was inserted in the outlet of the reaction chamber.
A typical test sheet as used in the tests at the manufacturers' works is shown on page 117.

146. STEAM UNIT TESTS, USING LIQUIDS IN PLACE OF AIR

Object of Test

To ascertain the temperature of generated steam using H_2O_2 and sodium permanganate and prove the function-

HISTORY SHEET No. ..... STEAM GENERATOR .....

(*a*) Items

NOMENCLATURE	REFERENCE NO.	REPORT NO./REMARKS
1 Container 130 I		
2 Container 11 I		
3 Combustion Chamber		
4 Pressure Reducing Valve		
5 Stop Valve h 4		
6 H.P. Valve Pe 10		
7 Solenoid Valve Pe 4 Type A		
8 Safety Valve Tp 16		
9 Inlet Valve Te 8		
10 Check Valve T 40 atm. 13		
11 Pressure Contact Switch 1·5 atm. hy 6		
12 Non-return Valve Tm 16		
13 Non-return Valve Zm 16		
14 Safety Valve Zp 16		
15 Check Valve Z 40 atm. 13		
16 H.P. Stop Valve Ph 10		
17 Inlet Valve Tp 25		
18 Solenoid Valve Pe 4 Type B		
25 Z Throttle 2·4 mm. diam.		
26 T Throttle 3·2 mm. diam.		Weight .....kg.

(*b*) TEST REPORT	WORKS INSPECTION	DATE	OBS/REPORT NO.
27 Tightness Test			
28 Electrical Test			
29 Final Examination			
30 Completed on :			

(*c*) Assembly and Test Remarks

ing of the unit as far as possible under working conditions.

The test rig used was the same as for air tests with the exception that instead of the solenoid operated valve fixed to the outlet of the reaction chamber, an exhaust pipe 50 mm. inside diameter was fitted and led outside the proof shed. This exhaust pipe was choked at the outlet to 28 mm. diameter in Test 1 and 27 mm. diameter in Test 2. Initially a thermometer reading from 0-400 deg. C. was inserted in the exhaust pipe. This failed on the first test due to vibration and was replaced by a thermocouple connected to a millivoltmeter reading from 0-12 millivolts. The result of the first test while unsuccessful served a purpose in that it proved the test rig. A cine-camera was used to photograph the action of the recording dials throughout the tests. The following table gives the results of both tests.

	TEST 1	TEST 2
H_2O_2	126 Litres	126 Litres
Concentration	78%	82%
27% Solution sodium permanganate	11 Litres	11 Litres
Initial Main Air Pressure kg/cm.^{2}	177	195
Final Main Air Pressure	80	100
Reducing Valve Pressure kg/cm.^{2}	31	32
Outlet Pressure	20-24 kg/cm.^{2}	23·5 kg/cm.^{2}
Temperature	Not recorded	372 deg. C.
Exhaust Orifice	28 mm.	27 mm.

Recorded times from the film were as follows: Test 1— Test 2: 62 secs.
From the film record of Test 2 it would appear that the steam pressure does not build up until 2 seconds after the operation is started. The pressure in the H.P. side dropped steadily at 1·3 ats. per sec.

NOTE:

REACTION CHAMBER PEROXIDE VALVE

The functioning of the valves described in para. 72, Section I, was not at all clear from interrogation, therefore, to determine (*a*) whether the pilot valve was opened by the pressure of the bye-pass on the peroxide line, and the main valve opened only when full pressure was obtained; (*b*) at what pressures these valves would function, the following test was carried out. The steam unit assembly was connected up as for the standard air test with the exception that the reaction chamber was cut away to expose the peroxide valves, and the peroxide tank was filled with water. To the main inlet of the reducing valve a pressure of 180 kg/cm.^{2} was applied. With the first test the reducing valve was set to pass 8 kg/cm.^{2} The bye-pass peroxide valve solenoid was operated, but no water was delivered from the peroxide valve. The main pressure operated peroxide valve was then operated through the solenoid, and again no water was ejected. The reducing valve was then reset to 15 kg/cm. and the operation was carried out successfully.
The test showed that at a minimum pressure of 10 kg/cm., both the pilot jet and the main jet operated when the bye-pass was opened. The opening of the main peroxide valve merely increased the volume of flow. From this it was concluded that the pilot valve serves to generate heat in the centre tube of the container, thus assisting the break-down of H_2O_2.

147. TAIL UNIT, ALIGNMENT OF FINS

(Plate 58, Section 3)
No apparatus existed for making a complete workshop test, and therefore a field test was carried out as follows:— A quadrilateral base A.B.C.D. was set up, side 12 metres approximately. The tail unit was placed in the centre of this base, and 4 points, 1,2,3,4, on the edge of each fin were plainly marked. From each corner of the base, angles were taken and recorded to each visible point by means of a theodolite. From the figures thus obtained, the angle of inclination of each fin to the major axis of the tail unit was calculated, together with the straightness of the fin edge.

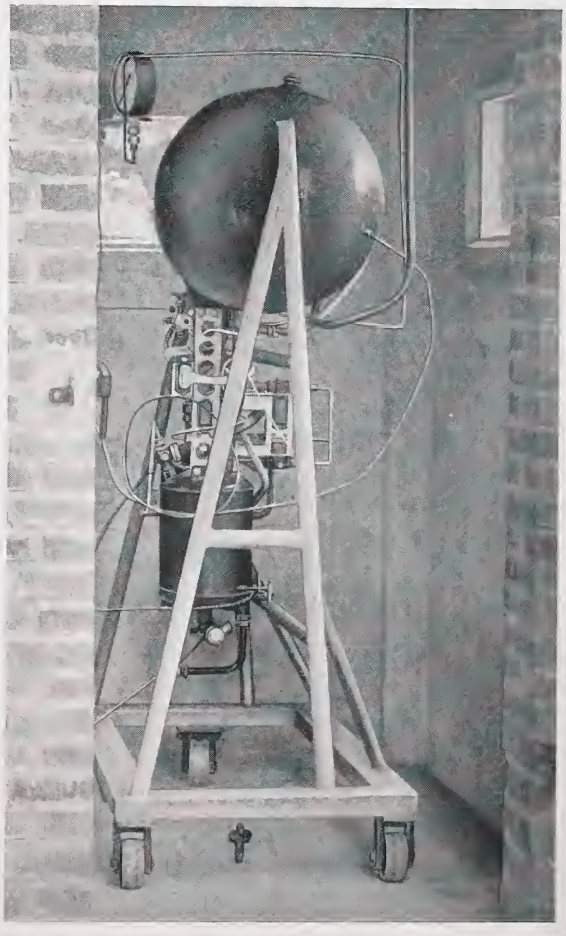
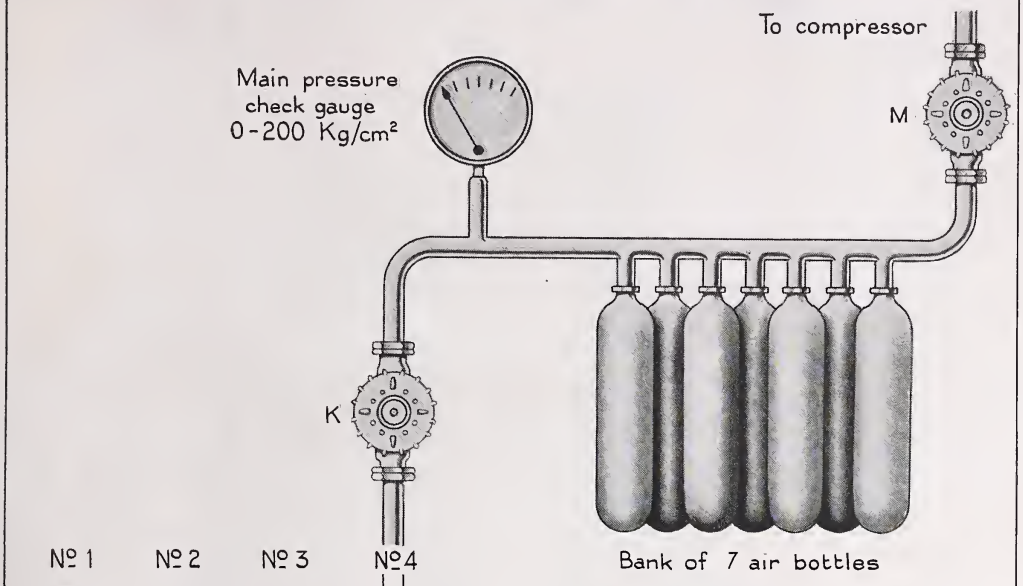


Fig. 70
Steam Unit set up in Test House

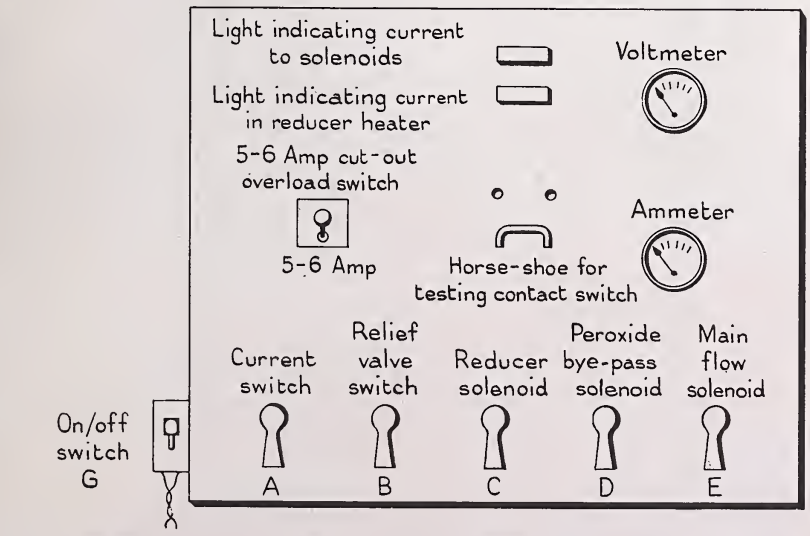
The following conditions must then obtain:—
The fins must be truly at right-angles to each other.
The sum of the angles of inclination of the fins (due account being taken of direction plus or minus) must not exceed one-seventh of a degree.

STEAM UNIT ASSEMBLY TEST

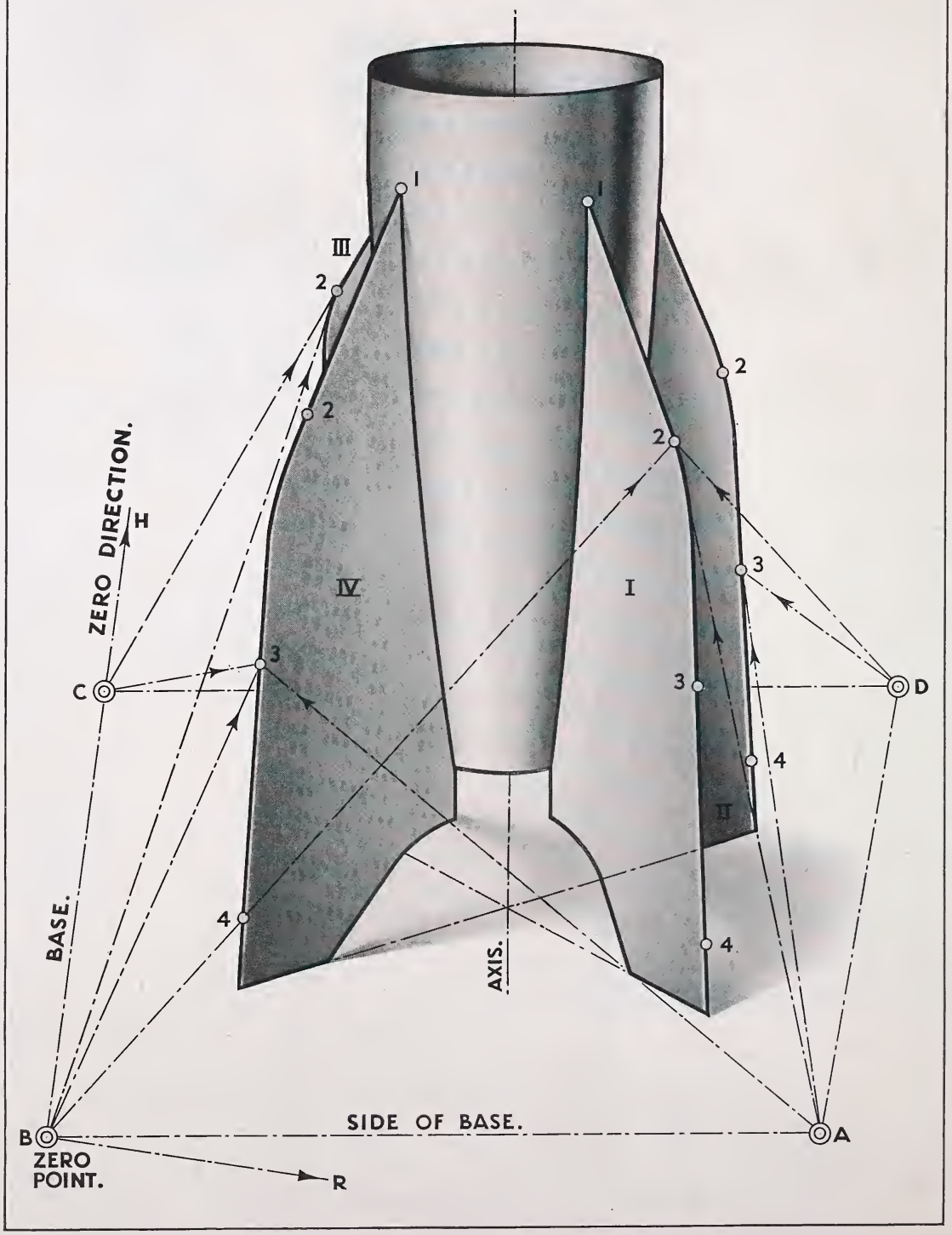
Plate 57



TEST PANEL



CHECKING ALIGNMENT OF TAIL.

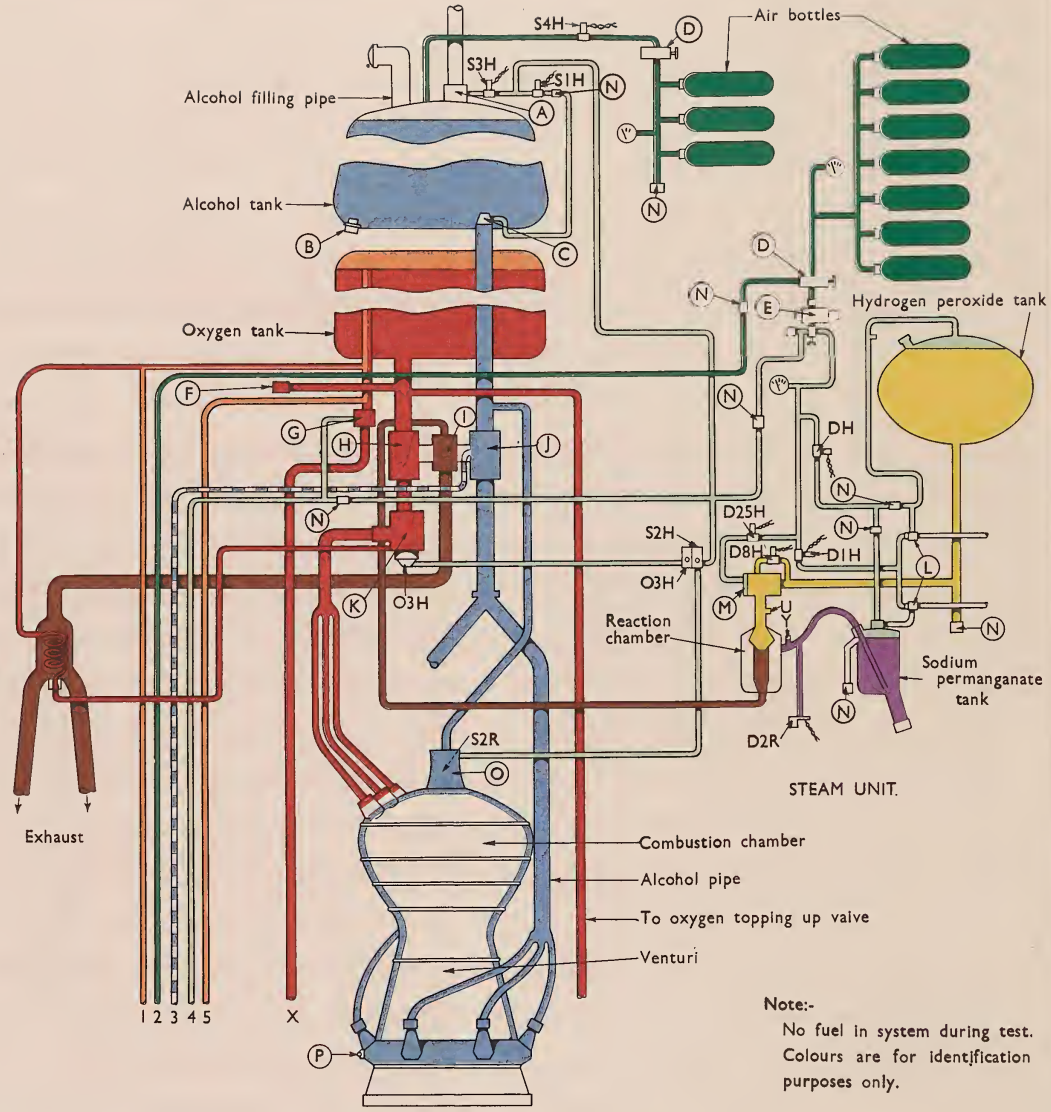


LEGEND.

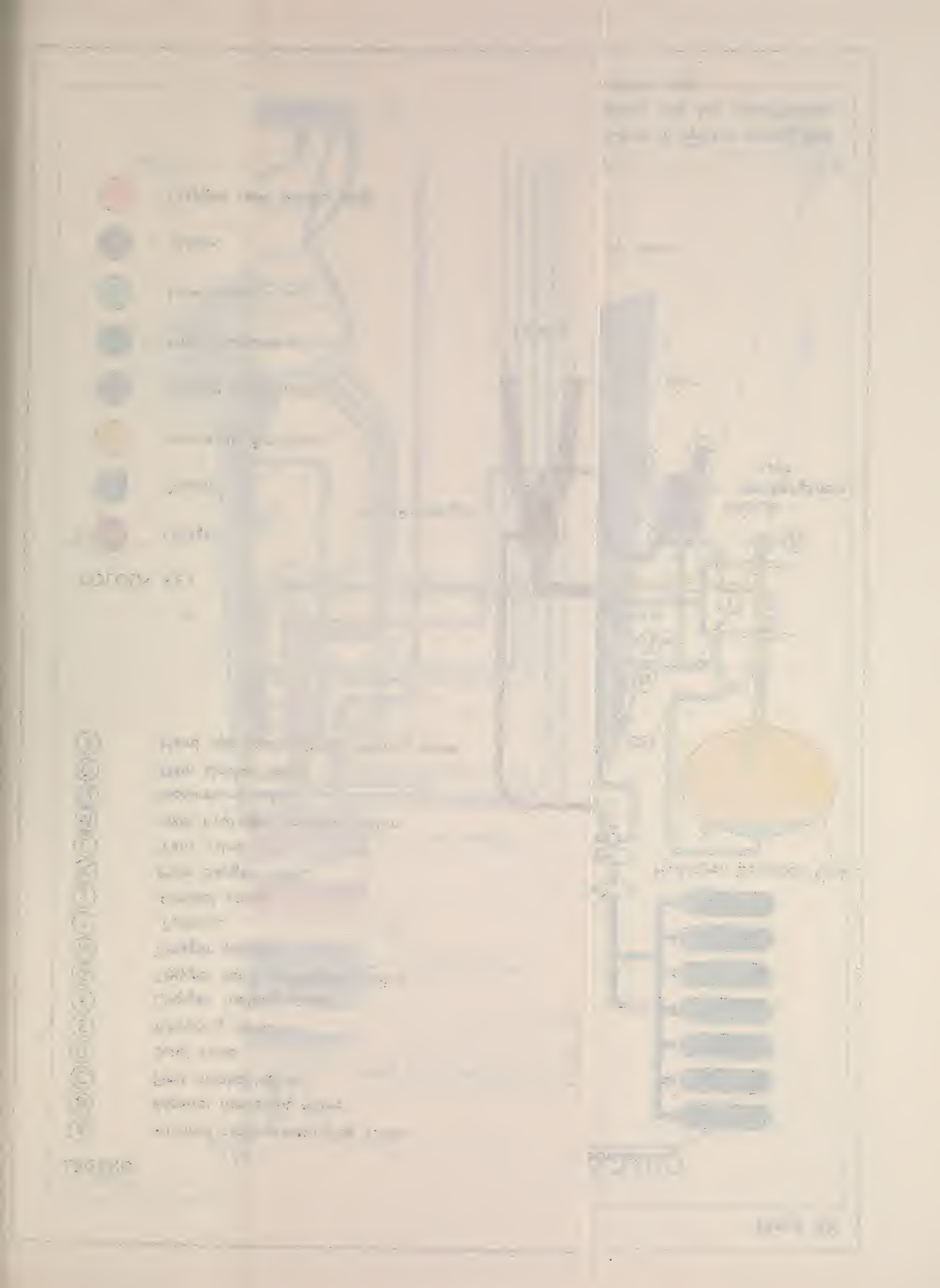
- (A) Alcohol tank pressurising valve.
- (B) Alcohol defuelling valve.
- (C) First alcohol valve.
- (D) Stop valve.
- (E) Reducing valve.
- (F) Oxygen fuelling valve.
- (G) Oxygen tank pressurising valve.
- (H) Oxygen pump.
- (I) Turbine.
- (J) Alcohol pump.
- (K) Main oxygen valve.
- (L) Vent valve.
- (M) Main hydrogen peroxide valve.
- (N) Non-return valve.
- (O) Main alcohol valve.
- (P) Hand operated alcohol draining valve.

COLOUR KEY.

- Oxygen.
- Alcohol.
- Hydrogen peroxide.
- Sodium permanganate.
- High pressure air.
- Low pressure air.
- Steam.
- Oxygen tank pressurising.



Note:-
No fuel in system during test.
Colours are for identification purposes only.



Sub-Section 3

148. HORIZONTAL TESTS (MECHANICAL)
(Plates 59 and 59A and Fig. 71, Section 3)
The assembled rocket placed on travelling bogies with the tail unit and warhead removed. Designations of valves as shown in schematic diagram attached. An illustration of the air supply control panel is given at Figs. 72 and 73, Section 3.

TEST 1

Oxygen tank delivery pipe system and exhaust system.

Preparation

Blank off oxygen exhaust port X. Connect an air supply delivering pressure at 1·5 kg/cm. to the ground equipment pipe 4. Stop valve in the connecting line closed. Connect an air line leading from a 2·5 kg/cm. capacity pressure gauge to the return oxygen pipe of the heat exchanger. Remove oxygen sprays from the combustion chamber and substitute blind cups.

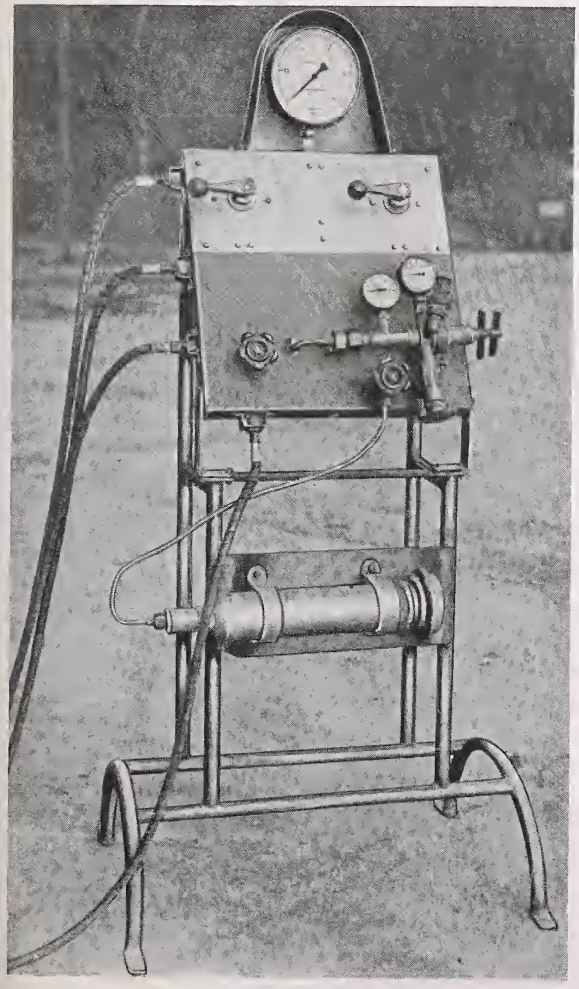


Fig. 72
Front View of Air Supply Test Panel

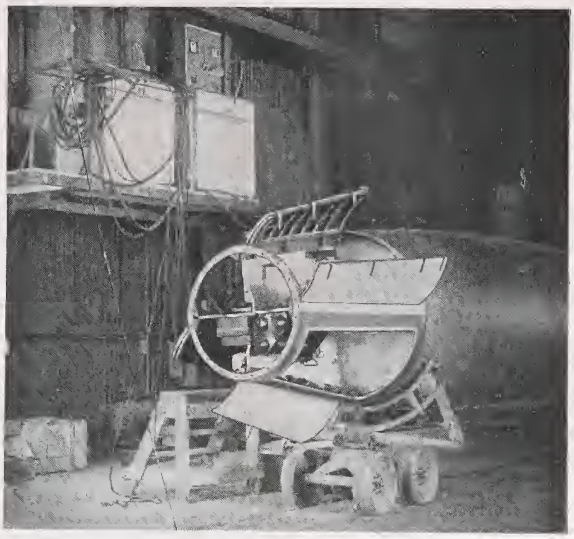


Fig. 71

Operation

Open the cock on line 4, thus pressurising the system to 1·5 kg/cm. Test joints for leakage with soap solution. Close 1·5 kg/cm. air line cock and observe gauge for pressure drop for approximately 10 minutes.

TEST 2

Test of the alcohol system.

Preparation

Connect ground pipe 4 to main air supply of 32 kg/cm. to operate valves. Close the alcohol main valve by the operation of solenoid S2H. Replace the 12 sets of 3 jets in the combustion chamber with blind plugs. Close alcohol pressurising valve through solenoid S3H. Open alcohol tank valve through solenoid S1H. Connect ground pipe 3 to an air supply delivering ·7 atmospheres.

Operation

Apply pressure of ·7 atmospheres to the system. Test all pipe joints for leakage with soap solution. Shut off ·7 kg/cm. air supply and observe gauge for any pressure drop.

TEST 3

Test steam system.

Preparation

Blank off steam outlets. Disconnect the pressure pipe from the permanganate tank at Y to the reaction chamber, Connect an air line through a stop valve and pressure gauge to the point Y.

Operation

Admit air at ·5 kg/cm. to the reaction chamber and pressurise the system. Check for leaks in pipe joints with soap solution.

TEST 4

Test of steam unit, air lines to valves and sequence.

NOTE: Cable forms to steam unit are tested for continuity and insulation.

Preparation

Disconnect pressure contact switch D2R on the pressure side and couple to an air line delivering 1·5 kg/cm. Disconnect permanganate tank connection to combustion chamber. Plug permanganate tank. Connect ground air

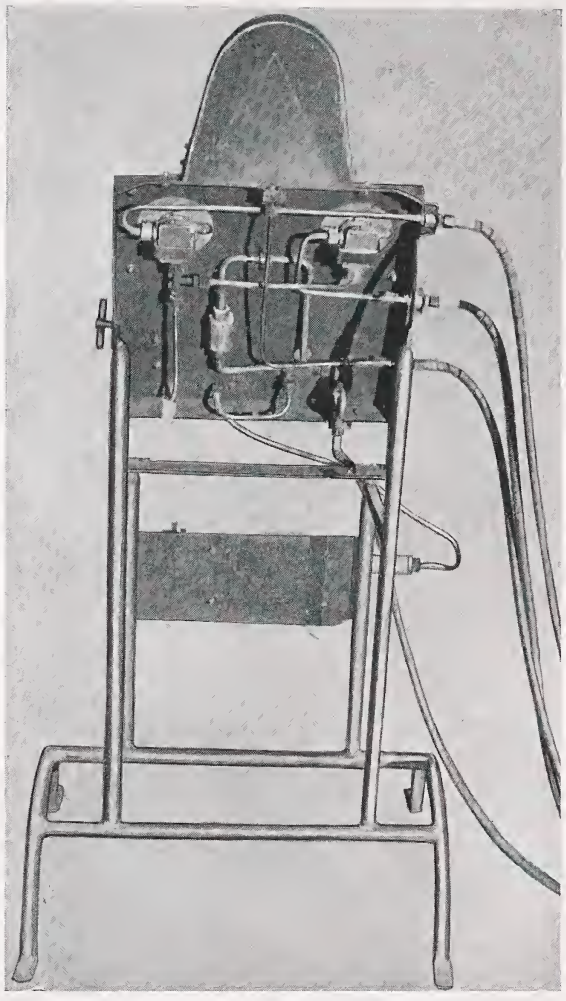


Fig. 73
Rear View of Air Supply Test Panel

pipe 2 to a pipe line delivering 200 kg/cm. for charging bottle reservoir. Connect a pressure gauge reading up to 25 kg/cm. to point Z to check the pressure in the peroxide tank. Remove plug U on the peroxide delivery line to the reaction chamber.

Operation

Through ground connection 2 charge air bottles to 20 kg/cm. With solenoids O3H and S2H de-energised the oxygen main valve and alcohol main valve close. Check that the period of delay in operation of the alcohol valve after the oxygen valve is less than 1 second. Energise S1H and check closing of the alcohol tank pressurising valve by sound. De-energise. Run the sequence switch in the control compartment and check that the alcohol pressurising valve functions after 40 seconds. Check programme cut-off at 65 seconds and operation of S4H. Energise solenoid D1H, thus closing permanganate and peroxide vent valves. Energise solenoid DH, allowing pressure to be applied to the peroxide and permanganate tanks. A pressure of 1·5 kg/cm. is already on the pressure contact switch so that peroxide bye-pass and main valves are open. When air is flowing from U de-energise D1H and vent to atmosphere, close DH. Disconnect the special external connections, re-make joints on permanganate tank and combustion chamber, fit tail unit and prepare for the remainder of the horizontal tests carried out from the electrical test board.

Sub-Section 4

149. VERTICAL TESTS AS CARRIED OUT IN THE SPECIAL PROOF TOWER

(*a*) The rocket is erected on the special proof table and checked for verticality with plumb bobs hung from a fitting on the nose of the warhead.

(*b*) The gyro plate is placed in position in the control chamber and by means of optical apparatus is fixed so that the two gyroscopes are parallel to the sets of fins. The plate is then levelled in the normal manner by means of a spirit level.

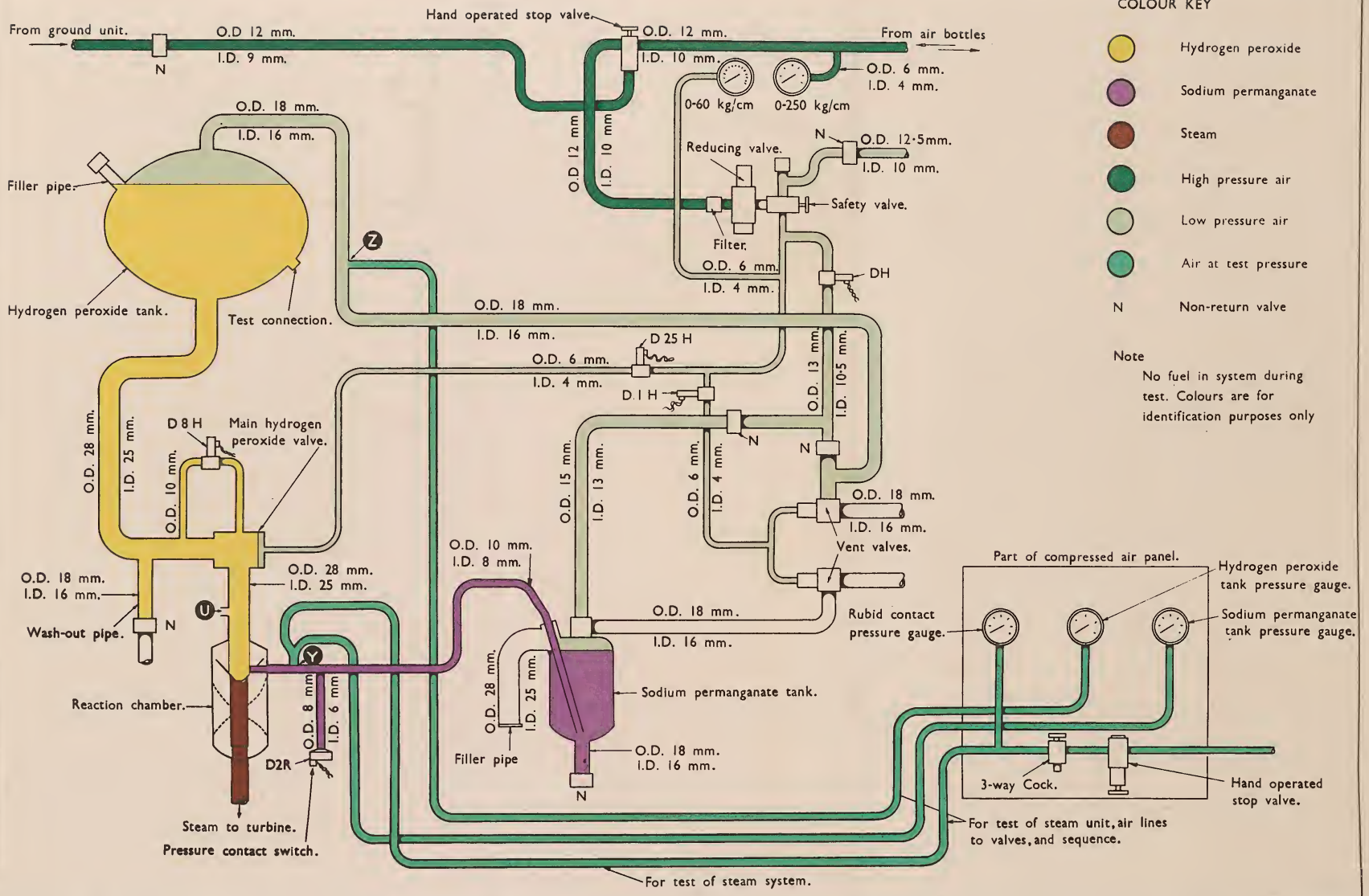
(*c*) *Alcohol Pressure Test.* A hose and pressure gauge is coupled up to one of the blind plugs in the combustion chamber. The three air bottles in the control compartment are pressurised to 200 atmospheres. The alcohol pressurising valve is closed, alcohol tank valve opened, alcohol main valve closed, and the air bottles are exhausted into the alcohol tank. This air then fills the complete alcohol system with the exception of the third skin in the head of the venturi chamber. The pressure gauge should read ·8 atmosphere and this pressure must be held for ten minutes as a test of absence of leaks.

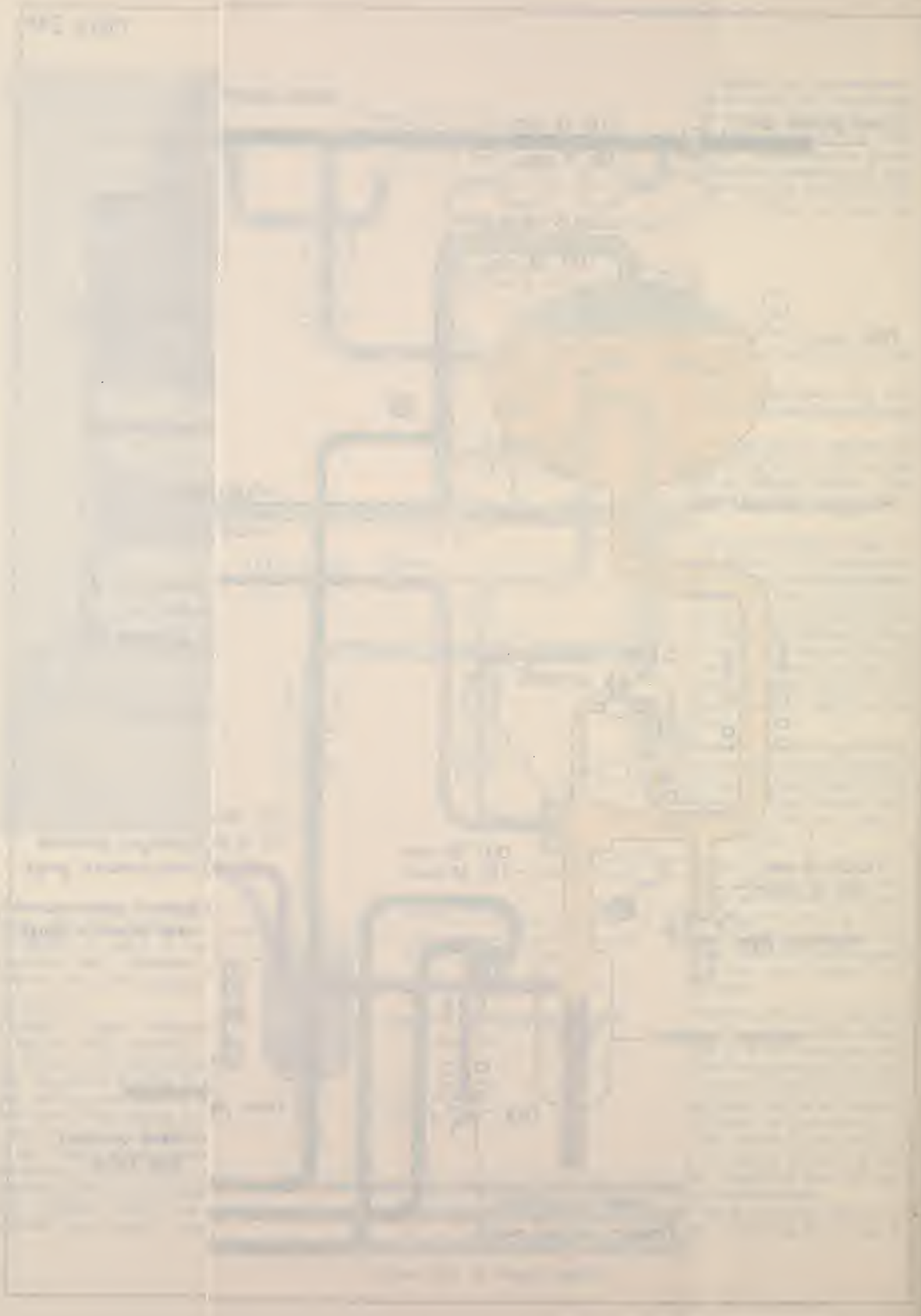
(*d*) *Oxygen Pressure Test.* Close the oxygen distribution valve, and through the valve box on the test stand and test pipe No. 1 charge the entire oxygen system forward of the distribution valve to 1·5 atmospheres. Slight leakage will occur from the oxygen pump bearings, but the pressure should not drop appreciably in 40 seconds.

(*e*) *Steam Unit Test.* Couple up main connections to valve boxes on proof stand and on first platform, disconnecting contact switch on the steam unit as for horizontal test. Insert a pipe line with pressure gauge in the plug of the permanganate tank. Pressurise the main bank of seven air bottles to 50 atmospheres and from this source apply a pressure of 10 atmospheres to the steam system, hold for five minutes, and check for leaks.

(*f*) *General Test.* This test is carried out from the electrical test boards. The gyroscopes are set running and the whole sequence of testing is carried out as at the launching site, the times of the various operations being checked by stopwatch. Programme starts at 4 seconds, alcohol pressurising valve closes at 40 seconds, programme ends at 48 seconds, fuel cut-off at 65 seconds, followed by pressurising of alcohol tank. This test from the electrical test board is then repeated, but using the emergency cut-off. A test sheet, sample attached, is then completed and this accompanies the rocket to the field technical troop.

NOTE: While these tests are taking place, the space between the outer wall of the venturi and the thrust ring is


From ground unit.
O.D 12 mm.
I.D. 9 mm.
N
Hand operated stop valve.
O.D. 12 mm.
I.D. 10 mm.
From air bottles
O.D. 6 mm.
I.D. 4 mm.
0-60 kg/cm
0-250 kg/cm
O.D 12 mm.
I.D. 10 mm.
Reducing valve.
N
O.D. 12·5mm.
I.D. 10 mm.
Safety valve.
Filter.
O.D. 6 mm.
I.D. 4 mm.
DH
O.D. 18 mm.
I.D. 16 mm.
Filler pipe.
Hydrogen peroxide tank.
Test connection.
Z
O.D. 18 mm.
I.D. 16 mm.
D 25 H
O.D. 6 mm.
I.D. 4 mm.
D 1 H
O.D. 13 mm.
I.D. 10·5 mm.
N
N
O.D. 28 mm.
I.D. 25 mm.
D 8 H
Main hydrogen peroxide valve.
O.D. 10 mm.
O.D. 15 mm.
I.D. 13 mm.
O.D. 6 mm.
I.D. 4 mm.
O.D. 18 mm.
I.D. 16 mm.
Vent valves.
O.D. 10 mm.
I.D. 8 mm.
O.D. 28 mm.
I.D. 25 mm.
O.D. 18 mm.
I.D. 16 mm.
Wash-out pipe.
N
U
Y
Rubid contact pressure gauge.
O.D. 18 mm.
I.D. 16 mm.
Reaction chamber.
O.D. 28 mm.
I.D. 25 mm.
Sodium permanganate tank.
O.D. 8 mm.
I.D. 6 mm.
D2R
Filler pipe
O.D. 18 mm.
I.D. 16 mm.
N
Steam to turbine.
Pressure contact switch.
Part of compressed air panel.
Hydrogen peroxide tank pressure gauge.
Sodium permanganate tank pressure gauge.
3-way Cock.
Hand operated stop valve.
For test of steam unit, air lines to valves, and sequence.
For test of steam system.
COLOUR KEY
Hydrogen peroxide
Sodium permanganate
Steam
High pressure air
Low pressure air
Air at test pressure
N Non-return valve
Note
No fuel in system during test. Colours are for identification purposes only



TEST SHEET NO. .....

Test Started ..... Time .....
Series No. ..... Warhead .....
Reducing Valve Setting ..... Tank contents .....
(Firing pressure) Tank contents .....

1. PROPULSION UNIT
   - (*a*) Venturi .....
   - (*b*) Turbine rotated : Easily : Medium : Tightly .....
   - (*c*) Governor (not) fitted.
   - (*d*) Reducing valve released ; Heater (not) fitted.
   - (*e*) A Tank pressurised at ..... ats.
   - (*f*) Pressure contact operated at ..... ats.
   - (*g*) B Tank pressurised at ..... ats.
   - (*h*) T and Z tanks .....
     Air bottles .....
   - (*i*) Air charging line tested : Air bottled filled to ..... ats.
   - (*k*) Five-way coupling .....

2. CONTROL
   - (*a*) Alternator 1 ..... volts. Alternator 2 ..... volts. Alternator 3 ..... volts.
   - (*b*) Horizontal Gyro ..... Servo Motor Current .....
   - (*c*) Vertical Gyro ..... Servo Motor Current .....
   - (*d*) Time switch ..... Programme complete .....
     Cut off at ..... secs.
   - (*e*) Control Unit .....

3. ROCKET CIRCUITS AND CABLES
   - (*a*) Insulation Resistance ..... M. Ohms.
   - (*b*) Circuit for Emergency Cut-off ..... M. Ohms.
   - (*c*) Cables .....
   - (*d*) box tested .....

4. FAULTS AND WORK INCURRED IN TESTING

5. GENERAL
   - General operation test .....
   - Rocket complete, covers fitted, smooth.
   - Rocket is ready for firing.
   - Completion of test .....

filled up as follows :—Synthetic rubber or asbestos is pressed into the recess and this is covered over with a mixture of magnesium oxide, talcum and water glass, which is then allowed to set. This seal is to prevent flames entering into the space between venturi and the tail skin.

A typical test sheet used for the vertical tests is shown above.

After testing, the gyros on their base plate are removed and transported to the firing site separately. This same procedure is adopted with the carbon rudders.

Electrical System of the A-4 Rocket . . SECTION 4

INTRODUCTION

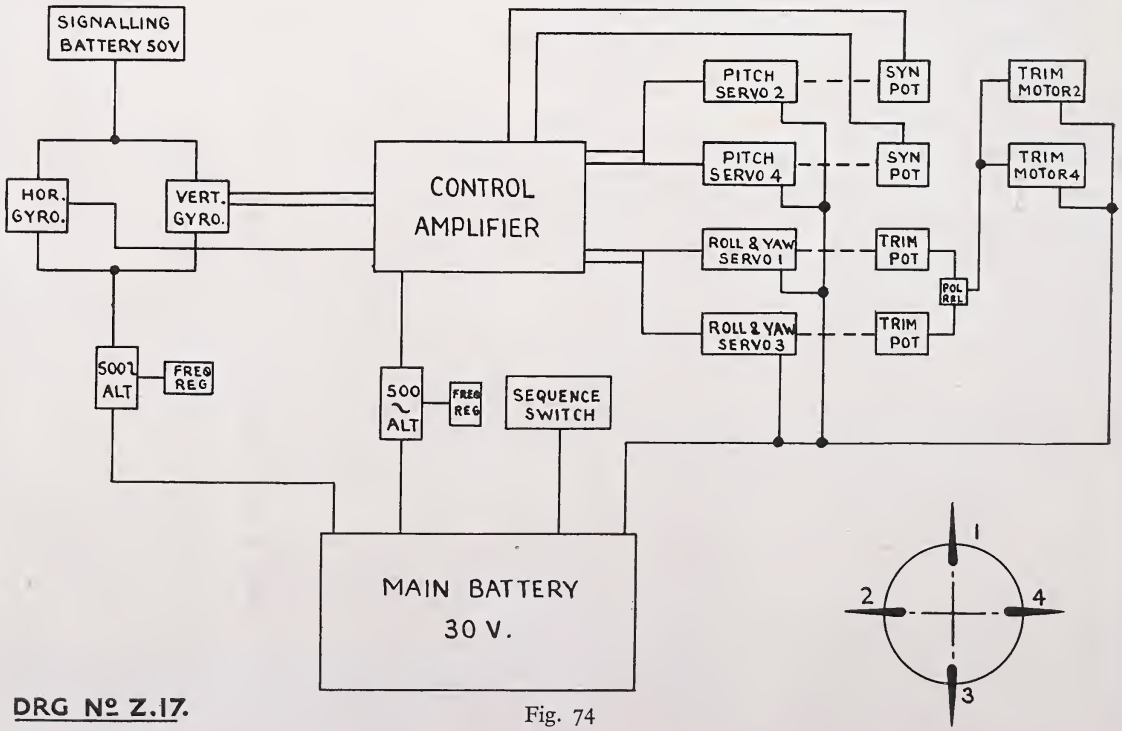
(Plates 60, 65, 68, 69, 70 and 71 are at rear of book.)

150. The electrical system of the A-4 rockets built for Operation " BACKFIRE " was designed to be as simple as possible. No radio control of any sort was used. The functions of the electrical system were the control of the steering of the rocket during its flight and the operation of the fuel and other valves associated with the driving of the rocket. A circuit diagram showing the connections used is given in Plate 60.

151. The electrical control apparatus was housed in a four-section control compartment in the nose of the rocket. It consisted of two batteries, two motor alternators with their frequency regulators, two gyroscopes, a control amplifier, a time or sequence switch, emergency switch box, and a number of relays. The actual steering of the rocket was controlled by four carbon rudders operating in the flame, controlled by four servo mechanisms. Small vanes were fitted as part of the large stabilising fins on the tail of the rocket to assist the carbon rudders in the flame. A block schematic diagram of the steering system is shown in Fig. 74, and the mechanical arrangement of the control of the steering vanes is shown in Plate 61. The connections between the apparatus in the control compartment and the other parts of the rocket were by cable forms through distribution boxes.

152. The electrical power for operating the steering system and fuel valves, etc., is obtained from a 32-volt lead-acid battery which will provide a discharge of about 100 amps. for about five minutes. This battery is in two sections of eight cells each. A second battery is used to provide signals between the gyroscopes and the control amplifier. This is a 30-volt nickel cadmium battery, which has to provide a current of 300 mA for about five minutes. These batteries are more particularly described in their own section of this report.

BLOCK SCHEMATIC OF FLIGHT CONTROLS, ROCKET A.4.



DRG Nº Z.17.

Fig. 74

STEERING

153. The steering of the rocket is controlled by two gyroscopes operated from a 500 cycle three-phase supply obtained from a motor alternator running from the lead-acid battery. One gyro is used to control the turning of the rocket into its trajectory and the other is used to control yaw and roll.

154. The control amplifier accepts signals from the gyroscopes and passes them on to the actual steering mechanism. A second 500 cycle alternator similar to the one used for driving the gyros and running off the same battery provides the power to operate the control amplifier

155. The motor alternators are small machines which take in direct current to a motor at one end and generate three-phase 500 cycles supply at 40-volts approximately. A separate frequency regulator is used with each machine to maintain the frequency at 500 cycles against variation of battery voltage.

156. The signals from the control amplifier are taken to servo mechanisms mounted on a ring in the tail of the rocket. From these they control the movement of the carbon rudders as shown on Plate 61. The outer vanes on the fins associated with yaw and roll control are directly coupled with the yaw and roll carbon rudders by a system of mechanical levers and a chain drive. The outer vanes on the rocket fins on the pitch axis are not connected with the carbon rudders controlling the pitch, but are driven by separate trim motors which are brought into operation when the roll and yaw rudders are out of synchronism. These outer vanes are only used to correct for roll of the rocket.

157. A sequence switch is fitted to control the operation of certain valves and to initiate the turning of the rocket from a vertical path into its trajectory. It is also used to ensure that certain parts of the rocket which have to perform a certain operation at a certain time are all at their normal setting when the rocket is launched.

158. The gyros, control amplifier, trim motors and sequence switch are described in separate parts of this section.

FUEL VALVES

159. The operation of the main fuel valves in the rocket together with the pressurising of some of the fuel tanks is controlled by electrically operated solenoid valves in conjunction with a supply of compressed air. These valves are all described in detail in Section 1 of this report.

160. The connections between the control compartments and the rest of the rocket is made by cable forms through distribution boxes. All the wiring from the control compartments is concentrated on a main distribution panel from where it is taken away by plug and socket connectors to the steering mechanism and fuel valves, etc. Two large multi-pin plugs are also mounted on this distribution panel to give access to the rocket circuits for test purposes from testing equipment remote from the rocket. Also included on this panel are relays which are used to change over the rocket circuits from the ground test equipment to the rocket itself, when the rocket is being launched.

161. The main distribution forms, between the control compartment and the servo motors, which run practically the whole length of the rocket are broken roughly half-way by a small distribution box consisting of a series of plug and socket connectors mounted in a framework. This is done as a manufacturing convenience.

162. The testing of the rocket after completion is made from special testing desks which are joined to the rocket by multi-core cables. A similar type of desk is used when the rocket is being launched. These desks are described in a separate part of this section.

THE DISTRIBUTION FRAMES

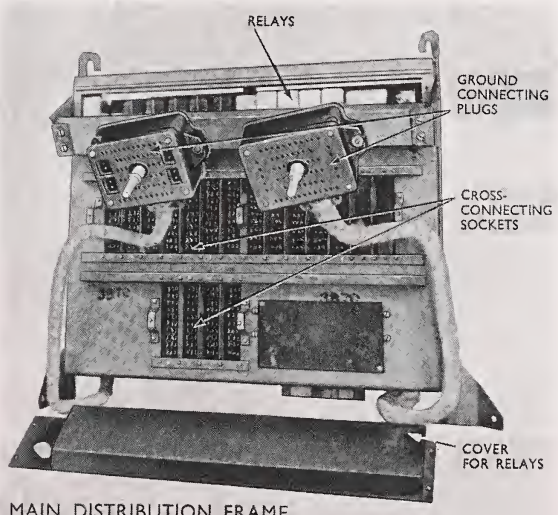
(*a*) THE MAIN DISTRIBUTION FRAME (Figs. 75 and 76).

163. General

The main distribution frame is a light steel framework mounted in one quadrant of the control compartment, and provides a convenient means of concentrating and cross-connecting leads from the steering control apparatus, mounted in the control compartment, to the steering mechanisms mounted elsewhere in the rocket. It also accommodates a number of relays necessary to the functioning of the rocket, and the ground connection plugs giving access to the rocket circuits from the ground test desks.

164. The Cross-Connecting Field

This consists of a series of multipoint sockets of two types. Type (*a*) has capacity for 30 connections for light current circuits and type (*b*) has capacity for 6 connections for

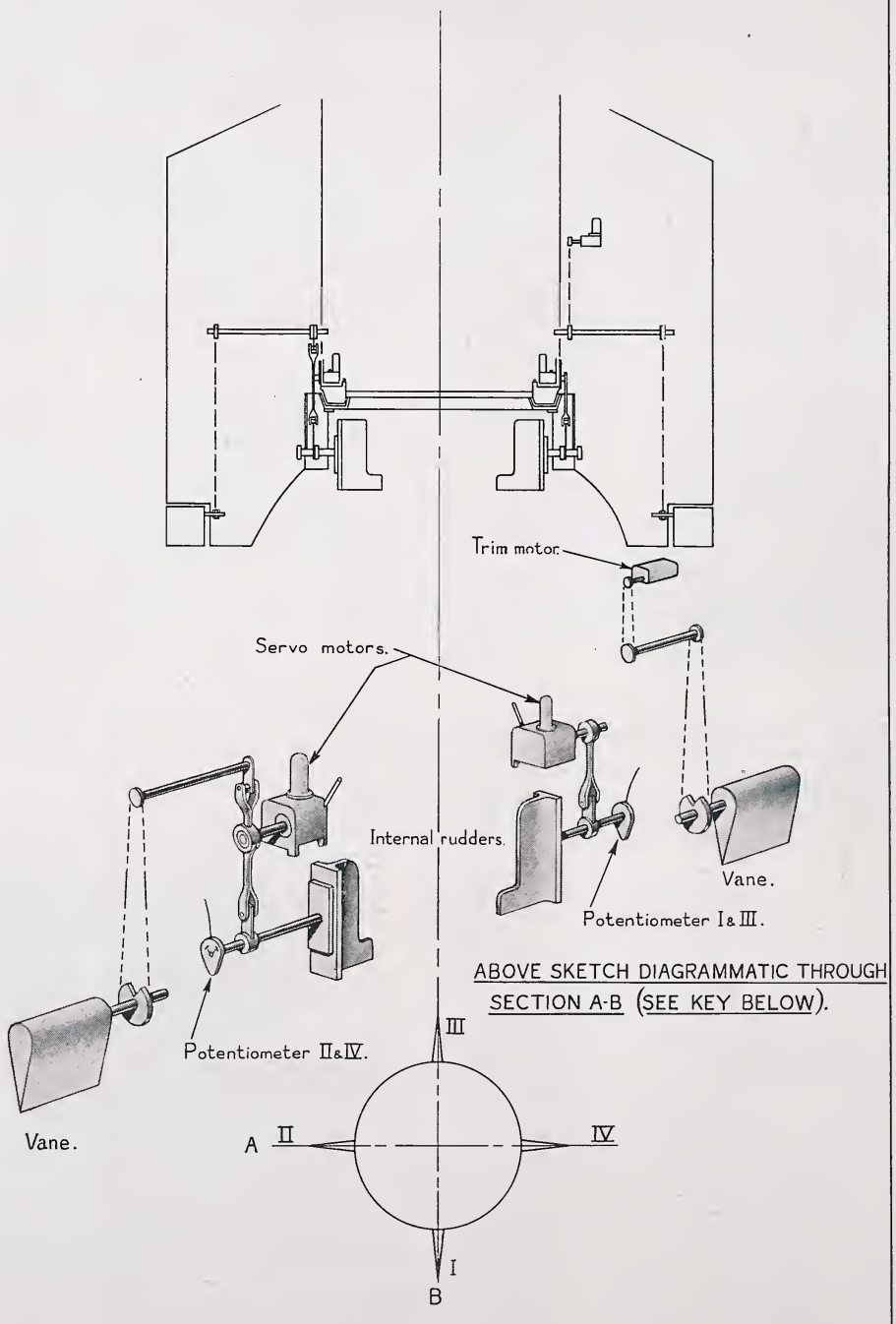


MAIN DISTRIBUTION FRAME
FRONT VIEW

Fig. 75

Plate 61

SCHEMATIC LAYOUT OF VANE & RUDDER DRIVES.



ABOVE SKETCH DIAGRAMMATIC THROUGH SECTION A-B (SEE KEY BELOW).

heavy current circuits. The sockets are fitted in black bakelite blocks of the same overall size for each type, and a variety of arrangements is therefore possible. For the rockets used in this operation, 13 of the connection blocks used were 30-way, and 3 were 6-way. The total capacity of the framework is 18 blocks, and the two spare positions were blanked off.

The leads from the control apparatus and from the steering mechanisms terminate on multi-point plugs which mate with the sockets in the distribution frame. The connections between the control apparatus and the steering mechanism are made by cross-connecting the sockets on the different blocks as required.

Each block is designated by a letter, and the sockets on each block are identified by a number. The block designation is marked on the steel framework above the appropriate block, but the socket numbers are not marked in any way on the blocks.

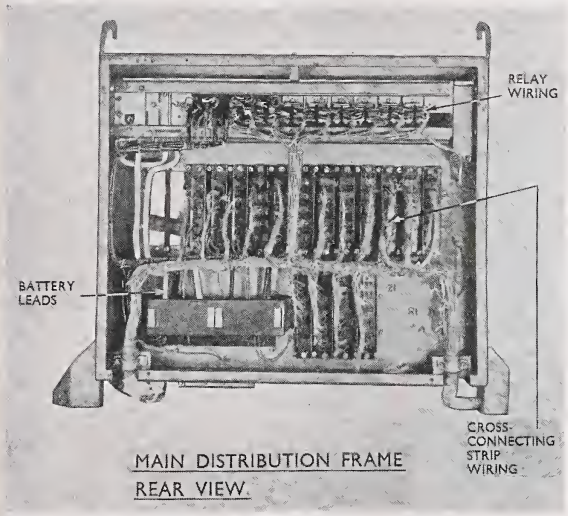


Fig. 76

165. The Relay Assembly

The relays necessary for the functioning of the rocket, and for changing over certain of the connections from ground test equipment to rocket are mounted at the top of the distribution framework.

The majority of the relays are of type 19-9005 (telephone type) or 19-9008 (solenoid type). A telegraph relay type 2Y11, a circuit-breaker relay type 19-5810, and a switch FLE 5002-09 are also fitted. These items are described in the section dealing with relays and switches.

The relays, etc., are not marked with circuit designations, but the relay arrangement used is given below.

LHS

R3p,R2x,Lx,A9z,A9y,A6y,A6x,A7y,B2y,B4a,B3a,B2a,B2.

The total available relay capacity of the framework is used except for one spare position. The whole relay assembly is fitted with a light sheet iron cover.

166. The Ground Connecting Plugs

In front of the relay assembly is a cross-member of the distribution framework, drilled to accommodate two ground connecting plugs. These are described in detail in the part dealing with ground connection plugs and sockets. The wiring from these plugs is taken over the front of the distribution panel to the soldering tags on the multi-point sockets and/or relays in what must be described as an untidy manner.

167. Miscellaneous

At the bottom right-hand corner of the distribution frame are ten heavy terminals for accommodating large cable leads. These are normally covered by a sheet iron cover, screwed to the distribution frame.

When the connection plugs are equipped in the multi-point sockets, cross-details, which are screwed to brackets, are arranged across the backs of the connection plugs to prevent them from being withdrawn.

(*b*) THE INTERMEDIATE DISTRIBUTION FRAME (Fig. 77)

168. General

The intermediate distribution frame is a metal box housed inside the rocket at the junction of the tail section and the main fuel compartment. It is provided for convenience in assembly and consists of a sheet iron box, accommodating on the front six (with capacity for seven) 20-way plug and socket connectors. On the rear of the box are mounted four cable glands, one of which accommodates battery leads and the other three of which carry multi-core cables. The battery leads are used to carry power from the main distribution frame to the servo-motors, tail-unit potentiometers, trim motors, etc., mounted in the tail of the rocket. The multi-core cables are used to connect the control circuits of the servos, trim motors, etc., to the control compartment, via the main distribution frame.

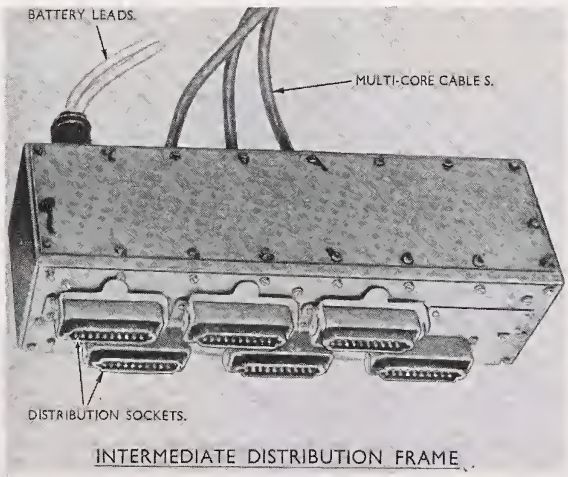


Fig. 77

BATTERIES

169. Two batteries are used in each rocket, one to supply the main power to the steering mechanism and the second to supply current to the potentiometers on the gyroscopes from which signals are sent to the control amplifier to effect the steering of the rocket.

170. The battery which supplies the main power is a lead-acid battery, consisting of two units, each unit having eight cells. It is similar to the commercial car starter battery and is designed to withstand a very heavy discharge for a few minutes. The actual capacity of this battery is about 20 A.H. at the 10-hour rate of discharge. The open circuit voltage is 32 V and the voltage on discharge of 100 Amps. should not fall below 25 V. The actual batteries made by the Germans for the rocket would provide a discharge of 100 Amps. for about five minutes without serious damage. They had to withstand an acceleration of 5g and be capable of being used in any position without leakage of acid. The cells were accommodated in two sheet iron boxes with sheet iron lids.

171. The signalling battery consists of 21 double nickel-cadmium cells mounted in a wooden box. The normal discharge from this battery was 300 mA. for five minutes, during which time the voltage at the battery terminals should not vary outside the limits 50 to 48 V. As this battery was used to provide signals from the gyros to the control amplifier the voltage variation at the terminals was most important. These cells also had to withstand an acceleration of 5g. and had to be capable of being worked in any position. The 300 mA. discharge for five minutes was well within the capacity of the cells used by the Germans.

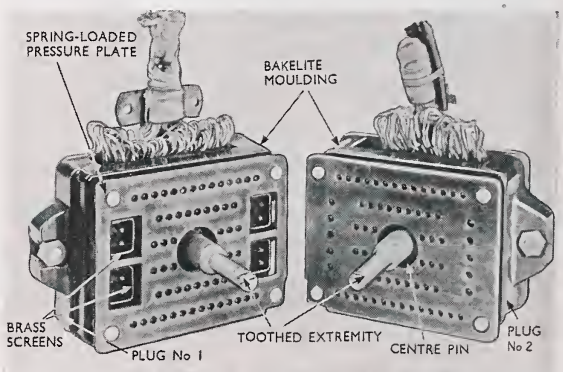
THE GROUND CONNECTION PLUGS AND SOCKETS

172. GENERAL

The ground connection plugs and sockets are used to give access to the internal circuits of the rocket from the ground test desks used for proving the operation of the steering control and solenoid operated fuel valves, etc., during manufacture and prior to firing. The plug portions are mounted on the rocket, and the socket portions are connected to the cables running to the ground test desks.
The number of connections required is large enough to warrant the use of two plugs and sockets per rocket. When the plugs and sockets are mated, they are held in position by a magnetic lock in the socket portion against the pressure of a spring-loaded bakelite face plate forming part of the plug portion. When the magnetic lock is released, the socket portion is thrown off the plug portion by the spring pressure exerted on the bakelite face plate.

173. THE GROUND CONNECTION PLUGS (Figs. 78 and 79)

Two of these, designated No. 1 and No. 2, are fitted to a cross bar of the main distribution frame located in one of the quadrants of the control compartment. They are generally similar in design but differ in the number and arrangement of the plug pins. Plug No. 1 is equipped with 66 pins of the same size. Plug No. 2 is equipped with 58 pins of the normal size plus 7 larger pins, which are used for the main power and other heavy current leads.
The body of the plug is a bakelite moulding which accommodates the plug pins. In front of this is the spring-loaded pressure plate of 3 mm. sheet bakelite, and used for throwing-off the ground connection socket units. Behind the plug body is a pressed steel back plate which provides the means of attachment of the complete plug to the crossbar on the main distribution frame, and also a convenient tying-in point for the leads from the plug pins. Projecting through the plug body and pressure plate, and secured to the back plate, is a stout steel centre pin with a toothed extremity. This is used to engage a part of the socket unit when mated to the plug unit to operate the magnetic lock.
The attachment between the plug unit and distribution panel crossbar is by a steel rod and staple, the staple being mounted in a steel cup and attached to the cross-bar. A strong spiral spring seats in this cup and presses on the plug assembly back plate. This method of fixing gives a large amount of play in the direction of the diameter of the rocket and takes up any drag on the plug unit by the socket unit from misalignment due to wind blowing on the connecting cables.
The plug pins are made of brass, nickel-plated, and appear to be moulded into the plug body. The contact ends are circular in section with two flats, diametrically opposite, and the wiring ends are drilled and tapped for grub screw connections. Each pin is identified by a number moulded on the plug body adjacent to the particular pin. The arrangement of the pins on plug No. 2 is straightforward, but on plug No. 1 there are 2 pairs of pins on the left and right-hand side, which are mounted in brass screens. It is probable that these pins are used in conjunction with screened leads for radio circuits.



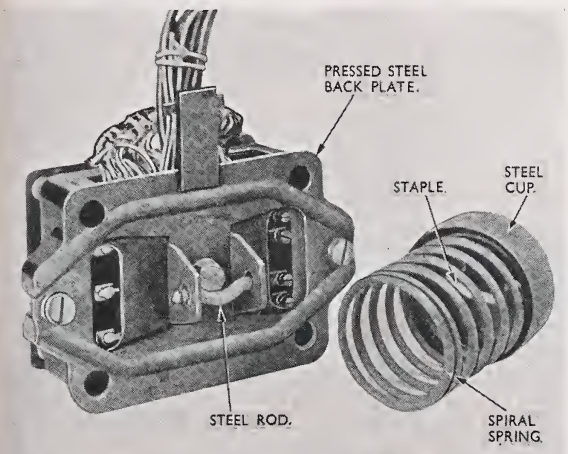
GROUND CONNECTION PLUGS
Fig. 78

174. THE GROUND CONNECTION SOCKETS (Figs. 80 to 84)

Two of these are used, one each to mate with ground connection plugs No. 1 and No. 2. They are exactly the same except for the arrangement of the connection sockets which are laid out to conform to their respective plugs.
The connection sockets are made of 4 phosphor-bronze leaves in the form of a square. Two of the leaves, on opposite sides of the square, are sprung to ensure good contact with the plug pins. They are mounted on a moulded bakelite plate backed by a sheet bakelite plate carrying screw connectors for the wires of the ground connecting cables. Each socket is identified by a number engraved on the rear of the sheet bakelite plate.
Through the centre of the bakelite details holding the socket assemblies is a bushed hole to accommodate the steel centre pin of the ground connection plug. When the

plug is inserted the toothed indentations on the end of this pin engage similar teeth on a detail in the body of the socket assembly and moves a soft iron armature towards the pole pieces of an electro magnet. As the armature approaches the pole pieces, it closes a contact in series with the magnet coil. This magnet is energised, and the armature is held when the plug portion is driven home to prevent it from being removed. Should the electro magnet be then de-energised, the armature releases and the spring-loaded pressure plate on the plug unit throws the socket unit off. A residual air gap of about 0·1 mm. is maintained between the armature and the pole faces of the electro magnet by brass strips attached to the armature. The resistance of the coil of the electro magnet is 73 ohms.

Behind the magnetic lock is a moulded bakelite end plate and an arrangement of cable cleats to accommodate the ground connecting cables. The complete assembly is held together by a round tie-bar at each corner, and mounts in a stout steel case, open at each end, with a handle at the back to facilitate handling.



GROUND CONNECTION PLUG.

Fig. 79

THE MOTOR-ALTERNATORS (Figs. 85 and 86)

175. The gyroscopes and control amplifier used in these rockets are operated from a 500 c.p.s. supply obtained from motor-alternators. These motor alternators appear to be a modified version of the German type GDU.87, described in R.A.E. Report No. E.A.M.—73, E.L.1305. Two such motor-alternators are fitted, one to drive both the pitch and roll/yaw gyros, and the other to drive the control amplifier.

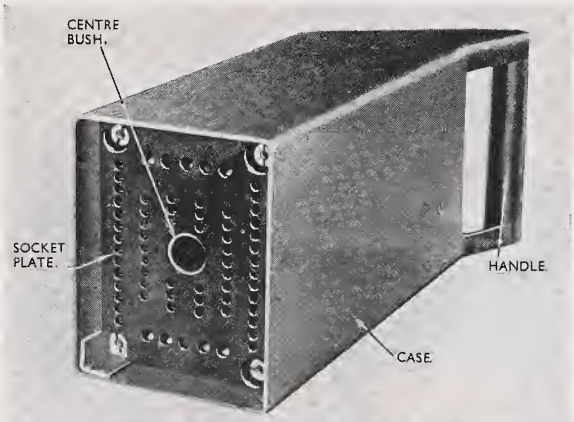
176. The set comprises an alternator, having a permanent magnet 6-pole rotor and a 3-phase Delta connected stator, driven by a compound wound D.C. motor. The motor receives its supply from the 32-volt lead-acid battery, forming the main D.C. supply for the rocket. The alternator output is approximately 150 volt-amperes at 42 volts r.m.s., and the frequency is 500 cycles per second.

177. The loading on the main lead-acid battery is very heavy, of the order of 3,000 watts and the terminal voltage consequently falls very rapidly. This alters the speed of the D.C. driving motor in the alternator set, with a consequent alteration in the frequency obtained from the alternator. This is undesirable to the correct functioning of the gyroscopes and control amplifier, and hence a frequency control unit, described separately, is used to keep the frequency constant, by controlling the speed of the D.C. motor.

THE FREQUENCY REGULATORS

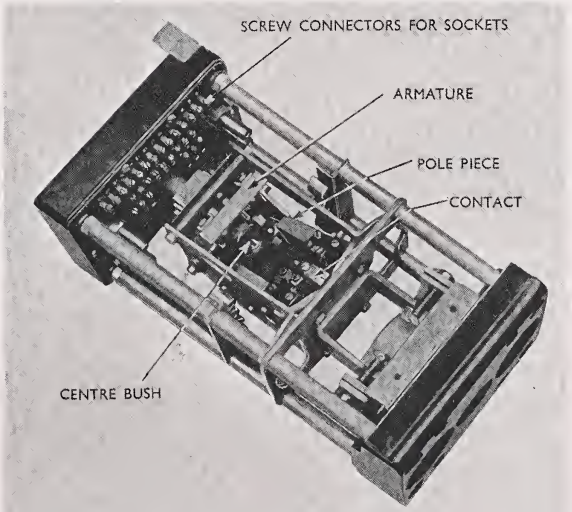
178. General

The gyroscopes and control amplifier are operated from a supply of 3-phase 500 p.s. alternating current obtained from motor-alternators running from the main lead-acid batteries. These batteries are very heavily loaded during



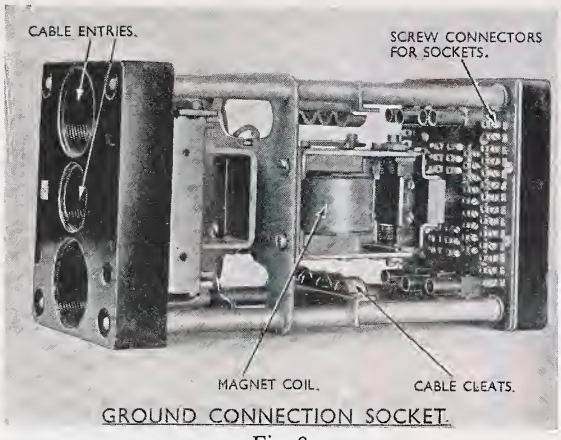
GROUND CONNECTION SOCKET.

Fig. 80



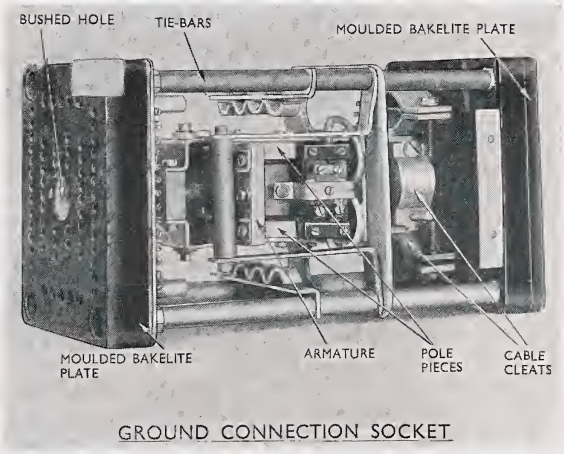
GROUND CONNECTION SOCKET

Fig. 81



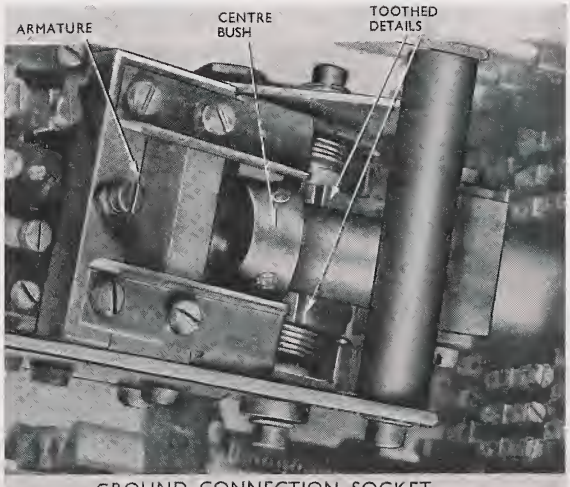
GROUND CONNECTION SOCKET.

Fig. 82



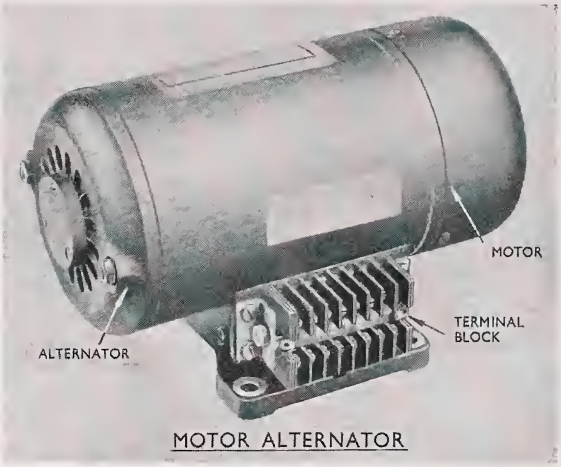
GROUND CONNECTION SOCKET

Fig. 83



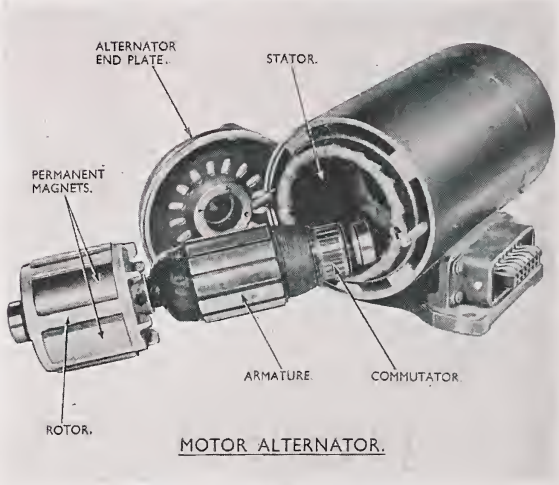
GROUND CONNECTION SOCKET.

Fig. 84



MOTOR ALTERNATOR

Fig. 85



MOTOR ALTERNATOR.

Fig. 86

the flight of the rocket, and their terminal voltage falls rapidly with a consequent alteration in the speed of the motor-alternators. It is essential that the frequency of the 3-phase supply remains constant to within narrow limits, and hence a frequency regulator is fitted at the rate of one per motor-alternator to control the speed of the motor section.

179. Construction (Figs. 87 to 89)

The frequency regulator unit is mounted on a die-cast light-alloy base-plate, and is fitted with a light sheet iron cover. Two iron-cored chokes are mounted at one end of the baseplate, at the other end of which is a vertical partition which carries on its inner face a large full-wave metal rectifier. On the outer face of this partition are mounted two adjustable iron-cored inductances and a centre-tapped condenser, connected to form two series-resonant tuned circuits. These tuned circuits are each connected to small full-wave metal rectifiers mounted on a bracket projecting

from the side of the partition. The remainder of the available mounting space is occupied mainly by electrolytic condensers.

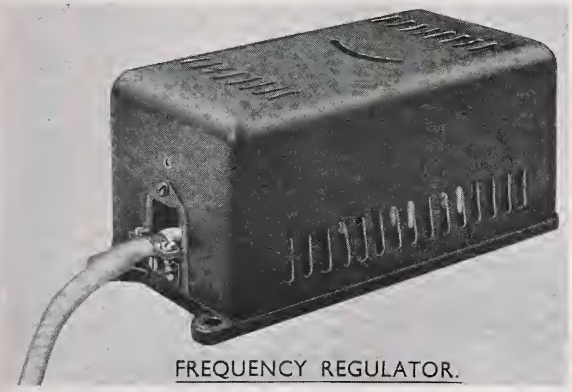
180. Circuit Description

The circuit of the frequency regulator, including its connections to the motor alternator, is shown in Plate 62. The speed control winding on the D.C. motor is supplied with direct current from the large full-wave rectifier, whose A.C. supply is obtained from one phase of the alternator, under the control of two iron-cored chokes. Each choke comprises five separate windings on a core of high-permeability material, e.g., mumetal. The windings are used as follows :—

(*a*) Winding No. 1 is connected in series with the A.C. supply to the large rectifier to act as a variable impedance.

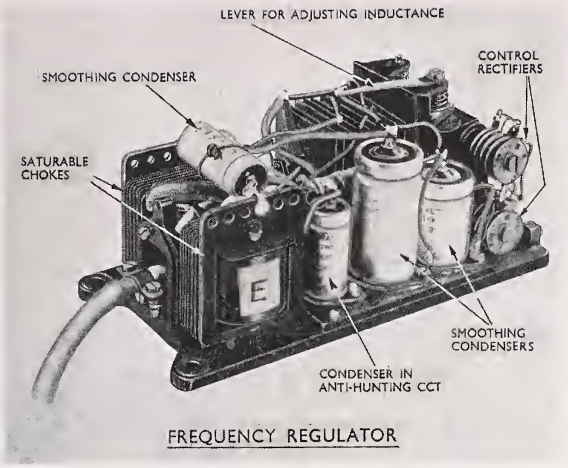
(*b*) Winding No. 2 is connected in series with the D.C. output from the large rectifier and provides the means for partially saturating the magnetic core.

(*c*) Winding No. 3 is connected in series with a condenser of 50 mf. and a resistance of 1,000 ohms across the D.C. output of the large rectifier to provide an anti-hunting control.



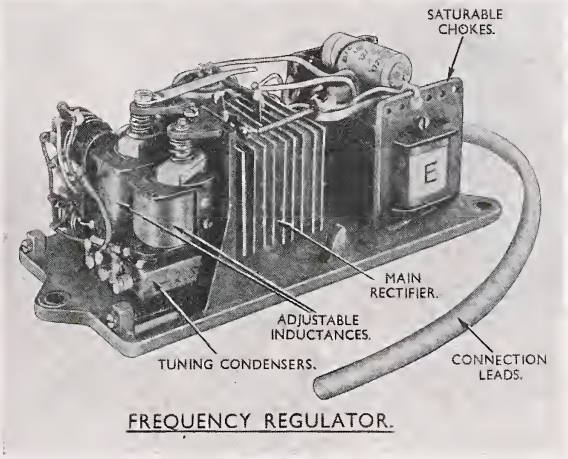
FREQUENCY REGULATOR.

Fig. 87



FREQUENCY REGULATOR

Fig 88.



FREQUENCY REGULATOR.

Fig 89.

(*d*) Windings No. 4 and No. 5 are connected respectively to the two small rectifiers associated with the series-resonant tuned circuits, and control the impedance of winding No. 1. They are arranged in opposition, so that at the controlled frequency the magnetic fluxes they produce are cancelled. One of the series-resonant circuits is tuned to a frequency above the controlled frequency, and the other to a frequency below. The small metal rectifiers to which windings No. 4 and No. 5 are connected are in series with these resonant circuits and any departure from the controlled frequency causes the current in one winding to increase and in the other to decrease. The result is either an increase or a decrease in the saturation of the cores of the choke. An increase in frequency causes an increase in core saturation and a decrease in the impedance of the choke. This permits an increase in current from the large rectifier to the motor control winding and causes a reduction in motor speed, i.e., a restoration of the frequency towards the controlled value. Similarly, a reduction in saturation caused by a reduction of frequency will result in an increase in motor speed to restore the frequency to the controlled value. The anti-hunting winding is so connected that transient currents through it, due to changes in the voltage of the D.C. output circuit, produce fluxes in cores of the chokes which oppose the control fluxes causing the change. In this way, hunting, which would accompany rapid changes of control, is damped out.

181. Operation

The following details of the operation of the frequency regulator are taken from R.A.E. Report No. E.L.1361. (E.A. No. 228-23.)

(*a*) The alternator frequency remains sensibly constant at 500 p.s. over a range of battery voltage to the D.C. side of the machine from 25 to 35 volts and at the same time, over a range of alternator loads from half to full load.

(*b*) If the battery voltage remains constant, the alternator frequency is closely controlled from alternator loads of 26 V.A. to 280 V.A., i.e., a load range of nearly 1 to 11.

(*c*) One of the series-resonant tuned circuits has a re-

sonance frequency of about 450 p.s., and the other provided with an external means for adjusting the inductance has a resonance frequency of about 570 p.s.
(*d*) Over the range of battery voltages likely to be experienced during the first two minutes of flight of the rocket, the frequency regulator will maintain the frequency constant to within 0·1 per cent. of the controlled value.

THE TIME OR SEQUENCE SWITCH

182. General

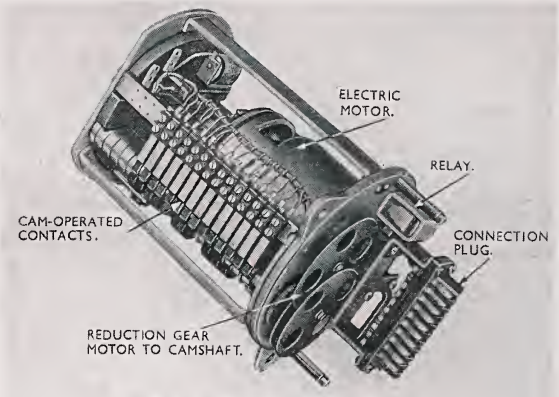
The sequence switch assembly consists of a cam shaft operating a number of contacts and driven by an electrical motor through a chain of gear wheels. The cam shaft makes one revolution in 90 seconds. Two types of sequence switch have been found (*a*) the older pattern in which all the cams are mounted on a common shaft and the drive is by a conventional series-wound electric motor, and (*b*) a newer and smaller pattern in which the cams are mounted on two separate shafts and the drive is by a ratchet type of motor.
The earlier type (Figs. 90 to 92) was used in the A-4 rockets built for Operation "BACKFIRE." Each pattern includes a reed type vibrator which is used for generating a supply of interrupted direct current. The early model has capacity for 18 cams and contacts. The cams are made from bakelite material and are adjustable through a small angle. A relay is fitted at the top of the housing, whose function will be described in the detailed circuit operation.
The newer type (Figs. 93 and 94) is fitted with 12 bakelite discs and a special contact arrangement. Fitted to the bakelite discs are small metal fingers held in position by locking screws. One of these fingers is used to operate the contact and a second is used to release it. These fingers can be placed in any position on the bakelite disc, and the result is to provide a contact timing of any desired length without the need for specially cut cams.

183. Function

The function of the sequence switch is to provide a means of controlling operations in the rocket which must occur at a definite time and in definite order. The function of the vibrator unit in the early model is to provide a source of interrupted current for driving the program motor in the horizontal gyroscope. In the later model the vibrator circuit also provides the interrupted current for operating that ratchet motor which drives the cam shafts.
Several of the cam-operated contacts are normally used in connection with radio equipment in the rocket. As the rockets built for Operation "BACKFIRE" contained no radio equipment these contacts are left spare. Other contacts control the operation of the program motor in the horizontal gyro, the operation of the pressurising valve in the alcohol tank, the fusing of the warhead (not fitted to these A-4 rockets) and the operation of the flame cut-off relay should the steam turbine over-drive. Other contacts control the resetting of the sequence switch to the initial start position after it has been used for test purposes in the rocket prior to launching. In the absence of any other form of control, e.g., integrating accelerometer, to initiate the final fuel cut-off, a contact on the sequence switch set to close at 65 seconds was used.

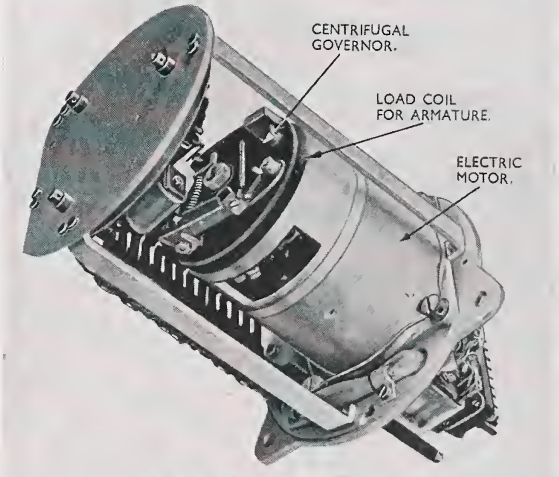
184. Circuit Description

The circuit diagram of the time switch used in the A-4 rockets built for Operation "BACKFIRE" is shown in Plate



TIME OR SEQUENCE SWITCH (OLDER PATTERN).

Fig. 90



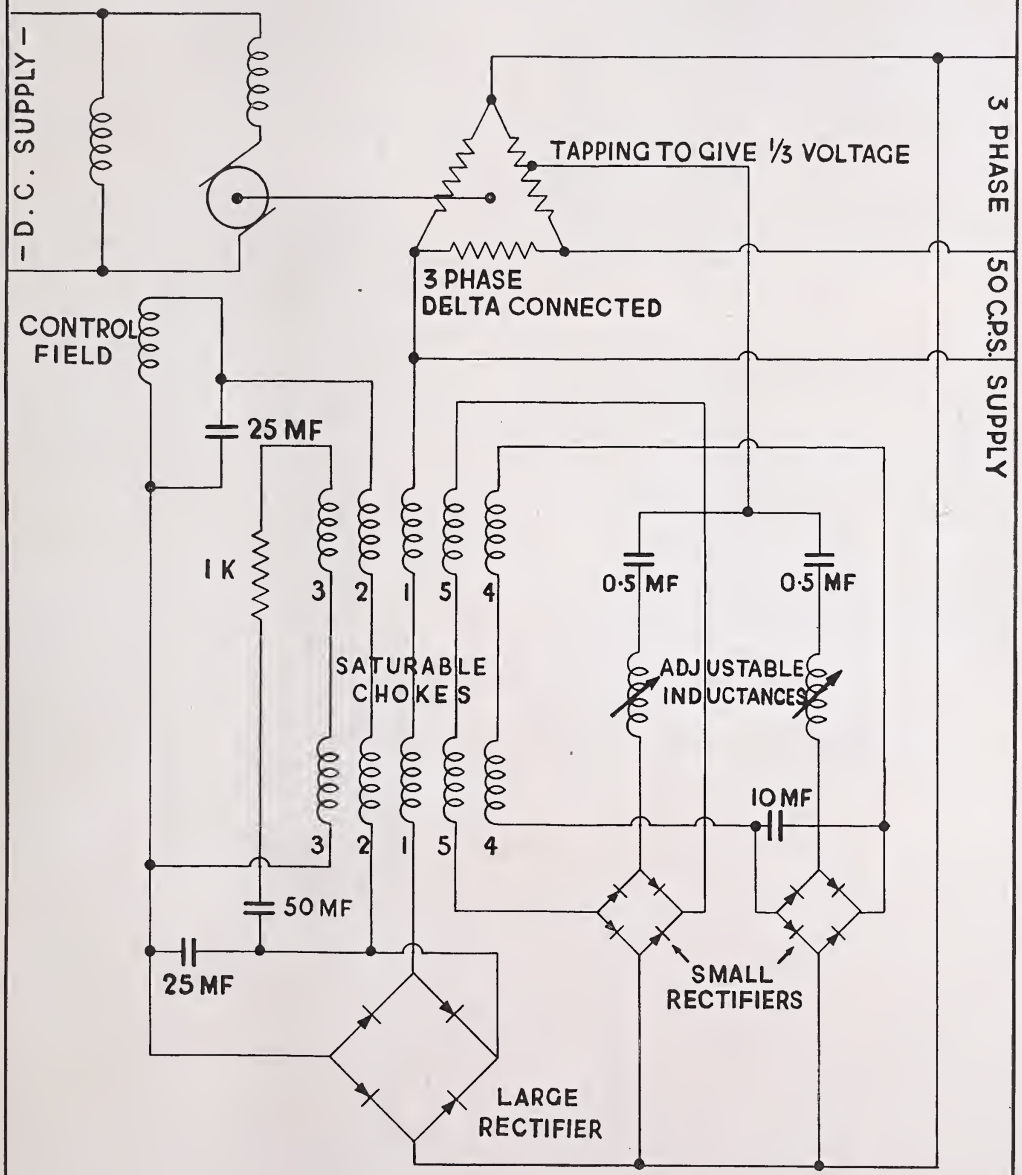
TIME OR SEQUENCE SWITCH (OLDER PATTERN).

Fig. 91

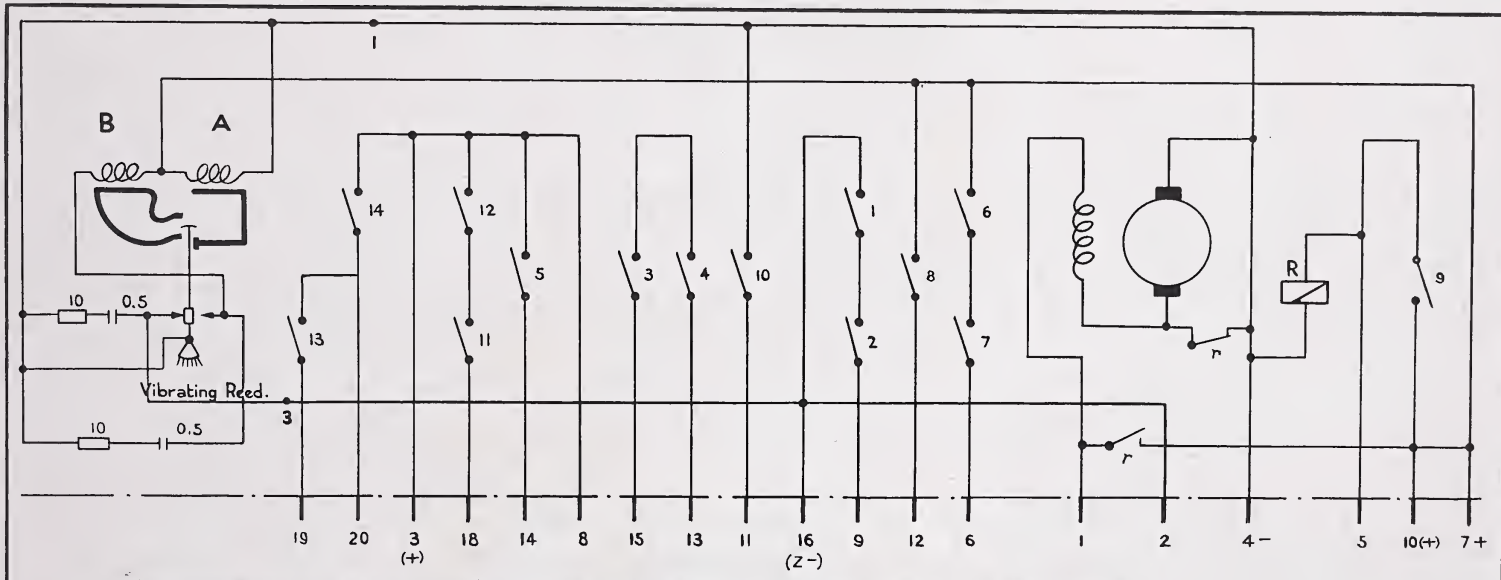
63. The time switch starts to work as soon as the rocket leaves the ground. Switch A72 in the tail of the rocket opens at the instant the rocket starts to rise and releases relay A7y. A contact of relay A7y falls back and operates relay R in the time switch. A contact of relay R removes a short circuit from the armature of the time switch motor and a second contact short circuits a 50 ohm resistance (not mounted in the switch) in series with the field winding of the motor. The motor then starts to drive. The reason for these contacts of relay R is as follows:—When the circuit of the time switch is broken the motor is required to stop as quickly as possible. One contact opens and inserts 50 ohms in series with the motor to keep the field energised.

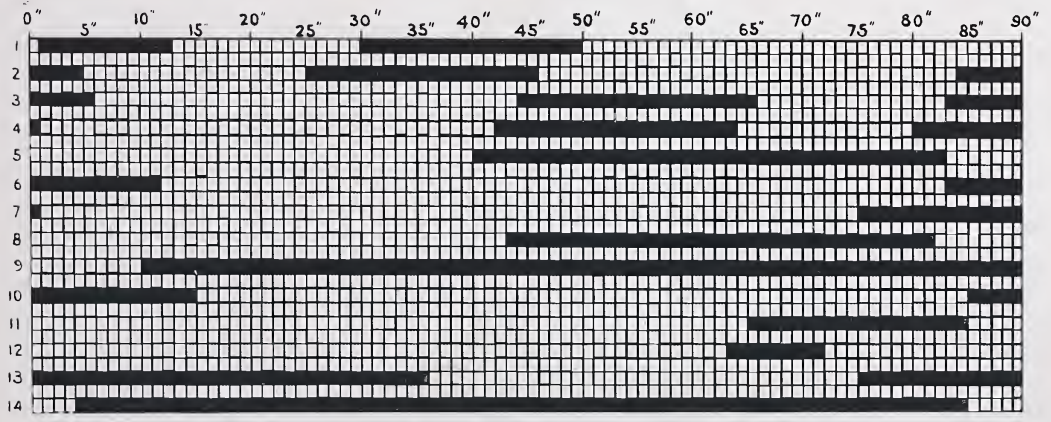
Plate 62

CIRCUIT OF FREQUENCY REGULATOR.



DRG. NO. Z 24.





CONTACT
TIMING
DIAGRAM.

DRG. Nº 49.

TIME OR SEQUENCE SWITCH.

Plate 63

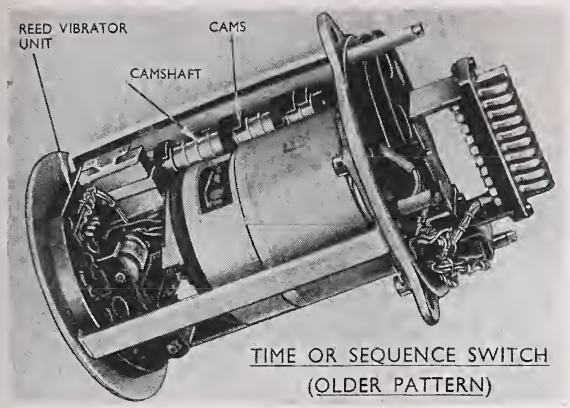


Fig. 92

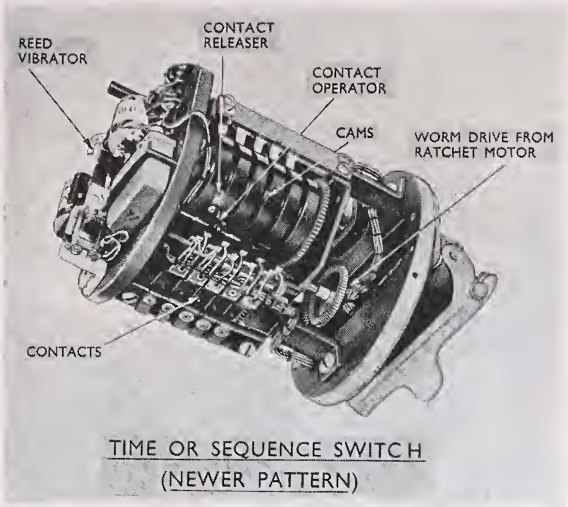


Fig. 93

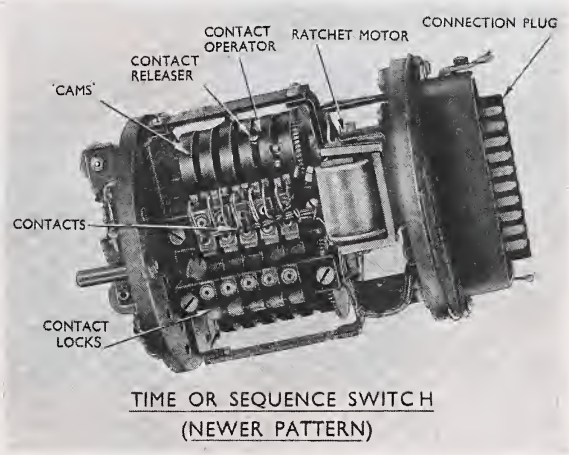


Fig. 94

The other contact short circuits the armature to act as a brake until the motor armature stops revolving.

A governor is fitted at the end of the motor shaft. This governor is of conventional design, consisting of a spring-loaded contact arm which moves when the speed of the armature rises above a predetermined value. The movement of the contact arm closes a contact which connects a coil of wire to an idle section of the armature winding. Current is thereby drawn from the armature and the braking effect reduces the speed of rotation until the governor contact reopens.

Cam operated contacts 1, 2, 3, 4, 8 and 10 are connected with radio equipment not used in this type of rocket. Contact 5 closes after 40 seconds and operates the pressurising valve in the main alcohol tank. It also fuses the warhead when fitted and applies battery to the flame cut-off relay A9z dependent on contact D9r which is fitted on the turbine shaft and operates when the turbine runs too quickly. This is done as a safety measure to avoid the rocket being prematurely cut off through a fault in the turbine system and falling to the ground in the vicinity of the firing site.

Contacts 6 and 7 are connected in series and together remain closed from 83 to 1 (or 91) second(s). These contacts apply battery to lamp M6l in the ground test equipment which can be used to see if the time switch is in its zero position.

Contact 9 is used to reset the time switch to its zero position after it has been used for tests. Switch A8od in the ground test equipment is closed for at least 10 seconds, the relay R operates and the time switch motor starts to drive. If the time switch were off normal, e.g., had run more than ten seconds of its travel, contact 9 would be closed. If the switch were in the zero position contact 9 would have been open, but depressing the switch A8od in the ground test equipment for at least 10 seconds ensures that contact 9 is closed when switch A8od is released. Relay R in the time switch remains operated over contact 9 until this contact opens at 90 seconds, i.e., the normal start position of the time switch. Relay R then releases and the motor stops. Contact 11 in the time switch closes after 65 seconds and remains closed for 20 seconds. This is the contact used in these particular rockets to initiate flame cut-off, i.e., it operates the flame cut-off relay A9z and the fuel is cut off. Contact 11 is in series with contact 12 which closes after 63 seconds and helps to prevent premature operation of the flame cut-off relay through a fault in the time switch contacts.

Contacts 13 and 14 are connected with the operation of the program motor in the horizontal gyro and will be described later.

The vibrator circuit (Fig. 95) which supplies an interrupted direct current to drive the program motor in the horizontal gyro operates as follows :—When battery is connected to the Z bus-bar of the rocket, winding A in the vibrator is energised and attracts a stop which held the reed of the vibrator off normal. The reed then starts to vibrate with a small amplitude at its natural frequency of 45 vibrations per second. At the first vibration contact B1 changes over and energises winding B in the vibrator, at the same time disconnecting battery from socket No. 2 of the time switch plug. The armature is attracted to winding B and the contact B1 returns to normal, re-connecting the battery

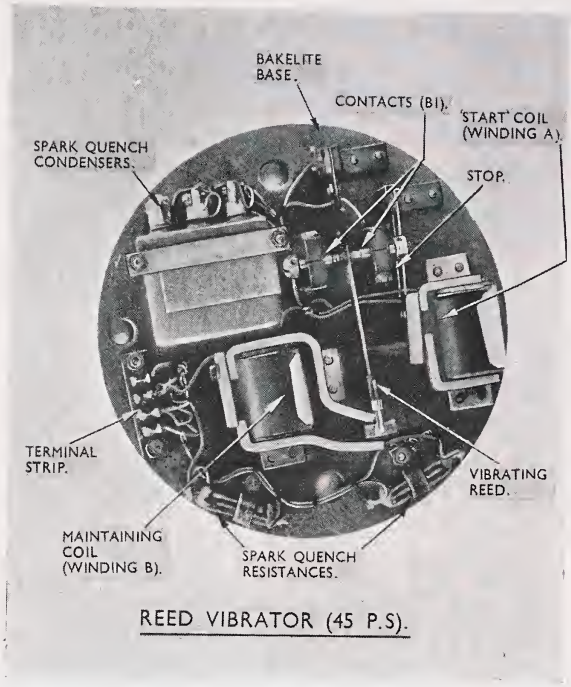


Fig. 95

to socket No. 2 of the time switch plug. The vibrating reed then travels in the opposite direction, contact B1 changes over again and the process is repeated *ad infinitum*. Contact B1, therefore, sends out pulses of current at 45 impulses per second to the program motor in the horizontal gyro which is connected to switch plug No. 2 in the time switch. Two bakelite cams are fitted to the program motor, one of which closes a contact at 0 seconds and the other one of which opens a contact after 45 seconds. When the program motor is in its zero position its magnet circuit is not complete. Contact 14 in the time switch closes after 4 seconds from the start of the flight of the rocket and completes the circuit of the magnet in the program motor which starts to drive. Contact 13 in series with contact 14 opens after 36 seconds, by which time both cam-operated contacts in the program motor are closed. The operation of the program motor magnet is, therefore, left dependent on the cam-operated contacts in the program motor itself, and not on the time switch. After 45 seconds the 45-second cam-operated contact in the program motor opens, breaks the circuit of the program motor magnet, and the program motor stops. This sequence of operation results in the rocket rising vertically for 4 seconds and then turning into its trajectory during the next 45 seconds.

To reset the program motor after a test the time switch is allowed to drive on, contact 13 closes after 75 seconds and the program motor magnet is re-energised since contact 14 in the time switch is also closed. After 85 seconds contact 14 opens, but by this time the cams in the program switch have continued revolving and the program motor continues to drive since both these cam-operated contacts are closed. These contacts remain closed until the 0-second cam is at zero when the program motor magnet circuit is broken.

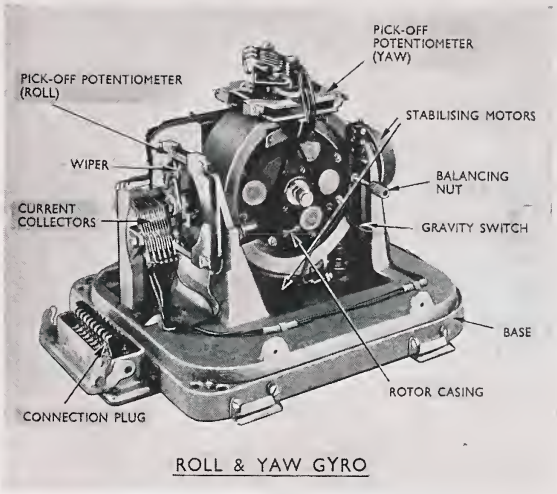


Fig. 96

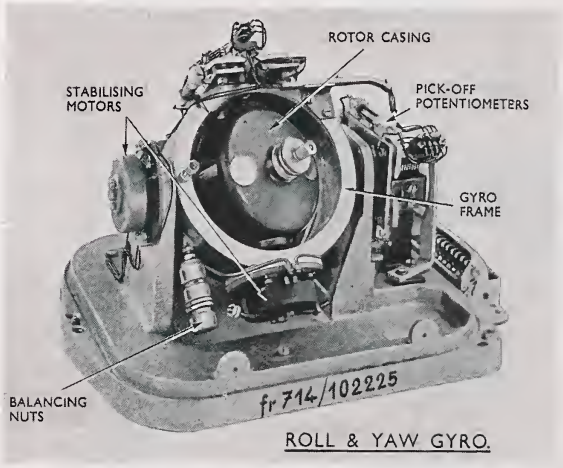


Fig. 97

GYROSCOPES

185. Two gyroscopes are fitted in each rocket, one (vertikant) to control the yaw and the roll (Figs. 96 and 97) and the second (horizont) to control the pitch (Figs. 98 to 100). They are essentially similar in design and the rotors are driven from a three-phase 500 cycle supply from alternator No. 2 at a speed of just under 30,000 r.p.m.

186. When running up to speed, the inner precision axis is maintained vertical by a stabilising motor under the mounting for the rotor housing, controlled by a gravity switch on the side of the mounting. The contact openings on this switch are very small, of the order of 0·1 mm., corresponding to an angular deviation from the vertical of about 0·05 degree. The contacts of this switch control the energisation of the coils of the stabilising motor, inside

which a magnetised disc produces a torque to counteract the tendency of the inner precision axis to move from the vertical.
A similar stabilising motor is fitted at the end of the gyro to counteract any tendency of the torque axis to move from a position at right-angles to the middle precision axis. This motor is actuated from contacts of a sensitive polarised relay, the tongue of which is normally centre stable and moving to one side or the other depending on the direction of current flowing in the relay winding. The relay winding is connected to the wipers of the pick-off potentiometer located on the top of the gyro, which are controlled by the movement of the torque axis from its true position.

187. The pick off potentiometers are wire wound and connected in parallel to the 50 V signalling battery. The resistance of each winding of each potentiometer is 1,000 ohms. The wipers are pieces of very thin wire, bent into the shape of a V, and moving over the potentiometer windings. The connections between the fixed and moving parts of the gyro are made through point swivel contacts accurately aligned.

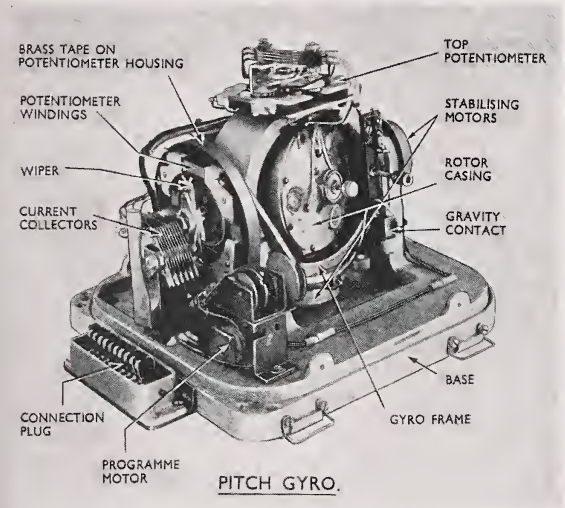


Fig. 98

188. The pitch gyro (Figs. 101 and 102) is fitted with a small motor, known as a program motor, to control the turning of the rocket into its trajectory. It consists of a ratchet-driven wheel which rotates a small cam shaft through a worm drive. The ratchet is driven by an electric magnet energised by interrupted direct current at 45 i.p.s. supplied by the reed interrupter fitted in the base of the sequence switch. Also on this cam shaft is a small loose pulley driven by an arm which is fixed to the shaft. This pulley winds up a brass tape which extends over a circular housing accommodating the front pick-off potentiometer. When it is desired to tilt the rocket in flight the program motor cam shaft (Figs. 101 and 102) revolves slowly and the brass tape is wound into the loose pulley. This causes the circular housing and the pick-off potentiometer to be slowly rotated, giving a signal to the control amplifier which is transmitted to the pitch rudders. If, during tests,

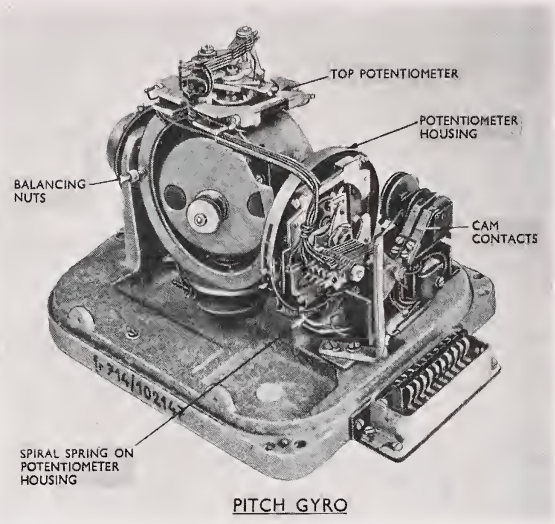


Fig. 99

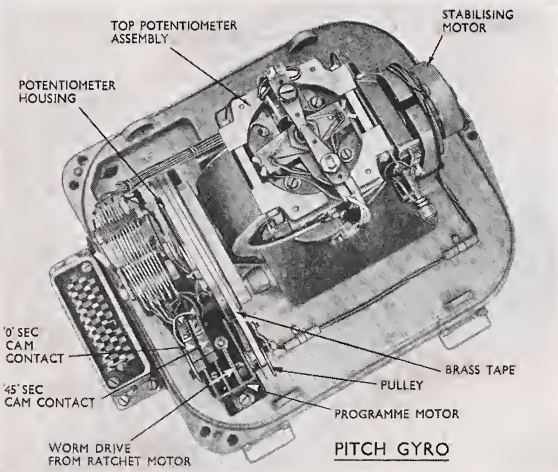


Fig. 100

it is desired to reset the pick-off potentiometer into its normal position the program motor continues to run until the arm driving the loose pulley is pushed out by a projection from the program motor framework. This causes the loose pulley to be disengaged from the drive, and the pick-off potentiometer and its housing return to a position a little behind the normal under the control of a spiral spring. The program motor drives on under the control of a cam contact and the arm re-engages the loose pulley and pulls the pick-off potentiometer into the normal position.

189. The circuit diagram of the pitch and the yaw and roll gyros is shown on Plate 64. A circuit diagram of the program motor and the associated contacts in the sequence switch is shown on Fig. 103. Contacts B1 in the reed interrupter in the sequence switch pulses out negative current at 45 impulses per second and energises the magnet M of the program motor dependent on contact 14 and 13 in the sequence switch. When the sequence

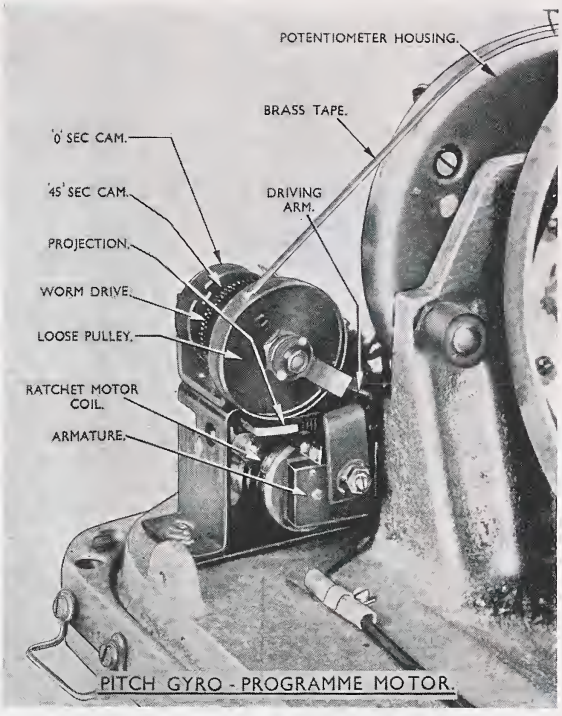


Fig. 101

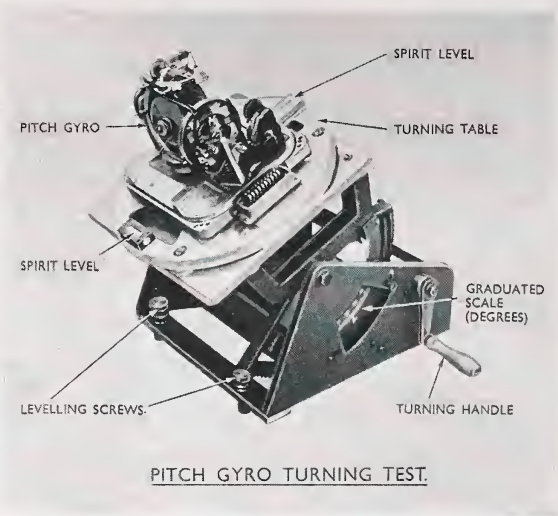


Fig. 102

switch is set to zero, contact 13 is closed and contact 14 is open. After the sequence switch has run for four seconds, contact 14 closes and the program motor starts to drive. The O-second cam on the program motor closes its contact and after 36 seconds the contact 13 in the sequence switch opens, leaving the program motor magnet dependent on the O-second cam contact and the 45-second contact in series. After 45 seconds the 45-second cam contact opens and the program motor drive circuit is broken and the program motor stops. It is during this period of 45 seconds that the rocket is gradually made to turn into its trajectory. After 75 seconds contact 13 in the sequence switch recloses and the program motor starts again, dependent on the sequence switch contacts 13 and 14 in series. The 45-second contact on the program motor then recloses. After 85 seconds contact 14 in the sequence switch opens and leaves the program motor drive circuit dependent upon the O-second and 45-second contacts on the program motor cam shaft. During this period the arm driving the loose pulley which winds the brass tape is disengaged, and the pick-off potentiometer returns to a position behind its normal position. The program motor continues to drive and starts to turn the pick-off potentiometer into its zero position. When this has been done the O-second contact on the program motor cam shaft opens and stops the motor.

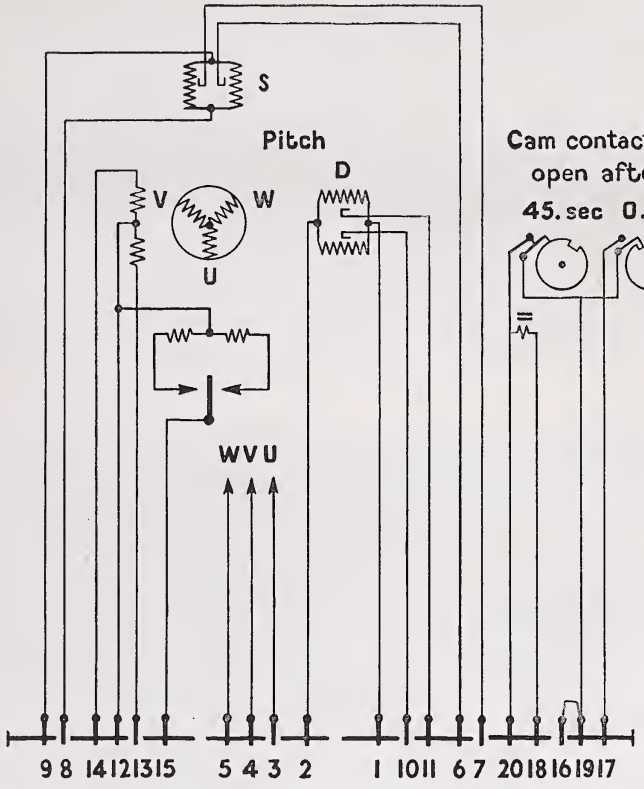
190. The method of testing the gyros used for this operation (Figs. 104 to 106) was briefly as follows :—
(i) When the gyro was stationary, the balancing nuts were adjusted as necessary until the gyro was balanced in any position.
(ii) The gyro was mounted on a swinging table, having sinusoidal tilting motions on two axes at right-angles of about 10 degrees at about 2 cycles per second. To reduce the effect of friction in the gyro bearings, an electric motor and counterweight were fixed to the swinging table to produce an additional vibration of about 50 pulses per second. The table was placed in a N.-S. direction and carefully levelled. The gyro under examination was connected to a test circuit which provided current for the gyro motor, stabilising motors, etc. A supply of 50 volts D.C. was connected to the windings of the pick-off potentiometers, and a voltmeter was connected to the wipers.
After running up the gyros for 15 minutes, the stabilising motors were switched off and the swinging table and vibration motor were switched on. After running for 5 minutes these were stopped and the deviation of the gyro axes from their original position was measured by observing the deflections of the voltmeters connected to the wipers of the pick-off potentiometers. With particular circuit arrangements used, the voltmeter connected to the wipers of the end potentiometer should read between 1·7 and 2·1 volts, and the voltmeter connected to the wipers of the top potentiometer should read between 2·25 and 2·75 volts These figures represent an accuracy of about $\pm 0{\cdot}1$ degree after 5 minutes running.
(iii) An additional test was made on the pitch gyro to ensure that the operation of the program motor was satisfactory. After the tests detailed above, the gyro was placed on a testing table whose base could be rotated about a horizontal axis. By operating the program motor, thereby moving the circular housing of the pick-off potentiometer, and by adjustment of the program motor cam contacts, the gyro was made to complete a turn of 47 degrees in 45 seconds.

THE CONTROL AMPLIFIER (Figs. 107 to 109)

191. General

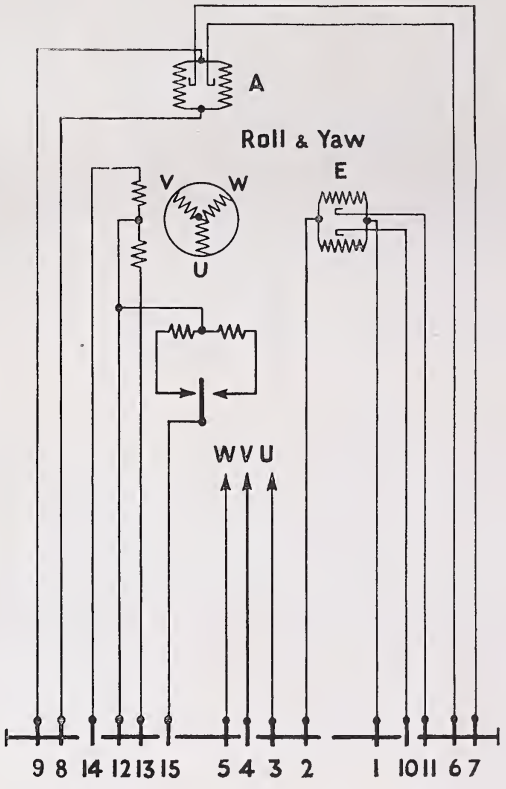
The control amplifier is a compact assembly of resistances, condensers, transformers, thermionic valves, etc., which is used to translate steering signals from the gyros into signals to the steering rudders in the tail of the rocket. It

CIRCUIT DIAGRAM FOR GYROSCOPES. Plate 64



CONNECTION PLUG No. 1.

Cam contacts to open after 45. sec 0. sec



CONNECTION PLUG No. 12.

DRG. No. T.B. 405.

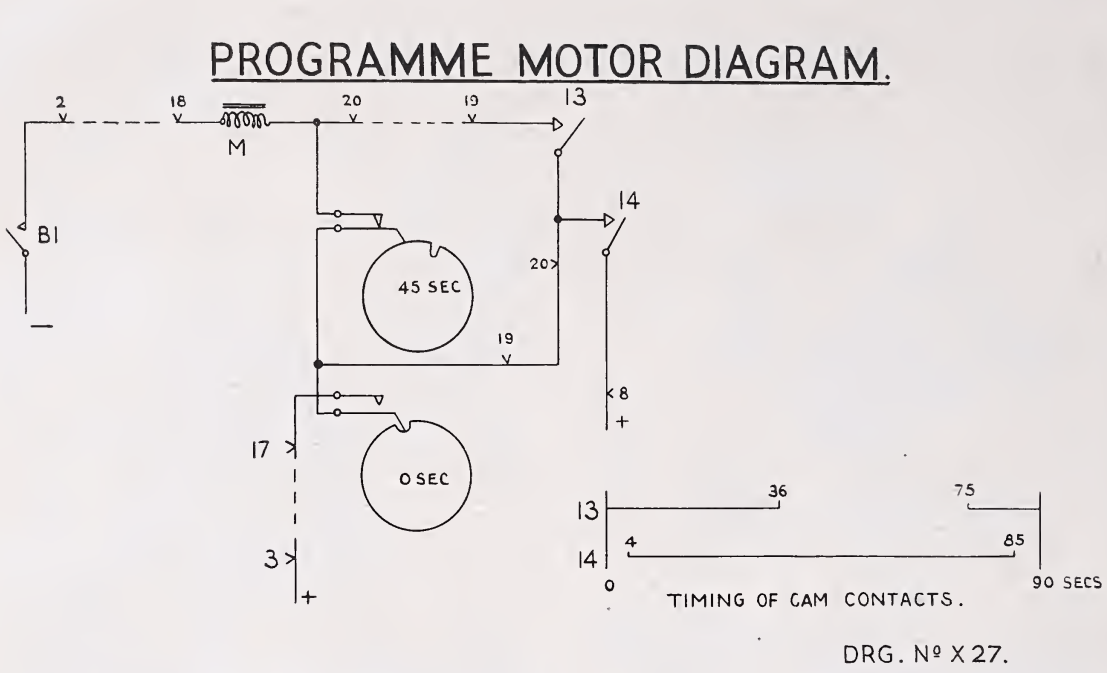


Fig. 103

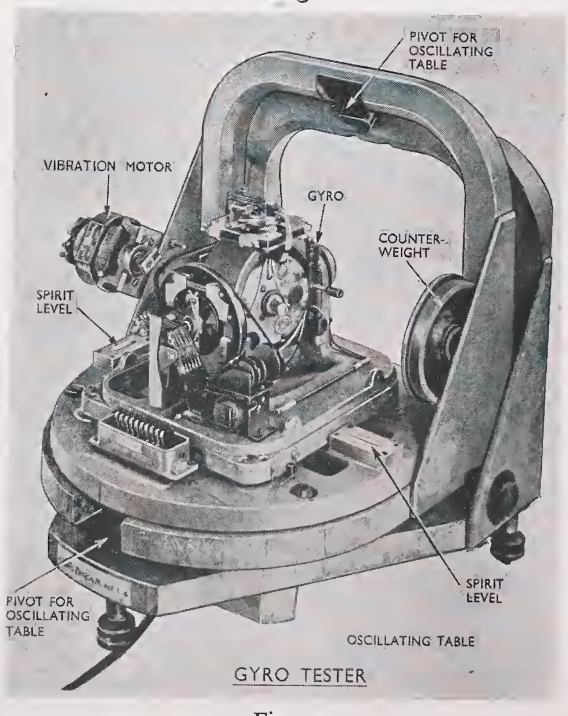


Fig. 104

consists of five separate units mounted on both sides of a common base plate and the individual units are interconnected by means of plugs and sockets. The main power supply for operating the control amplifier is taken from one phase of the 500 cycle alternator U.1 in the rocket. The circuit diagram of the control amplifier is shown in Plate 65.

192. Function

The control amplifier can be divided roughly into two equal parts which are generally similar. One part accepts direct current signals from the pitch gyro which are used to control the magnitude and phase of a 500 cycle supply. The 500 cycle signals so produced are amplified in a push-pull amplifier and after rectification are used to operate the control relays in the servo motors associated with the pitch steering mechanism. Facilities are also provided for synchronising the pitch rudders by means of signals sent back to the control amplifier from the potentiometers on the pitch rudder spindles.

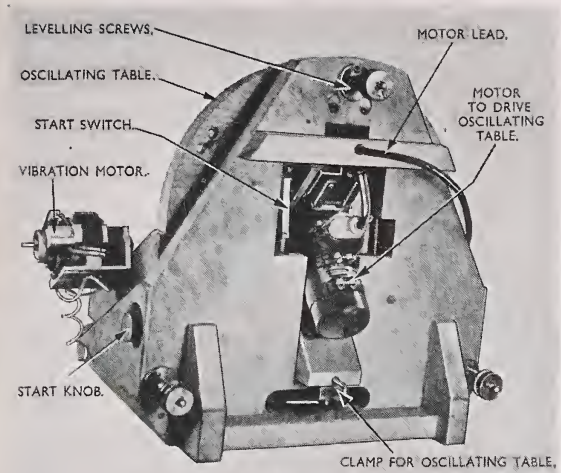
The second part of the control amplifier accepts D.C. signals from the potentiometers on the yaw and roll gyro. These are also transposed into 500 cycle signals which are amplified, and after rectification are used to operate the relays which control the operation of the servo motors associated with the yaw and roll rudders.

The power supply for driving the two push-pull amplifiers is provided by a power pack consisting of mains transformer, rectifying valve, etc., mounted together in one unit of the amplifier. The push-pull amplifiers with their input and output transformers are mounted in two more of the units and the D.C. to A.C. signal conversion circuits are mounted in the remaining two units.

CIRCUIT DESCRIPTION

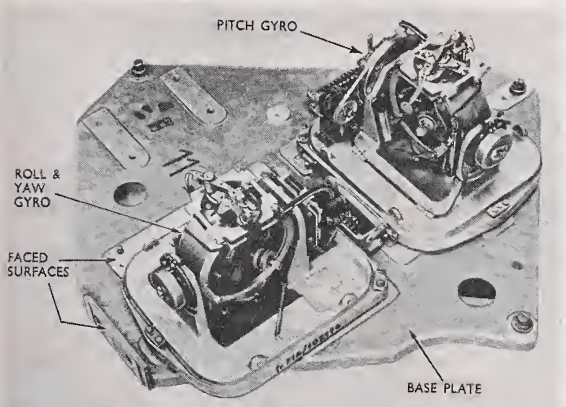
193. Unit No. 1—Power Supply

Alternating current at 500 cycles per second, 40 volts, is fed to the primary winding of the mains transformer 1. Secondary windings 2 and 3 provide a low voltage supply for heating the valves in the push-pull amplifiers. The



GYRO TESTER. UNDERNEATH VIEW.

Fig. 105



GYROS ON MOUNTING.

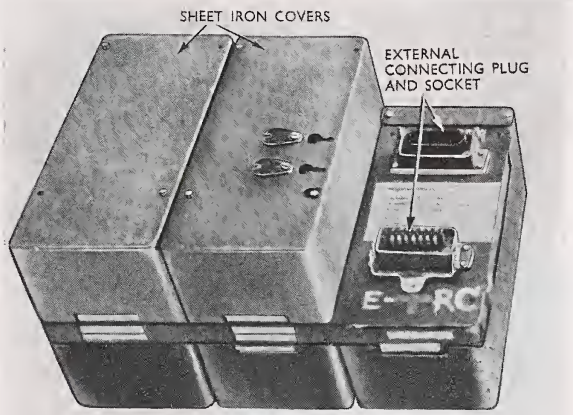
Fig. 106

centre tapped high-voltage secondary winding 5 and 6 provides the anode supply for the full wave rectifying valve 2, whose heater is supplied from the low voltage secondary winding 1. The rectified current produced by rectifying valve 2 is smoothed by the iron cored chokes 3 and 5 in conjunction with the electrolytic condensers 4 and 6. The centre point of the anode windings 5 and 6 is joined to chassis by condenser 7.

194. Unit No. 2—Signal Transposer (Pitch)

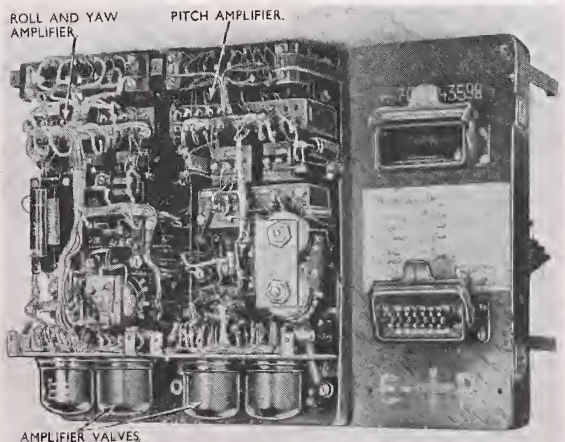
Alternating current 500 cycles is fed to this unit from one phase of alternator U.1. It goes first to a bridge connected phase shifting network consisting of resistances 13, 14 and 15 and condensers 16a, 16b and 16c. It is important that the phase of the 500 cycle current which passes to the output transformer of the push-pull amplifier is the same as that originally produced by the alternator, and this phase shifting network is used to correct for any phase shift in the signal transposing circuit or amplifier components. The phase shift through the network can be changed by connecting in circuit one or more of condensers 16a, b or c. The output from this phase corrector is taken to the primary winding of transformer 17, whose secondary is connected to a Wheatstone bridge network consisting of four copper oxide or selenium dry plate rectifiers 18 and resistances 19a, b and c. Resistance 19c is adjustable to compensate for differences in the resistance characteristics of the rectifiers. Resistances 19a and b are used to compensate for the portions of resistance 19c in the other arms of the bridge. The output from this bridge is taken to primary winding of transformer No. 20.

The centre point of the secondary of the transformer No. 17 and the centre point of the primary of transformer No. 20 are connected via a differentiating network to the wipers of the potentiometers on the pitch control gyro. The windings of these potentiometers are supplied with 50 volts D.C. from the signal battery in the rocket. The exact



CONTROL AMPLIFIER

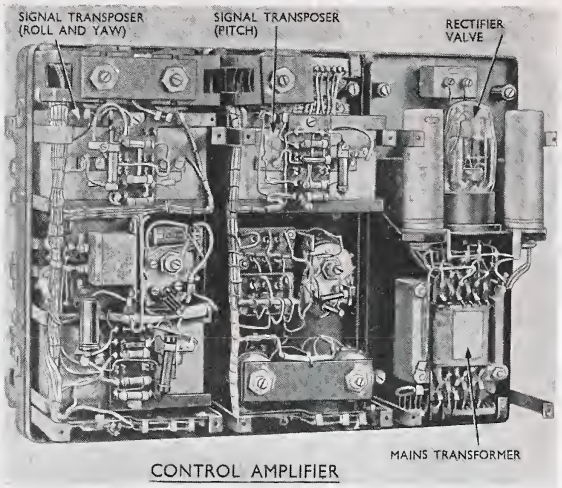
Fig. 107



CONTROL AMPLIFIER

Fig. 108

purpose of this differentiating network has not been properly ascertained. It consists of series of condensers and shunt resistances with the series condensers shunted by additional resistances which spoil the differentiating qualities of the circuit, but allow direct current to pass to the centre points of transformer 17 and 20.



CONTROL AMPLIFIER

Fig. 109

In the absence of any direct current signal from the pitch control gyro the rectifier bridge 18 is balanced and none of the 500 cycle current applied to its input terminals appears at its output terminals. When a direct current signal appears, it flows through the rectifiers and changes their resistance in such a way that the rectifier bridge is no longer balanced. A 500 cycle current, therefore, appears at the bridge points, and the magnitude of this current is dependent on the magnitude of the D.C. signal.

Should the direction of the D.C. signal to be reversed the rectifiers whose resistance was previously reduced will carry current in the opposite direction, and their resistance will be increased. Similarly, the rectifiers whose resistance was previously increased will have their resistance reduced. The result is that the phase of the 500 cycle current which now appears at the output terminals of the rectifier bridge will be different by 180 degrees from that which appeared previously. This circuit, therefore, transposes the direct current signals from the pitch control gyro into alternating current signals whose magnitude and phase are governed by the magnitude and direction of the gyro signal.

One terminal of the secondary winding of transformer No. 20 is connected to the centre point of the secondary winding of the input transformer to the push-pull amplifier. The other terminal is connected to the low potential side of the amplifier valve cathode biasing resistance. The resistances 25, 33, 34, 35, 36 and 37 mounted in this unit are part of the roll and yaw control circuit. They are only mounted here for space considerations.

195. Unit No. 3—Amplifier Circuit (Pitch)

The amplifier is a push-pull circuit using indirectly heated pentodes with heaters operated from 500 cycles. The anode supply to each valve is fed through iron cored chokes 57 and 67 with stabilising resistances 55 and 66. The screens of the valves are fed from potential dividers consisting of resistances 59 and 60 and 69 and 70 respectively. The screens are held at chassis potential from the A.C. point of view by condensers 58 and 68.

The signal output from each valve is taken via condensers 56 and 66 to the output transformers 76 and 80. These are special transformers with a three limb iron core. On the centre core is wound the main output winding for the associated amplifier valve, which is tuned to resonance at 500 cycles by the condensers 77a, b, c or 81a, b and c. The reason for tuning this winding is not to increase its impedance at 500 cycles, but to eliminate any phase shift to the signal which would otherwise be caused by having an inductance in the anode circuit of the valve. Windings 2 and 3 of this transformer are wound one on each of the outer limbs, and are connected to the same phase of the 500 cycle alternator as is used to provide the 500 cycle signals from the rectifier bridge network in unit 2. When current flows in these windings the magnetic fluxes produced travel down the centre limb of the core in opposite directions. Since the windings 2 and 3 have each the same number of turns and the current flowing in them is the same, no residual flux appears in the centre limb of the core. Windings 4 and 5 are also wound one on each of the outer limbs of the output transformer and are joined to bridge connected dry plate metal rectifiers, e.g., 78 and 79. The output from these rectifiers is taken to the control relays in the servo mechanism which operate the pitch rudders.

In the absence of any signal from the amplifier the magnetic flux produced by the current flowing in windings 2 and 3 induces a voltage in windings 4 and 5 which is rectified and flows to the servo control relay. The number of turns in windings 4 and 5 are equal and hence equal currents should flow from each rectifier bridge circuit to produce a stabilising bias on the servo control relay. Small inequalities of current may be compensated by adjusting potentiometer 85 or 88 which, with resistances 84, 86 or 87, 89, are joined across the outputs of the rectifier bridges.

When a signal is received from the amplifier, alternating current flows in the winding on the centre limb of the output transformer, and a magnetic flux flows from this centre limb through the outside limbs in such a direction that the steady flux produced by windings 2 and 3 is reduced in one outer limb and increased in the other. The voltage induced in winding 4 or 5 is proportional to the flux linking that particular winding, and the voltage, therefore, which is applied to the rectifier networks, e.g., 78 or 79 can be reduced or increased by an amount which is proportional to the signal current flowing from the amplifier valve. Should the phase of the signal be such that the voltage applied to rectifier network 78 is increased, then the voltage applied to rectifier network 79 must be reduced. If the phase of the signal from the valve is changed by 180 degrees, the voltage applied to rectifier network 78 will be reduced while that applied to rectifier network 79 will be increased.

The primary winding of the input transformer 44 is connected to the sliders of the potentiometers attached to the spindles of the pitch rudders in the tail of the rocket. The windings of these potentiometers are supplied with 500 cycles from alternator U.1. The secondary winding of transformer 44 is connected to the primary winding of transformer 43 whose secondary winding is centre tapped to provide for push-pull operation of the amplifier.

When a D.C. signal is received from the pitch control gyroscope a corresponding 500 cycle signal is produced by unit 2 and applied to the centre point of the secondary winding of transformer 43. This signal is, therefore, applied to the grids of both the amplifier valves in parallel. It is amplified and passed to the output transformers 76 and 80 where it changes the voltages applied to the rectifier bridges to produce signals to operate the control relays in the servo mechanisms in such a way as to make the servos move the pitch rudders in accordance with the request from the gyros.

196. Unit No. 4—Yaw and Roll

To operate the yaw and roll controls it is necessary to have two signal transposer circuits, each of which is essentially the same as that used for the pitch control. As it is not possible to mount all the components associated with two signal transposers in one unit, the rectifier network and phase compensator for the yaw control is mounted in unit No. 5.

The phase compensator for the roll control consists of resistances 113, 114, 115 and condenser 116. This circuit is fed from one phase of the 500 cycle supply and the output passes to transformer 117, rectifier bridge network 118 and transformer 120 to the centre point of the input transformer of the yaw and roll control amplifier. The differentiating network for this circuit consists of resistances 122, 123, 126, 128a, 130 with condensers 127 and 129. A second transformer 146 is connected with its secondary in series with transformer 120. This transformer was used in German rockets to inject a signal when radio control was fitted. For Operation "BACKFIRE" the primary winding of this transformer was short circuited.

The operation of the signal transposer for the roll control is exactly the same as for the pitch control already described except that the D.C. for controlling the operation of the rectifier bridge is taken from the roll potentiometer on the yaw and roll gyro.

Resistances 103, 106, 108a, 110 and 112 and condensers 107 and 109 form the differentiating circuit for the yaw control.

197. Unit No. 5—Amplifier Circuit (Yaw and Roll)

This is essentially the same as the pitch amplifier circuit and uses the same type transformers, valves and general circuit arrangements. There is, however, an additional rectifier bridge signal transposer consisting of rectifier network 98 working between the secondary winding of transformer 97 and the primary winding of transformer 100. The D.C. control current for this circuit is obtained from the yaw potentiometer on the yaw and the roll gyro via the differentiating net work in unit 4.

In the absence of any signal from the yaw or the roll potentiometers a steady current flows in the three wire circuit to the relays controlling the operation of the servo mechanism. This is provided by windings 2 and 3 on each of the output transformers fed from the 500 cycle alternator. When a yaw signal is received from the gyros, rectifier network 98 produces a 500 cycle signal whose magnitude and phase correspond to the magnitude and sense of the gyro signal. This alternating signal passes through transformer 100 and is applied to the grids of valves 152 and 161 in push-pull. The resulting signals which are produced by the bridge connected rectifiers 178, 179, 182 and 183 cause the servo mechanisms to move the yaw and roll rudders through the desired angle in synchronism. Should a signal be received from the roll gyro it passes through its differentiating network and unbalances the rectifier bridge 118. This produces a 500 cycle signal, of magnitude and phase corresponding to the roll signal from the gyro, which passes through transformer 120 to the centre point of the secondary winding of the amplifier input transformer 100 and thence to the grids of both valves in parallel. This causes the signal on the grid of either valve 152 or 162 to be different by 180 degrees from that produced from a yaw signal and consequently one of the yaw and roll rudders will move in the opposite direction from the other and correct the roll.

198. Setting Up of Control Amplifier

It was not possible with the facilities available at the time to make any fundamental measurements on the behaviour of the control amplifier and its effect on the flight of the rocket. The following procedure, however, was adopted to ensure that the control amplifier performance was not unreasonable.

(*a*) Voltage and current measurement were made on the power pack and on each valve.

(*b*) Potentiometers 33, 36, 85 and 88 were adjusted to ensure balance between the biasing currents flowing in the circuit of the servo control relay.

(*c*) 500 cycles was applied to the primary winding of transformer 44 in the pitch control amplifier. It was observed that connecting this frequency one way round increased the current in one half of the circuit of the servo control relay and decreased it in the other half. It was also observed that the dissymmetry between these control currents was reversed when the phase of the 500 cycles applied to transformer 44 was reversed. At this stage also the adjustment of the anode transformer tuning condensers 77 and 81 was checked to get the maximum unbalance current.

(*d*) 500 cycles was connected to the primary winding of transformer 17, and potentiometer 19c on rectifier bridge 18 was adjusted until there was no output current from the amplifier.

(*e*) A direct current signal was connected to the centre points of the secondary of transformer 17 and the primary of transformer 20, to check that, with one polarity, the unbalance current was in one direction and with the other polarity, it was in the other direction.

(*f*) 500 cycles was connected to the bridge-connected phase shifting network connected to the primary of transformer 17. A direct current signal was applied to the rectifier bridge network 18, and condenser 16 in the phase shift network was adjusted until the out-of-balance current at the output of the control amplifier was a maximum.

(*g*) A D.C. signal of 6 volts was applied to the input of the differentiating circuit for the pitch control. This produces a biasing potential of about 0·06 volts at the rectified bridge 18 and it was observed that the out-of-balance current at the output of the control amplifier was between 9 and 10 mA.

199. A similar procedure was adopted for setting up the yaw and roll circuit with its two rectifier bridge signal transposers. After the voltage and current measurements on the circuit were complete and potentiometers 33 and 36 had been adjusted to balance the currents in the servo control circuits, the following tests were made :—

(*a*) 500 cycles was connected to the primary winding of transformer 146, and the condensers 177 and 181 across the output transformers of the valves were adjusted to produce zero phase shift. 500 cycles was connected to the primary winding of transformer 117 and the balance of the rectifier bridge 118 was adjusted for no output from the amplifier.
(*b*) 500 cycles was connected to the input of the phase shifting network and a D.C. signal was applied to the rectifier network 118. Phase shifting condenser 116 was adjusted to give the maximum unbalance between the currents in the servo control relay circuit: 500 cycles was applied to the primary winding of transformer 97 and the rectifier bridge network 98 was adjusted until there was no output from the amplifier.
(*c*) 500 cycles was connected to the phase shifting network and a D.C. signal was applied to the rectifier bridge network 98. Phase shifting condenser 96 was adjusted for maximum unbalance between the currents in the servo control circuits.
(*d*) With a D.C. potential of 6 volts applied to the input of each differentiating network in turn and with 500 cycles connected to the phase shifting network, potentiometers 123 and 103 were adjusted until the out-of-balance current in each case was 9 to 10 mA in the servo control circuit.
(*e*) It was observed that when a D.C. signal was applied to the yaw control differentiating network associated with the rectifier bridge 98, the senses of the unbalance currents in the control circuit of each servo were the same, and were reversed when the D.C. signal was reversed in polarity.
(*f*) It was observed that when a D.C. signal was applied to the roll control differentiating network associated with the bridge connected rectifier 118, the senses of the unbalance currents in the servo control circuits were different and were reversed when the polarity of the D.C. signal was reversed.

SERVO MOTOR (Figs. 110 to 112)

200. This consists essentially of two identical oil pumps (gear type) driven through a common shaft by an electric motor, the necessary valves, which are interconnected and are controlled by a polarised electromagnetic relay, and an operating cylinder.
It was not designed for the A-4 rocket but adapted from use on aircraft.
The pumps are submerged in the oil reservoir and on the delivery side have two branches; one delivers oil to one side of the piston which moves in the operating cylinder incorporated in the pump casing, and the other delivers oil back to the reservoir. The operating valves of the pumps are placed in the delivery side back to the oil reservoir. Relief valves are provided on the delivery side to the piston and are set to 40 atmospheres (600 lb. per sq. inch).
The piston is connected on one side by a rod and bell crank to the output shaft which operates the control rudder on the rocket. The total travel of the piston in the cylinder is 55 mm. approx. and this gives an angular movement of 90 degrees to the output shaft. To balance any inequalities due to temperature differences, etc., each end of the cylinder, i.e. each side of the piston, is provided with a further small capillary valve consisting of a series of baffles pierced by a very fine hole.
The control valves are fixed to a cross member which is in turn controlled through a lever system by the relay, and the fulcrum on the cross member is so arranged that as one valve closes the other opens by an equal amount. Final adjustment is obtained by knurled nuts on the connecting

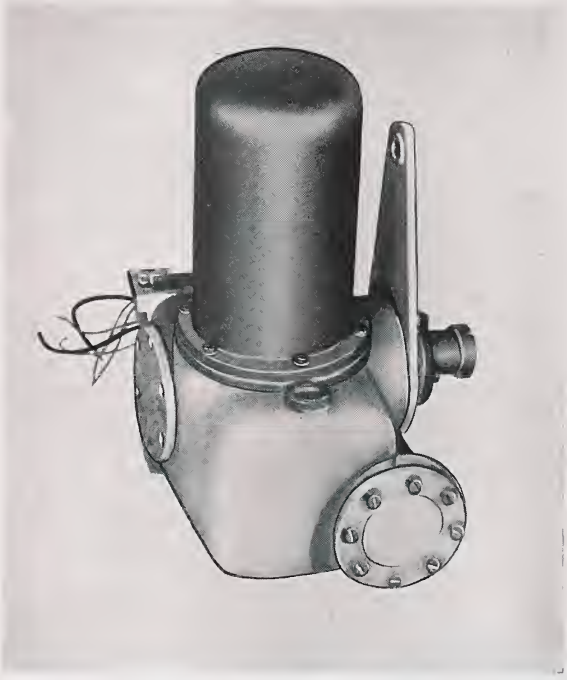


Fig. 110

rods. When no operating current is passing through the relay the valve system is in the neutral position and the flow of oil is as shown in Plate 66, the piston being in the middle or zero position. If now the relay is operated it will cause the cross member to rock in one direction, partially closing valve 2 and opening valve 1. This upsets the oil equilibrium, causing more oil to flow to the left-hand side of the piston than to the right. The piston, therefore,

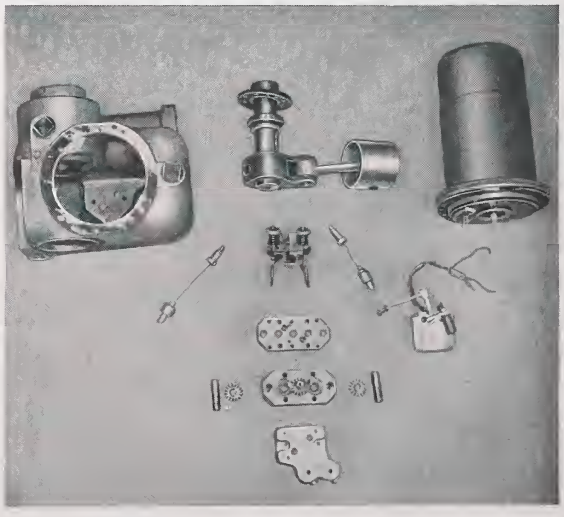
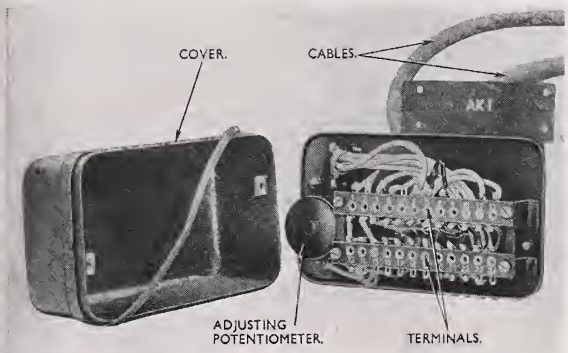


Fig. 111

moves to the right. If the current is now cut off the relay, the valves will return to the neutral position and the flow of oil will be equalised, bringing the piston back to the central position.

It will be noted that the only two positions at which the piston can stop are neutral or right over. Intermediate positions are obtained momentarily, the control being one of rate and direction only.



SERVO MOTOR TERMINAL BOX.

Fig. 112

THE TAIL UNIT POTENTIOMETERS (Figs. 113 and 114)

201. General

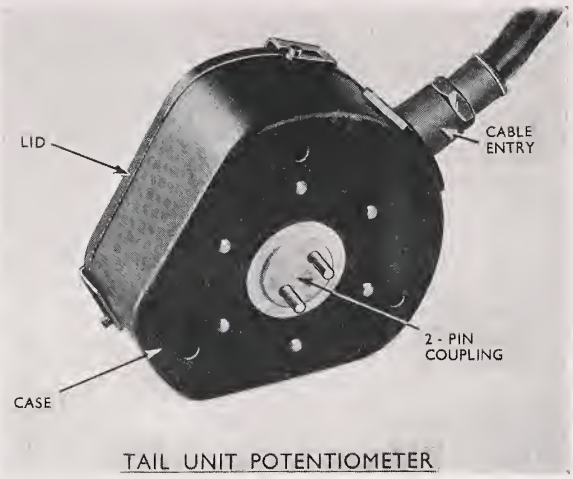
The tail unit potentiometers are mounted on the thrust ring at the venturi end of the rocket, on the brackets used for mounting the carbon rudders. They are fitted at the rate of two potentiometers per carbon rudder, the pairs of potentiometers being accommodated in a common case, and are actuated by a 2-pin coupling from the spindle of the carbon rudder.

202. Construction

Pairs of potentiometers are mounted in a pear-shaped sheet iron case with lid, fitted with a cable entry hole and bush for the connecting wires. Each potentiometer winding of 300 ohms resistance is accommodated on a rectangular metal former bent into an arc, and is insulated from this former by bakelite varnish. The wipers are phosphor bronze pressings and are mounted on adjustable steel details attached to a bakelite driving plate. The ends of two other steel details are shaped to actuate " end " contacts which close when the potentiometer wipers have reached the end of their travel. The assembly of two potentiometers mounts on a moulded bakelite framework which is riveted to the pear-shaped case.

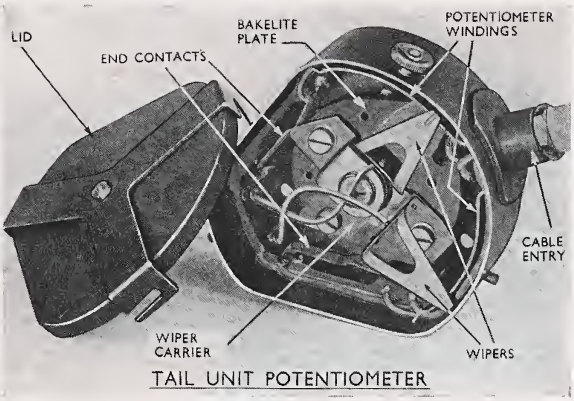
203. Operation

One of each pair of potentiometers is used to indicate to the ground test desk the position of the carbon rudders during ground tests in the assembly shops or at the launching site. On the pitch rudders, the second potentiometer of each pair is used to indicate to the control amplifier any tendency for the pitch rudders to become unsychronised. On the yaw and roll rudders the second potentiometer of each pair is used to indicate to the trim motors any lack of synchronism of the yaw and roll rudders, and so to bring into operation the separate trimming vanes on the pitch axis fins to assist in controlling roll.



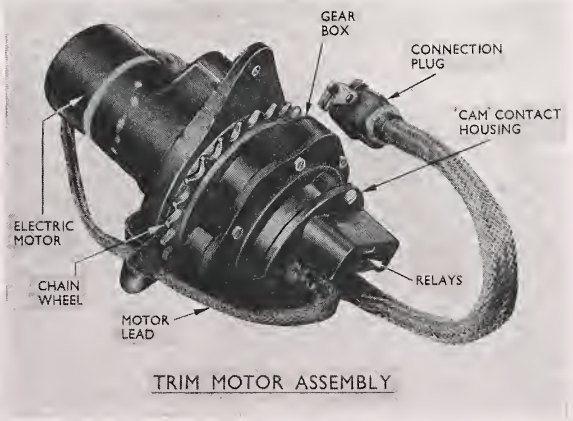
TAIL UNIT POTENTIOMETER

Fig. 113



TAIL UNIT POTENTIOMETER

Fig. 114

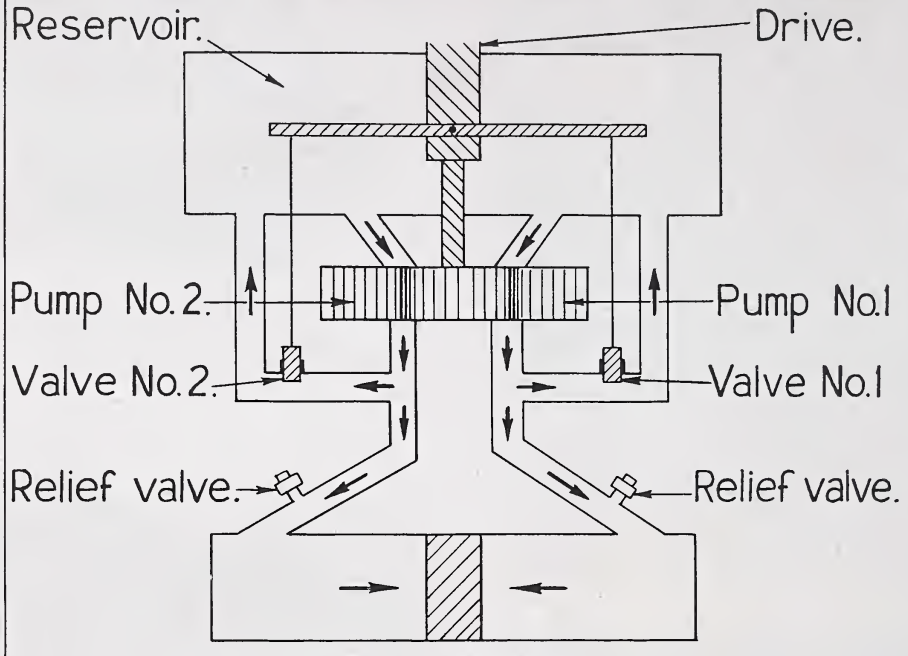


TRIM MOTOR ASSEMBLY

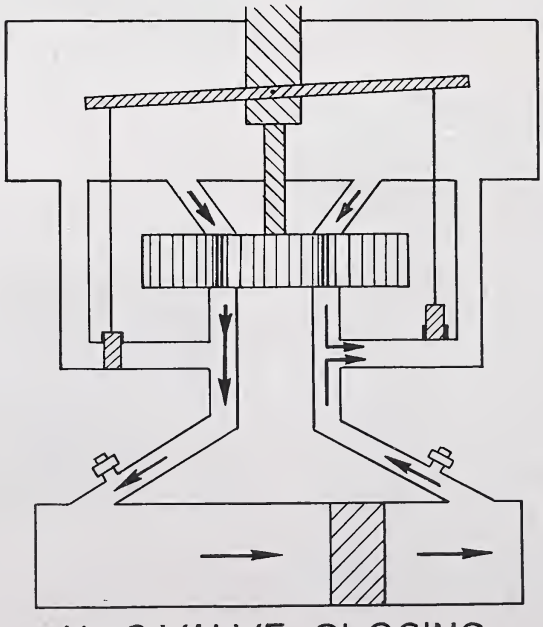
Fig. 115

Plate 66.

SCHEMATIC DIAGRAM OF SERVO UNIT.



EQUILIBRIUM.



No. 2 VALVE CLOSING.

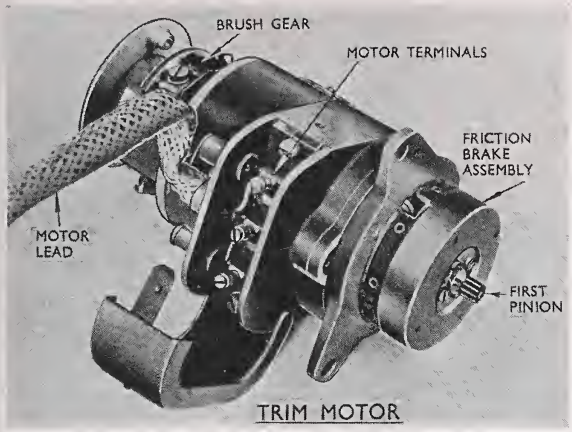


Fig. 116

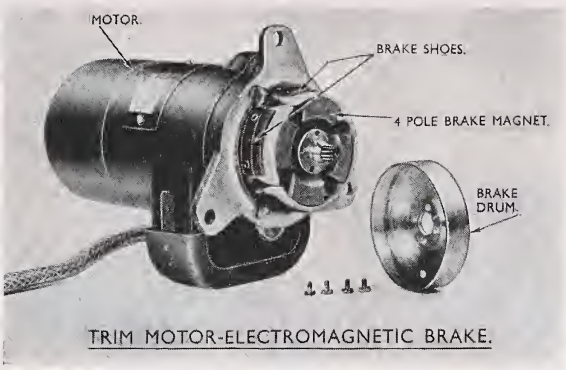


Fig. 118

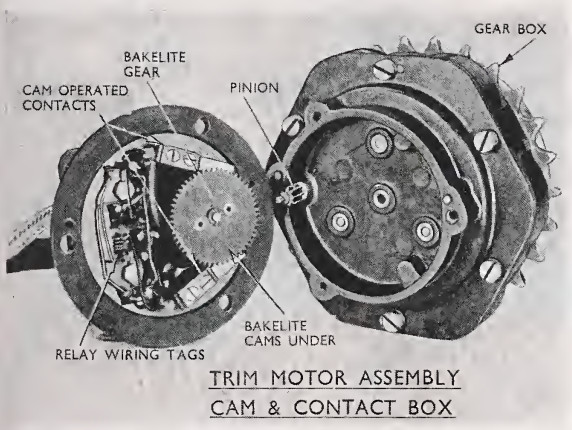


Fig. 117

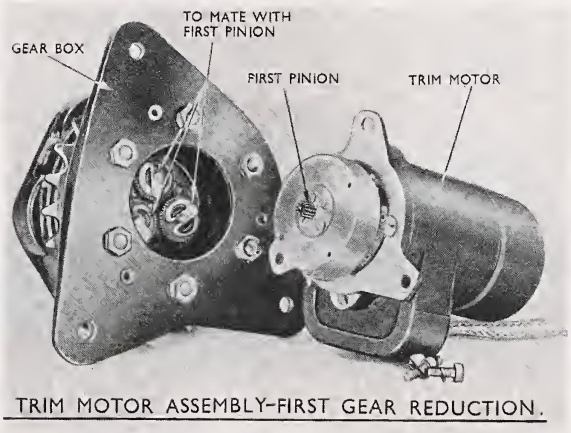


Fig. 119

THE TRIM MOTOR ASSEMBLY (Figs. 115 to 117)

204. General

The trim motor assembly consists of a small electric motor and a gear box through which is driven a chain wheel. The electric motor has two field windings, and by suitably arranging the circuit the motor may be run either clockwise or anti-clockwise. Fitted to the motor shaft is a four-section electro-magnetic friction brake (Fig. 118) which is on when there is no current in the motor. Thus the motor armature cannot move unless it is being driven by the armature current.

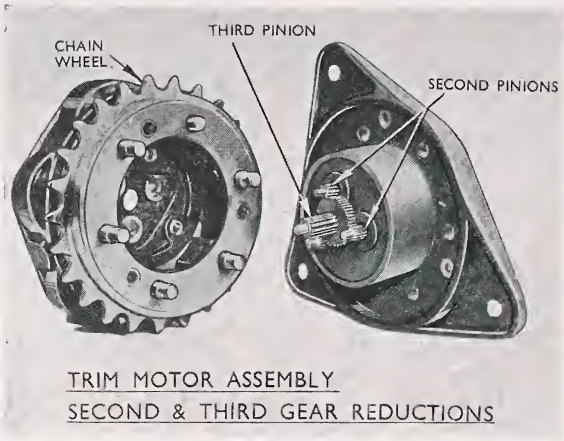
At the end of the assembly remote from the motor are two cams, controlling contacts which are used to indicate when the vane which is driven from the motor has reached the limit of its travel, and when the vane is central. Also mounted on this assembly are two small relays which are used to control the direction of the rotation of the motor.

The reduction gear ratio between the motor armature and chain wheel is about 3,000 to 1 (Figs. 119 to 123).

205. Function

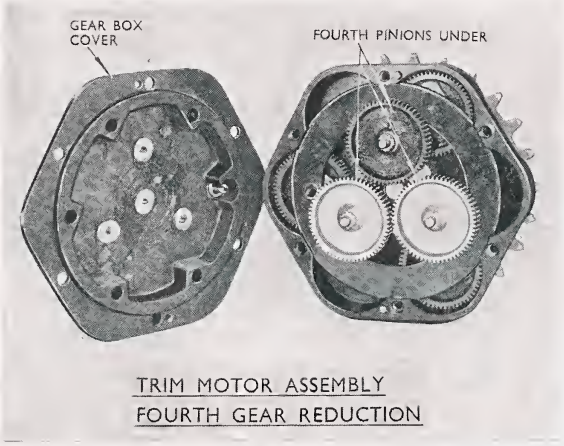
The function of the trim motor is to control the outer vanes on the fins on the pitch axis and so help to correct any tendency of the rocket to roll. They are operated independently of the pitch rudders through a separate chain drive from the chain wheel on the trim motor assembly.

The method of control is as follows. Should the carbon yaw rudders be out of synchronism when the rocket is flying it indicates that the rocket is inclined to roll. Wire-wound potentiometers are fitted on the yaw rudder shafts and connected to the main battery. Wipers of these potentiometers are connected together through a telegraph type relay. When the yaw rudders occupy the same relative position, the potential difference between the wipers of the potentiometers is zero, and the relay does not operate. When the relative position of the yaw rudders is different, the wipers of the potentiometers are at different potentials and the relay operates. Normally, the relay is centre stable, i.e. the tongue lies midway between the contacts and does not touch either of them. Depending on the relative position of the yaw rudders, current flows through the relay coils in one direction or the other and this causes the relay tongue to move either to the left-hand contact or to the right-hand contact. The circuit is so arranged that this causes the trim motor to revolve either clockwise or anti-clockwise and so move the outer vanes through the chain drive to correct the roll.



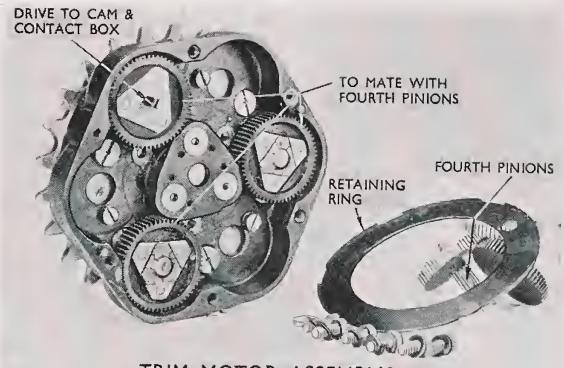
TRIM MOTOR ASSEMBLY
SECOND & THIRD GEAR REDUCTIONS

Fig. 120



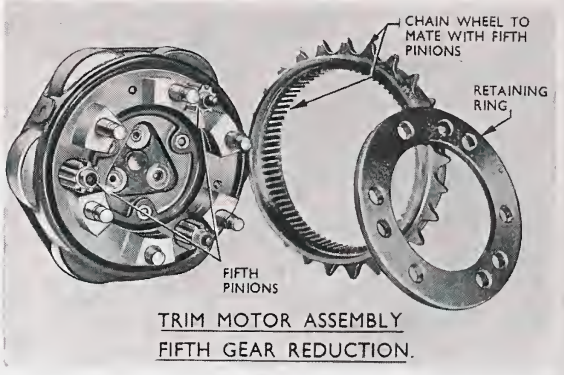
TRIM MOTOR ASSEMBLY
FOURTH GEAR REDUCTION

Fig. 121



TRIM MOTOR ASSEMBLY
FOURTH GEAR REDUCTION

Fig. 122



TRIM MOTOR ASSEMBLY
FIFTH GEAR REDUCTION.

Fig. 123

206. Detailed Circuit Operation

The circuit connections of the trim motor and its control circuit are shown on Fig. 124. Relay R3p is the polarised telegraph relay operated from the potentiometers on the yaw rudders, whose contact controls the operation of the trim motor. Contacts El and Er are two of the cam-controlled contacts in the trim motor assembly, and open when the trim vane has reached the limit of its travel. Contacts Nl and Nr are similar cam-operated contacts and both open when the vane is exactly central, and one or other closes as soon as the vane moves off normal. Relays 1X and 3X are the small relays on the trim motor assembly. These relays are operated by contact R3p and their contacts control the actual running of the motor. Contact A9z is a contact of the flame cut-off relay in the rocket and closes when the fuel in the rocket is cut off.

When the wipers of the potentiometers connected with the yaw rudders both occupy the same relative position, i.e. when the yaw rudders are synchronised relay R3p is not operated and relays 1X and 3X are released. When the wipers on the potentiometers are not synchronised relay R3p operates and its contact moves to left or right as determined by the direction of current in the relay coils, i.e. by the sense of the lack of synchronism. Assume that contact R3p moves to the left, then battery is connected via contact R3p, contact El closed, contact 3X closed through relay 1X coil, and relay 1X operates. A contact 1X opens the circuit of relay 3X and prevents it from operating. The second contact 1X closes and connects battery through the motor armature and the left-hand field winding, and the motor revolves in a clockwise direction. Should contact R3p move to the right, battery is connected through contact R3p, contact Er closed, contact 1X closed to relay 3X coil, and relay 3X operates. A contact 3X opens to prevent relay 1X from operating, and the second contact 3X closes and connects battery through the motor armature right-hand field winding to make the armature drive in an anti-clockwise direction. The trim motor continues to drive in a clockwise or anti-clockwise direction as determined by the sense of the roll until the yaw rudders become synchronised. Then relay R3p releases, since the wipers on the potentiometers are also synchronised, relay 1X (or 3X) releases and the trim motor stops driving.

Should the roll be such that the trim vanes move to the limit of their travel, contact El (or Er) opens and releases the appropriate relay (1X or 3X) and stops the motor.

Should the trim vanes be off normal when flame cut-off occurs, contact Nl or Nr will be closed, depending on which way the trim vane has moved. The flame cut-off

relay A9z operates and contact A9z in the trim motor circuit closes to connect battery to the appropriate relay 1X or 3X via contact Nl or Nr, whichever is closed. The motor drives in such a direction as to return the trim vanes to normal. When this has happened contact Nl or Nr, whichever was closed, opens, releases the appropriate relay, and the motor stops.

The electro-magnetic brake on the motor (Fig. 118) is normally on, i.e. prevents the armature from rotating when the armature carries no current. Consequently the vanes can be turned through the appropriate angle and locked in position until such time as they are required to execute any further movement. After flame cut-off, therefore, the trim vanes are locked in the normal position irrespective of whether the rocket tries to roll or not.

RELAYS AND SWITCHES

207. Several different types of relays are used in the A-4 rockets built for Operation "BACKFIRE." They are described individually in the notes below.

(1) Relay Type 19-9005 (Figs. 125 to 128)

This is a small telephone type relay made by Siemens and Halske. It is a miniature relay of fairly orthodox design with silver contacts and phosphor bronze springs. It is a donkey type of relay and is used in fair quantities in the rocket and ground test equipment. In the rocket it is mounted on the main distribution frame and is used chiefly for changing over the connections from the ground test equipment to the rocket itself. It is the commonest type of relay used. The contact arrangements are quite

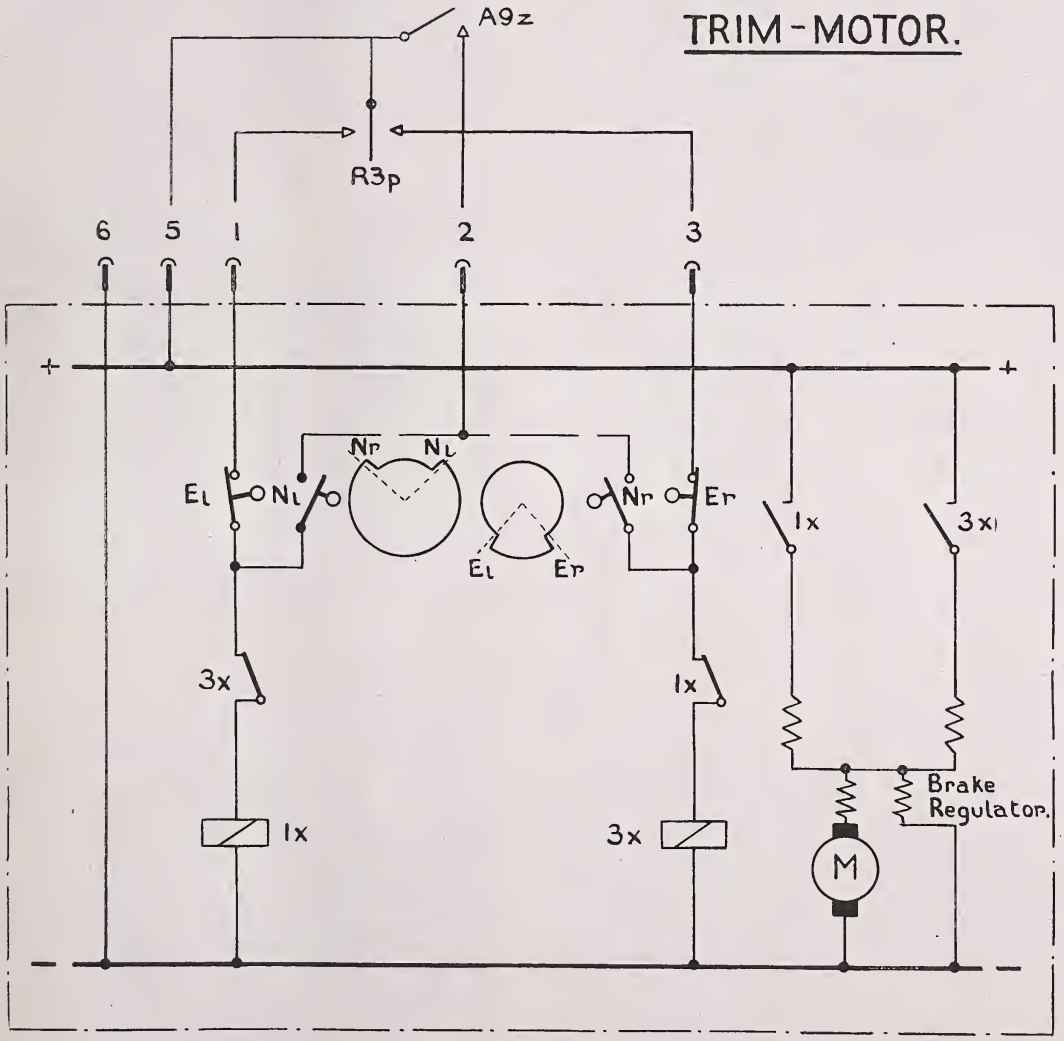
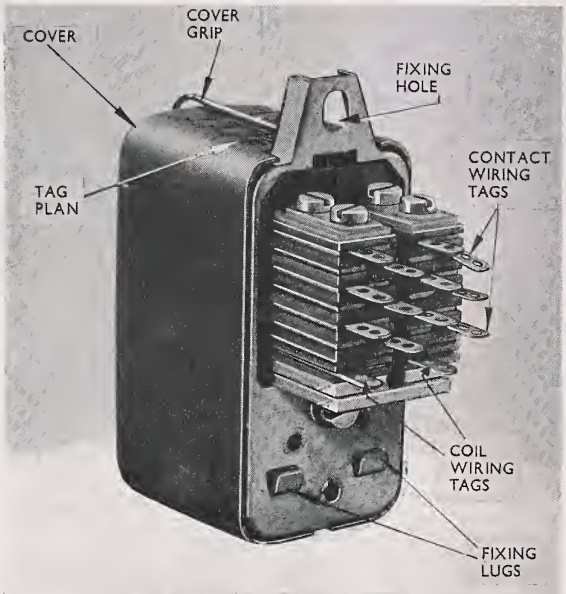


Fig. 124



RELAY TYPE 19-9005.

Fig. 125

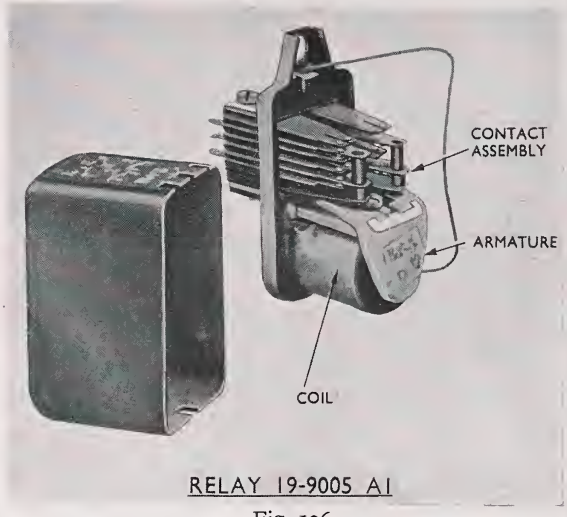
orthodox, consisting of make contacts, break contacts and change-over contacts. No relay of this type has been found with make before break contacts. It is provided with a pressed steel cover held in place by steel wire.

(2) Relay Type 19–9008 (Figs. 129 to 134)

This is a single coil solenoid type of relay made apparently by Schile. The plunger of the solenoid operates a contact bar through levers and the number of contacts which can be fitted is restricted. It appears to be used mainly where the contacts are required to carry heavy current. The contacts appear to be made of silver and the contact pressure is provided by a spring or series of springs inside the operating bar. The current carrying capacity of the contacts in the relays used appear to vary from 10 amperes to 40 amperes. The relay is extremely robust and is a donkey relay for use in heavy current circuits. It is fitted with a pressed steel case.

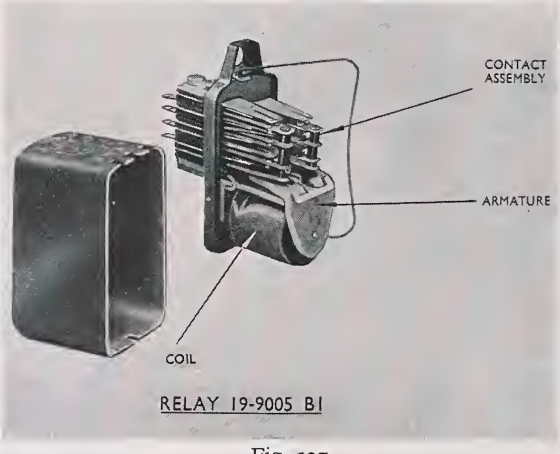
(3) Relay Type 19–5810 (Figs. 135 to 137)

This is a small compact type of circuit breaker with very heavy contacts rated at 100 amperes. It is made by Bosch. It consists of a solenoid, to the plunger of which is attached a bridging detail insulated from the plunger, and which makes contact with two large contact surfaces connected to the main circuit. The solenoid has two windings, one a very heavy operating coil which is cut out of circuit when the main contacts are made, leaving the circuit breaker dependent on a smaller holding coil. The assembly is mounted on a diecast aluminium base fitted with a pressed steel cover. Large screw type terminals are provided for the connection of external leads. This relay is used in the rocket as a main switch to change from the ground battery supply to the rocket battery.



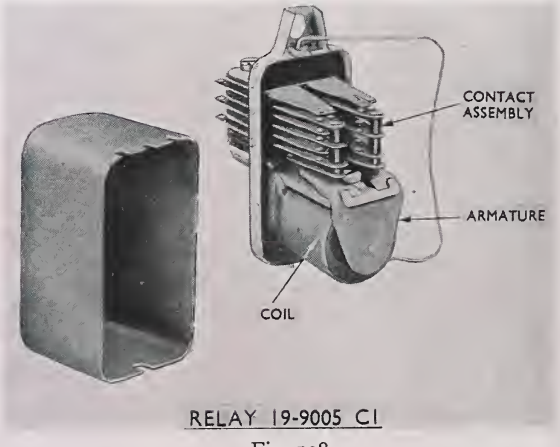
RELAY 19-9005 A1

Fig. 126



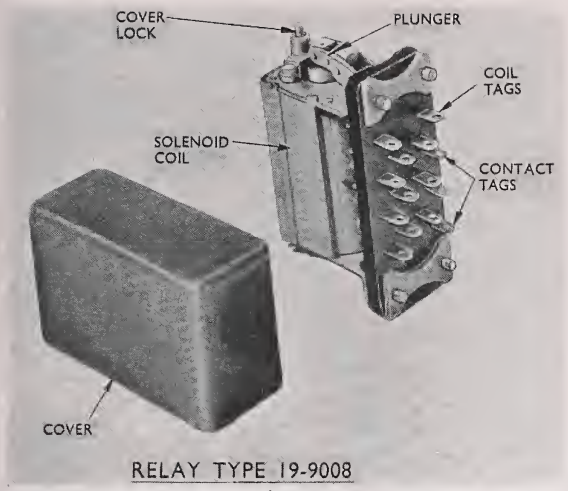
RELAY 19-9005 B1

Fig. 127



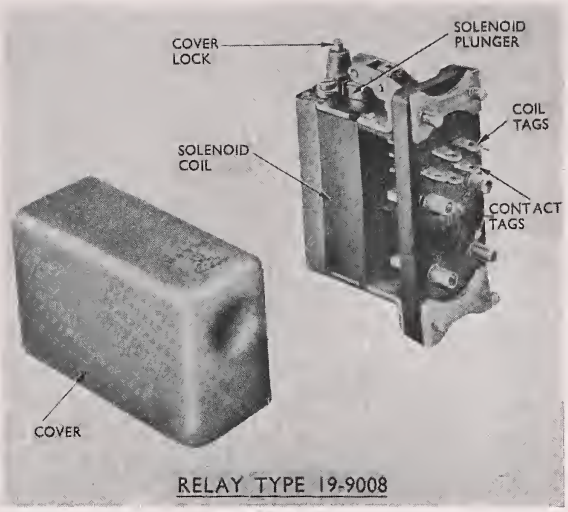
RELAY 19-9005 C1

Fig. 128



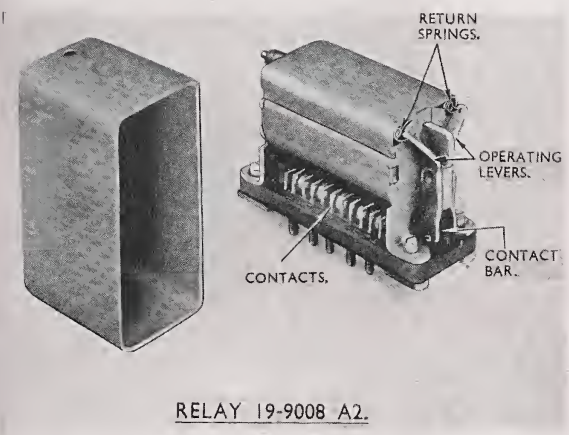
RELAY TYPE 19-9008

Fig. 129



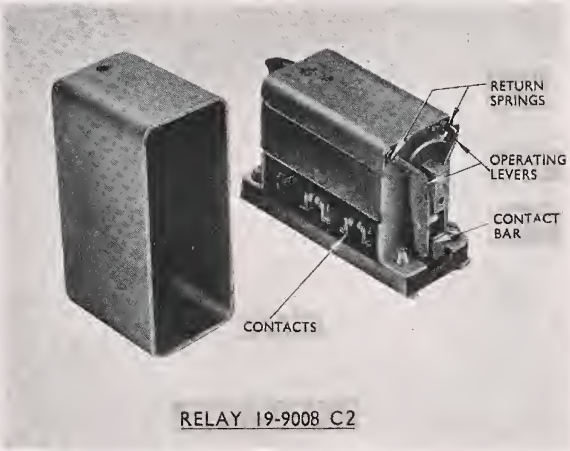
RELAY TYPE 19-9008

Fig. 132



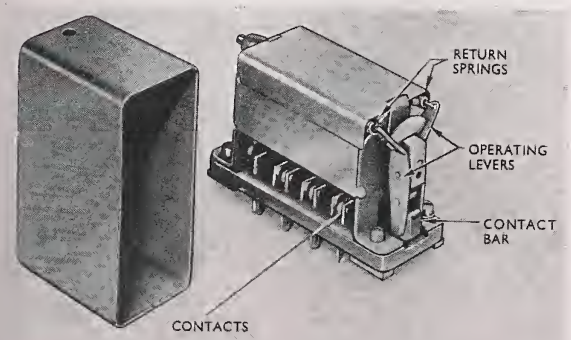
RELAY 19-9008 A2.

Fig. 130



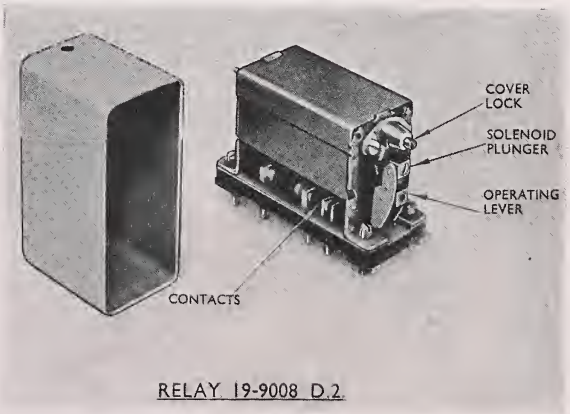
RELAY 19-9008 C2

Fig. 133



RELAY 19-9008 B1

Fig. 131



RELAY 19-9008 D.2.

Fig 134

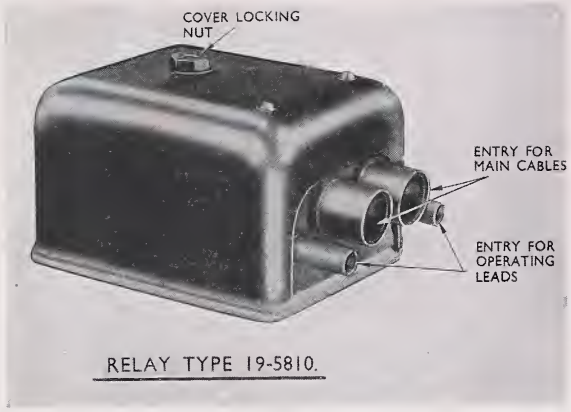


Fig. 135

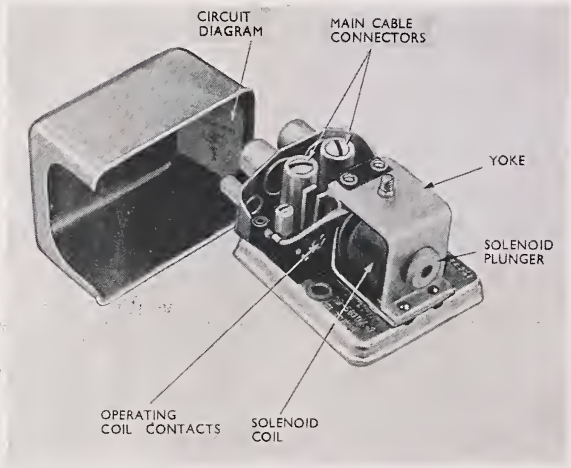


Fig. 136

(4) Relay Type 2Y11 (Figs. 138 and 139)
This is a neat compact and robust type of telegraph receiving relay. It is polarised and the contacts are normally centre stable, i.e. with no current in the windings, the relay tongue lies midway between the contacts without touching either. It is made by Siemens and Halske and appears to have six windings, as is not unusual with telegraph type receiving relays. It is used in the rocket to control the operation of the trim motors from the dissymmetry of the position of the potentiometers associated with the roll and yaw rudders. It is mounted on a diecast aluminium chassis and is provided with a drawn aluminium cover. The contacts on the actual model used are mounted on a bar of ceramic-like material. It is understood that this gave a certain amount of trouble at extremely low or high temperatures, due to expansion and contraction, and that later versions had the contacts assembled on a ceramic plate.
(5) Switches Type FLE 5001 and FLE 5002 (Figs. 140 to 143)
These switches are very similar in construction, the type FLE 5001-02 being rated at 50 amperes and the type FLE 5002-09 being rated at 100 amperes. They are

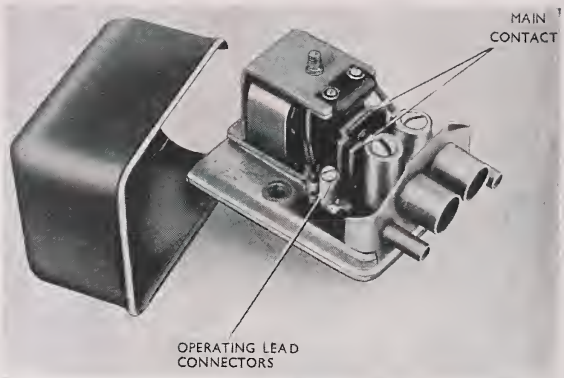


Fig. 137

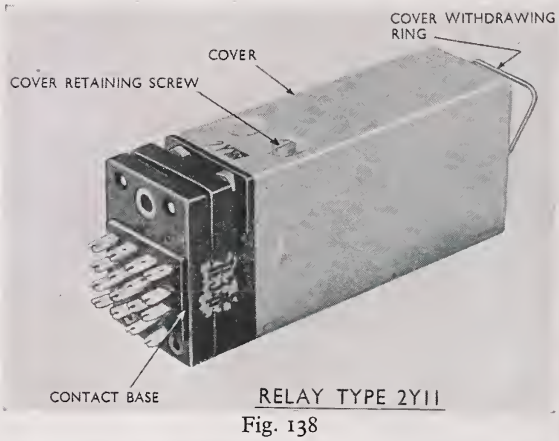


Fig. 138

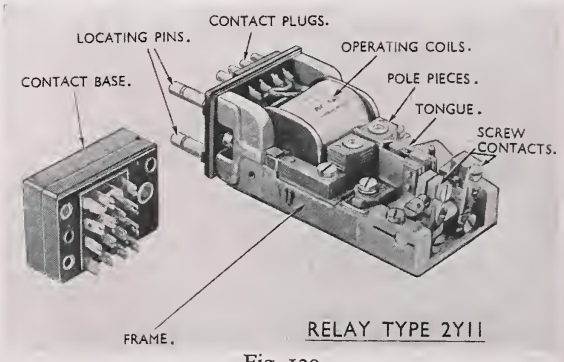


Fig. 139

extremely compact and made up mainly of pressings. The contact arrangement in each case is a single make which is operated by pressing in a large knob on the front of the switch. The contact is released by depressing a smaller knob, also on the front of the switch. On model FLE 5002 one current lead is taken through a loop of mild steel extending right across the switch base. The function of this loop has not been satisfactorily ascertained, but it has been reported that it has some form of magnetic spark quench.

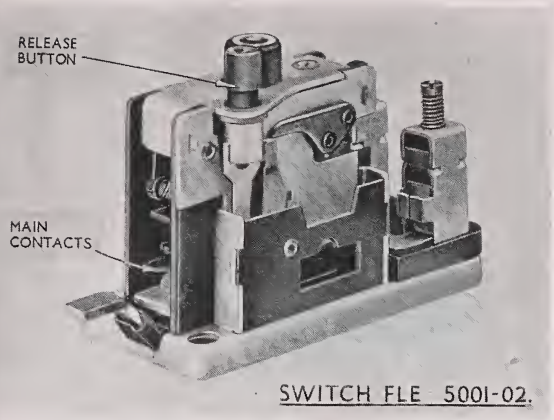


Fig. 140

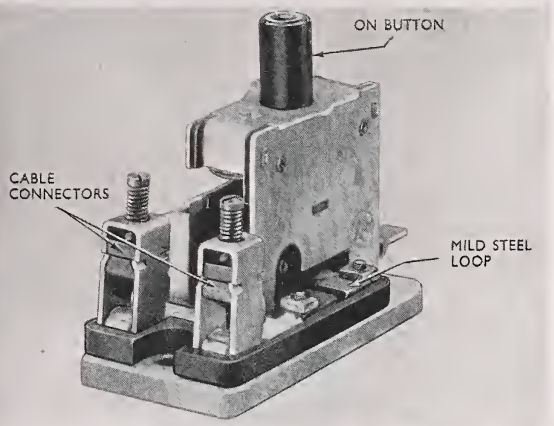


Fig. 141

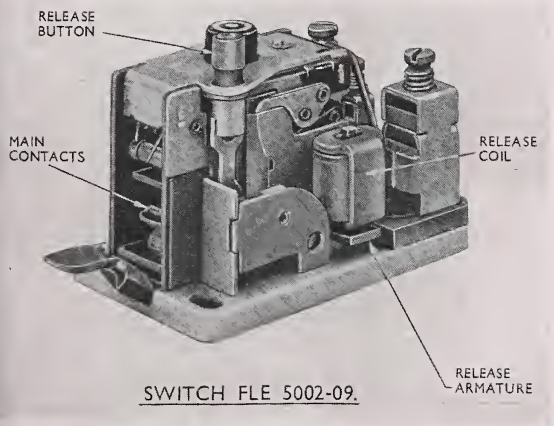


Fig. 142

Switch type FLE 5002-09 is fitted with a small coil which can be used to operate the release mechanism by a soft iron armature. This coil is connected in circuit when the main contacts are made. This switch may, therefore, be released either by using the small knob on the front in the usual way or by energising the release coil from a distance.

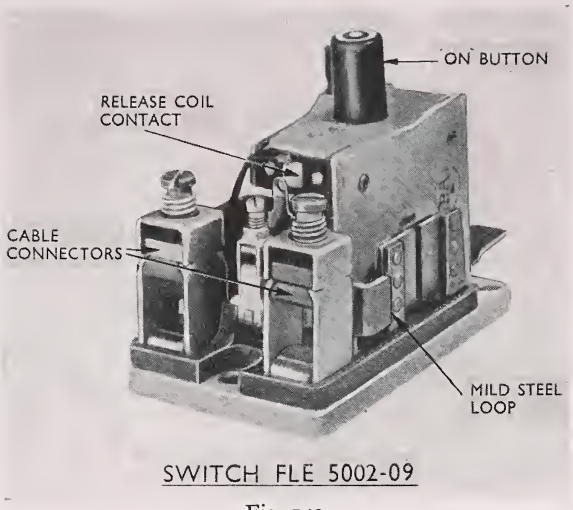


Fig. 143

This switch is also fitted with a mild steel loop extending right across the switch. The function of this loop has not been satisfactorily ascertained.

(6) Servo Relay (Figs. 144 and 145)
A further type of relay is used in the servo motor mechanism for operating the valves controlling the movement of the piston in the servo. It consists of two outer windings mounted on magnetic limbs and two centre windings wound on the same bobbin. Inside the centre windings is a small soft iron armature pivoted at the top which can be moved through a small angle. In operation the outer coils are energised and produce opposing magnetic fluxes in the armature which cancel and leave the armature unmagnetised. The two coils wound on the inner bobbin are supplied with current from the control amplifier and may be made to induce a magnetic flux in the armature in either direction as required. This will cause the armature to

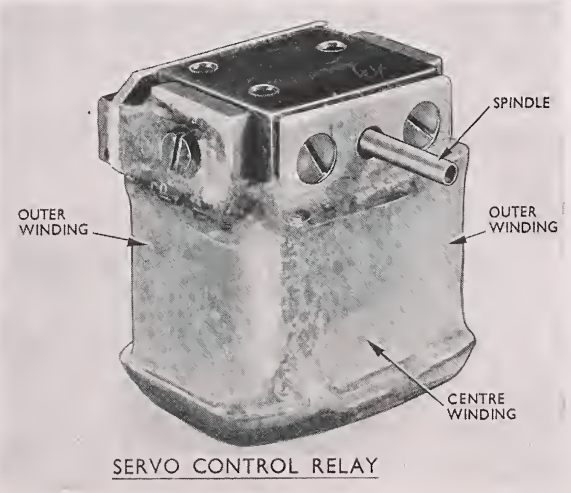
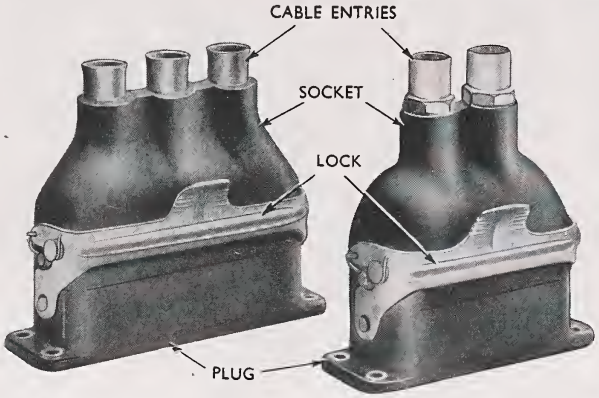


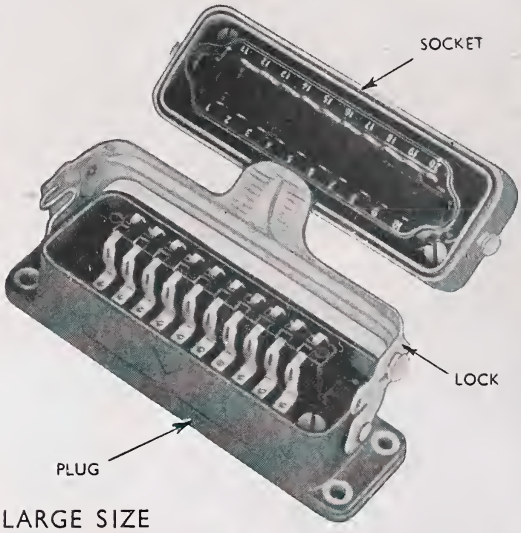
Fig. 144

TYPICAL LIST PLUGS & SOCKETS.

Plate 67.



LARGE SIZE



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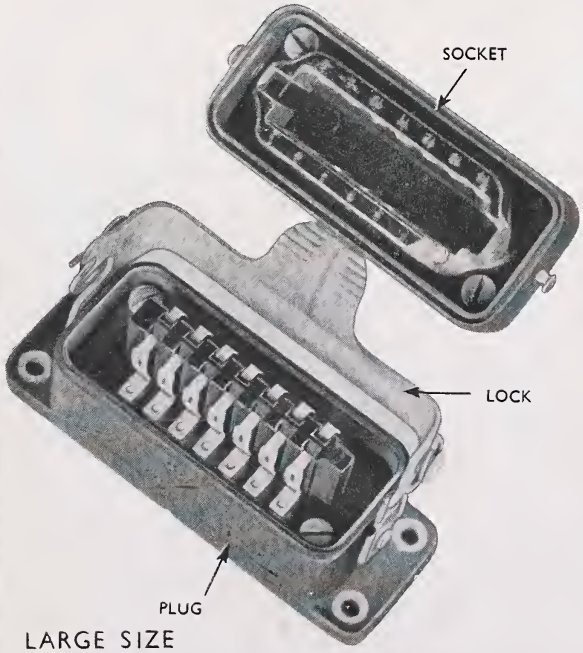
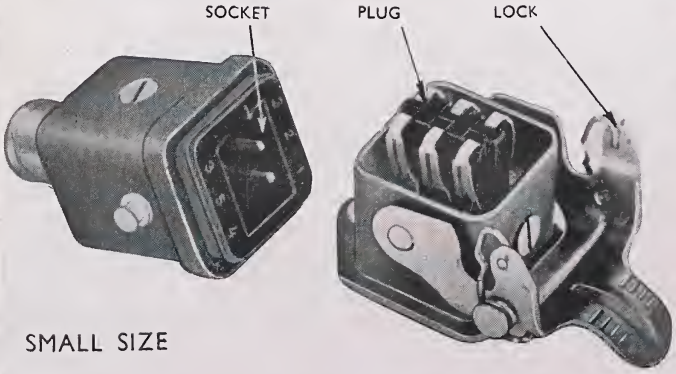


LARGE SIZE

SMALL SIZE



SMALL SIZE

move towards one or other of the outer coils. This relay carries no contacts, but a lever is attached to a small spindle connected with the armature. This lever is connected to the oil valves in the servo motor and opens or closes them as the case may be, determined by the direction in which the relay armature moves.

208. Plate 67 shows typical plugs and sockets used.

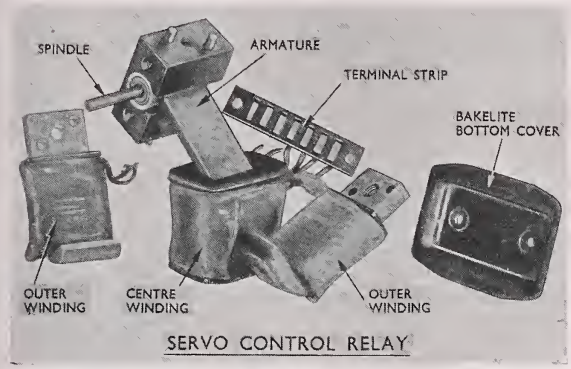


Fig. 145

TEST DESKS

GENERAL

209. It had been the practice of the Germans to build a desk type of testing instrument in which was mounted all the apparatus, e.g. meters, switches, relays, etc., used for testing completed rockets. The tests were carried out at three stages of manufacture—(*a*) when the assembly of the rocket in the main assembly hall was finished and the rocket was in a horizontal position, (*b*) when the rocket was taken to the testing tower and tested in a vertical position and (*c*) when the rocket had been transported to the launching site where it was finally tested in the vertical position on the firing table.

210. The tests at stages (*a*) and (*b*) were different because it was not possible at stage (*a*) to fit the gyroscopes. These were not fitted until the rocket was in the vertical position. A test box was used in place of the gyros when testing in the horizontal position to check that the wiring in the rocket to and from the gyros was correct. The tests at the launching site were made to ensure that the rocket had not been damaged in any way in transport.

211. Connection between the rocket and the ground test equipment was made by multiple point plugs and sockets which formed part of the main distribution frame in the control compartment of the rocket. From these plugs and sockets multiple core cables were taken to the testing desks situated some distance away. The multiple point sockets could be thrown off automatically from the rocket by operating a switch on the testing desk. A separate outside power supply was used to operate the various parts inside the rocket when testing, to avoid using the main lead-acid batteries which formed the power supply of the rocket when it is in flight. This separate power supply was normally obtained from a motor generator set.

212. The types of test applied from the test desk were such as to ensure that the steering mechanism and the fuel valves, etc., were in working order. The circuit diagram of the test desks used for tests at stage (*a*) and (*b*) were identical, while that used for stage (*c*) differed in small details.

CIRCUIT DESCRIPTION (Test Desks Type A and B)

213. The circuit diagram of this type of desk is shown on Plates 68 and 69. This diagram also shows the connection inside the rocket. The connections above the chain line are those of the test desk, the connections below the chain line are those in the rocket. The plugs and sockets on the chain line are the connection points in the multiple pin plugs and sockets which give access to the rocket circuits.

214. Referring to Plate 68, the network at the top left-hand corner is the power distribution diagram for the test desk. For purposes of circuit description the same voltage, i.e. 27v DC is applied to the three busbars +M, +P, (+)M. The negative busbar is connected to the negative source of supply. During the tests power is supplied to the rocket busbars +BO and —BO from the (+) M and negative busbars in the test desk direct, via the multiple pin plugs and sockets.

215. Switch B1 is operated and operates relay B2y in the rocket. It operates also relay B1a and Bx in the test equipment in the test desk. If switch A72 in the tail of the rocket is closed, it also operates relay A7y. Contacts of relay B2y connect power to the heaters B2 which were sometimes fitted round the lead-acid batteries in the rocket, in extremely cold weather, to keep the electrolyte at a reasonable temperature. Other contacts of relay B2y are concerned with the changing over of the power supply in the rocket from the external supply particular to the test desk, to the lead-acid and nickel-cadmium batteries installed in the rocket. The contact of relay B1a connects power to the (+) M busbar on the testing desk and thence to the rocket. Contacts of relay Bx extinguish lamp B2l and light lamp B1l to show that power is being supplied to the rocket busbars. The voltage on the rocket busbars may be read from the voltmeter VM6.

216. Operate press switch Bd1. This operates relay B1b which closes its contact to read the current consumption on the ammeter AM6.

217. The nickel-cadmium signalling battery is connected, via a contact of relay B2y operated, to the polarised relay B20p which operates if the battery is connected the right way round. The contact of relay B20p closes and lights lamp B20l. Relay A6y in the rocket operates as soon as the multiple pin plugs and sockets are connected. A contact of this relay closes and lights lamp A67l.

218. Switch B4 is closed and operates relay B4a in the rocket. Contacts of this relay connect power to the + G busbar and the Z busbar in the rocket. When power is applied to the +G busbar, lamp B4l in the test desk lights.

219. Operate switch B31. This operates relay B3b in the test desk. A contact of this relay connects power to the + U1/2 busbar and starts the alternators U1 and U2.

These alternators provide 500 cycles per second three-phase supply for operating the control amplifier and gyroscopes respectively. The voltage across one phase of each of these machines may be read on voltmeter VM5 by operating the rotary switch VMu5. A third alternator U3 can be started by operating switch B33 and relay B3c. This alternator was used to provide power to the radio equipment. As the rockets built for Operation "BACKFIRE" were not equipped with radio, the alternator U3 was not fitted. The second contact of relay B3b connects negative battery to the centre spring of the gravity switches controlling the self-erecting motors on the horizontal and vertical gyroscopes and also to the tongues of relays R11p and R12p. These relays R11p and R12p are operated from the top potentiometers on the gyroscopes also to control self-erecting motors on the gyros. This was an expedient adopted because of a lack of complete horizontal gyros.

220. When alternator U2 starts to work, three-phase 500 cycles is supplied to the stator windings of the gyro motors, which start. The load on the alternator as the gyro is running up to speed is heavy and the phase voltage of the alternator is, therefore, reduced. When the gyro has reached its maximum speed the load on the alternator is reduced and the phase voltage rises. Use is made of this to determine when the gyro has reached its working speed, i.e. when the voltmeter VM5 reads 42 volts. Should the program motor in the horizontal gyro be off normal, battery is supplied by a contact 8 on the sequence switch through the O-second cam on the program motor to lamp M51 which lights.

221. When the rocket is tested in the horizontal position, the gyroscopes are not fitted. Instead, a test box as shown in the top right-hand corner of Plate 68 is used. A three-phase supply at 500 cycles is applied to terminals 3, 4 and 5 of this test box and to the condenser and resistance network connected thereto. The condenser introduces a 90 degrees phase shift to one phase and the increased current produced in the second phase causes lamp RHl to light. Should the connections between the alternator and the test box be incorrect, the increased current would appear on the wrong phase and the lamp RHl could not light as brightly.

222. Alternator U1 supplies power to the control amplifier whose purpose it is to take signals from the gyroscopes and to translate them into signals to the servo mechanisms which operate the rudders on the tail unit of the rocket and so control the steering. As the gyroscopes are not fitted to the rocket when it is at the horizontal stage, artificial signals can be supplied by the test box used to check the wiring to the gyroscopes as previously described. Three of these artificial testing circuits are provided for checking the operation of the pitch, yaw and roll controls. Each circuit consists of a Wheatstone bridge of four resistances in which two arms are fixed, and the other two consist of a potentiometer. These bridges are supplied from the 50-volt signalling battery and a voltmeter VM10 may be connected through voltmeter switch VMu10 across the bridge points to read the out of balance potential, which may be varied in magnitude and direction by altering the position of the sliders on the potentiometers. These three bridge networks may be used to provide manually the same type of signal as is normally provided from the potentiometers on the horizontal and vertical gyros.

223. Switch R21 is closed in the test desk and operates relay R2x in the rocket. Contacts of relay R2x in each of the centre leads of the three-wire control circuits from the control amplifier to the servo motors open, and when the contacts of switch R20 are closed, four centre-zero milliammeters AM1, AM2, AM3 and AM4 are inserted to read any out-of-balance current in the servo control circuit. This out-of-balance current may be reduced to a small figure by adjusting the 100 ohms potentiometer fitted in the terminal box associated with each servo motor.

224. Press switch R21d may be operated to connect resistances W15 and W17 across one of the operating windings of the valve-controlling relays R1 and R3 in the servo mechanism associated with the yaw rudders. Some of the relay current is shunted through these resistances, so that the relay becomes unbalanced and causes the servo mechanism to move the rudders. The current unbalance may be observed on milliammeters AM1 and AM3. The operation of press switch will unbalance the servo-controlling relay in the other direction. Similarly, switches R22d and R24d may be closed to apply a similar test to the pitch rudders.

225. The operation of the controlling amplifier may be checked by adjusting the slider of the potentiometers in the test box which simulates the gyros until the voltage registered on the centre-zero voltmeter VM10 is 6 volts. This voltage is applied to the control amplifier and it may be observed that the reading on the appropriate milliammeter AM1 to AM4 rises to about 12 mA in one direction or other depending on the sense of the out-of-balance voltage measured on voltmeter VM10.

226. Fitted in the tail unit and associated with each rudder is a pair of potentiometers. One of each pair is used to determine when the appropriate rudder lies at the mid-point of its travel On the diagram these are the 400 ohm potentiometers designated M. They are supplied from a 6v battery located in the test desk and each forms the arms of a Wheatstone bridge. The other arms are resistances W1 and W2, W3 and W4, W5 and W6, W7 and W8, which are all of equal resistance. Connected across the bridge points of each of these bridges is a centre-zero voltmeter VM1, VM2, VM3 and VM4. When a particular rudder is central the slider of its associated potentiometer will also be central and the particular Wheatstone bridge will be balanced so that there will be no reading on the voltmeter. Should the rudder be off normal the bridge will be unbalanced and the direction of the unbalance will be indicated on the appropriate voltmeter. When an artificial signal is applied to the controlling amplifier from the test box simulating the gyros, the direction of movement of the appropriate rudder can be seen from the voltmeter connected to the relevant bridge.

227. Switch B4 operated relay B4a in the test desk, and a contact of this relay connected power to the + G busbar. This causes the motors in the servo mechanisms to start. The artificial signals applied to the control amplifier from the potentiometers in the test box simulating the gyro can, therefore, be made to operate the actual rudders in one direction or the other. The correctness of the rudder movements can be checked by observing the movement of the needles on the voltmeters VM1 to VM4.

228. Should the rudders move to the full extent of their travel a contact in the potentiometer box associated with the particular rudder is closed. This connects a 100 ohm resistance across the operating coil of the relay in the appropriate servo mechanism and the current of this coil is, therefore, reduced. The rudder then starts to return to normal until such time as its end contact is opened, when the 100 ohm resistance is removed and the rudder drives back to the end of its travel, again closing the end contact. This sequence of operations continues indefinitely, resulting in a small vibration of the rudder. The second of each pair of potentiometers on the pitch rudders, i.e. the potentiometers designated S on the diagram, are supplied with 500 cycle single phase current via a 70-ohm resistance from alternator U1. This arrangement is used to provide a signal to the control amplifier to indicate when the pitch rudders are moving out of synchronism.

229. The second of the pair of potentiometers attached to the yaw and roll rudders, i.e. those designated Tr on the diagram, are supplied with direct current from the main lead-acid battery in the rocket and again are used to indicate when the yaw and roll rudders are out of synchronism. This indicates that the rocket has a tendency to roll, and the difference of potential between the sliders of these potentiometers, which is proportional to the angular difference in the positions of the vanes, is used to operate the polarised relay R3p. The contact of relay R3p is used to control the trim motors which operate the external trimming vanes of the main fins on the pitch axis of the rocket. The actual operation of these motors is given in detail in the section dealing with trim motors. Contacts of relay B3a are connected in the trim motor circuit to guard against possible damage to the trim motor mechanism should the speed of the trim motors be different. When the rocket is flying relay B3a is operated, and the contacts of this relay in the trim motor circuit are open. Should trim motor No. 2, for example, reach the end of its travel, its contact Ev will open. Should trim motor No. 1 be slower, current will flow from contact R3p, contact Ev and Nv on trim motor No. 1 to contact Nv and relay 3x on trim motor No. 2, thus making this trim motor drive still more. Contact of relay B3a is fitted to prevent this. The break contact of relay A9z also connected in the trim motor circuits is stated to prevent the trim motors from interfering with each other when they are returning to normal after flame cut out.

230. The operation of the trim motors may be tested manually by operating switch B40 in the test desk and moving the carbon yaw rudders in opposite directions by hand. The servo motors associated with these vanes should, of course, be switched off. Switch A72 in the tail of the rocket should be opened, thus releasing relay A7y. Current is supplied to the trim motor circuit via switch B40 and the back of the change-over contact of relay A9z. Relay R3p should operate when the pitch and yaw rudders are a few degrees out of synchronism and cause the outer vanes on the fins on the pitch axis to move in opposite directions. At flame cut off relay A9z operates, and battery is applied to the trim motor from the battery busbar in the rocket via the break contact of relay A6y released, the front of the change-over contact of relay A9z and the contacts of relay R3a released, causing the trim motors to return to normal under the control of the off-normal cam contacts in the trim motor assembly. Should the adjustment of relay R3p be faulty, i.e. should the tongue be touching either control when there is no current in the coil, the trim motors will drive when the yaw and roll rudders are synchronised.

231. Lamp Pl in the the desk indicates when the switch E is not operated. This is important, because a contact of relay E controls the release of the multi-pin plugs and sockets connecting the rocket to the ground test equipment. Switch A2 is operated and energises the valve D1h in the rocket in series with relay D1i in the test equipment. A contact of relay D1i lights the lamps D1l, thus testing that the valve D1h is carrying current but not necessarily that it is operated. Valve D1h controls the closing of the vent valves in the steam unit.

232. A separate test box containing valves O1h and N1h and contacts N1or is used in conjunction with a compressed air supply to test the operation of the fuel valves, and to check that the condition of the oxygen tank is satisfactory. Switch A2 on the test desk is closed and applies current to valve O1h in the test box. This causes the main oxygen and alcohol valves to close. Compressed air is then applied to the oxygen tank until a pressure of 1·5 atmospheres is reached. Below this pressure contact N1or is closed.

233. Switch N1 is closed and operates relay N1x via contacts N1or of a safety valve on the test box set to blow off at 1·5 atmospheres. A contact of relay N1x energises valve N1h in the test box and allows compressed air to flow into the oxygen tank. A second contact of N1x closes when the relay operates and the lights lamp N1l. When the pressure in the oxygen tank reaches 1·5 atmospheres contact N1or opens, releases relay N1x, closes valve N1h, thus stopping the supply of compressed air to the oxygen tank, and lamp N1l goes out.

234. Switch A3 in the test desk is closed and energises valve S1h. This causes the main alcohol valve in the tank to open, and opens the main alcohol delivery pipe as far as the main alcohol valve. When valve S1h is operated, a contact S1r on the valve closes and lights lamp S1l on the test desk.

235. Switch A4 in the test desk is operated and energises valve O3h. This opens the main oxygen valve in the rocket, and when this has been done contact O3r which is attached to the main oxygen valve closes and energises valve S2H which operates the main alcohol valve in the rocket.

236. When valve O1h in the test box was energised the main oxygen valve should have closed and opened its contact O3r. If this oxygen valve had not closed satisfactorily, contact O3r would have remained closed and lamp M2l would have lit, from battery via contact O3r and valve S2h. When switch A4 is operated, this lamp is short circuited and cannot light. Switch A4 also operates relay A4z, which has an operating lag of about one second. After one second, therefore, contact A4z closes and tries to operate relay Ax.

237. When the main alcohol valve opens its contact S2r closes and operates relay S2x. When this contact S2r is

not fitted, its function is performed by contact O3r of the main oxygen valve, by strapping terminals 9, 7 to 29, 15 as shown dotted on the diagram.

238. When the tests on the main fuel valves are completed, switch A4 is released and the valves are de-energised.

239. Press switch A6d is operated and energises valve Dh, which pressurises the hydrogen peroxide and sodium permanganate tanks in the steam unit. When the pressure in the permanganate tank reaches 1·5 atmospheres, contact D2r on the diaphragm switch closes and energises valve D8h, which opens a bye-pass on the main hydrogen peroxide valve. At the same time valve D25h is energised dependent on relay A9y being released, and this opens the main hydrogen peroxide valve. Lamp A6l in the test desk lights.

240. Resistance D2w is a heater round the pressure reducing valve in the air line from the compressed air bottles to the hydrogen peroxide tank. It is used in very cold weather.

241. Contact N4r is a contact on the pressure gauge on the low pressure side of the reducing valve. It opens when the reducing valve is passing a pressure of 30 to 40 atmospheres. When it opens, relay N4x in the test desk releases, and its contact lights lamp M3l.

242. Switch A8od is operated for at least 10 seconds and connects battery to terminal 5 of the sequence switch. This causes the sequence switch to drive until it reaches its zero position as determined by the cam contact 9. At this position battery is applied to lamp M6l which lights.

243. When switches A2, A3 or A5 were operated, additional contacts started to operate relay Th1 in relay unit A2t. This is a thermal type of relay with an operating lag of about one minute. Should relay Th1 operate, its contact operates a similar relay Th2, whose contact then operates an electro-magnetic relay A2t. A contact of relay A2t operates a thermal relay Th1 in relay unit A4t. A contact of relay Th1 operates relay Th2 and a contact of relay Th2 operates the electro-magnetic relay A4t. The contact of relay A4t closes and energises the alarm Klaxon in the test desk. An additional contact of switch A4 can effect a similar sequence starting with relay Th1 in relay unit A4t. This circuit ensures that if the steam unit valves and valve S1h are energised for more than four minutes, or the main fuel air supply valves energised for more than two minutes, an alarm is sounded. This avoids the danger of the solenoids in the valves being burnt out.

244. When a rocket is being launched, the steam unit is brought into operation when the ground connecting plugs are disengaged. To test this, switch E is operated and then switch A5. Relay A5x in the test desk and relay A6x in the rocket both operate, and relay A6x locks over one of its own contacts and a contact of relay A9x. Relay A6y in the rocket is operated, and one of its contacts holds open the operating circuit of the hydrogen peroxide and sodium permanganate pressurising valve Dh. The contact of relay A5x opens the circuit of the magnet A5l, which normally holds the ground plug No. 1 locked into the socket on the main distribution panel and this plug is thrown off. Contacts 5 and 6 on plug No. 1 are, therefore, broken, and relay A51x in the test desk releases. Contacts of this relay extinguish lamp A51l and open a circuit of the magnet A52, holding the ground connecting plug No. 2 in position. This plug is then thrown off and its contacts 5 and 6 open a circuit of lamp A52l and the lamp goes out.

245. Contact 48 on plug No. 1 and contact 14 on plug No. 2 are connected in parallel, and when both these contacts are freed relay A6y in the rocket releases. One of its contacts in falling back completes the circuit for the pressuring valve Dh, and in turn valves D8h and D25h are energised.

246. When press switch A91d is operated, it operates relay A9y in the rocket and relays A90x and A9s in the test desk. Relay A9s has an operating lag of about three seconds and switch A91d must, therefore, be closed for longer than this. When relay A9s operates about three seconds later its contact operates relay A9z in the rocket. Contacts of this relay release relay A6x, close the hydrogen peroxide bye-pass valve, D8h, cut off the supply of compressed air to the hydrogen peroxide and sodium permanganate tanks in the steam unit by releasing valve Dh, fuze the warhead, release relays B3a and B4a, thus stopping the servo motors and the 500 cycle alternators and hence the gyros, and return the trim motors to normal. Contacts of relay A6x release the main alcohol and oxygen air valves S2h and O3h, and the supply of fuel to the pumps is cut off. Relay A9z remains operated during the rest of the flight of the rocket.

247. An emergency flame cut-out control is fitted should it be desired to shut off the fuels after the ground connected plugs have been thrown off. This emergency control is obtained over a special pair of wires which are connected to a plug and socket on the tail of the rocket. To test this, press switch A91d is operated momentarily, so that the slow-operating relay A9s does not operate. Relay A90s in the test desk operates and its contacts connect current over the special emergency wires to relay A90z, which operates. The contact of this relay operates relay A9z, which closes down the steam unit and the fuel valves as described above.

248. The flame may also be cut out should the turbine in the steam unit run too quickly. After 40 seconds the time switch connects battery to relay A9z should contacts D9r be closed. These are contacts on a centrifugal switch on the turbine shaft and close when the turbine speed exceeds 4,000 r.p.m. When this happens relay A9z operates and closes down the steam unit and the main fuel valves.

249. After the rocket has been flying for 40 seconds valve S3h is energised over a contact of the time switch and closes the vent from the alcohol tank to the atmosphere. At flame cut-off when relay B4a releases, one of its contacts operates valve S4h which admits compressed air to the alcohol tank to prevent it collapsing when the rocket re-enters the atmosphere on the downward part of its trajectory.

250. When the tests on the rocket in the horizontal position are completed, the rocket is transported to a special testing

tower where it is erected vertically. The gyros are fitted, and a series of tests similar to those made in the horizontal position are applied using the same test desk. This enables the operation of the gyroscopes to be checked in addition to the tests on the steering and the fuel control system. The axes of the gyroscopes may also be lined up at this stage with the axes of the rocket.

TEST DESK TYPE C

251. The circuit diagram of this type of desk is shown on Plates 70 and 71, which also show the connections inside the rocket. The connections above the chain line are those of the test desk, the connections below the chain line are those on the rocket. The plugs and sockets on the chain line are the connection points in the multiple pin plugs and sockets which give access to the rocket circuits. This desk has three functions : (*a*) testing of the steering, (*b*) testing of the valves before fuelling, and (*c*) the actual launching of the rocket.

252. Referring to Plates 70 and 71, 27v DC is applied from the motor generator set to the + M busbar. Switch A72 in the tail of the rocket is closed and relay A6y in the rocket operates. The + B busbar on the test desk is supplied from a special 27v. battery which is used to hold the ground plugs locked to the rocket. Ground plug No. 1 is inserted and relay A51z operates. A contact of this relay lights lamp A51l. Ground plug No. 2 is then inserted, relay A52z is operated, and lamp A52l lights.

253. The main switch P in the desk is closed and relay Px operates. A contact of this relay connects 27v DC to the + B busbar. Relays B1x1 and B2x2 operate. A contact of relay B1x1 closes and connects 27v DC to the + B1x busbar and operates B1a. A contact of relay B1a closes and connects 27v DC to the (+) M busbar. Switch Si1 closes and connects 27v DC to the + Bo busbar in the rocket. Relay B2y in the rocket operates from the + B busbar in the test desk. A contact of relay B1x2 lights the lamp B1l. Switch Si2 is closed and switch B31 when closed operates relay B3b. The contact of this relay connects 27v DC to the + U1/2 busbar in the rocket and the 500 cycle alternators U1 and U2 start. Across one phase of each alternator is a bridge-connected metal rectifier G1 or G2, across the DC terminals of which is connected a relay B31v or B32v. Contacts of these two relays open and prevent lamp A1 from lighting. Should either of these alternators fail, the alarm will be given by the lighting of lamp M8l. The voltage across this particular phase on each alternator can be read on the voltmeter VM7 by setting the rotary switch VMU to the appropriate position.

254. Switch D4 in the test desk is closed and operates relay B4a in the rocket. A contact of this relay connects 27v DC to the + G busbar to drive the servo motors and to operate relay B4v in the test desk. A contact of relay B4v lights lamp B4l. The voltage between the + Bo and — Bo busbars in the rocket can be read on the voltmeter VM6.

255. The voltage of the 27v DC machine is controlled by a voltage regulator connected to plug sockets L6/3 and L6/6. The machine itself is connected to plug sockets L6/2 and L6/5. When relay B1x1 in the test desk was operated, one of its contacts operated relay Bx whose contacts switch the voltage regulator from the machine to the positive and negative busbars in the rocket. Thus in the final tests the actual busbar voltage in the rocket is controlled. An additional voltmeter may be connected in parallel with the voltmeter VM6 on the test desk at plug points L6/4 and L6/1. This voltmeter is normally fitted on a power distribution panel near the machine but not necessarily near the test desk.

256. The small busbar + Pr is connected to the machine dependent on a break contact of relay Ex1. Relay B20x operated as soon as the main switch P on the desk was closed and one of its contacts disconnected the 50 v signal battery in the test desk from the signal battery busbars in the rocket. When switch B20 is opened relay B20x releases and since relay B2y in the rocket is operated, the 50v signal battery in the test desk is connected to the signal battery busbars in the rocket. If the polarity of the signal battery is correct, relay B20p1 operates. Its contact operates relay A67x since polarised relay A67p in the test desk operated if the polarity of the power supply to the main rocket busbars was correct when relays A6y and A7y operated. Contact of relay A67x removes a circuit path for lighting lamp MA1. If the polarity of the signal battery were incorrect, polarised relay B20p2 would operate and its contact would light lamp B20l.

257. The horizontal and vertical gyroscopes started when the alternator U2 was connected in circuit. When relay B32v connected across one phase of the alternator operated, its contact completed the circuits of the self-erecting motors in the gyroscopes under the control of the centre-stable polarised relays R10p and R11p and the gyroscopes are, therefore, brought into their correct initial positions.

258. The tests on the steering mechanism which are made at the launching site are very similar to those made in the horizontal or vertical positions using the test desks type A or B. The operation of the servo motors may be tested by closing switch B4 and thereby operating relay B4a in the rocket, a contact of which relay connects power to the + G busbar in the rocket and starts the servo motors running. Switch R21 in the test desk is closed to operate relay R2x in the rocket to enable, in conjunction with the switch R20, the out-of-balance current in the three-wire servo control circuit to be measured on milliammeters AM1 to AM4.

259. Press switches R21d to R24d may be closed to operate relays R21x, R22x, R23x or R24x, whose contacts connect resistances, e.g., R22W1 or R24W1 across the servo control circuit. These resistances upset the balance of the currents in the three-wire circuits and by operating the servo mechanism cause the rudders on the rocket to move. This movement can be observed by watching the needle of the centre servo voltmeters VM1 to VM4 which are connected in Wheatstone bridge circuits using the positioning potentiometers attached to the carbon rudders. In addition the trim motors may be tested by releasing switch A72 on the tail of the rocket and de-synchronising the yaw and roll rudders by hand with the servo motors switched off. Switch A72 is held operated by an adjustable plate on the launching platform and this plate has to be lowered when the switch has to be released.

260. A rough and ready test to see that the gyroscopes are working is applied by moving the nose of the rocket a few inches so as to bring the major axis of the rocket out of vertical. This causes the gyroscopes to send a signal to the control amplifier and the effect of this may be seen on the milliammeters AM1 to AM4 on the test desk.

261. Should the program motor in the horizontal gyro be off normal, relay R1z in the test desk is operated and its contacts light the lamps M6l and M61l.

262. When the tests on the steering are completed satisfactorily, the carbon rudders are brought back to their central position and held there by metal clips which form part of the launching table. The trim motors return the trimming vanes to normal when the fuel cut off is checked later in the test.

263. When switch P was closed, relay Px operated and locked over its own contact. Also lamp Pl lights dependent on a contact of relay Ex1.
The four-position rotary switch is first set to position P1u and press switch Pd is closed and relays Pp and P12x operate. Relay Pp locks over its own contact independent of press switch Pd. One contact of relay P12x opens the operating circuit of the "firing" relays Ex1 and Ex2. A second contact operates relay A1x and lights lamp A1l. A contact of relay A1x connects power to the +A1x busbar in the test desk. When press switch A2d is closed, relay A2x1 and A2x2 operate and lock over an A2x2 contact. When ground connecting plugs are connected to the rocket, contacts 5 and 6 on plug No. 1 operate relay A51z. A contact of this relay opens and releases valve Nh in a special test box which is used to pressure test the oxygen tank with compressed air. Valve Nh, therefore, opens and admits compressed air to the test box. A contact of relay A2x1 energises valve O1h in the test box, which admits compressed air to the main oxygen and alcohol valves, and closes them. A second contact of relay A2x1 energises valve D1h which closes the vent valves in the steam unit.

264. A third contact of relay A2x1 operates relay N1x in the test desk via the valve contacts N1or which open when the air pressure in the oxygen tank reaches 1·5 atmospheres. One contact of relay N1x energises valve N1h which allows compressed air to pass to the main oxygen tank and also lights lamp N1l, while a second contact prepares a circuit for relay N2x which operates when contacts N11r close. These contacts are valve-controlled and close when the air pressure in the oxygen tank reaches 1·2 atmospheres. Relay N2x then operates and locks over one of its own contacts independent of relay N1x. When the pressure in the oxygen tank reaches 1·5 atmospheres, contacts N1or open and relay N1x releases. A contact of this relay falls back and with relay N2x operated causes relay N3x to operate and lock independent of relay N1x or N2x over one of its own contacts. A second contact of relay N1x extinguishes the lamp N1l and releases valve N1h, thus cutting off the compressed air to the oxygen tank.

265. A further contact of relay A2x1 tests the circuit of the flame igniter. If the wiring to this circuit is correct relay Zx operates from the special 6vZu battery via switch Z1. Contacts of relay Zx close and light lamp Zl and operate relay A3x provided relays N2x and N3x are already operated. Lamp A2l also lights. A contact of relay A3x closes and operates relay A3y over contact P12x and starts to operate relay Zs which has an operating lag of about 10 seconds. A contact of relay A3y tests the wiring to the second part of the flame igniter circuit by lighting lamp Z1l from the 6vZu battery. A second contact of relay A3y closes to provide an alternative holding circuit for relay A3x independent of relay Zx. When the wiring to the flame igniter circuit has been tested relay Zx is released by opening switch Z1. A further contact of relay A3y operates valve S1h opening the main alcohol delivery from the tank to the alcohol pump. When valve S1h has opened, its contact S1r closes and operates relay S1x in the test desk. A contact of relay S1x lights lamp S1l.

266. With relays A3y and S1x operated and with relays Zx and Zs released relay A4x in the test desk is operated and lamp A3l is lit. Relay A4x locks over one of its own contacts independent of relays Zx or Zs. The operation of relay A4x is dependent on the fact that relay Zs has not operated. Thus a time limit of ten seconds is set on the operation of the alcohol valve S1h. Should this valve fail to operate in the prescribed time relay Zs operates and since relay A4x has not yet operated relay Mx releases, and its contact operates the alarm klaxon. A contact of relay A4x energises valve 03h in the rocket and opens the main delivery from the oxygen tank to the combustion chamber. When this valve has opened satisfactorily its contact O3r closes. Should this contact have been closed before relay A4x operated due to a fault in the valve, relay O3x in the test desk would be operated and its contact would have opened the circuit of relay Mx. The contact of this relay in falling back would have operated the alarm klaxon M.

267. When the contact O3r in the oxygen valve closes, valve S2h is energised to open the main alcohol valve, whose contact S2r then closes to operate relay S2x in the test desk. When contact S2r is not fitted, this function may be performed by contact O3r of the oxygen valve by strapping terminals 9/7 to 29/15. A contact of relay S2x lights lamp A4ol. A contact of this relay lights lamp A4ol.

268. The four-position rotary switch is moved from position Pu1 to position Pu2. Relay P12x releases and its contact releases relay A1x which in turn releases relays A2x1 and A2x2. This releases all relays associated with the tests on the fuel valves. With the four-position rotary switch at position Pu2 relay P13x operates when the press switch Pd is closed. A contact of relay P13x closes and energises valve Dh in the steam unit which pressurises the hydrogen peroxide and sodium permanganate tanks. When the pressure in the permanganate tank reaches 1·5 ats., contact D2r on the diaphragm switch closes and energises valve D8h which opens a bye-pass on the main hydrogen peroxide valve. At the same time valve D25h is energised dependent on relay A9y being released and this opens the main hydrogen peroxide valve. Lamp A6l in the test desk lights. A special circuit is used to check that the diaphragm contact D2r is open when valve Dh is not energised. Relay D2p in the test desk is normally operated, but should the diaphragm contact D2r in the steam unit be closed when valve Dh is not energised, i.e., before relay

P13x was operated, relay D2p is short-circuited and releases. The contact of relay D2p completes the circuit of relay D2x, which operates, and its contact releases relay Mx. A contact of relay Mx falls back and operates the alarm klaxon M. The 300-ohm resistance D2w associated with relay D2p is used to prevent the valve Dh in the steam unit being energised from the +M busbar in the test desk prior to the operation of relay P13x.

269. The four-position rotary switch is changed from position Pu2 to position Pu3 and relay P13x releases. In position Pu3 relay A3x is operated when press switch Pd is closed. A contact of relay A3x releases relays B1x1 and B1x2. A second contact of relay A3x then operates relay B2x in the test desk, one of whose contacts releases relay B2x in the rocket. When switch B2 in the rocket is closed relay B2a is operated from the lead-acid battery in the rocket and a contact of this relay connects the lead-acid batteries to the main rocket distribution busbars. A contact of relay B2y in falling back connects the nickel-cadmium signalling battery in the rocket to the signalling busbars. Relays B3a and B4a in the rocket operate and contacts of these relays connect the alternators and servo motors to the lead-acid battery. The voltage of the lead-acid battery may be observed on the voltmeter VM6 in the test desk. If the polarity of the lead-acid battery is correct, the polarised relay A67p in the test desk operates. If the polarity of the signalling battery in the rocket is correct, polarised relay B20p1 in the test desk operates. With the relays A67p and B20p1 operated, relay A67x operates and its contact opens the circuit of lamp M8l. During these tests power is removed from the +M busbar in the test desk by the release of relays B1x1 and B1x2 consequent upon the opening of a contact of relay A3x. A contact of relay B1x1 releases relay B1a in the test desk and a contact of this relay disconnects the power supply from the (+)M busbar.

270. The four-position rotary switch is moved from position Pu3 to position Pu4 and relay P14x operates when the press switch Pd is closed. A contact of this relay energises the alcohol delivery valve from the tank to the pump, i.e., valve S1h. When this valve has operated, its contact S1r closes and operates relay S1x in the test desk, a contact of which relay lights lamp S1l. This is a special test put on this particular valve after all the other fuel valves have been checked, because this valve has apparently given a good deal of trouble through faulty operation.

271. Switch A8od is operated for at least ten seconds and connects power to terminal 5 of the sequence switch. This causes the sequence switch to drive until it reaches its zero position as determined by the cam contact 9. At this position power is connected to relay A8y in the test desk which operates. Its contact opens the circuit of lamps M7l and M71l, which are extinguished.

272. The flame cut-out control may be tested by operating press switch A9d which operates relay A9x in the test desk. Contacts of this relay operate relays A9y and A9z in the rocket which lock over their own contacts. A contact of relay A9z releases relays B3a and B4a, which disconnect the power from the alternators and servo motors. The emergency flame cut-out control cannot be tested at this stage. Should either of the relays A9y or A9z be permanently operated in the rocket due to a fault, power is supplied from the rocket busbar over contacts of these relays to relay A90x in the test desk. This relay operates and its contact opens the circuit of relay Mx which releases. A contact of relay Mx falls back and closes the circuit of the alarm klaxon.

273. Contact N4r is a contact on the pressure gauge on the low pressure side of the reducing valve. It opens when the reducing valve is passing a pressure of 30 to 40 atmospheres. When it opens, relay N4x in the test desk releases. One contact of this relay extinguishes lamp M3l. The second contact holds relay Mx operated, thus preventing the alarm klaxon from sounding.

274. To avoid damage to the pins of the ground connecting plugs when being inserted into the sockets, a special guard circuit is used to ensure that no power is connected to the +P and (+)M busbars until the ground plugs are in position. Should the switch P be closed before the ground plugs are inserted relay A5y in the test desk will be operated over one of its break contacts. A contact of relay A5y changes over to provide an alternative locking circuit and to prevent the operation of relay Px should the second ground plug be inserted and operate relay A52z. Thus relay Px cannot operate unless relay A5y is released. No power can, therefore, be applied to the +P busbar since this is under the control of a contact of relay Px. Also no power can be applied to the (+)M busbar since this is under the control of contact of relay B1a which is operated from the +P busbar. Should relay A5y have become operated, any attempt to insert plug No. 1 would be unsuccessful since the power supplied to the solenoid on this plug is controlled by a break contact of relay A5y from a separate battery.

275. The above completes the tests made on the rocket at the launching site prior to fuelling. After fuelling has been completed switch E on the test desk is closed and relays Ex1 and Ex2 operate. A contact of relay Ex1 extinguishes lamp P1 and lights lamp E1. A second contact locks relays Ex1 and Ex2 dependent only on the switch E. If the time switch is at its zero position relay A8y in the test desk is operated and one of its contacts in conjunction with a contact of relay Ex1 operates relay A1x, a contact of which relay connects power to the +A1x busbar. Lamp A1l lights.

276. Press switch A2d is closed and operates relays A2x1 and A2x2 which lock. A contact of relay A2x1 energises valve O1h in the compressed air test box to hold the main oxygen and alcohol valves closed. Relay N1x operates if the pressure in the oxygen tank is below 1·5 ats., and operates relay N2x when the pressure rises above 1·2 ats. Relay N2x locks over one of its own contacts. As the pressure in the oxygen tank increases, contact N1or opens and relay N1x releases. A contact of this relay falls back and operates relay N3x which locks over one of its own contacts.

277. A contact of relay A2x1 completed the circuit of relay Zx via the bridge piece in the igniter and relay Zx operates. A contact of this relay closes and with N2x and N3x operated, relay A3x operates. A contact of this relay operates relay A3y and starts to operate relay Zs which has a ten second operating lag. A second contact energises

valve S1h which opens the main alcohol delivery pipe as far as the combustion chamber. When this valve has opened contact S1r closes and operates relay S1x. A further contact of relay A3y connects the 6vZu battery to the special puffer used to light the first section of the igniter which then starts to burn. Should three or more sections of the igniter burn satisfactorily the body of the igniter starts to revolve and eventually breaks the bridge piece in the holder. This opens the circuit of relay Zx which releases.

278. With relays A3y and S1x operated and with relay Zx and Zs released relay A4x operates and locks over its own contact. This operation is dependent on relay Zs having not operated, consequently the igniter is allowed a maximum period of ten seconds to produce satisfactory burning before the sequence of operations can proceed.

279. A contact of relay A4x energises valve O3h which opens the main oxygen supply. When the valve has opened satisfactorily its contact O3r closes and energises the main alcohol valve, whose contact S2r, when fitted, closes to operate relay S2x. When contact S2r is not fitted, its function is performed by contact O3r as before described. With relays A4x and S2x operated, a circuit is prepared for the operation of relay A5x consequent upon the closing of the actual firing control A5d. If a launch is actually being made the flame from the rocket may be observed at this stage.

280. Press switch A5d is closed and operates relay A5x whose contact changes over and operates relay A6x in the rocket. This relay locks dependent upon a contact of the flame cut-out relay A9z. Contacts of relay A6x provide alternative holding circuits for the fuel valves after the ground connecting plugs have been disconnected. When the press switch A5d is released relay A5x releases, and its contact falls back to operate relay A5y in the test desk from the main distribution busbar in the rocket.

281. A contact of this relay opens the circuit of the solenoid on ground connecting plug No. 1 which falls away. Contacts 5 and 6 on this plug release relay A51z in the test desk and a contact of this relay opens the circuit of the solenoid in ground connecting plug No. 2, which also falls away. Contacts 5 and 6 on this plug release relay A52z in the test desk and contact 14 on this plug releases relay A6y in the rocket.

282. A contact of relay A6y falls back and energises valve Dh which pressurises the hydrogen peroxide and sodium permanganate tanks in the steam unit. When the pressure in the permanganate tank has reached 1·5 ats., contact D2r on the diaphragm switch closes and energises valve D8h which opens a bye-pass on the main hydrogen peroxide valve. At the same time valve D25h is energised dependent on relay A9y being released and this opens the main hydrogen peroxide valve.

283. If an actual launch is taking place the rocket starts to leave the launching platform and switch A72, fitted in the tail of the rocket, opens. This releases relay A7y in the rocket which starts the sequence switch working. If an actual launching is not taking place, switch A72 may be opened by lowering the small plate in the launching platform which normally holds the switch closed. Relay A7y then releases and starts the sequence switch and the whole programme may be run through with the rocket on the platform.

284. The emergency flame cut off control can only be tested when the test desk circuit is set for firing. When it is set for testing it is not possible to throw off the ground connection plugs and this must be done before the emergency flame cut-off control can operate. When the second ground connecting plug is thrown off, relay A52z in the test desk releases and the normal flame cut-off control is disconnected from the test desk at pins 26 and 27 on ground plug No. 2. Then switch A9d on the test desk is closed, relay A9x operates and its contacts complete the circuit of the emergency flame cut-off relay A90x over the emergency cable which is led into the tail of the rocket. The contact of this relay operates the normal flame cut-off relay A9z in the rocket, the steam unit is shut down, the fuel valves are closed and the alternators and servo motors are stopped.

285. Illustrated descriptions of these vehicles have been made by the U.S. Forces under E.T.O. Ordnance Technical Intelligence Reports to which reference should be made.

286. These were made available by Big Ben Sub-Committee under references B.B.S./P (45), 21, 22, 23, 24, 25 dated 27th, 28th June, 1945.
The list is :—

Alcohol Tank Truck: E.T.O. Ord. Tech. Int. Report No. 277, dated 13th May, 1945.
Liquid Oxygen Tank Trailer: E.T.O. Ord. Tech. Int. Report No. 280, dated 14th May, 1945.
Hydrogen Peroxide Tank Truck: E.T.O. Ord. Tech. Int. Report No. 284, dated 15th May, 1945.
Meilerwagen: E.T.O. Ord. Tech. Int. Report No. 252, dated 2nd May, 1945.
Launching Platform: E.T.O. Ord. Tech. Int. Report No. 263, dated 4th May, 1945.

287. Further notes and details of these vehicles and ancillary pumping units are given below and should be read in conjunction with the above reports.

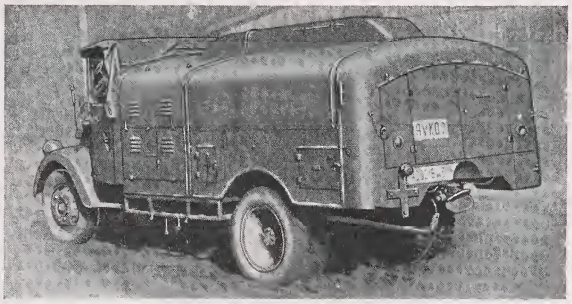


Fig. 146

288. ALCOHOL TANKER (Fig. 146, Section 5)
This is of similar construction as the normal petrol tanker and is built on a standard 3-ton chassis.

289. ALCOHOL PUMPING SET (Figs. 147 to 151, Section 5)
The pumping set which accompanies the alcohol tanker

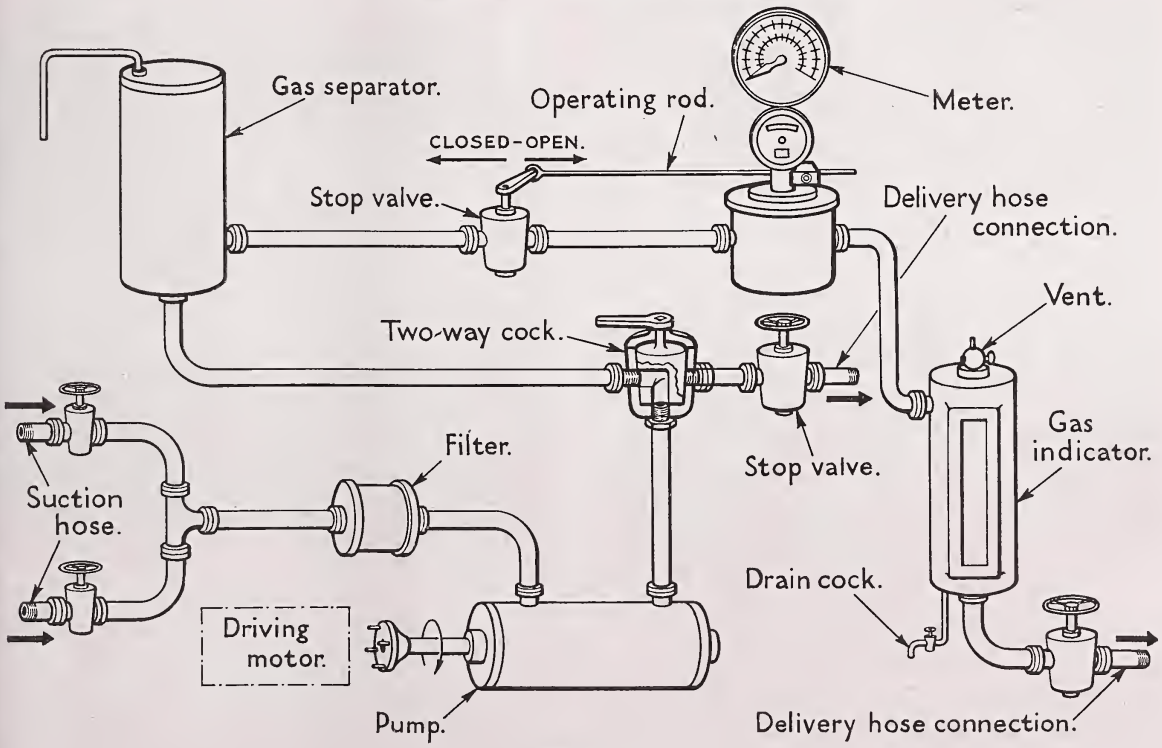


Fig. 147

is shown in the above figures, and the circuit is as shown on Fig. 147, Section 5.
The electric driving motor is of 4 horse-power, and the two stage centrifugal pump delivers 250 litres per minute when running at 1,430 r.p.m. Incorporated in the flow meter is a limit switch which cuts off the fuel delivery at any pre-determined setting. The suction pipe has a twin branch enabling fuel to be drawn from two tanks simultaneously. The diameter of the suction and delivery hoses is 70 mm.

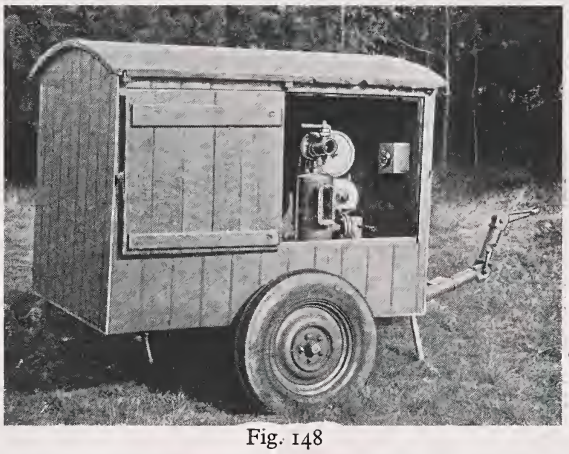


Fig. 148

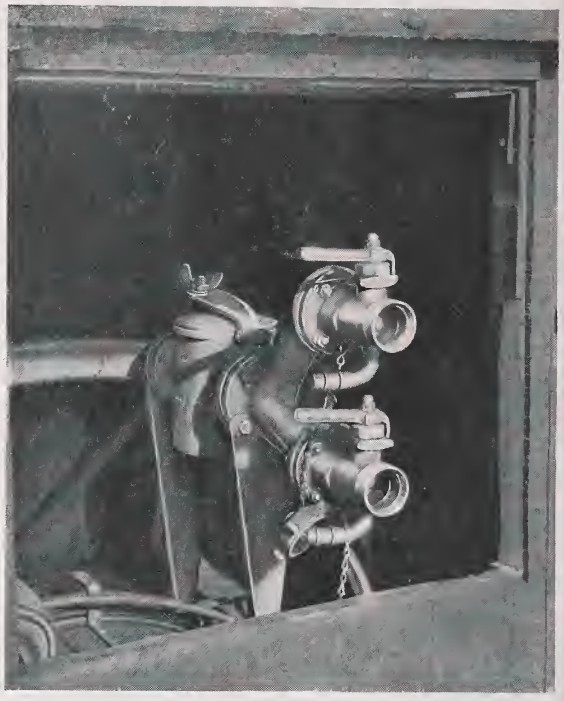


Fig. 149

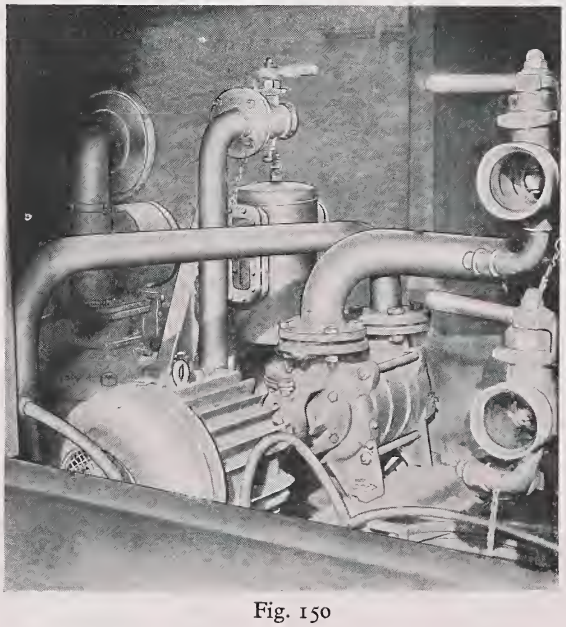


Fig. 150

Fig. 151

290. Liquid Oxygen Tanker (Fig. 152, Section 5)
This consists of a special insulated tank mounted on a trailer chassis.
The arrangement of the tank is shown in Fig. 153, Section 5, and is indexed as follows :—

1. Thawing mantle for indicator pipe.
2. Hot gas pipe to mantle.
3. Gas vent from gas separator.
4. Filling pipe.
5. Indirect gas drain coil.
6. Connection for hot gas flow.
7. Connection for hot gas return.
8. Bottom indicator pipe.
9. Stop valves for liquid level indicator.

Fig. 152

10. Liquid level indicator.
11. Top indicator pipe.
12. Valve for indirect gas drain.
13. Gas connection.
14. Valve for direct gas drain.
15. Safety valve.
16. Direct gas drain pipe.
17. Pressure gauge.
18. Safety valve.
19. Filling connection.
20. Bayonet coupling.
21. Handwheel on liquid valve.
22. Spray ring.
23. Inner tank.
24. Outer tank.
25. Insulating space.
26. Right angle valve.
27. Discharge pipe and connection.
28. Gas separator.
29. Gas vent valve.

291. TANK

The tank consists of an inner and outer container, the interspace being filled with insulating material called Iporka (said to be Urea Formaldehyde).

292. THE INNER TANK containing the liquid oxygen is made of aluminium and holds 6,000 litres, the permissible working pressure being 1·5 kg/cm.^{2} Two perpendicular baffle plates are fitted into the tank to reduce the surging effect of the liquid while travelling, and so avoid evaporation of the liquid and stress in the material. On account of the large temperature difference between liquid oxygen and the atmosphere and to minimise conduction of heat to the inner tank, it is suspended in the outer tank by chains attached to eyes welded on to the inner tank. A thin brass bursting disc is fitted on to the manhole cover of the tank to guard against excessive pressure which might burst the tank.

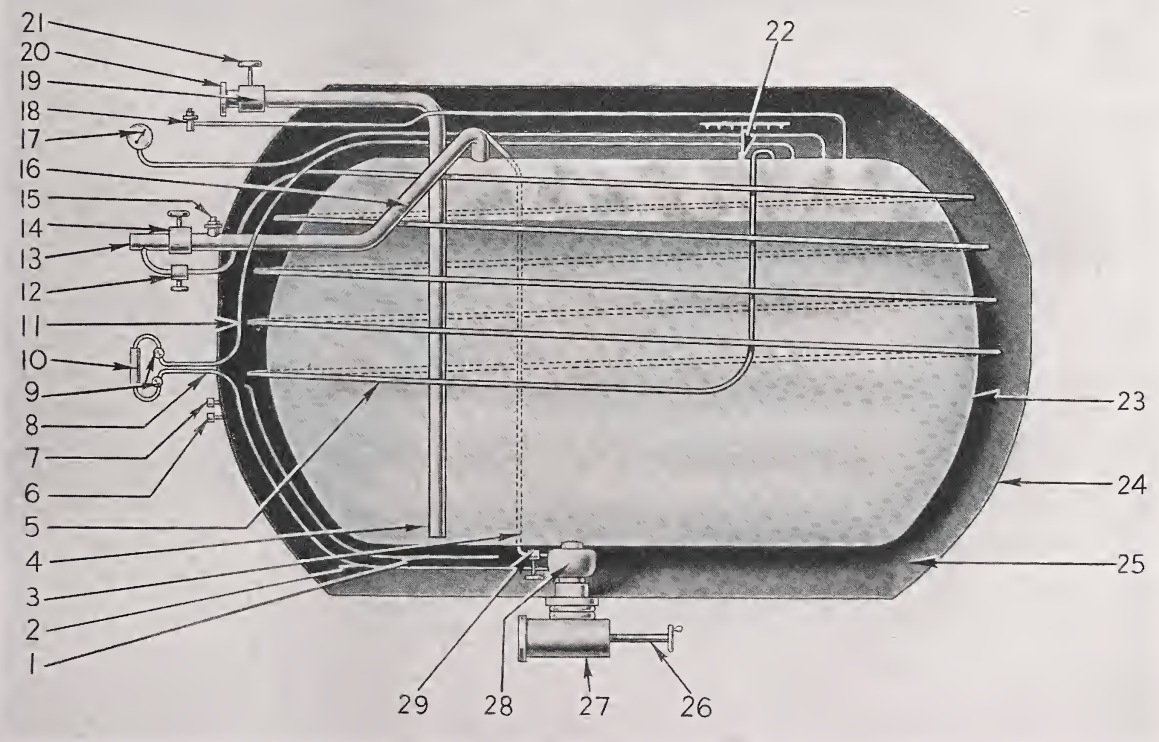


Fig. 153

293. THE OUTER TANK is made of steel, the lower part of which is secured to the framework of the chassis. The upper part is removable and is joined to the lower part by bolts. A manhole cover is fitted immediately above that in the inner tank, and here again a bursting disc is fitted to guard against excessive pressure in the insulating space.

FITTINGS

294. FILLING CONNECTION 70 MM.
The filling connection fitted with a bayonet coupling is situated at the top rear of the tank and is closed by a sluice valve with extended spindle reaching through the insulating space. The filling pipe drops inside the tank to within a few cms. of the bottom.

295. DISCHARGE CONNECTION 100 MM.
The discharge from the lowest point of the tank passes firstly through a gas separator, then into the pipe terminating in a right angle valve at the edge of the chassis. Between the gas separator and discharge pipe a corrugated flexible connection of copper-plated brass is fitted. The valve outlet is fitted with a bayonet connection, and the spindle is not sealed with a normal gland, but by means of a spring bellows (copper or brass) soldered to both the valve itself and the valve cover, the bellows moving with the spindle.
The purpose of the gas separator is to produce gas and act as a hydraulic seal, thus allowing the discharge pipe between it and the right angle valve to be filled with gas, and remain so. This then prevents evaporation of liquid which would be in the discharge pipe and which would be difficult to insulate completely. Two pipes lead away the gas from the top of the separator cowl through a vent valve mounted on the side of the tank.
A section of the gas separator is shown in Fig. 154, Section 5, and is indexed as follows :—

1. Liquid pot.
2. Shell.
3. Weir.
4. Gas collector.
5. Deflector.
6. Gas vent.

296. GAS DRAINS
The direct gas drain runs from the top centre of the inner tank immediately to the top right-hand of the rear of the outer tank and passes to atmosphere through a vent valve. A safety valve and connection are fitted to this pipe prior to the vent valve.
The indirect gas drain has a smaller cross section than the direct, and is run in coils round the inner tank for the purpose of cooling the insulation, and keeping the interspace cold. This drain connects into the direct drain through a valve just outside the tank.
To prevent sub-normal pressures in the insulation space, and to keep the insulating material dry, a very small quantity of cold dry gas is continually allowed to leak through a fine spray from the inner tank to the interspace.
A pressure gauge is fitted to record the pressure at the top of the tank.
A safety valve is connected directly to the gas space in the inner tank.
A liquid level indicator is fitted to show the contents of the tank. This indicator measures the pressure difference between the top and bottom of the tank, and the fluid

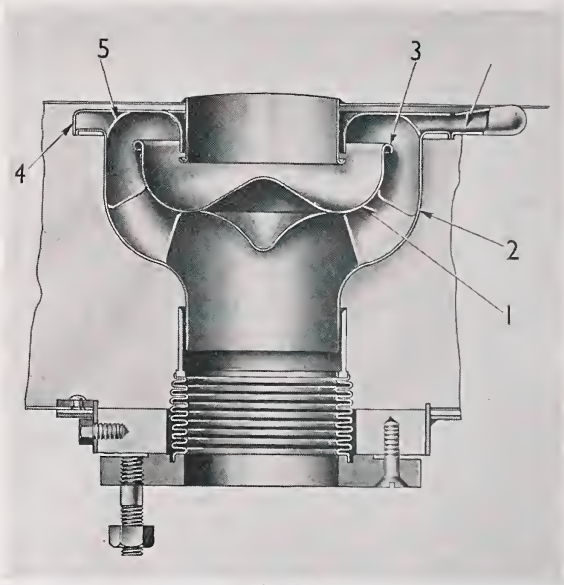


Fig. 154

used for this purpose is acetylene tetrabromide (SG 2.96). The contents of the tank are marked on the scales in kgs. The tank when full holds 6·8 tons.
The diameter of the inner tank is 170 cms. (5 ft. 7 in.), and the width of the insulation space is 22 cms. ($8\frac{3}{4}$ in.).
Our experience showed us that over a fifty-mile journey the losses including those during pumping amounted to about 12 per cent. In some cases where the tanks did not travel smoothly on the rough roads the losses were sometimes as high as 28 per cent. Under similar conditions transfer by superimposed pressure would give losses amounting to about 8 per cent.
The use of the gas separator on the gas tank discharge is a novel feature, but has not proved to be thoroughly practicable. In fact the whole weakness of these oxygen tankers centres around the discharge connection. The flexible connecting piece between the gas separator and discharge pipe is weak and breakages occurred here during transit.
This led to the recovery of liquid oxygen tankers used for industry (see Fig. 155, Section 5) where there is no bottom discharge connection, the liquid being transferred by superimposed pressure. These trailers covered the distance of 120 miles without any trouble or excessive losses. These tanks are of more robust construction. The time for discharging the liquid was about twice as long as that with the centrifugal pump.
It has been frequently mentioned that liquid oxygen was nearly always in short supply at the launching sites, this being mainly due to transport difficulties involving delay and consequent evaporisation losses of oxygen. For the 6·8 ton tank the road losses when travelling are about 800 to 1,000 kgs. per 24 hours. The losses when standing are about 350 kgs. per 24 hours. These figures are for tanks in average condition.

297. LIQUID OXYGEN PUMP (Figs. 156 and 157, Section 5)
This pump is carried either on the rear platform of the liquid oxygen tanker or in the alcohol pumping set trailer.

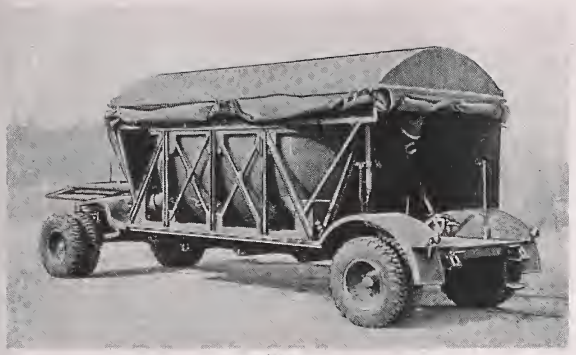


Fig. 155

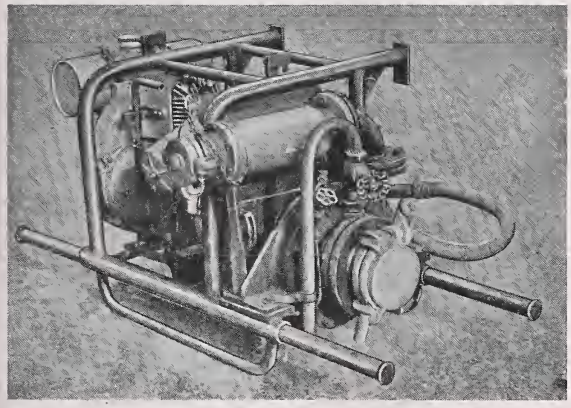


Fig. 156

A section of the pump is shown in Fig. 158, Section 5, and is indexed as follows :—

1. Felt ring.
2. Bearing housing.
3. Protection sleeves.
4. Exhaust gas entry.
5. Felt ring.
6. Top gas drain.
7. Vent connection.
8. Securing ring.
9. Vent connection.
10. Bearing rings.
11. Impeller.
12. Cap nut.
13. Feather.
14. Locking plate.
15. Suction cover.
16. Paper joint.
17. Volute housing.
18. Bottom drain.
19. Paper joint.
20. Cover plate.
21. Bearing cover.
22. Paper joint.
23. Bearing.
24. Shaft.
25. Exhaust gas exit.
26. Bearing.
27. Bearing cover.
28. Plastic sealing ring.
29. Gland cup.
30. Spring.
31. Locating pin.
32. Three-piece split packing.
33. Special lantern ring.

This pump is driven by a petrol motor of 6½ h.p. 3,000 r.p.m. The drive to the pump is through a gear and clutch so that the final speed of the pump is 1,670 r.p.m., and at this speed the pump delivers between 8 and 10 kg/sec.
The pumping set is assembled on a tubular steel frame which carries the base plate for motor and pump. This frame is so built as to allow it to be mounted on the side of the tanker trailer, thus enabling fixed connection to be made.

The diameter of suction hose is 100 mm. The delivery hose is 70 mm. diameter and when filling the rocket the normal delivery pressure is about 1½ kg/cm². Before the pump can be used it must be cooled down to the temperature of liquid oxygen (minus 183 deg. C.). This is done by allowing a small quantity of liquid to come from the tank, evaporate and vent through the valves on the pump and may take up to 15 minutes. When the pump is sufficiently cooled the liquid oxygen will be found to flow from the vent connection on the pressure side of the pump housing. The indication, of course, that the pump is working is that the pressure gauge will indicate a pressure of above, say, 1 kg/cm².
The aluminium alloy (silumin) impeller is fitted on a steel shaft and secured by means of key and shaped cap nut, and is located in the housing by means of the suction cover.

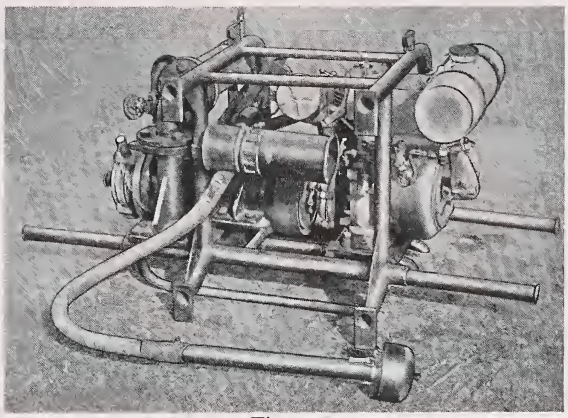


Fig. 157

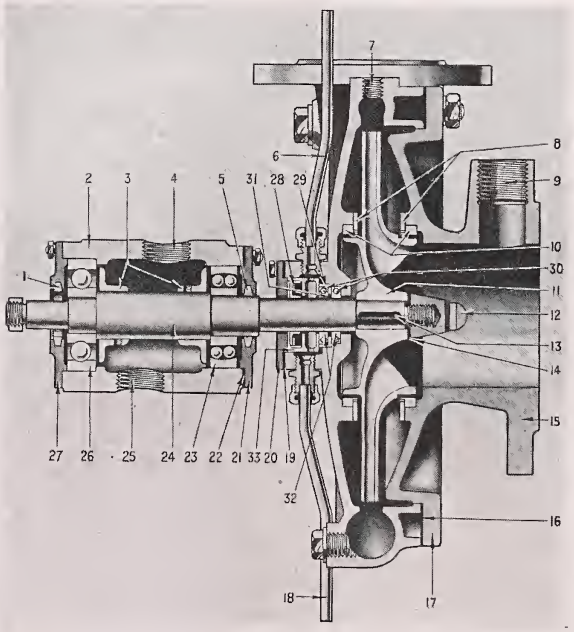


Fig. 158

The impeller is floating, and to take the thrust in the housing and cover, cast iron bearing rings are fitted. At normal temperatures the clearance between the impeller and thrust rings is about ·2mm.
The shaft is supported in a bearing between the pump and motor, and in order to keep this bearing at normal temperatures when the pump is working at abnormally low temperatures the exhaust gases from the driving motor are led into this bearing housing. The bearing consists of one fixed ball bearing and one self-aligning ball bearing, and in order to protect those bearings from direct contact with the hot gases aluminium sleeves are assembled on the shaft inside the bearing housing. To prevent transfer of heat from the motor to the pump a metal shield is placed between the two units.
The sealing gland on the pump shaft consists of two split cast iron rings held together by spiral springs, then follows a lantern piece to lead away any gas which escapes past these two rings, then the final seal is made by a synthetic plastic ring and the whole gland held in position by means of a cover plate. The leakages through the gland are led away from both above and below the lantern piece.
Any gas which is locked in the pump housing is led away from the highest point of the housing, and any gas which is trapped in the suction pipe is led away from a connection fitted there. The pressure gauge is connected to the pressure side of the housing to show the working pressure of the pump.

Fig. 159

298. HYDROGEN PEROXIDE TANKER (Figs. 159 and 160, Section 5)
This is built on a standard 3-ton chassis, and is composed of three sections. The water tank and hose compartment immediately behind the cab, the peroxide tank central, and the pump compartment at the rear.
The peroxide tank, holding 2,100 litres is made of aluminium, and has a wall thickness of 6 mm. The water tank holding 160 litres is made of sheet steel 2 mm. thick. To act as a safety measure the peroxide tank lid is cemented into the frame ring on the top of the tank. Under excess pressure this cement will break and release the pressure in the tank.
An air filter is built into the tank vent and is filled with Raschig rings, thus preventing the entry of dust or other foreign matter which is liable to decompose the peroxide.
The power-driven pump is of two-stage centrifugal type, the shaft being supported on ball bearings mounted outside the pump casing. Between the glands on the pump casing and the bearing housing is a water bath, this to dilute any peroxide which may leak through the glands. A cross section of the pump is shown in Fig. 161. The pump delivers 250 litres per minute at 1,430 r.p.m., and can deliver to a height of 30 metres. In view of the specific gravity of the peroxide it is necessary to have a positive suction head to give a maximum performance. The pump must always be primed before starting.
A section of the pump is shown in Fig. 161, Section 5, and is detailed as follows :—

1. Inner bearing cover.
2. Ball bearing.
3. Outer bearing cover.
4. Cover.
5. Tie bolts.
6. Impeller.
7. Extractor.
8. Thrust ring.
9. Circlip.
10. Pump shaft.
11. Grease boxes.
12. Bath.
13. Gland nut.
14. Gland.
15. Gland packing.
16. Disc.
17. Bearing.
18. Pump housing.
19. Reinforcing rings.
20. Bath.

299. PEROXIDE PRE-HEATER (Fig. 162, Section 5)
The purpose of this apparatus is to prevent hydrogen peroxide freezing in cold weather (– 10 deg. C.).
This pre-heater is mounted on a trailer unit as shown. It consists of an inner aluminium container holding about 200 litres and surrounded by a jacket space through which hot gases can pass to the atmosphere. The heating is produced by burning alcohol or petrol in a burner at the bottom of the tank.

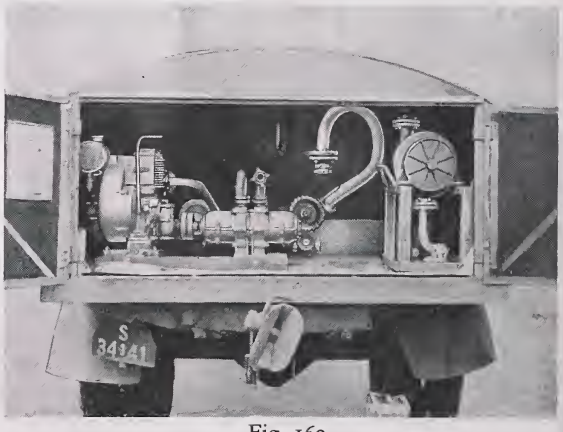


Fig. 160

300. MEILERWAGEN (Plates 72 and 73, Section 5)
It is not proposed in this report to give more than a brief description of this equipment since it is dealt with fully in E.T.C. Ord. Tech. I. Report, No. 252.
The vehicle is a long three-axle trailer, fitted with a hydraulically operated lift frame equipped with clamps for holding the rocket. (Plate 72, Section 5.)
Two of its axles are on the forward bogie with the third at the rear. A pair of outrigger arms are fitted to the rear of the third axle. These are equipped with jacks, and before lifting a rocket into the vertical position the outriggers are swung out and jacks operated to raise the rear wheels from the ground. (Fig. 163, Section 5.)

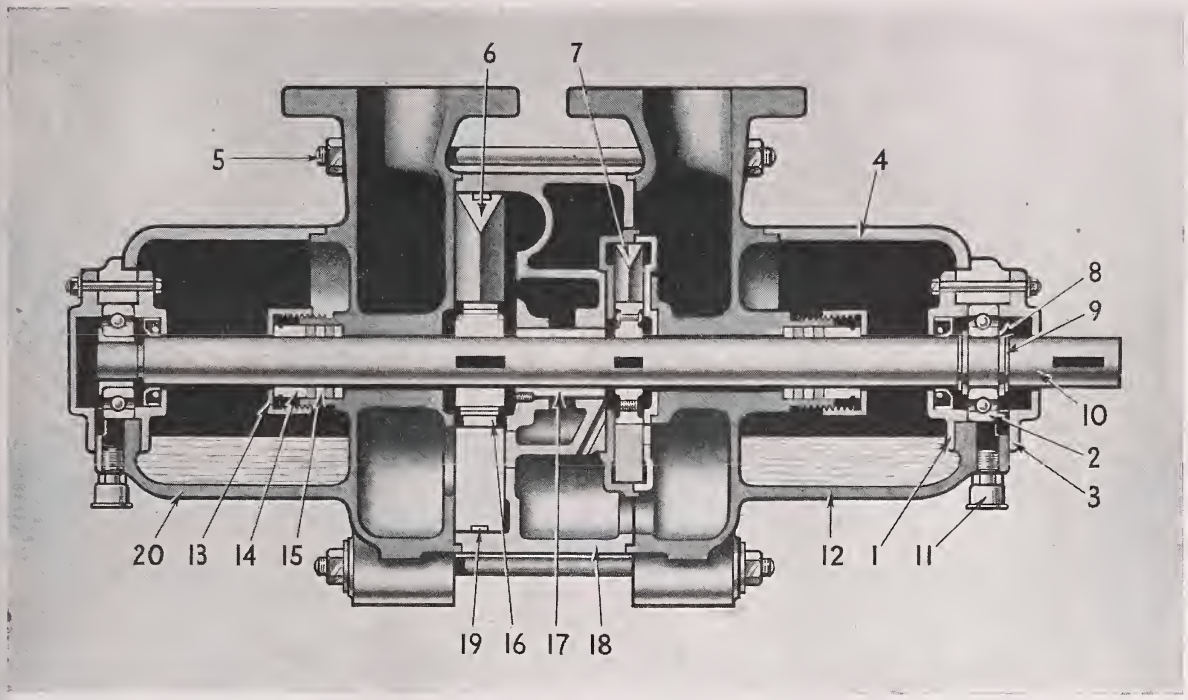


Fig. 161

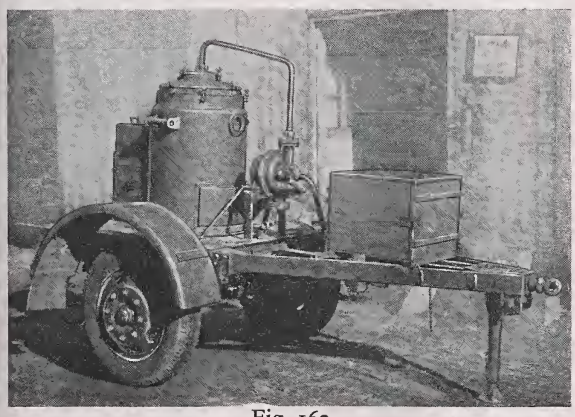


Fig. 162

The lift frame in addition to carrying the rocket clamps is fitted with collapsible platforms and a scaling ladder to enable final tests and fuelling to be carried out with the rocket in the vertical position. Air and fuel delivery lines, together with electric cables, are run within the framework. Approximately half-way up the frame a hydrogen peroxide tank is mounted, the capacity of which corresponds to that of the tank in the rocket. An overflow tank is connected and housed alongside.

The lift frame is raised or lowered by means of two hydraulic cylinders with multiple extension pistons which telescope in the lowered position. Oil for the hydraulic system is stored in a cylindrical tank on top of the chassis and pressure is obtained by a single-acting three-cylinder high-pressure pump.

A diagram showing the stages of operation and the hydraulic circuit is illustrated in Plate 74, Section 5. It will be seen from these diagrams that the control is by means of two shut-off valves A and B and two spring-loaded relief valves on a common shaft. The setting of the relief valves controlling the return oil and pressure on the rams is such that with the valves shut a pressure in the lift line of 125 kg/cm.^{2} can be maintained and on the lowering side a pressure of 90 kg/cm.^{2}

Inset A represents the condition appertaining with the lifting frame in the lower or horizontal position before raising commences.

Inset B shows rams H and I fully extended.

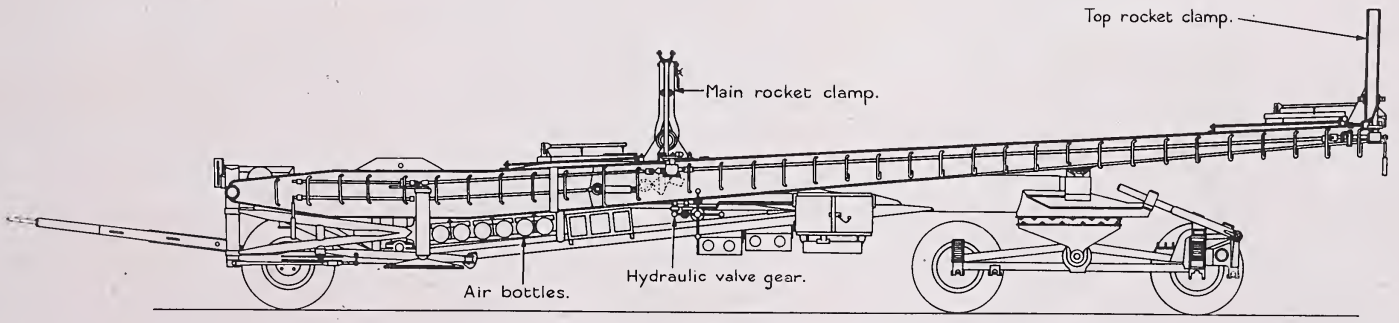
Inset C illustrates the conditions at the last stage of the lift. It will be noticed that lowering valve B is opened to allow oil in F which was preventing ram L from raising to be released through relief valve D. During this stage when the lift frame is nearing the vertical the rate of travel control should be throttled to its maximum.

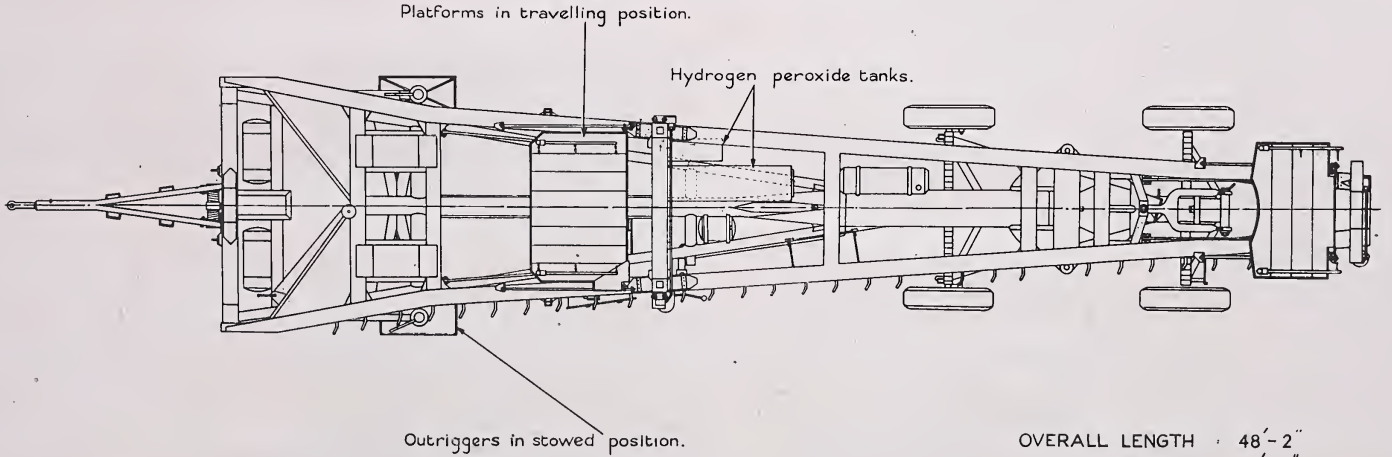
Inset D is the start of lowering with valve A closing the liftside and valve B open putting pressure on cylinder F.

The oil pump was originally driven by a 4 h.p. engine, but since this proved unsatisfactory for Operation "BACKFIRE" the drive was changed to a 4 h.p. electric motor. Control is through a valve assembly mounted between the air bottles and the motor. A battery of compressed air bottles is slung under the chassis which serve to pressurise the oxygen tanks and fill the air bottles in the rocket.

Fig. 164, 165 and 166 show the stages of the mounting of the rocket from the Meilerwagen to the firing platform.

MEILERWAGEN IN TRAVELLING POSITION.





OVERALL LENGTH	:	48′-2″
" WIDTH	:	9′-2″
" HEIGHT	:	10′-9″
TOTAL WEIGHT	:	24,900 LBS.

Fig. 163

Fig. 164

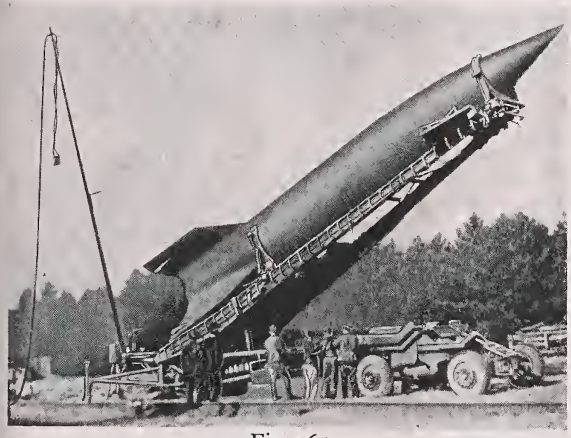


Fig. 165

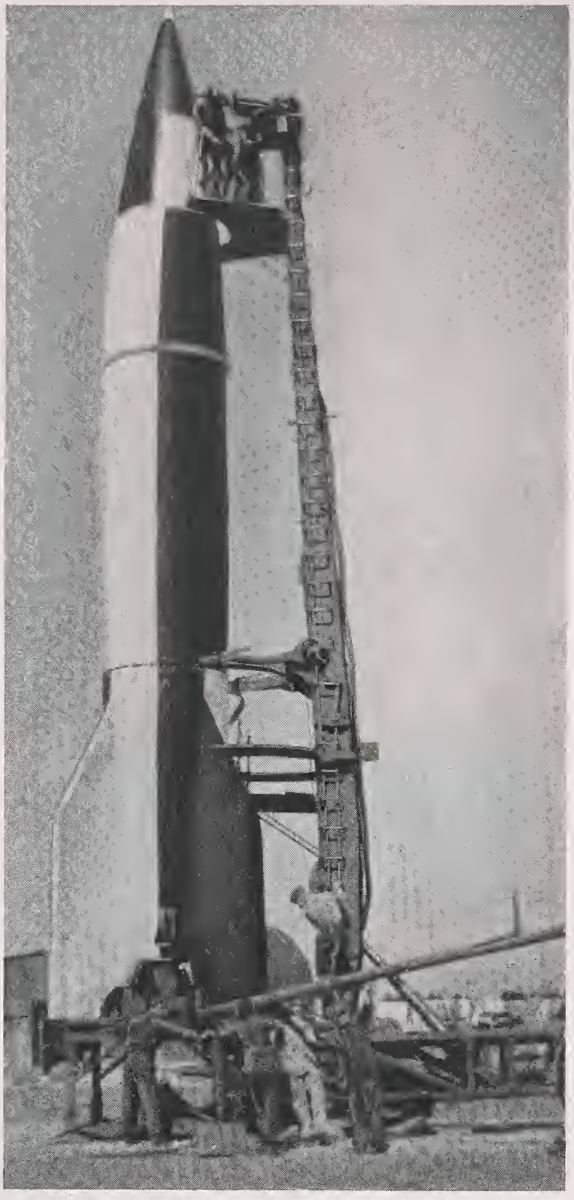


Fig. 166

301. FIRING PLATFORM AND TRAILER

A full description of this apparatus is given in E.T.O. Ord. Tech. Int. Report, No. 263. The platform serves as a table on which the rocket can be levelled and prepared for firing and orientated to its target bearing.

It consists of a lower platform supported by four adjustable legs on which a turntable is mounted on a ball race. Rotation of the turntable is by means of ratchet-driven chain pinions engaging a static chain secured to the lower platform. A section through the upper and lower platforms is shown at Plate 75, Section 5.

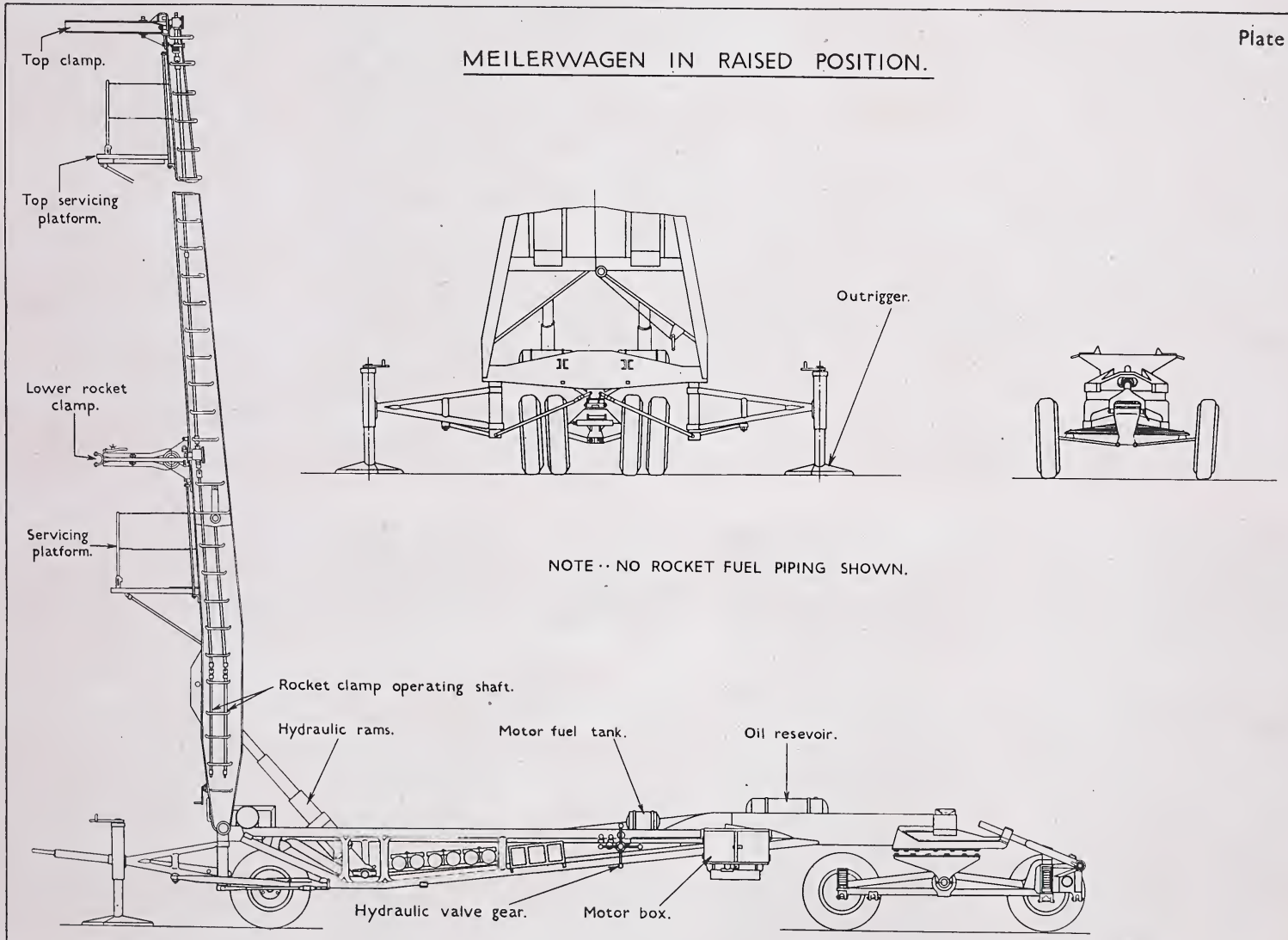
The adjustable legs are raised and lowered by means of built-in jacks, the footplates of which are on ball and socket joints to facilitate levelling on uneven ground.

Attached to the fixed portion of the legs is a pyramid shaped blast deflector, two sides of which incorporate flaps to receive the trailer wheels.

The turntable ring is fitted with four extensions located at 90 deg., each of which carry an adjustable plate on which the rocket fins rest.

Various holders for the accommodation of the oxygen topping up pipe connection, the five-way coupling connection (Figs. 167 to 168, Section 5), and the air supply

MEILERWAGEN IN RAISED POSITION.



NOTE · · NO ROCKET FUEL PIPING SHOWN.

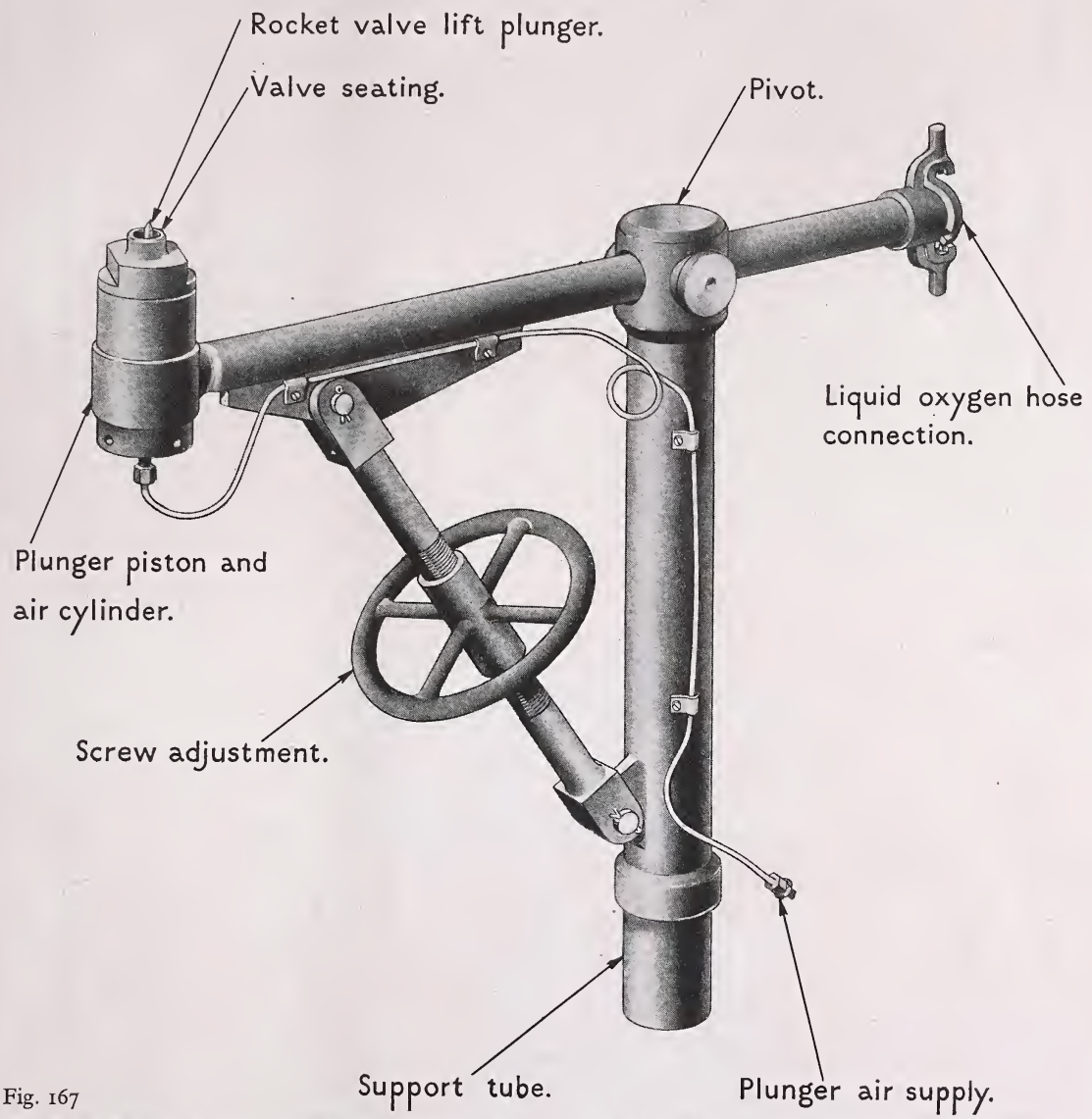


Fig. 167

valve box are located on the turntable. Electrical connections for the emergency cut-off cables and programme release switch are fitted before firing. A tubular socket is affixed to the turntable to carry a mast which supports the ground connection cables to the control compartment of the rocket. (Plate 75, Section 5.)

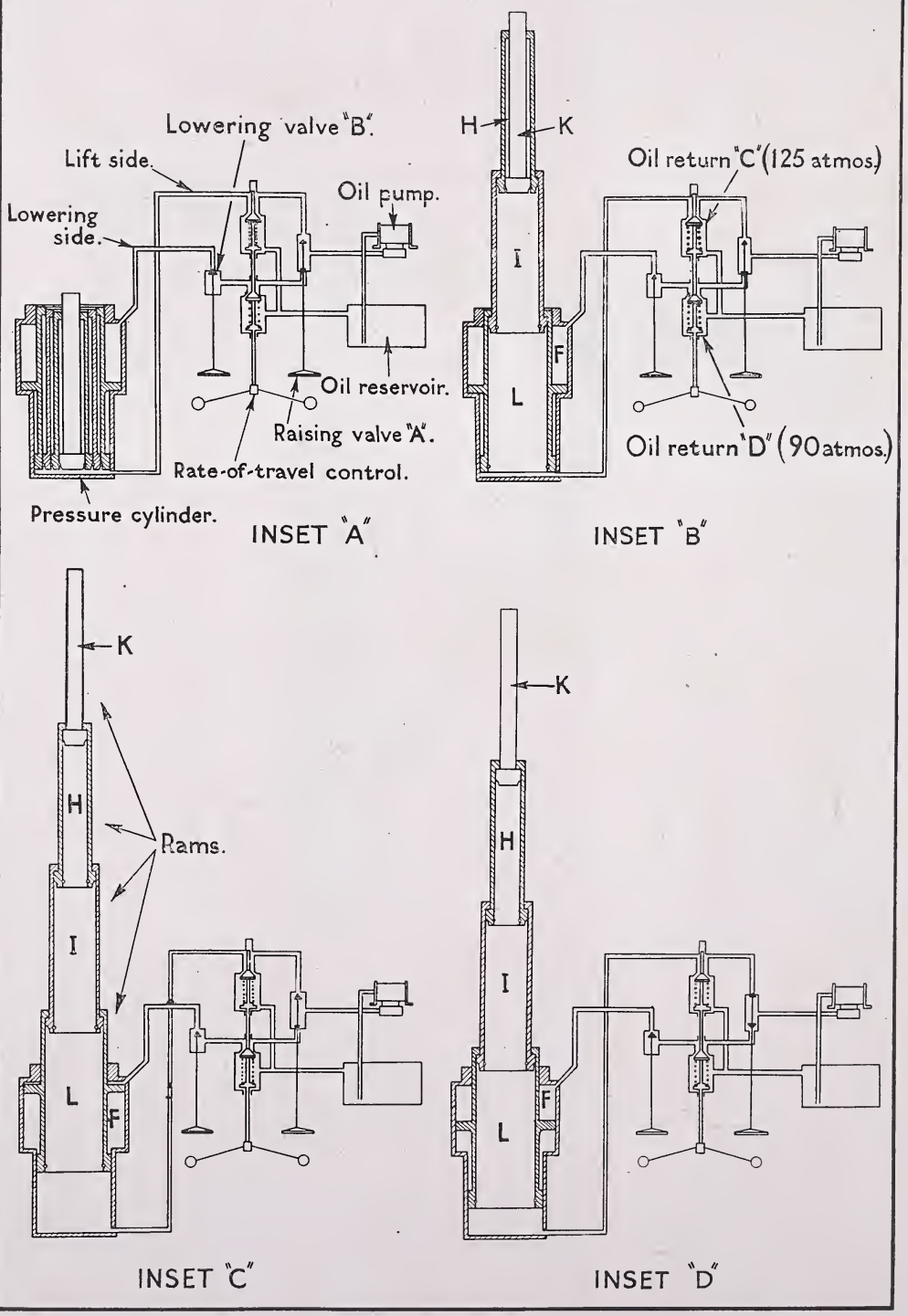
In operation after the Meilerwagen has been manœuvred into position and the rocket raised to the vertical position, the platform is raised until the four pads in their lowest position are about 4 in. below the supports on the rocket fins. The pads are now adjusted to make contact with the rocket fins and transfer the weight from the wagon to the platform.

THE TRAILER is of the two-wheeled type, the chassis being of fabricated steel tube ; as illustrated in Fig. 169, Section 5.

302. VALVE BOX

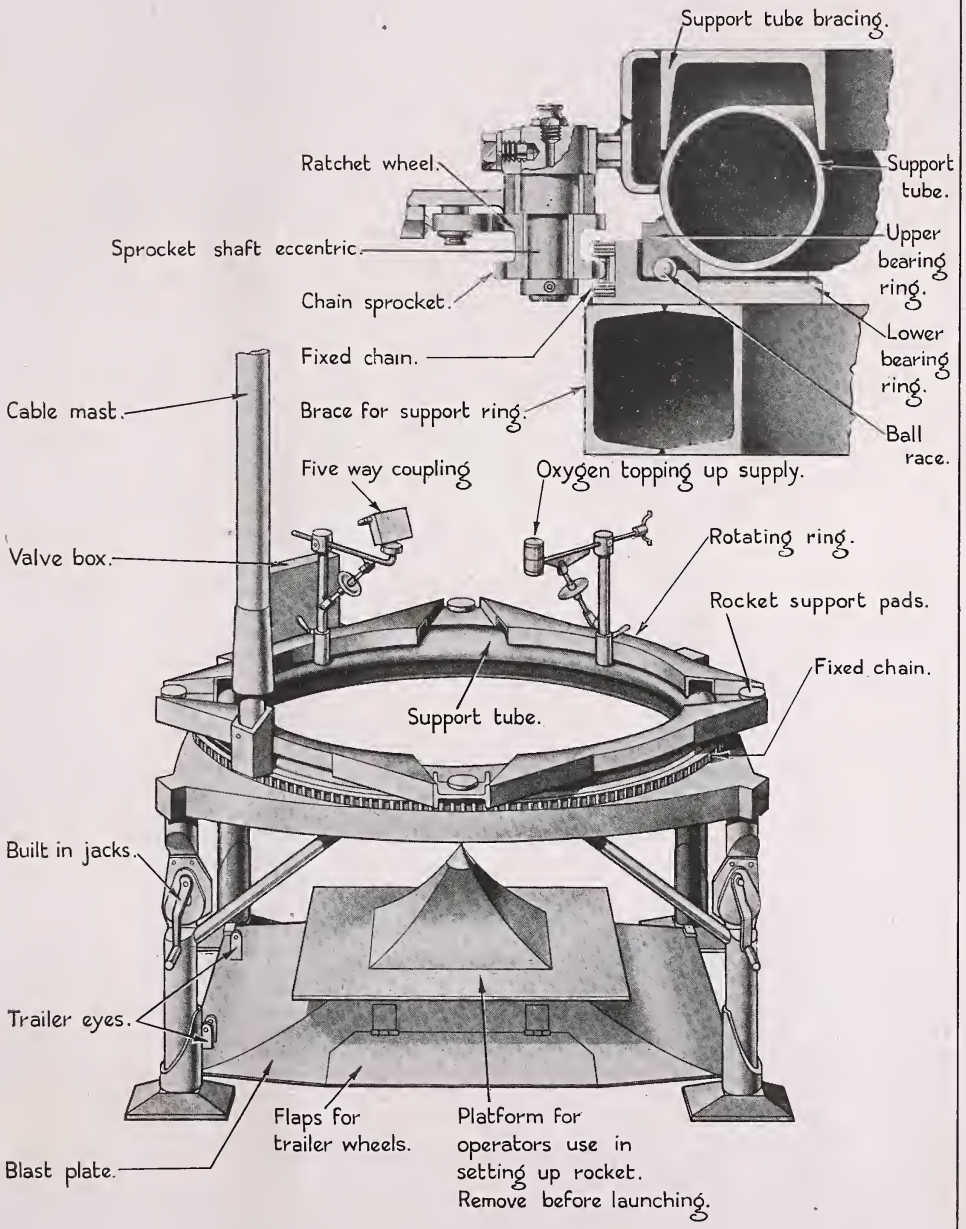
This is really an intermediate control box acting as a central distribution point of the various services to the rocket with the exception of the main power supply to the control compartment. The apparatus is built into a flame-proof steel box fitted with lugs for attachment to the firing platform. Figs. 170, 171 and 172, Section 5, shows the various connections and services, while Plate 76, Section 5, gives details of the air circuit. The operation is described in Section 4 under the heading of electrical tests.

HYDRAULIC CIRCUIT OF THE MEILERWAGEN.

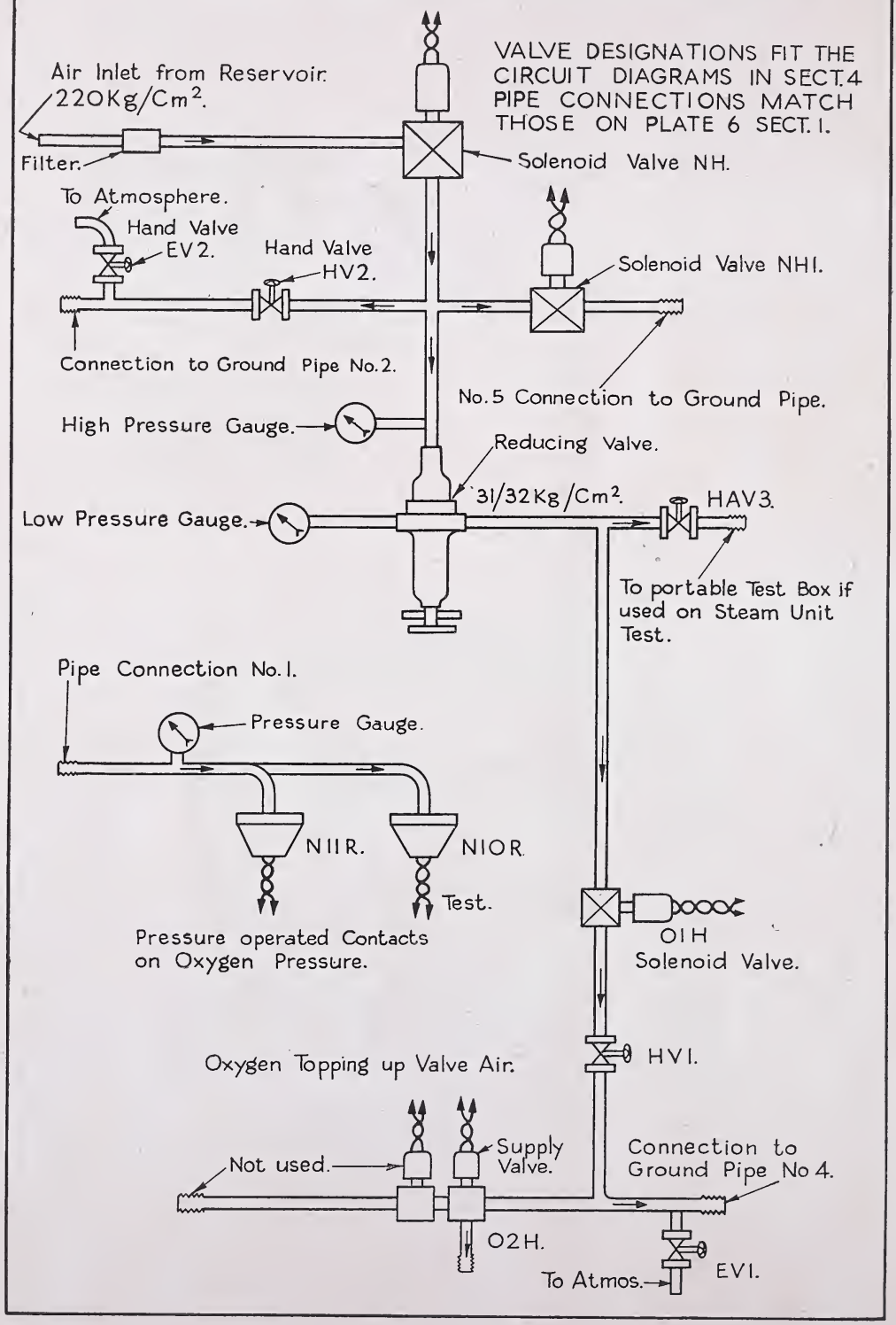


FIRING PLATFORM.

SECTION THROUGH THRUST BEARING OF TURNTABLE & TURNING MECHANISM.



FLOW DIAGRAM OF VALVE BOX. Plate 76



SERVICE MANIFOLD FOR GROUND CONNECTIONS.

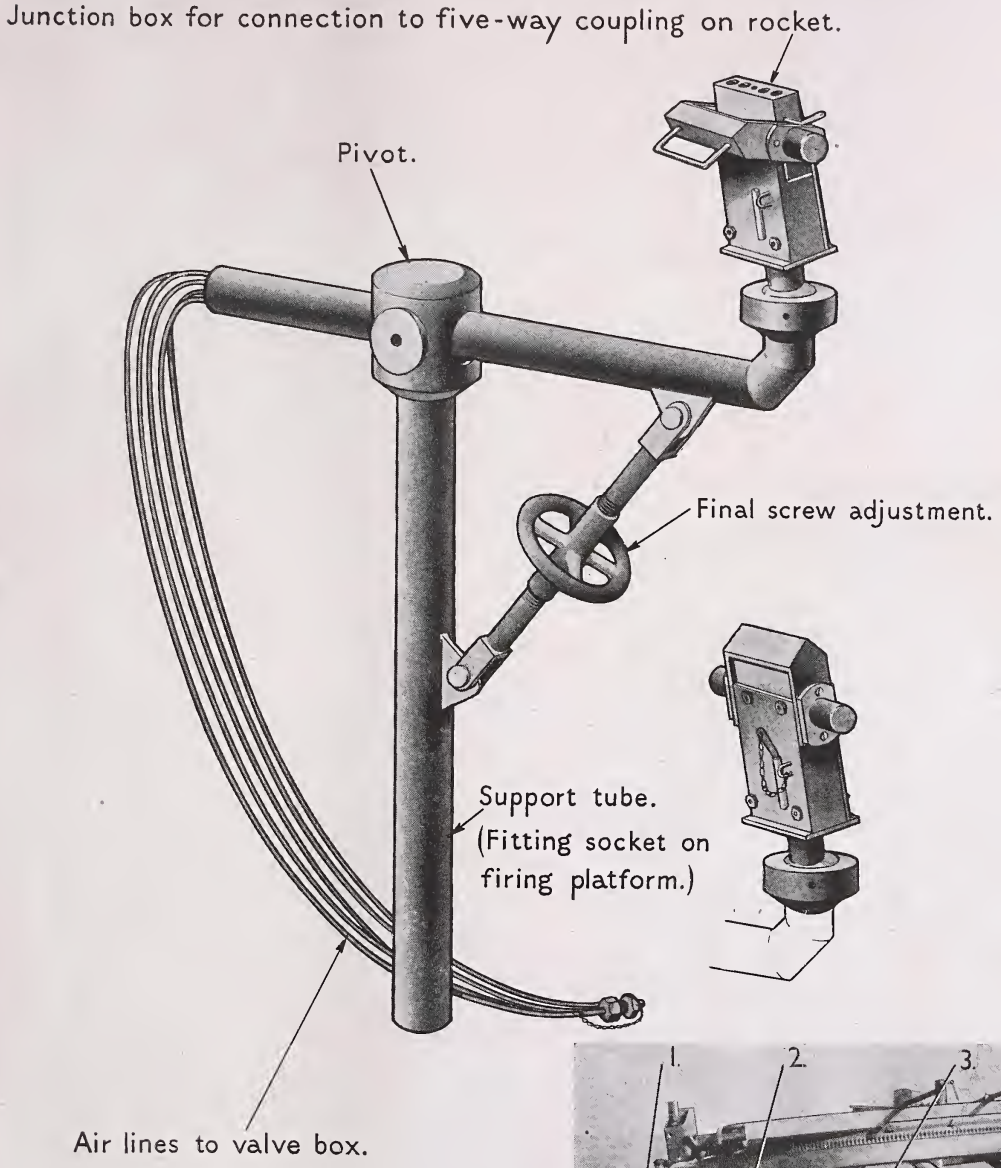


Fig. 168

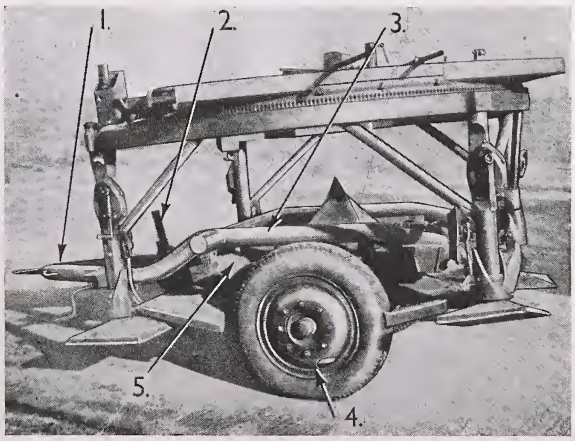


Fig. 169

1. Towing Hook
2. Built-in Jack
3. Tubular Chassis
4. Tyres 7·5 × 20
5. Springs

Fig. 170

1. E.V.2
2. HV.2
3. Valve NH
4. HV.1
5. E.V.1
6. Valve NH1
7. Contact N10R
8. Contact N11R
9. HAV3
10. O.1.H
11. Valve 02H

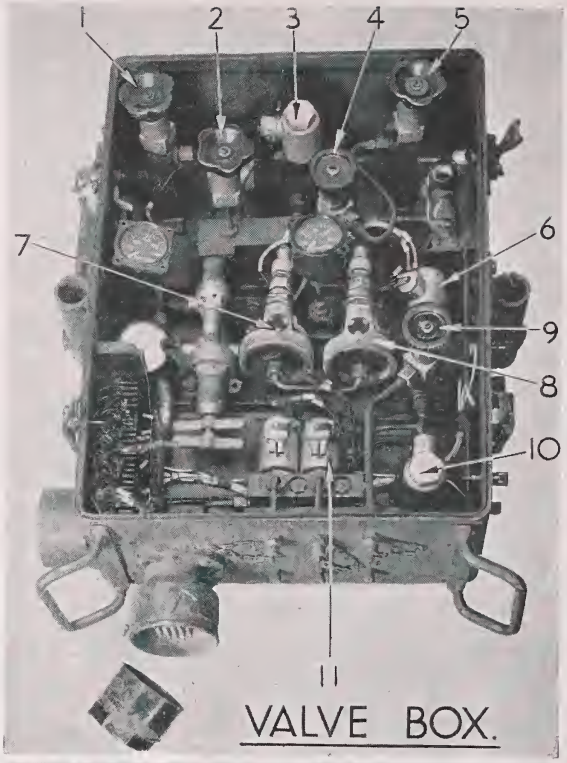


Fig. 171

Fig. 171

1. Oxygen Tank Pressure Gauge
2. Brackets for Attachment to Firing Platform
3. Telephone Connections
4. Main Cable Connections to Test Desks
5. Cable Connection Panel
6. Reducing Valve
7. Low Pressure Gauge
8. Main Air Supply Pressure Gauge
9. Pyrotechnic Connections to Emergency Cut-out Connections

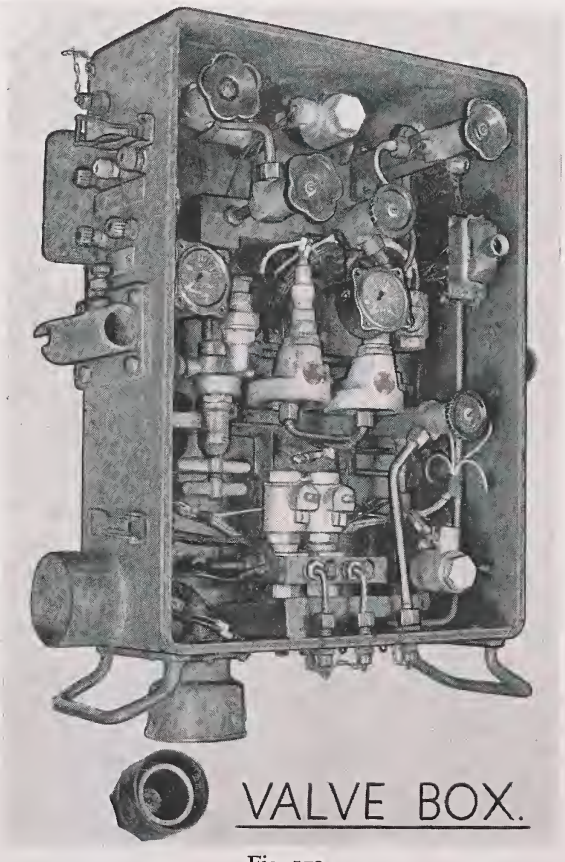
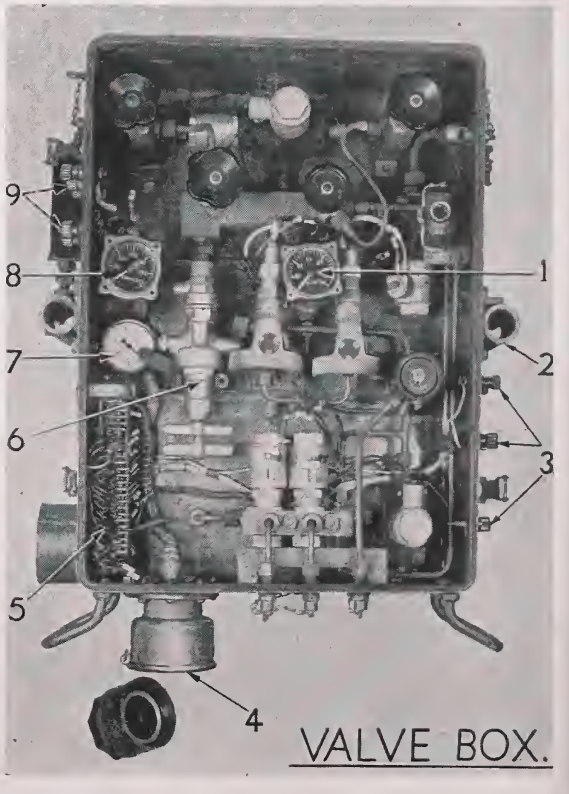


Fig. 172



THE PYROTECHNIC IGNITER (Figs. 173 to 177)
This consists of the following parts :—
1. The body.
2. The supporting head.
3. The supporting tube, etc.

303. THE BODY consists of four cardboard tubes each containing a suitable mixture of gunpowder, fine metal, etc., pressed together and forming in fact a single "Roman Candle." Each tube is finished off with an orthodox priming. These four tubes are mounted in a frame of inflammable plastic, so that on ignition the whole body spins at a designed speed of approximately 400 r.p.m. Quick-match is led from a central annular recess to all four primed heads.

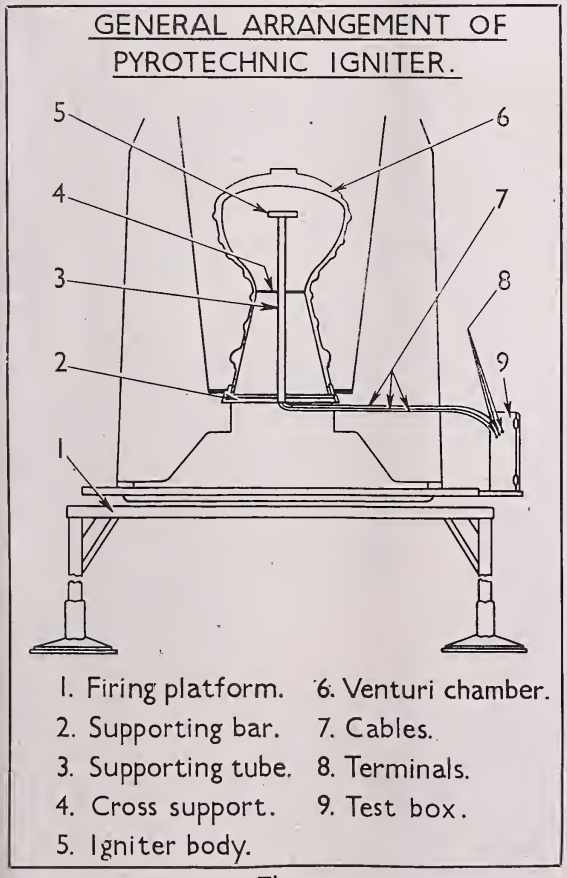


Fig. 173

The frame is pierced by a hole in the centre, and on the upper surface are fixed two small springs forming a jaw to engage in the cannelure at the top of the pin of the supporting head. On the underside and slightly offset is a small pin which engages the barrel on the supporting head.

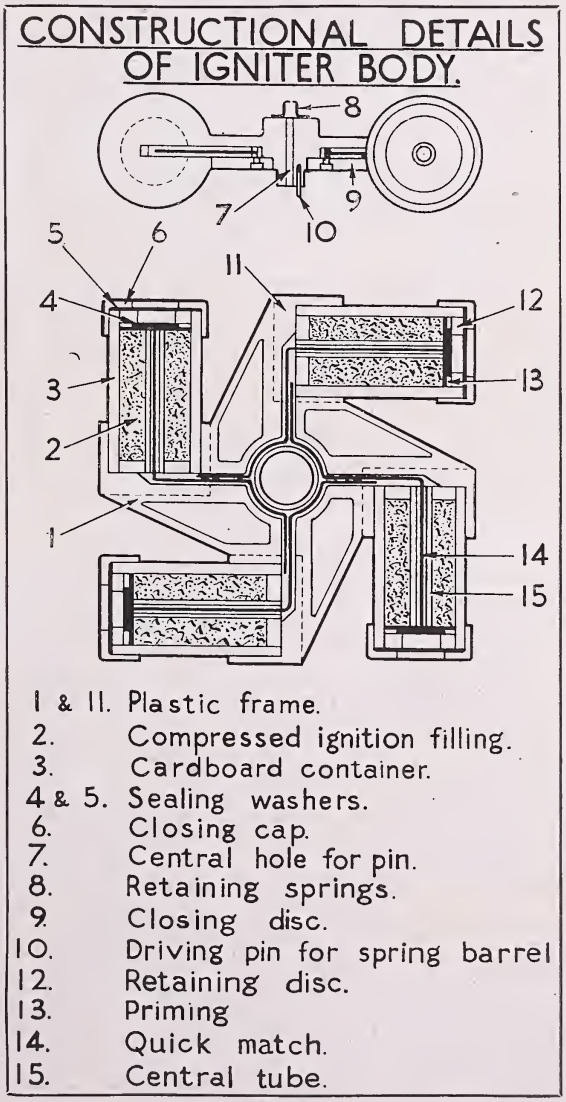


Fig. 174

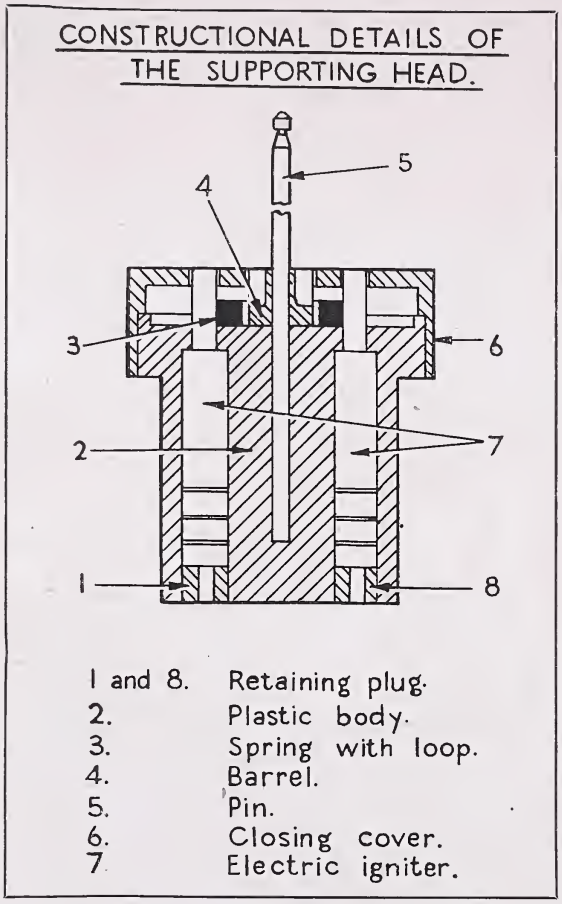


Fig. 175

304. THE SUPPORTING HEAD consists of a plastic body pierced by two holes in which are placed electric igniters and a central pin on which the body spins. Over this pin is fitted a small barrel free to revolve. To the periphery of the barrel is anchored the inner end of a light steel spring. The spring is wound round the barrel and has its outer end anchored to a copper wire bridge piece fixed to two terminals in the head. The spring is of such a length as will allow the barrel to make 10 revolutions before it is completely tight. The copper bridge piece is of such thickness as will allow it to break under the momentum imparted if three or four " candles " are burning. The barrel also has an offset hole to correspond with the offset pin in the body.

305. THE SUPPORTING TUBE is of strong cardboard, and is in two halves for convenience in packing and transport. The supporting head is cemented firmly to the upper end and the lower end is slotted to take the wooden crossbar which supports the whole system in the venturi chamber. A lateral support is obtained by a wooden stick which is pushed into holes in the tube, and lies across the throat of the venturi when the whole assembly is in position.

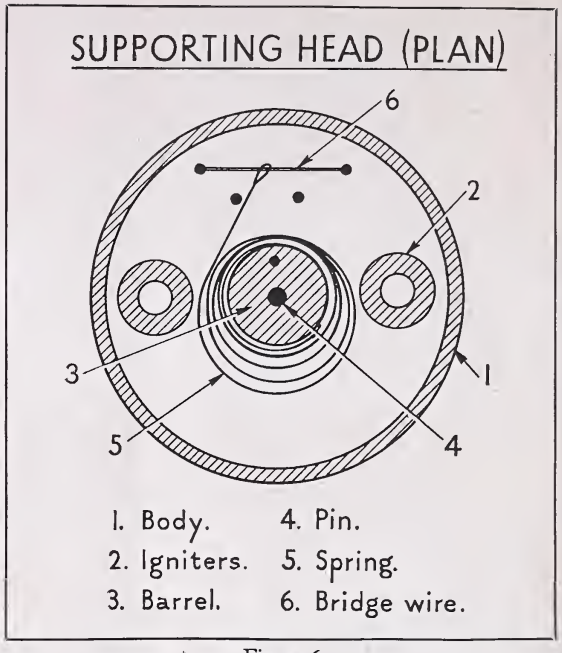


Fig. 176

306. ACTION

On the closing of a circuit the small electric igniters in the supporting head ignite the quick-match in the body, which in turn ignites the four " candles." These commence spinning and as the rate increases so a perfect ring of flame is formed. If 3 or 4 of the candles are alight, after 10 revolutions, the spring in the head is tightened and breaks the copper bridge wire. This releases a relay and allows the first stage of main ignition to proceed. If only two " candles " light up the flame will be imperfect and liable to cause bad ignition, also the momentum will not be sufficient to break the bridge wire, and therefore ignition cannot proceed. The construction of the igniter is such that it is completely combustible and quickly destroyed, leaving the inside of the combustion chamber free from foreign matter.

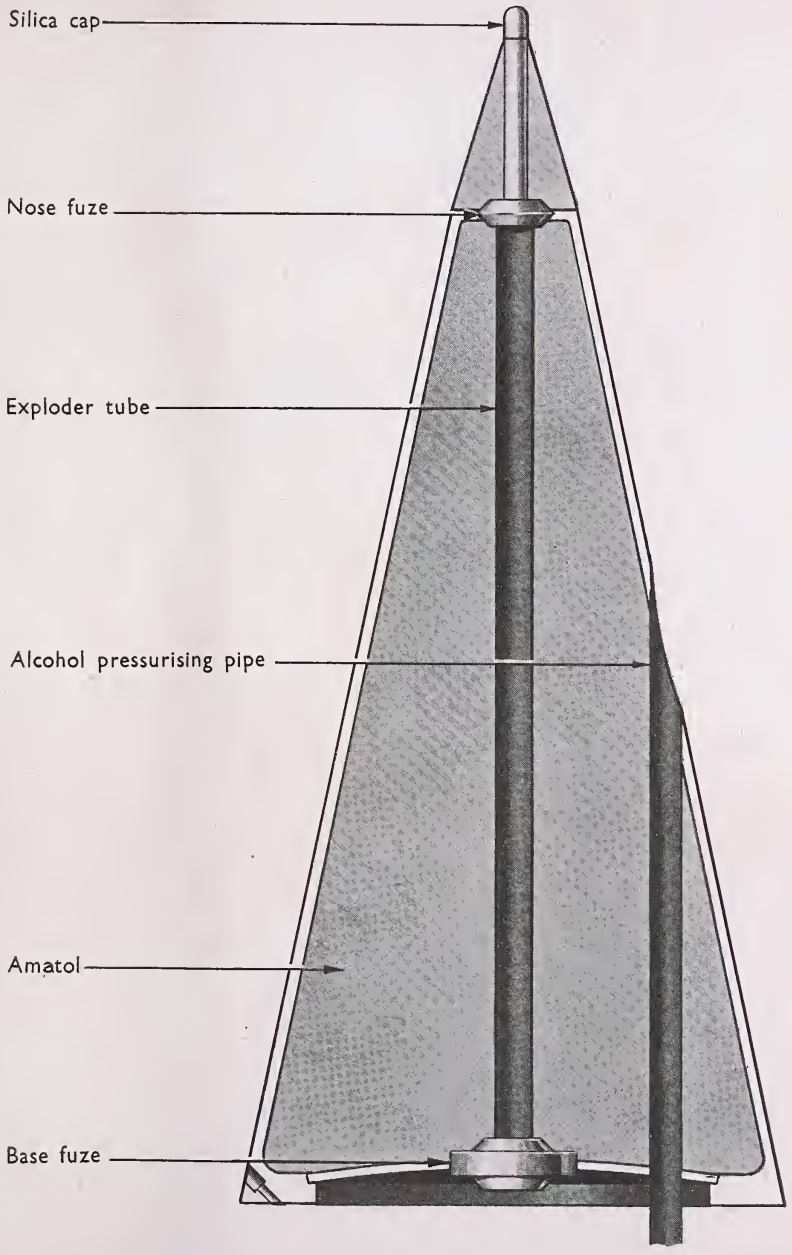
DETAILS

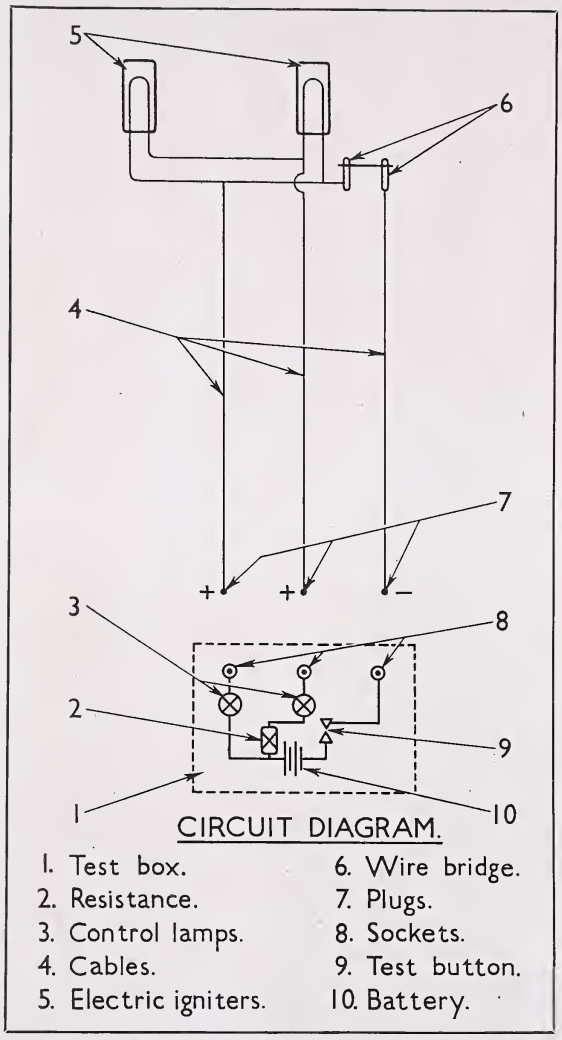
Total weight	= 3·2 lb.
Time of burning	= 10 secs.
Time from ignition to breaking of wire bridge	= 2·5 secs.
Fire voltage	= 4·5 volts.
Flame temperature	= 1,400 deg. C. approx.
Speed	= 400 r.p.m.

307. THE WARHEAD (see Plate 77)

The warhead exhibits no unusual features. It is conical shape to comply with the aerodynamic outline of the rocket and contains the explosive charge of amatol and the exploding and fuzing system. Externally there are three holes in the casing. Two situated opposite each other and about half-way from the nose are blind holes into which can be screwed suitable lifting eyes; the third hole, which is about one-fifth of the way from the nose, runs right

THE WARHEAD


Silica cap
Nose fuze
Exploder tube
Alcohol pressurising pipe
Amatol
Base fuze



CIRCUIT DIAGRAM.

1. Test box.
2. Resistance.
3. Control lamps.
4. Cables.
5. Electric igniters.
6. Wire bridge.
7. Plugs.
8. Sockets.
9. Test button.
10. Battery.

Fig. 177

through the warhead to the base and forms the inlet pipe for the alcohol pressurising system. In addition, there is the normal central exploder tube. It is described in RAE Report No. 288/4.

The fuze system consists of two electric fuzes, one situated in the nose of the warhead and the other in the base. These are described in some detail in RAE Report No. EL 1362.

The base fuze consists essentially of two inertia switches set at right angles to each other, one in a plane at right angles to the major axis of the rocket and the other parallel to this axis. The switches are connected in parallel, and the combination is in series with the supply and electric detonator which is situated in the centre of the base of the fuze. The fuze circuit is finally completed through an electrical unit in the control compartment (sterg).

The nose fuze is exactly similar to the base fuze with the addition of a nose contact switch. This nose switch, which consists of a central electrode and an outer dome electrode suitably weakened to allow of contact being made on comparatively light collision, is situated at the forward end of a long tube fixed to the fuze body and running up to the apex of the streamlined head, and is protected against premature collapse by a domed cover made of fuzed silica. The contact switch is in parallel with the two inertia switches; the circuits of both fuzes are in parallel.

The fuzes are armed, i.e. circuit on, by the sequence switch in the control compartment operating the "fuze control" (sterg), also situated in the control compartment, 40 seconds after launching.

The total weight of the warhead filled and fuzed is adjusted to 1,000 kilogrammes (2,204 lb.).

308. The rocket thrust is produced by the combustion of alcohol with oxygen in the ratio of approximately ·8 to 1 by weight. These fuels are delivered for combustion through pumps driven by a steam turbine, the steam for which is generated through the decomposition of concentrated hydrogen peroxide and sodium permanganate. The nature and quantity of these fuels are as follows :—

309. Alcohol

The alcohol used is ethanol (ethyl alcohol) containing 25 per cent. by weight of water, this mixture having a specific gravity of 0·86 at 15 per cent. It is important that no solid impurities be present which would choke the jets in the combustion chamber nozzles.
The quantity required for each rocket is 3,700 kg. or 8,150 lb.
The plants producing ethanol were located in various parts of the country, and so far as is known no plant was specially built for the sole supply of the A-4 programme. The capacity of some plants was no doubt increased, but no great difficulty seems to have been met in supplying the demands.
The raw material from which the bulk of the spirit was distilled was potatoes, and the yield of alcohol was of the order of 10 per cent. by weight, i.e. about 28 gallons per ton of potatoes having a 20 per cent. starch content. The quality supplied was "industrial alcohol," containing about 5 per cent. water and often containing a denaturant to make it unfit for human consumption.
The precautions to be taken in the handling of this fuel are similar to those in operation for petrol or other high inflammable liquids.

310. Oxygen

The liquid oxygen used must have a purity of not less than 98 per cent., the impurity being mainly nitrogen. It is important that this be free of oil which would cause explosions in the pumps. The specific gravity is 1·12 and at atmospheric pressure it boils at —183 degrees C.
The quantity required for each rocket is 5,000 kg. or 11,000 lb.
The demand for liquid oxygen was one that could not be met by existing industrial plants. This resulted in the construction of plants solely for the purpose of supplying the A-4 requirements.
Two such factories are known to have been built, one in the Saar capable of producing 120 tons per day, the other in Thuringia producing 160 tons per day. Plans had also been made to convert certain ammonia plants in the Ruhr to produce liquid oxygen.
Oxygen is extracted from the air by liquidification and subsequent rectification of the liquid. This involves compression of the air to at least 160 atmospheres, entailing a considerable power demand. The purity of the oxygen produced is approximately 99 per cent., and it is a characteristic of the liquid that it cannot be stored without loss ; hence, in transport, time is a vital factor to be considered.
Oxygen itself does not burn, but actively supports and accelerates combustion. Combustible materials saturated in oxygen ignite explosively and highly inflammable liquids explode with oxygen in certain proportions. It is important, therefore, that no naked light or glowing material be brought near combustible materials in an oxygen ridden atmosphere. Asbestos clothing should be worn when handling the liquid since contact with the body causes severe scalds.

311. Hydrogen Peroxide

The quality used is known as TSS, which contains as stabilisers 25 mgs/litre of phosphoric acid and 100 mgs/litre of ortho-oxy-quinoline. The concentration must be between 78·5 and 80 per cent., the remainder being water. The specific gravity of this concentration is about 1·345. It is important that no foreign matter be present in this peroxide which would then be liable to decomposition.
The quantity required for each rocket is 126 litres or 370 lb.
Concentrated hydrogen peroxide was not a normal industrial demand, and to meet the requirements of the A-4 and other war programmes a special plant had to be built. This plant was built at Bag Lauterberg in the Hars district and was capable of producing over 35 tons per day. A second factory was in course of construction nearby.
Briefly, the peroxide is produced by electrolysing a solution of ammonium bisulphate to form the persulphate. This is then treated with sulphuric acid to give hydrogen peroxide of a concentration of about 30 per cent. The further concentration is carried out by successive distillation and rectification, giving finally a concentration of about 84 per cent.
Large quantities of steam are required for the concentration plant and power for the electrolytic cells.
The storage of the concentrated peroxide demands certain precautions, and stabilisers are added according to the use of the peroxide.
Concentrated hydrogen peroxide in contact with inorganic matter decomposes rapidly with an evolution of heat giving an oxygen rich atmosphere. The heat evolved is sufficient to ignite combustible materials, especially clothing. Peroxide burns the skin and blisters rapidly. Protective clothing, gloves and goggles must be worn, these to be made preferably of mipolam or pure rubber.
It is important that no sand, earth or pieces of metals be introduced into the peroxide. These are liable to start decomposition of the peroxide which may lead to an explosion if the temperature rises high enough. Explosion due to rapid decomposition is certain above 90 degrees C. Storage of the peroxide is safer in large containers than in smaller containers.

Troops handling this product must be specially trained and aware of the dangers involved. Special care must be taken to keep the equipment clean and free from contamination and adequate supplies of water must be available for dilution of spilt liquid.

312. SODIUM PERMANGANATE

The solution required is a 27·5 per cent. concentration by weight with water. The specific gravity of this mixture is about 1·245 at 20 degrees C. For this application the crystals must be chemically pure and the solution must not contain any impurities or undissolved crystals.

This being a simple solution and a moderate requirement sufficient supplies were forthcoming from existing sources. It is a stable liquid, and apart from the fact that it stains the skin and tends to burn, is quite harmless. Gloves, however, should be worn.

313. TRANSPORT OF FUELS

In all cases supplies generally left the factories by rail and were delivered to central stores from whence they were delivered by road vehicles to the launching site. These vehicles are described in Section 5 of this report and were designed to carry quantities bearing a relation to the individual rocket requirements.

Capacities of the vehicles are as follows :—

Alcohol Tankers	2,900 litres or 2,500 kg.	2 required for rocket
Oxygen Tankers	6,000 litres or 6,700 kg.	1 required for rocket
Hydrogen Peroxide	2,100 litres	1 required for 16 rockets
Sodium Permanganate	11 litre cans	1 required for rocket

314. TRANSFER OF FUELS TO THE ROCKET

The special vehicles carry or tow as accessories the necessary equipment for transferring the fluids from the tankers to the rocket tanks.

The alcohol is transferred through a power pumping set mounted on a trailer which is equipped with a flowmeter. It takes about twenty minutes to fill the rocket tank, the suction side of the pump having a twin connection drawing from the two tankers simultaneously.

The liquid oxygen is transferred by means of a power driven centrifugal pump which is hung on the frame of the oxygen tanker. Once the pump is cooled down the rocket tank is filled in about twelve minutes.

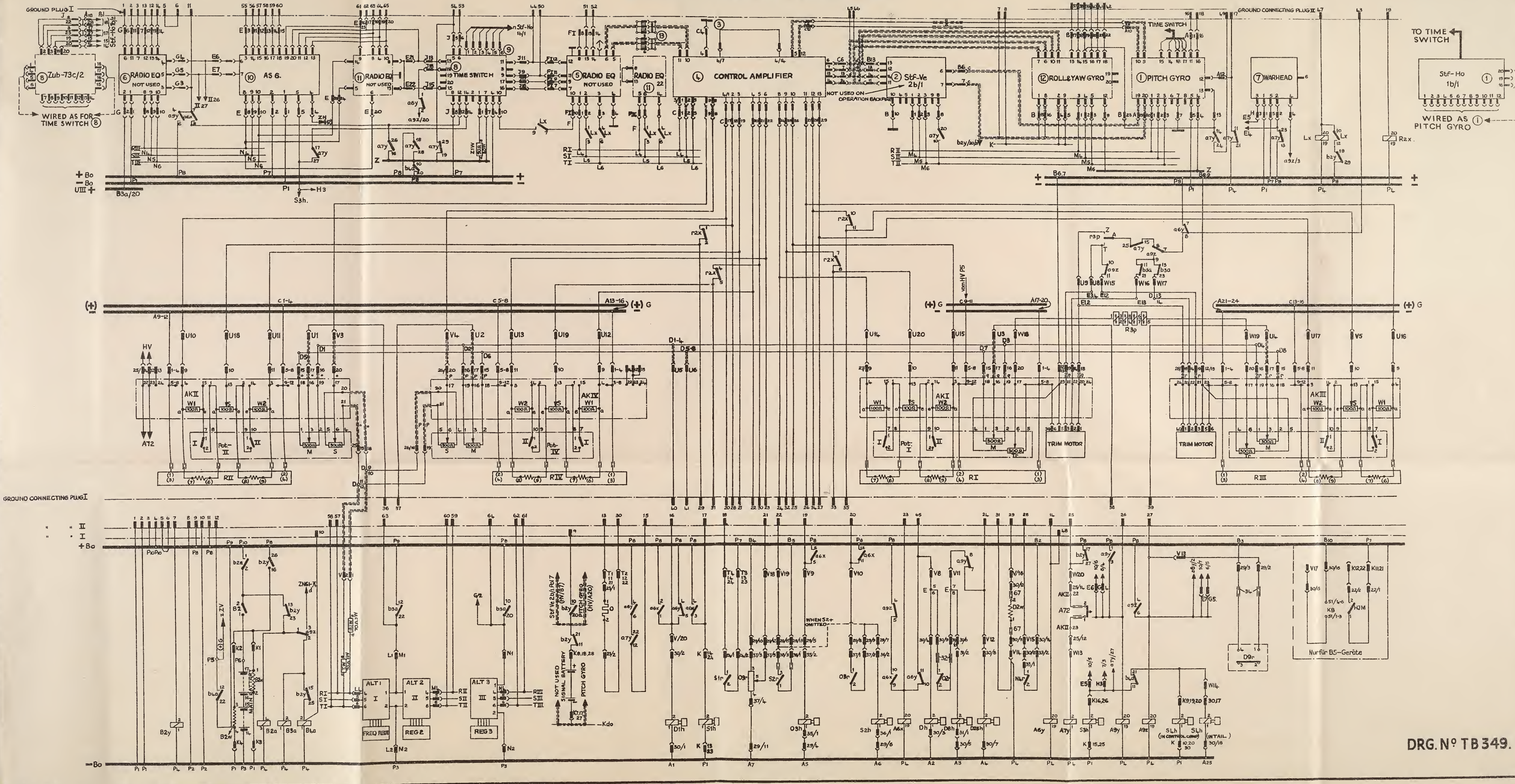
The hydrogen peroxide is filled into the Meilerwagen tank by means of a semi-rotary hand hump and takes up to five minutes. From the Meilerwagen tank it gravitates to the rocket tank.

A power pump is fitted in the peroxide tanker, but is seldom used by the troops.

In cold weather (below about —10 degrees C.) the peroxide must be heated to prevent freezing, and this is done in a special preheating tank assembled on a trailer. This tank holds sufficient for one charge.

The sodium permanganate is poured into the rocket tank from the can through a funnel. Before pouring, the permanganate is heated slightly to obviate the presence of crystals and to ensure the desired even decomposition of the peroxide. This heating is done simply by leaving it near a running I.C. engine.

ROCKET CIRCUIT DIAGRAM.



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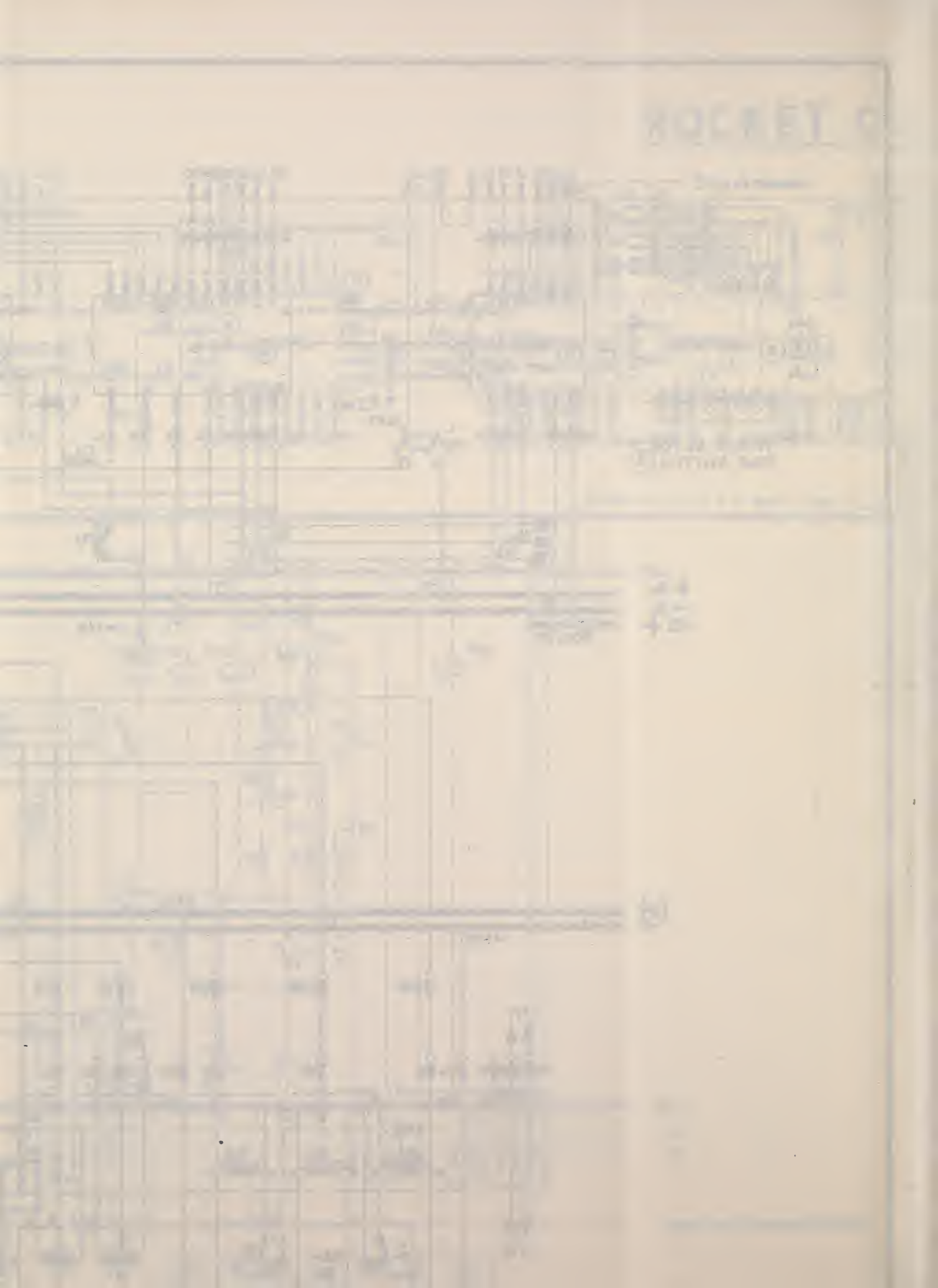


CIRCUIT FOR CONTROL AMPLIFIER.

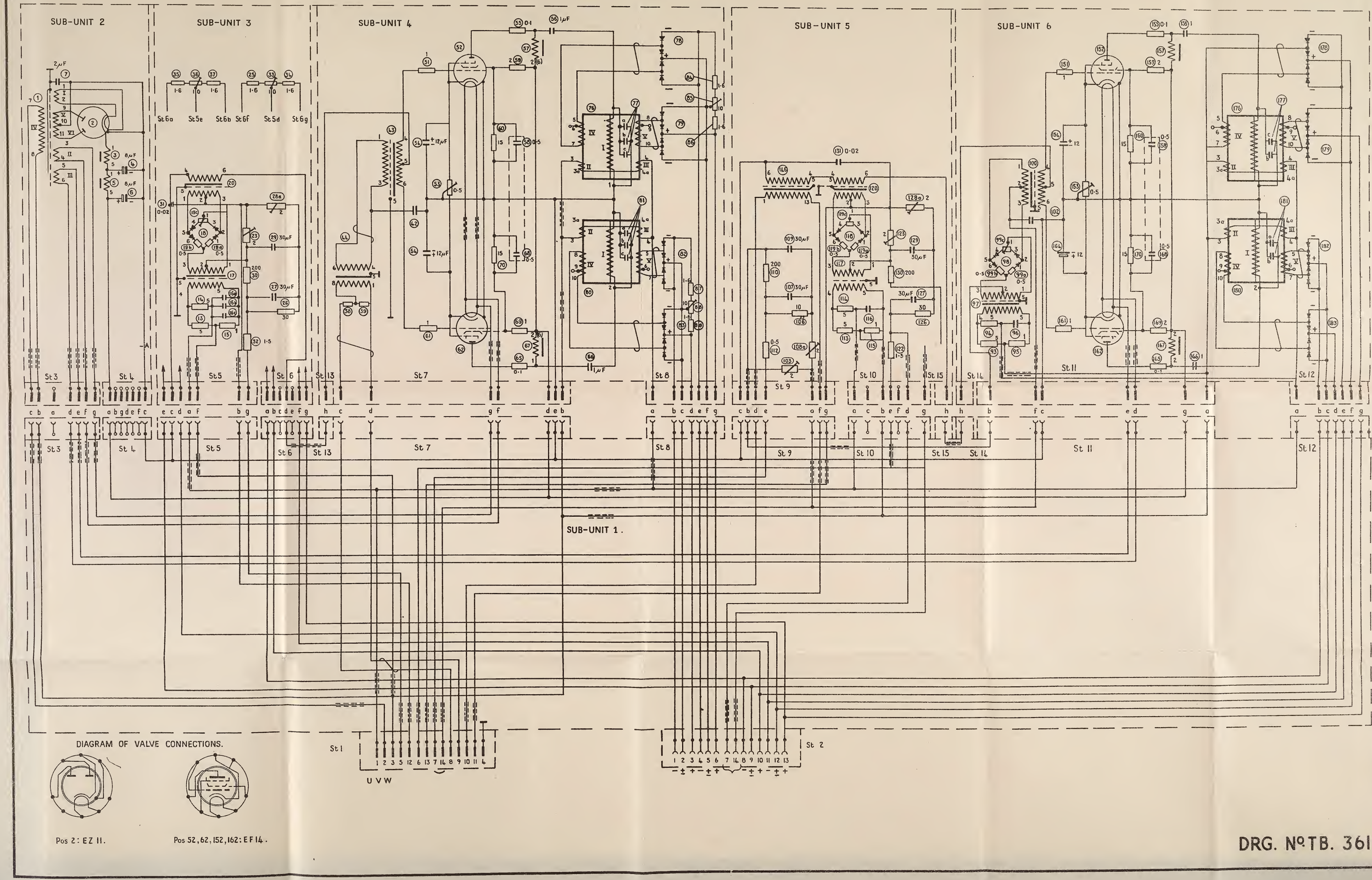
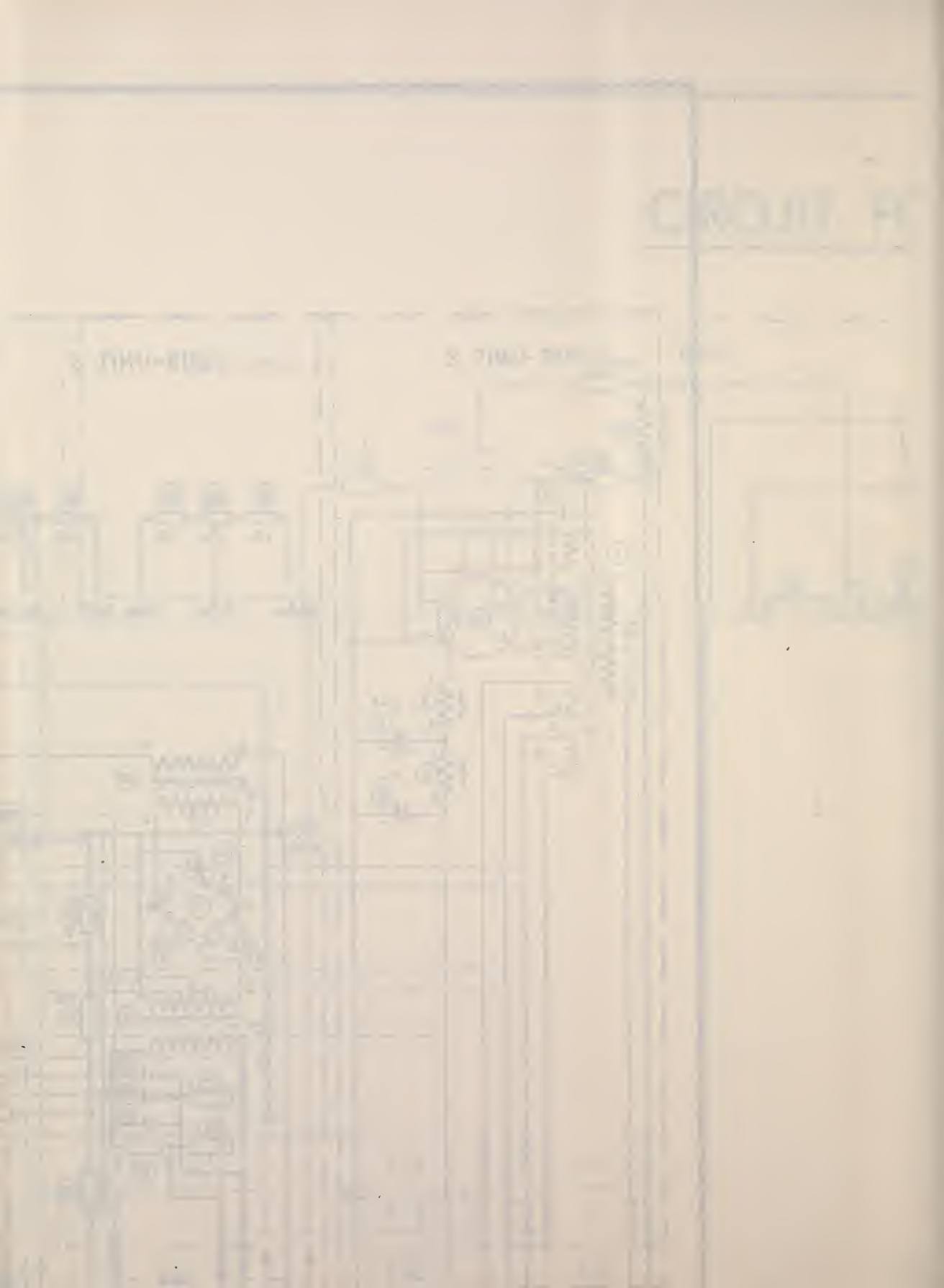


DIAGRAM OF VALVE CONNECTIONS.

Pos 2: EZ 11.

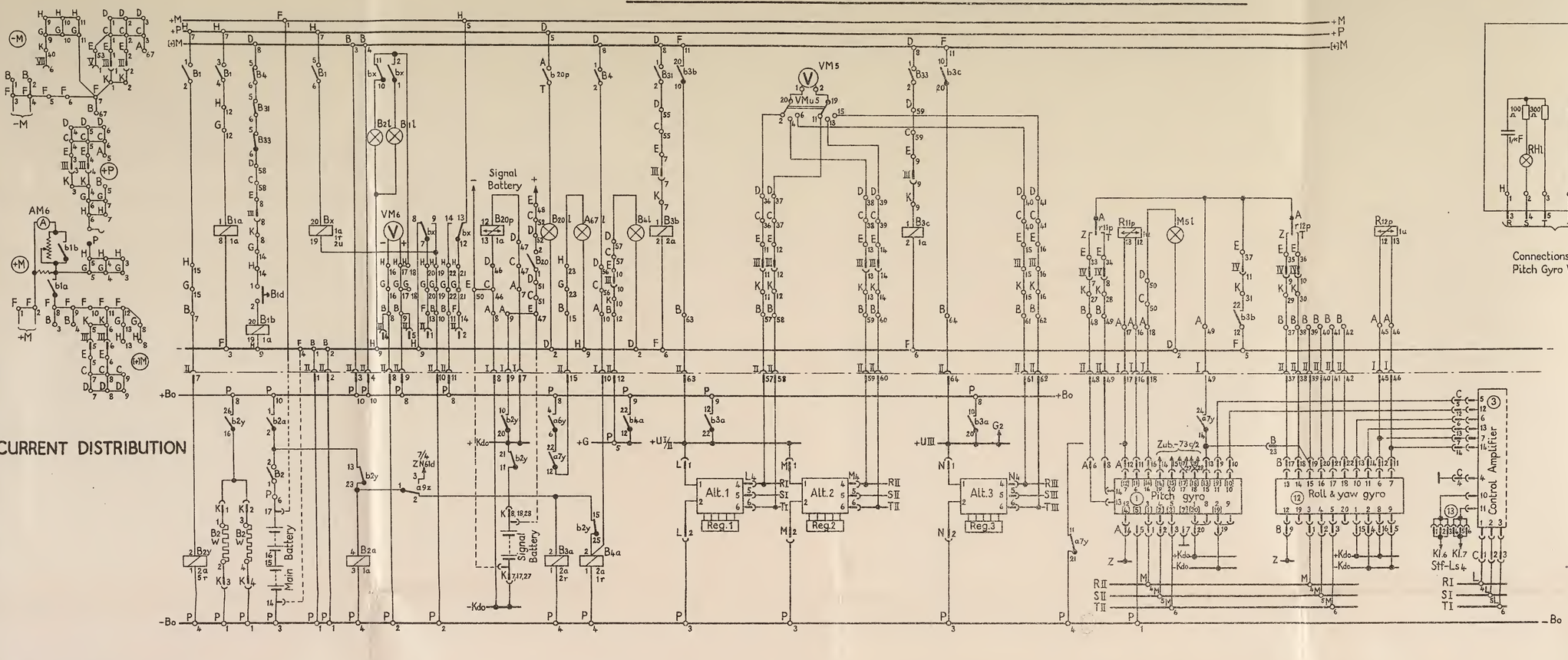
Pos 52, 62, 152, 162: EF 14.

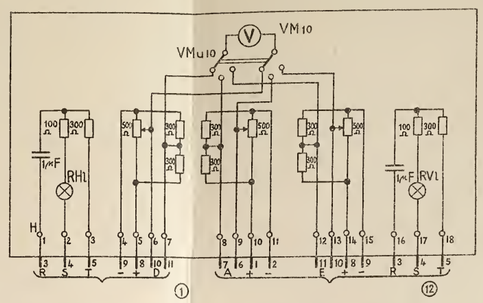
DRG. Nº TB. 361.



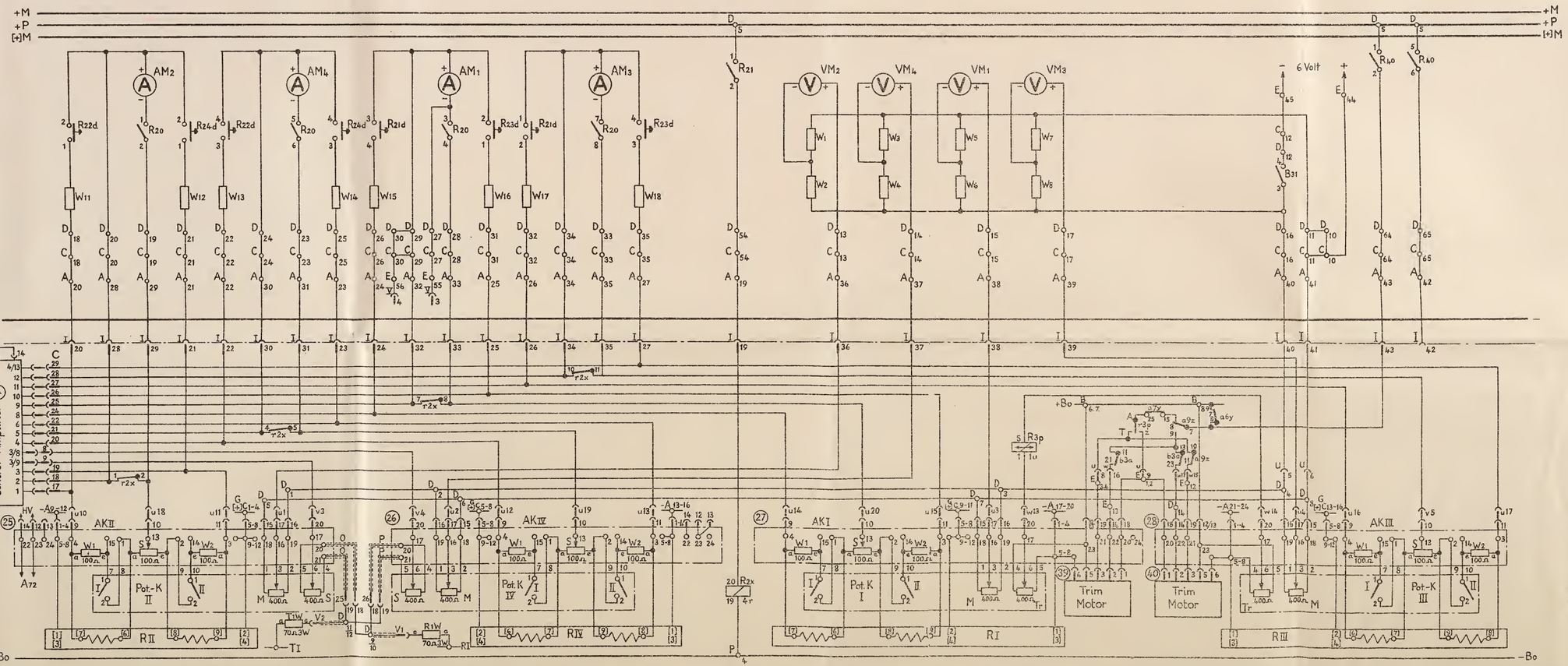
CIRCUIT FOR ASSEMBLY TEST DESKS (SHEET 1.)

CURRENT DISTRIBUTION

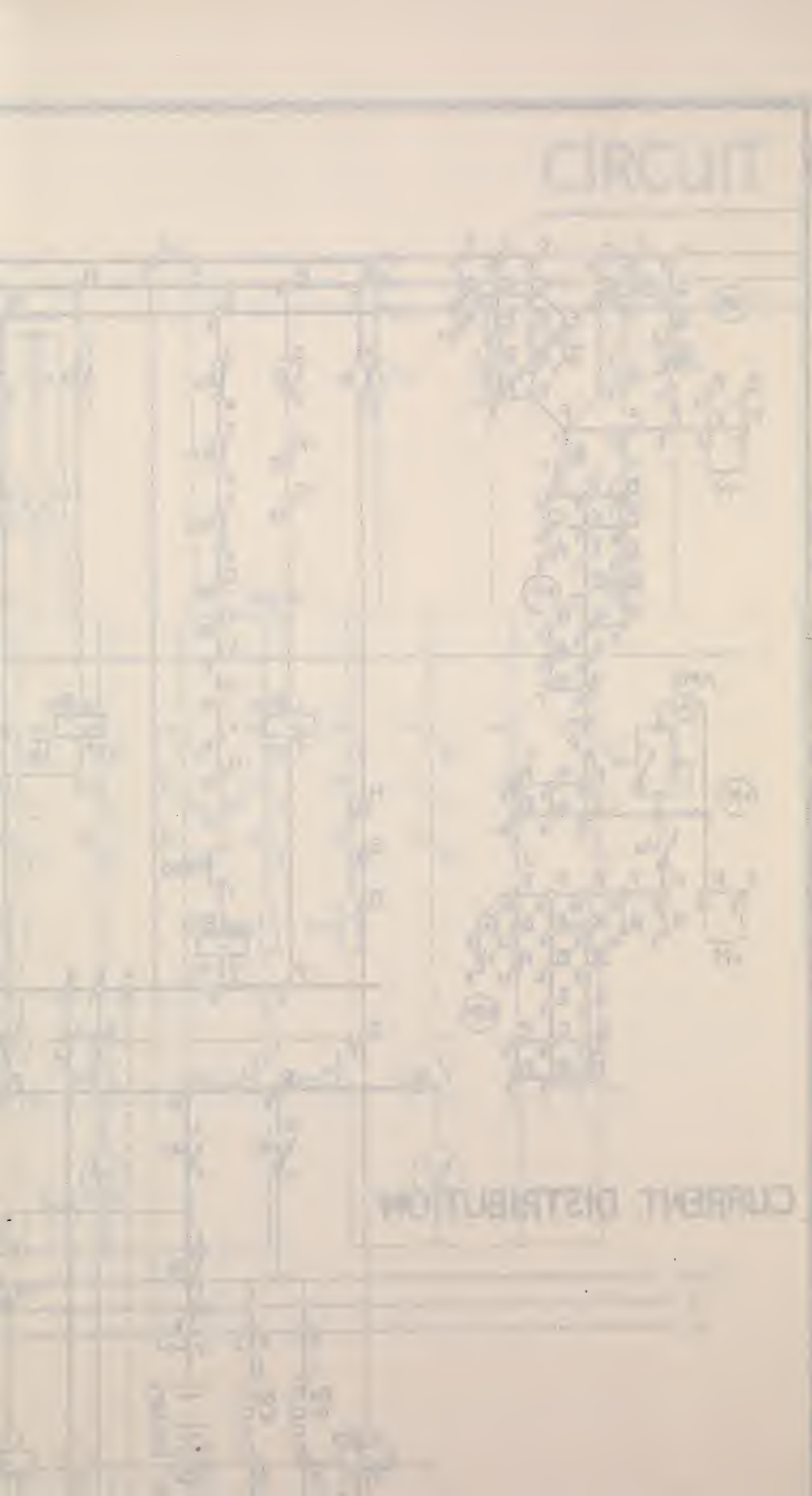




TEST BOX

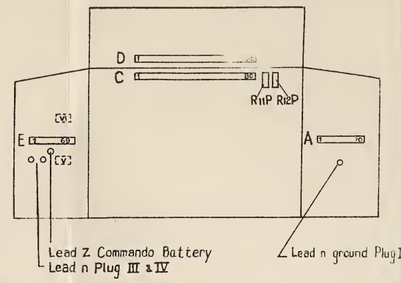


DRG. Nº 356
(SHEET 1)

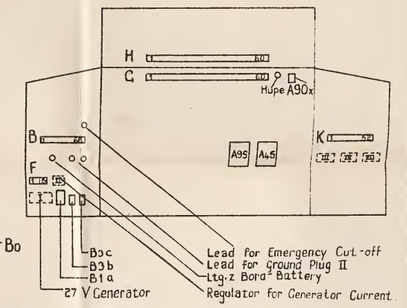


CIRCUIT FOR ASSEMBLY TEST DESKS. (SHEET 2.)

TEST DESK FOR CONTROL SYSTEM



TEST DESK FOR VALVE SYSTEM.



RADIO EQUIPMENT NOT USED ON OPERATION BACKFIRE.

Not used on Operation Backfire.

DRG.Nº T.B.356
(SHEET 2)

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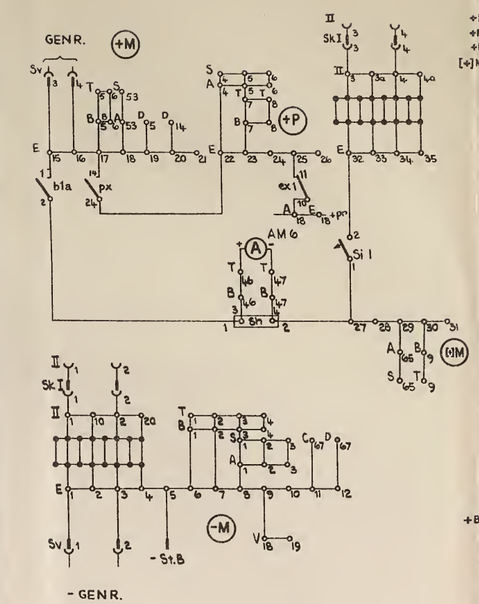
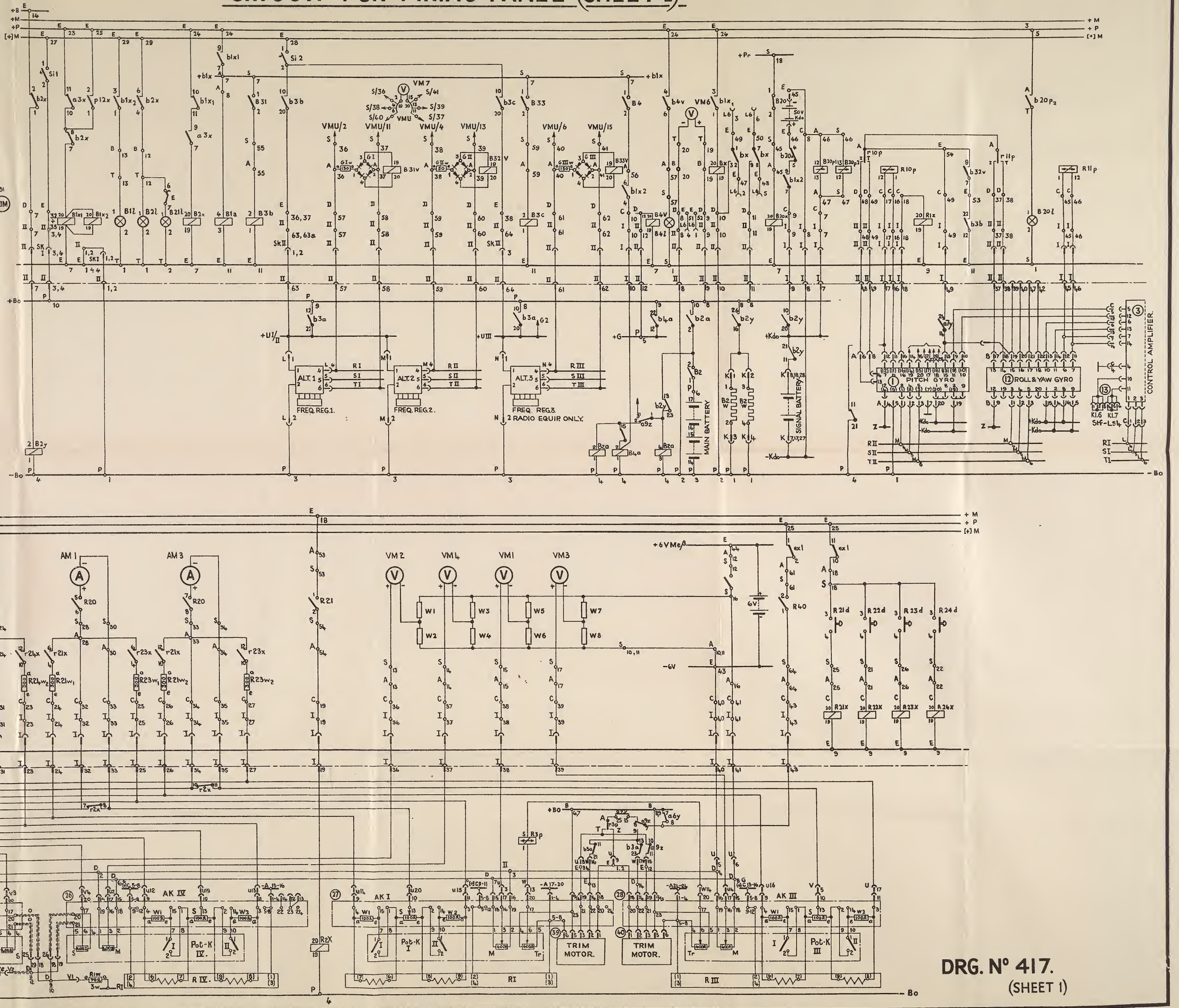
CIRCUIT FOR FIRING PANEL (SHEET 1)



Current Distribution.



DRG. Nº 417.
(SHEET 1)

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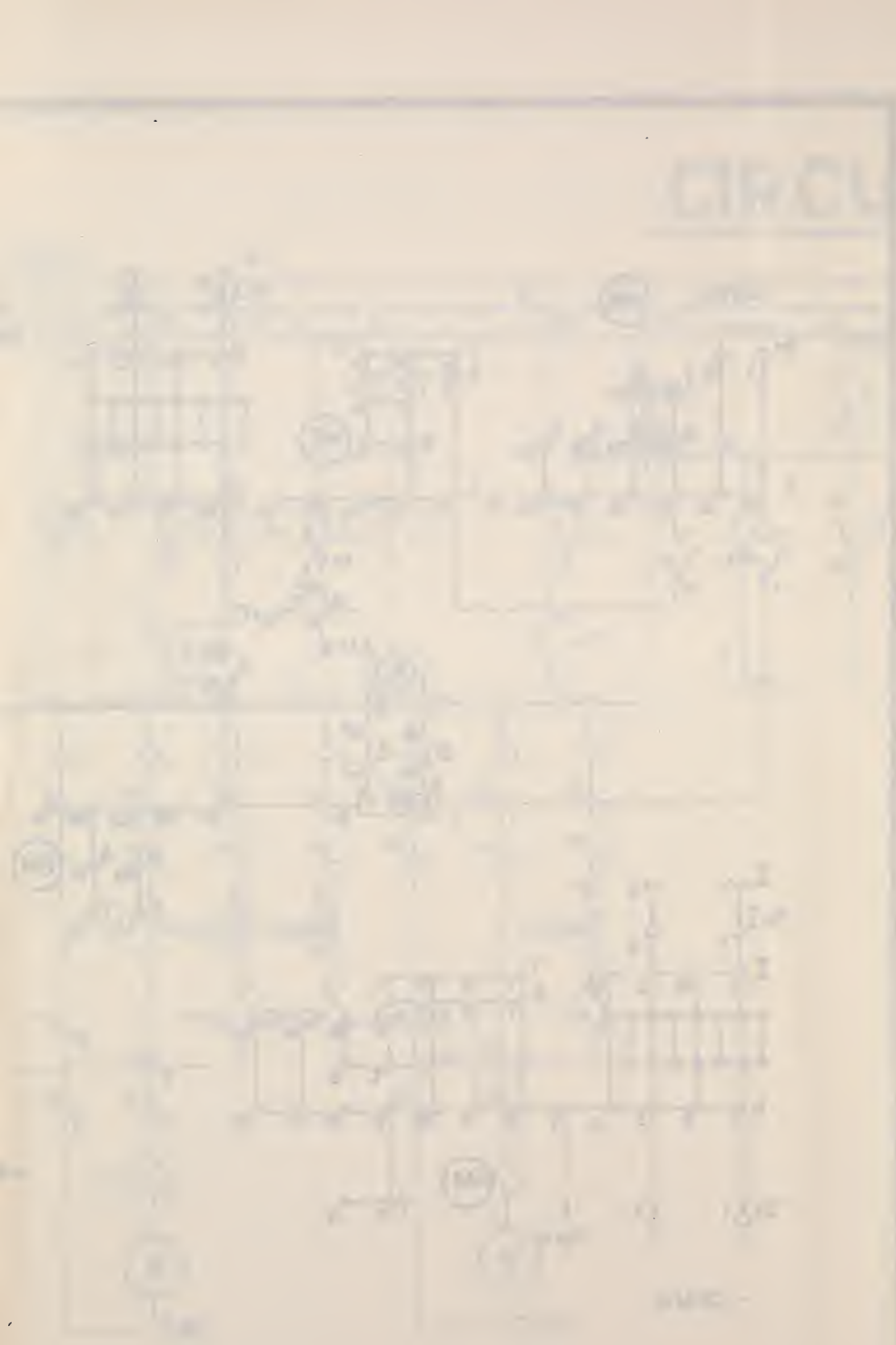

CIRCUIT FOR FIRING PANEL (SHEET 2)

+M
+P
(+)M
-Bo
+Bo
+B

When S2r is omitted.

Telephone.

8 Time or Sequence Switch

Pitch Gyro.

Strf-LS 4

FT-Kdo 22

7 Warhead

6V Zü

27V

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