AMENDMENT RECORD SHEET

Incorporation of an Amendment List in this publication is to be recorded by signing in the appropriate column and inserting the date of making the amendments.

A.L.No.	AMENDED BY	DATE	A.L.No.	AMENDED BY	DATE
1-13	Incorporated in this reprint	June 1951	38		
			39		
14			40		
15			41		
16	C. Deckcoat	17.1.52	42		
17	C. Deckcoat	10.7.52	43		
18	D. Medcraft	9.9.52	44		
19	C. Glover	22.9.52	45		
20	C. Glover	9.12.52	46		
21	C. Glover	26.6.53	47		
22			48		
23	D.D. Bennett	5/54	49		
24	D.D. Bennett	5/54	50		
25	D.D. Bennett	6/54	51		
26	B.G. Buck	17/5/62	52		
27 ✓	"	"	53		
28 ✓	"	"	54		
29 ✓	"	"	55		
30 ✓	"	"	56		
31 ✓	"	"	57		
32 ✓	"	"	58		
33 ✓	"	"	59		
34 ✓	"	"	60		
35 ✓	B.G. Buck	17/5/62	61		
36			62		
37			63		

(Continued overleaf)

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★An Amendment Record Continuation Sheet (R.A.F. Form 2096B) will be required when this page is full. Order it now.

LETHAL WARNING

EJECTION SEATS AND CANOPY JETTISON MECHANISMS

1. Ejection seats and canopy jettison mechanisms are sources of potential danger to personnel and of damage to the aircraft. Serious injury (possibly fatal) may result if any firing mechanisms are inadvertently operated whilst the aircraft is on the ground.

2. The following instructions are to be obeyed:—

R.N. **Safety Precautions contained in A.P.(N.)140—Naval Aircraft Maintenance Manual.**

R.A.F. **ALL PERSONNEL before entering the cockpit or cabin of an aircraft fitted with an ejection seat are to report to the N.C.O. immediately in charge of airframe servicing who is to ensure that all safety pins (or other safety devices) are correctly positioned to render the seat and canopy jettison firing mechanisms safe. On completion of servicing, tradesmen are to report to the N.C.O.**

3. Full instructions for rendering the firing mechanisms safe are contained in the A.P.4288 and A.P.(N.) 1023 series, in Aircraft Servicing Schedules and in the A.D.5037 series.

NOTE TO READERS

The subject matter of this publication may be affected by Admiralty Fleet Orders, Air Ministry Orders, or by " General Orders and Modifications " leaflets in this A.P., in the associated publications listed below, or even in some others. If possible, Amendment Lists are issued to correct this publication accordingly, but it is not always practicable to do so. When an Order or leaflet contradicts any portion of this publication the Order or leaflet is to be taken as the overriding authority.

Each leaf bears the date of issue and, when applicable, the number of the Amendment List with which it was issued. New or amended technical information on new leaves which are inserted when this publication is amended will be indicated by a vertical line in the margin. This line merely denotes a change and is not a mark of emphasis. When a Section or Chapter is issued in a completely revised form, the line will not appear.

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LIST OF ASSOCIATED PUBLICATIONS AND AIR DIAGRAMS

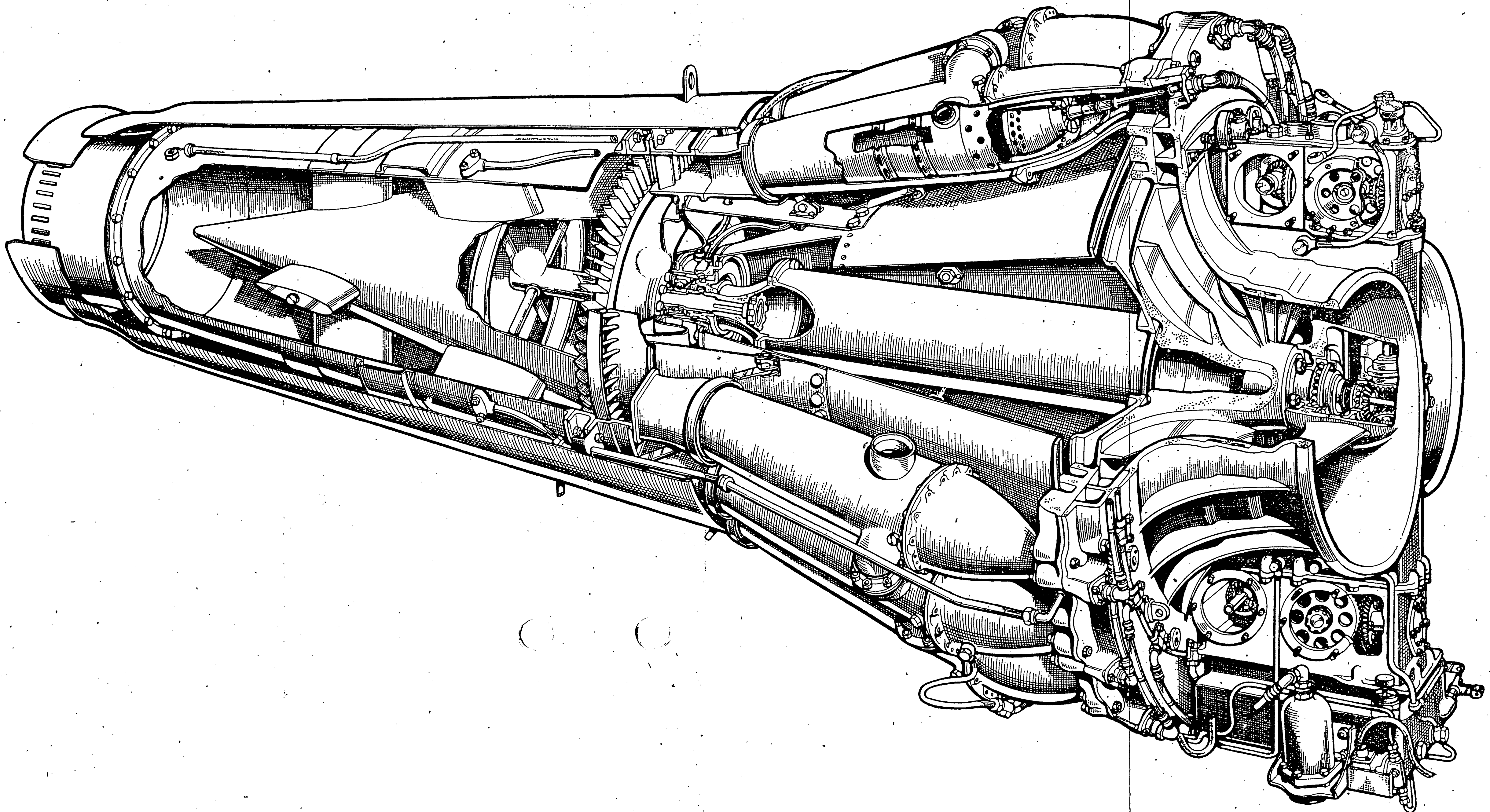
	A.P.
Aero-engine ignition equipment	*1374 Series*
Aircraft hydraulic equipment—Lockheed	*1803B*
Aircraft pneumatic equipment—Hymatic	*4303C*
Electrical equipment manual—general (airborne)	*1095A*
Fuel system components (general) for gas turbine aero-engines	*4282*
Fuel system components (Lucas) for gas turbine aero-engines	*4282A*
Instrument manual—general instruments	*1275A*
R.A.F. engineering and relevant Aircraft Publications and Pilot's Notes	*1464 Series*

	A.D.
Goblin Mk. 2 aero-engine	*4614*
Goblin Mk. 2 Servicing information	*4481*

	R.N.D.
Goblin Mk. 2 Combustion chamber and burner	*ON 682*
Goblin Mk. 2 Fuel system (Sheet A)	*ON 680A*
Goblin Mk. 2 Fuel system (Sheet B)	*ON 680B*
Goblin Mk. 2 Rotor shaft assembly	*ON 675*

LAYOUT OF
A.P.4121B & C GOBLIN Mk. 2 AND 3 AERO-ENGINES

VOL. 1	**SECT. 1** Operation	**SECT. 2** Description
VOL. 2	**PART 1** **(Leaflets)** **General orders and modifications**	**PART 2** **Servicing schedule** **(See relevant Aircraft A.P. Vol. 2, Part 2)**
	PART 3 **Servicing**	**PART 4** **Minor repairs**
	PART 5 **Depot repair**	**PART 6** **Schedule of Fits and Clearances**
VOL. 3 **(Schedule of spare parts)**		
VOL. 6		**PART 2** **Major repairs**



GOBLIN Mk. 2 AERO-ENGINE

RESTRICTED

LIST OF SECTIONS

Note.—*A list of chapters appears at the beginning of each section*

INTRODUCTION

General

1. The Goblin jet propulsion engine uses air as the working medium and kerosine as the fuel. The air supply is drawn in through twin air-intakes at the front of the engine and after passing through the system, where it is heated and expanded, it is expelled at very high velocity through the jet pipe at the rear. By comparison with a reciprocating engine and propeller, the jet propulsion engine throws back a much smaller mass of air at a relatively higher velocity. The reaction of the jet in static pounds thrust constitutes the power rating of the engine.

Goblin Mk. 2 aero-engine

2. The engine consists of a compressor, a combustion system, a turbine, and an exhaust assembly. Air is drawn through two large intake ducts at the front of the engine by the rotating impeller of a single-stage centrifugal compressor, and discharged radially at increased velocity into sixteen specially shaped diffuser passages which are connected directly with sixteen combustion chambers placed equidistantly around the axis of the engine. Kerosine fuel, under pressure, is delivered to fixed orifice burners located in the flame tube of each combustion chamber. As the air flows through these chambers it is heated and expanded by the burning fuel; consequently, the air velocity is greatly increased and, passing from the combustion chambers, the mixture of burnt fuel and air is used to drive a single-stage axial flow turbine. The turbine wheel is mounted on the same shaft as the impeller, this assembly being the only major component of the engine which rotates.

3. The gas, after leaving the combustion chambers, is passed through a stationary ring of guide vanes set at an angle to the engine axis, and these deflect the gas so that it impinges on the blades of the turbine wheel. An angular velocity is imparted to the turbine wheel with the minimum loss of speed to the gas which then leaves the turbine in an axial direction and passes down the exhaust cone assembly to the propelling nozzle where it emerges.

4. The mass of gas discharged from the propelling nozzle is dependent upon the mass of air entering the air-intakes and, therefore, on the impeller r.p.m. The speed of the compressor depends on the power of the turbine and this is governed by the rate at which fuel is burnt in the combustion chambers. A variation in the flow of fuel to the burners causes either an increase or decrease in the rate of air expansion and this produces a sympathetic response in r.p.m. Regulation of the fuel flow controls r.p.m. and is, in fact, the throttle of the engine.

5. Fuel is delivered to an engine control box by a high-pressure pump, a barostat being interposed in the line to regulate the pressure according to altitude. From the control box the fuel passes through a starting valve to the burners; an overspeed governor is fitted in the line to prevent the engine r.p.m. from exceeding the stipulated maximum, and there is also a connection to a fuel accumulator.

Lubrication system

6. The lubrication system is self-contained: oil is supplied from a sump in the front of the engine and delivered by a pressure pump to the two bearings on the rotor shaft, and to such of the accessories as require an oil supply.

Starting system

7. The engine is started by an electric motor which rotates the turbine impeller shaft until such time as the turbine develops sufficient power to dispense with the starter motor. As conditions for successful starting are critical, the starting cycle is automatic; the engine will normally run up to its idling speed within approximately 60 seconds of pressing the starting button.

Accessories

8. The engine and aircraft accessories are mounted on the top and bottom accessory boxes on the front of the engine, and are driven through suitable gear trains from shafts driven off the front of the impeller shaft.

Instruments and controls

9. To enable the pilot to keep within Operating Limitations, an r.p.m. indicator, a jet pipe temperature gauge, and oil temperature and pressure gauges are provided in the cockpit. With the exception of the starting switches and L.P. fuel cock, there are two engine controls only, the lever controlling the throttle and the lever controlling the H.P. fuel cock.

Engine handling

10. Throughout this Air Publication the *port* side refers to the *left-hand* side of the engine facing the direction of flight, and the *starboard* side to the *right-hand* side.

LEADING PARTICULARS

GOBLIN Mk. 2

GENERAL

Type of engine	Turbo-jet
Length (to rear of exhaust cone)	100·5 in.
Arrangement of engine	Single-stage centrifugal compressor with straight-flow combustion and single-stage axial-flow turbine.
Rotation	Clockwise, viewed from the rear
Weight (net dry) with exhaust cone assembly, fireguard, fuel pumps and propelling nozzle, but excluding the electric starter and aircraft accessories	1,577 lb. + 2½ per cent.
Compressor	Single entry with bifurcated air-intake, single-stage centrifugal with single-sided impeller.
Combustion system	Straight flow
No. of chambers	16
Arrangement	Conical chambers arranged round, and with their axes inclined to, the engine axis.
Numbering	No. 1 at the top, 5 deg. to the left of the centre, and numbered clockwise viewed from the front.
Turbine	Single stage, axial flow
No. of nozzle blades	77
No. of turbine blades	83
Exhaust cone:	
Length, including propelling nozzle	52·75 in. (cold)
Diameter of propelling nozzle (internal)	16 in. (cold)
	(Mod. No. 936) 16·125 in. (cold)

Note:—No change is permitted in the size of the propelling nozzle fitted to any particular engine. The correct size to control the J.P.T. is determined by test bench calibration.

FUEL SYSTEM

Fuel	Aviation turbine fuel 100, AVTUR (Stores Ref. 34A/179) Spec. D.Eng. R.D.2482.
	Aviation turbine gasoline, AVTAG (Stores Ref. 34A/251) Spec. D.Eng. R.D. 2486, Vol. 2, leaflet A.P.1464C/4 refers.
Fuel pump	Dowty A.260Y Mk. 5
	Dowty Eng. 300 Mk. 1 (Mod. No. 724)
	Dowty Eng. 300 Mk. 2 (Mod. No. 904)
Speed of rotation	1/3 x engine speed
Max. pump pressure	1,000 lb. per sq. in.
Governor	D.H. Mk. 4
Governing speed	Maximum r.p.m.
Speed of rotation	1/3 x engine speed
Barostat	Lucas ACU/M18 and ACU19/1A
	(Mod. No. 939) Lucas ACU19/1A
Control box	D.H. Mk. 16
Accumulator	Lucas—A2/1A
Pressure limiting valve	Hobson, Mk. 8
Burner, atomiser	Lucas F.A.20/21/22/23
Element	Fixed orifice with 83 deg. spray angle (four different calibrations for burners)

LUBRICATION SYSTEM

Type .... *Self-contained. Oil carried in sump. Pressure oil to main bearings and governor via metering pumps*

Oil .... *OM-71 (Stores Ref. 34A/187). Key letter B*
OEP-71 (Stores Ref. 34A/206). Key letter V

Consumption max. .... *2 pints per hour*

Pressures and temperature .... *see Operating Limitations*

IGNITION SYSTEM

Type .... *Two K.L.G. 994/9 or Lodge LH100 igniter plugs energized by two B.T.H. C2TS booster coils.*
High energy ignition system (Mod. No. 894). Two K.L.G. 164 or Lodge 324-1 igniter plugs energised by two B.T.H. C10TS/2 condenser units.

Igniter plug gap .... *K.L.G. 994/9 0·060 ± 0·002 in.*
Lodge L.H.100 0·040 to 0·045 in.

STARTING SYSTEM

Starter .... *Rotax C.3804/1, 24v.*

Type .... *Electric turning gear with Bendix engaging mechanism*

ACCESSORIES

The following accessories are approved for this engine. The specific accessories for any particular installation will be found in the relevant aircraft Air Publication.

Accessory	Speed of accessory relative to impeller shaft	Direction of rotation looking on driving spindle of accessory
Starter motor (Rotax C.3804/1)	0·984 (Internal Gears 3·305:1)	Clockwise
Tachometer generator Mk. 7A (Stores Ref. 6A/1560)	0·25	Counter-clockwise
Vacuum pump (B3X Mk. 2)	0·311	Clockwise
Hydraulic pump (Lockheed Mk. 6, or Mk. 7)	0·149	Clockwise
Generator (Newton HX.2, 29V., 50A) .... (Type KX., 29V., 60A) (B.T.H. O.2, 29V., 100A)	0·618	Counter-clockwise
Cabin supercharger (Marshall Mk. 22)	0·618	Clockwise
Compressor (Hymatic SH6/2A)	0·143	Clockwise

LEADING PARTICULARS

GOBLIN Mk. 3

GENERAL

Type of engine	Turbo-jet
Length (to rear of exhaust cone)	100·5 in.
Arrangement	Single-stage centrifugal compressor, straight flow combustion and single-stage axial-flow turbine.
Rotation	Clockwise, viewed from the rear
Weight (net dry) with exhaust cone assembly, fireguard, fuel pumps and propelling nozzle, but excluding the electric starter and aircraft accessories	1,620 lb. (dual pump) 1,580 lb. (single pump)
Compressor	Single entry, single-stage centrifugal, with bifurcated air-intake
Combustion system	Straight flow
No. of chambers	16
Arrangement	Conical chambers, arranged round the engine axis
Numbering	No. 1 at the top, 5 deg. to the left of the centre, and numbered clockwise viewed from the front
Turbine	Single stage, axial flow
No. of nozzle blades	77
No. of turbine blades	83

Exhaust cone :

Length, including propelling nozzle	52·75 in. (cold)
Diameter of propelling nozzle (internal)	Pre-mod. 820, 16·5 in. (cold) Mod. No. 820, 16·375 in. or 16·5 in. (cold)

Note:—No change is permitted in the size of the propelling nozzle fitted to any particular engine. The correct size to control the J.P.T. is determined by test bench calibration.

FUEL SYSTEM

Fuel	Aviation turbine fuel 100, AVTUR (Stores Ref. 34A/179) D. Eng. R.D.2482 Aviation turbine gasoline, AVTAG (Stores Ref. 34A/251) Spec. D.Eng. R.D. 2486. Vol. 2, leaflet A.P.1464C/4 refers.
Fuel pump (dual pump system)	Lucas, Port G.C. 16/9J or G.C. 236/10J Lucas, Starb. G.C. 15/24J or G.C. 237/11J
(single pump system)	Lucas G.C. 221/19N (Mod. No. 700) 221/19AH (Mod. No. 941)
Speed of rotation	1/3 x engine speed
Governor	Incorporated in fuel pumps
Governing speed	Maximum r.p.m.
Barometric pressure control	Lucas B.P.C. 3/7G Lucas B.P.C. 11/7G (Mod. No. 898)
Control box	D.H. Mk. 13
Accumulator	Lucas A2/2A
Pressure limiting valve	Hobson, Mk. 9
Burner, atomiser	Lucas F.A. 52/53/54/55/57/58
Element	Fixed orifice with 83 deg. spray angle (six different calibrations for burners)

LUBRICATION SYSTEM

Type .... *Self-contained. Oil carried in sump. Pressure oil to main bearings via metering pumps*

Oil .... *OM-71 (Stores Ref. 34A/187). Key letter B*
OEP-71 (Stores Ref. 34A/206). Key letter V
OM-31 (Stores Ref. 34A/200). Key letter Q
OX-38 (Stores Ref. 34A/266 Key letter S

Note.— *Embodiment of modifications No. 867 and 951 is essential standard for the use of oil OX-38*

Consumption max. .... *2 pints per hour*
Pressures and temperature .... *see Operating Limitations*

IGNITION SYSTEM

Type .... *Two K.L.G. 994/9 or Lodge LH100 igniter plugs energized by two B.T.H. C2TS booster coils.*
High energy ignition system (Mod. No. 830), Two K.L.G. 164 or Lodge 324-1 igniter plugs energized by two B.T.H. C10TS/2 condenser units.

Igniter plug gap .... *K.L.G. 994/9 0·060 ± 0·002 in.*
Lodge L.H./100 0·040 to 0·045 in.

STARTING SYSTEM

Starter .... *Rotax C.3804/1, 24 v.*
Type .... *Electric turning gear with Bendix engaging mechanism.*

ACCESSORIES

The following accessories are approved for this engine. The specific accessories for any particular installation will be found in the relevant aircraft Air Publication.

Accessory	Speed of accessory relative to impeller shaft	Direction of rotation looking on driving spindle of accessory
Starter motor (Rotax C.3804/1)	0·984 (Internal Gears 3·305:1)	Clockwise
Tachometer generator Mk. 7A (Stores Ref. 6A/1560)	0·25	Counter-clockwise
Vacuum pump (B3X Mark 2)	0·311	Clockwise
Hydraulic pump (Lockheed Mk. 6 or Mk. 7)	0·149	Clockwise
Generator (B.T.H. 0. 2, 3 kw.)	0·618	Counter-clockwise
Alternator (Newton. U.2)	0·618	Clockwise
Compressor (Hymatic SH6/2A)	0·143	Clockwise

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September, 1960 AP8

Air Publication 4121B & C,
Volume 1

ADMIRALTY
AIR MINISTRY

GOBLIN MK.2 & 3 AERO-ENGINES

ADVANCE INFORMATION LEAFLET NO.1/60

Insert this leaflet in A.P.4121B & C, Vol.1, to face the Operating Limitations for Goblin Mk.2 aero-engines.

GOBLIN MK.2 AERO-ENGINES
OPERATING LIMITATIONS

1. Experience with Goblin engines, in which Modification 1087 has been embodied, shows that the recommended Operating Limitations must be revised.

(1) Where Modification 1087 has not been embodied, it is recommended that operation of the engine at speeds between 7800 and 8200 rev/min, and between 8800 and 9200 rev/min, should be kept to an absolute minimum.

(2) Where Modification 1087 has been embodied, it is recommended that operation of the engine at speeds between 8150 and 8650 rev/min should be kept to an absolute minimum.

2. It is most important to note that the restricted engine speeds differ according to the modification standard of the engine, and it is equally important to ensure that all pilots and ground personnel, who operate these engines, are aware of this, and know the modification standard of the engine which they are running. A suitable notice should be displayed in the cockpit of each aircraft; this notice must be changed if the engine is changed for one of a different modification standard.

3. Pending the issue of revised instructions, the two lines which commence with the words "Any running at" should be ignored, and reference made to this A.I.L.

Notes

(1) The information contained in this leaflet will be incorporated by normal amendment list action in due course.

(continued overleaf)

(Continued from overleaf)

(2) If, after receipt of this leaflet, an amendment list with a prior date and conflicting information is received, the information in the leaflet is to take precedence.

ENGINEER

OPERATING LIMITATIONS

GOBLIN Mk. 2

The following operating limitations must on no account be exceeded.

When an order or leaflet is found to contradict these operating limitations, the order or leaflet is to be taken as the overriding authority.

Condition	Engine Speed r.p.m.	Jet pipe temperature* deg. C	Limitations
Take-off and operational necessity	10,200	745	30 min.
Maximum continous	9,700	620	—
Approach idling	5,500	—	—
Ground idling	3,000 ± 200	600	—
Any running at	7,800 to 8,200	—	Minimum possible
Any running at	8,800 to 9,200	—	Minimum possible

***Note . . .**
These values apply only to Foster type single-point chromel-alumel thermocouples, SK.20762/1 (Assembly SK.20764/2) fitted in top position on the vertical centre line, 2 in. forward of the propelling nozzle flange.

Oil pressures

Normal (at 9,700 r.p.m.) .... 40 to 45 lb. per sq. in.
Minimum (at 9,700 r.p.m. and above) .... 25 lb. per sq. in.

Oil temperatures

Maximum .... + 80 deg. C.
Minimum .... — 10 deg. C.

Rear bearing temp.

Maximum .... 130 deg. C. It will normally be necessary to connect a thermocouple instrument to indicate this temperature

PPY

ADMIRALTY
AIR MINISTRY

GOBLIN MK.2 & 3 AERO-ENGINES

ADVANCE INFORMATION LEAFLET NO.2/60

Insert this leaflet in A.P.4121B & C, Vol.1, to face the Operating Limitations for Goblin Mk.3 aero-engines.

GOBLIN MK.3 AERO-ENGINES
OPERATING LIMITATIONS

1. Experience with Goblin engines, in which Modification 1087 has been embodied, shows that the recommended Operating Limitations must be revised.

(1) Where Modification 1087 has not been embodied, it is recommended that operation of the engine at speeds between 7800 and 8200 rev/min, and between 8800 and 9200 rev/min, should be kept to an absolute minimum.

(2) Where Modification 1087 has been embodied, it is recommended that operation of the engine at speeds between 8150 and 8650 rev/min, and at 10500 rev/min, should be kept to an absolute minimum.

2. It is most important to note that the restricted engine speeds differ according to the modification standard of the engine, and it is equally important to ensure that all pilots and ground personnel, who operate these engines, are aware of this, and know the modification standard of the engine which they are running. A suitable notice should be displayed in the cockpit of each aircraft; this notice must be changed if the engine is changed for one of a different modification standard.

3. Pending the issue of revised instructions, the two lines which commence with the words "Any running at" should be ignored, and reference made to this A.I.L.

Notes

(1) The information contained in this leaflet will be incorporated by normal amendment list action in due course.

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(Continued from overleaf)

(2) If, after receipt of this leaflet, an amendment list with a prior date and conflicting information is received, the information in the leaflet is to take precedence.

ENGINEER

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RESTRICTED

OPERATING LIMITATIONS

GOBLIN Mk. 3

The following operating limitations must on no account be exceeded.

When an order or leaflet is found to contradict these operating limitations, the order or leaflet is to be taken as the overriding authority.

Condition	Engine Speed r.p.m.	Jet pipe temperature* deg. C.	Limitations
Take-off and operational necessity	10,600†	710	30 min.
Maximum continuous	10,250	650	—
Approach idling	5,500 (min.)	—	—
Ground idling	3,000 ± 200	600	—
Any running at	7,800 to 8,200	—	Minimum possible
Any running at	8,800 to 9,200	—	Minimum possible

***Note . . .**
These values apply only to Foster type single-point chromel-alumel thermocouples, SK.20762/1 (Assembly SK.20764/2) fitted in top position on the vertical centre line, 2 in. forward of the propelling nozzle flange.

Oil pressures

Normal (at 10,250 r.p.m.) .... 35 to 45 lb. per sq. in.
Minimum (at 10,250 r.p.m. and above) .... 25 lb. per sq. in.

Oil temperatures

Maximum .... + 80 deg. C.
Minimum .... — 10 deg. C. (using oil OEP-71)
— 20 deg. C. (using oil OM-31)
— 40 deg. C. (using oil OX-38)

Rear bearing temp.

Maximum .... 150 deg. C. It will normally be necessary to connect a thermocouple instrument to indicate this temperature.

† *To be reduced to 10,500 r.p.m. above 25,000 ft.*

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SECTION 1

OPERATION

Section 1

This Section supersedes that issued with A.L. No. 26

OPERATION

Note.—*This Section applies to Goblin Mk. 2 and 3 aero-engines*

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

General

1. This section is intended to provide a description of the principles obtaining in the operation and control of the engine on the ground and in flight. Where applicable to enable an understanding of the sequence of events reference is made to certain fuel system components, but it will be necessary to refer to Section 2, Chapter 2, for more detailed information of the function performed by these components. Precise instructions for starting, ground running and stopping the engine are contained in Vol. 2, Part 3, Sect. 2, Chap. 2, of this Air Publication, and reference must be made to the relevant Pilot's Notes for specific details of flight operation.

2. The Operating Limitations specified are those for which the engine has been approved for Service use, and infringement of these limitations may lead to defects which will render the engine unserviceable before the normal period between reconditioning has been completed.

Precautions

3. The precautions detailed in Vol. 2, Part 3, Sect. 2, Chap. 2 should be observed during any period of ground running. Carelessness in respect of these precautions may result in injuries to personnel and damage to aircraft.

4. Dust covers must be kept on the air-intakes and propelling nozzle whenever the engine is not running, and they should not be removed until immediately before starting. If a take-off is not contemplated, the air-intake covers should be replaced by wire-mesh debris guards.

Controls

5. The pilot controls engine speed and thus the thrust developed, by a throttle lever in the cockpit which is connected to the control valve plunger in the control box on the engine. The control valve plunger is a graduated needle calibrated to provide a variable orifice through which the fuel delivered by the engine-driven fuel pump is metered proportional to thrust for equal increments of travel.

6. A high pressure fuel cut-off valve which is operated by a second lever in the cockpit enables the pilot to stop the engine both when stopping normally and in an emergency, by shutting off the high pressure fuel supply to the burners. This cut-off valve is also incorporated in the control box. On Mk. 2 engines a dump valve which is attached to the side of the control box automatically opens when the H.P. fuel cut-off valve is closed and allows any unburnt residue of fuel in the burner ring to drain to waste. To safeguard against failure of the barometric pressure control, the servo connecting pipes, or of either fuel pump in the case of a dual pump system, a fuel pump isolating switch in the cockpit operates a servo isolating valve fitted to the fuel pump on Mk. 3 engines.

7. In addition to these controls, which are engine components, the following controls which are airframe items, are necessary for operating the engine.

8. The low pressure fuel cock is the main fuel cock between the fuel tanks and the engine-driven fuel pump; a low pressure fuel filter is fitted between this cock and the engine-driven fuel pump. A master (ground/flight) switch, a starter (linked master) switch, a starter push button and an auxiliary starting switch form part of the electric starting circuit.

9. Prior to the introduction of high energy ignition equipment, Goblin engines pre-mod. 830 (Mk. 3) or 984 (Mk. 2), Vampire aircraft (pre-mod. 963, 995, or 3194) according to the Mark of aircraft, were fitted with a booster coil test push switch to enable the booster coils and igniter plugs to be tested independently of the automatic starting cycle. When high energy ignition equipment is fitted (Goblin Mod. No. 830 (Mk. 3) or 984 (Mk. 2), and Vampire Mod. No. 963, 995, or 3194 according to the mark of aircraft), a Venner time switch is provided. The dial of this switch is marked IGNITION-OFF-ON, and turning this switch in a clockwise direction, from OFF to ON, winds a clockwork mechanism in the switch and supplies current to the high energy ignition units which are mounted on the engine. Immediately this switch is released, the clockwork mechanism commences to return the dial pointer from the fully ON position to the OFF position and, after a period of about 20 seconds, cuts off the supply of current to the high energy ignition equipment. This time switch is used for testing the ignition equipment on the ground and for relighting in flight. In Vampire aircraft fitted with an ejector seat (Vampire Mod. No. 3167), the ignition control takes the form of a push-button mounted on the H.P. cock lever; this facilitates relighting in flight as the H.P. cock lever and the ignition control can be operated simultaneously, using one hand only. In these aircraft, the push-button on the H.P. cock lever is also used for testing the ignition equipment on the ground.

10. To reduce risk of damage to the engine by incorrect operation of the controls, mechanisms are provided which automatically control the starting cycle once the pilot has initiated a start. In flight the fuel supply to the burners is automatically adjusted to compensate for changes in altitude and ram pressure in the engine air-intake. The starting cycle is controlled by an electrically wound, clockwork time switch through magnetic switches (relays) and speed limiting resistances. Once the engine is running, the fuel pressure is controlled by the barostat in the case of the Mk. 2 or the barometric pressure control in the case of the Mk. 3. A pressure limiting valve provides a safeguard against flame extinction at very low burner pressures, and overspeeding of the engine is prevented by an overspeed governor in the case of a Mk. 2 or by a governor mechanism integral with the single or dual fuel pumps in the case of a Mk. 3.

Instruments

11. To inform the pilot of the functioning of the engine and so ensure that the Operating Limitations are not exceeded, a tachometer, jet pipe temperature gauge, and oil temperature gauge (*Mk. 2 only*) are provided in the cockpit. A thermocouple is provided from the rear bearing so that, if required, a temperature gauge can be connected to check the rear bearing temperature during ground tests.

Starting

12. The engine is started by an electric motor, which rotates the engine to a self-sustaining speed in three stages. The first stage is a slow-engagement period, during which the starter motor rotates sufficiently slowly to permit the starter dog jaws to engage without shock and to prevent damage to the drives within the engine. The second stage is then introduced by the time switch and rotates the engine up to " light-up " speed, after which the third stage assists the engine to attain a self-sustaining speed from which it can accelerate under its own power to idling r.p.m. The starter motor is controlled by an automatic time switch and rotates the engine to the required speed in increments of time. In the case of the Mk. 2 the automatic time switch operates in conjunction with a manually operated auxiliary starting switch (Vampire Mod. No. 489). In the case of the Mk. 3, the automatic time switch cycle is used and the auxiliary starting switch is wire-locked in the ON position.

13. The current consumption of the starter motor during the starting cycle is very heavy, and to ensure that starter motor assistance is available to the engine, the ground batteries must always be maintained in a serviceable and fully charged condition. Starting troubles have frequently been due to the use of very long leads from the ground battery to the aircraft, resulting in an excessive voltage drop; it is therefore essential to keep the lead length to a minimum in order to utilize the maximum efficiency of the ground battery. The combined resistance of battery and leads should be such as to give one volt drop for 70 amperes flowing. The aircraft batteries must also be maintained fully charged as the ignition equipment, and the second and third stage relays are operated from this source as shown in fig. 1.

14. The function performed by the starting valve and the fuel accumulator as part of the starting cycle is explained in more detail in the description of the fuel system contained in Section 2, Chapter 2, these components being fully described in A.P. 4282, Vol. 1, Sect. 3 and A.P.4282A, Vol. 1, Sect. 5. The starting valve enables the fuel accumulator to fill with fuel during the engine starting cycle, and then to discharge this stored fuel under pressure into the burner ring to obtain an atomised spray of fuel at each burner; the burner ring having previously filled with fuel during the few seconds immediately after the fuel accumulator becomes fully charged. The starting valve must therefore be adjusted to discharge the fuel accumulator into the burner ring at the precise moment that the burner ring becomes fully primed. The time taken for the fuel to charge the burner ring after the spring in the fuel accumulator has been fully compressed is approximately five to seven seconds, therefore, there will be this period of delay before the starting valve opens fully and the accumulator discharges as shown by the line of burner pressure in fig. 2.

15. It is important that the starting valve is not set to open at a higher pressure than 24 lb. per sq. in. as any increased delay between the fuel accumulator being fully charged and the starting valve opening, reduces the overall time during which the third stage of the starter motor can assist the engine to attain its self-sustaining speed of approximately 1,600-1,700 r.p.m. This increased delay would be evident by the engine "labouring" at a speed below the self-sustaining speed without the ability to accelerate; this condition would be accompanied by over-fuelling resulting in a visible long flame and high jet pipe temperature. If, conversely, the starting valve is set to open at too low a pressure, the fuel accumulator will discharge at a reduced pressure and only part of its capacity. This may result in a "wet" start due to insufficient boosting pressure in the burner ring to produce an ignitable spray at the burners and can lead to an excess of wet fuel in the combustion chambers. The method of adjusting the starting valve and checking the fuel accumulator is described in Vol. 2, Part 3, Sect. 3, Chap. 1.

16. Where high energy ignition equipment is fitted, direct current at 16 to 29 volts and approximately 2 to 2½ amp. is supplied, through a relay, from the aircraft battery to the two high energy condenser units, which are mounted on the engine. The high energy condenser units discharge through two surface discharge igniter plugs situated in No. 2 and 14 combustion chambers respectively. The discharge at the igniter plugs ignites the fuel issuing from the burners in No. 2 and 14 combustion chambers, and the flame spreads to the remaining fourteen combustion chambers through the interconnector passages. The igniter plugs are in operation throughout the starting cycle. Failure to start can be attributed to electrical trouble as, although operation of the ignition switch may indicate the ignition equipment to be serviceable, it will be appreciated that only a simulated start will prove whether or not the equipment is functioning during a starting cycle, since the ignition switch by-passes the ignition relay. In the case of high energy ignition, operation of the surface discharge igniter plugs will be

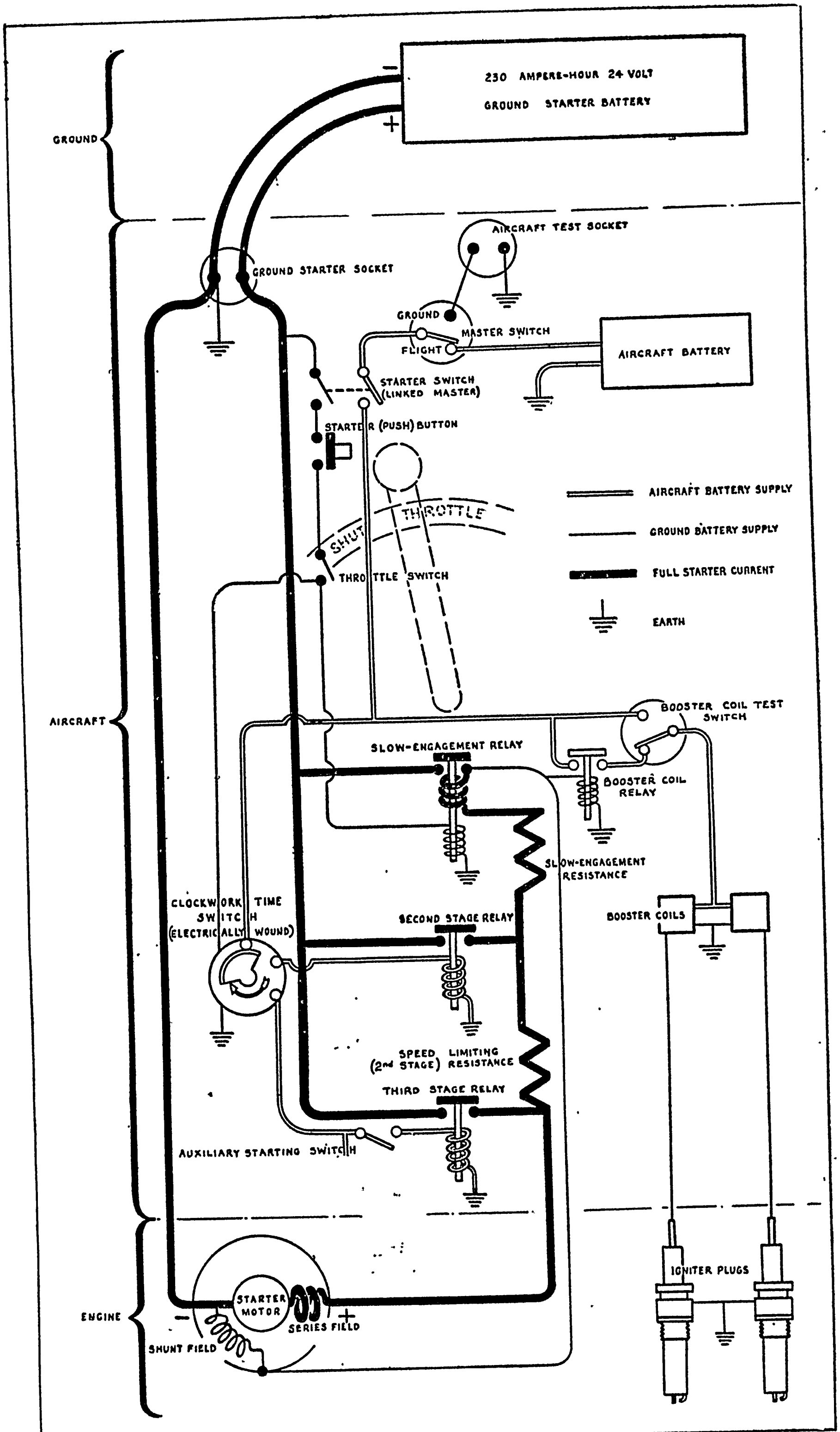


Fig. 1. Diagram of the electric starting equipment (pre-mod. 830, Mk. 3, or pre-mod. 984, Mk. 2)

In the case of Mk. 3 engines the auxiliary starting switch is wire-locked ON.

audible, particularly during the initial stage of the starting cycle. On systems which are pre-mod. 830 (Mk. 3) or 984 (Mk. 2), the booster coils, which were airframe components, provided a high tension spark at each H.T. igniter plug. To ignite the atomised spray of fuel from the burners with this type of ignition equipment, it is essential that the centre electrodes of the plugs are incandescent at the moment of discharge of the fuel accumulator. A spark only is insufficient to cause ignition and failure to start can arise from the igniter plug being too cold due to excessive air flow through the engine as a result of the engine r.p.m. being in excess of that required for "light-up". The starting equipment shown in fig. 1 represents the system pre-mod. 830 (Mk. 3), or pre-mod. 984 (Mk. 2). When Mod. No. 830 or 984 is embodied, the booster coil test switch, booster coils and H.T. igniter plugs are superseded by a Venner time switch (or by a push-button on the H.P. cock lever), high energy condenser units, and surface discharge igniter plugs; basically the electric circuit is otherwise unchanged.

17. Before a start can be initiated by pressing the starter push-button, the controls must be set correctly and connection made to a 230 ampere-hour 24 volt ground starter battery in accordance with the starting drill specified in Vol. 2, Part 3, Sect. 2, Chap. 2. When the starter button is pressed two things occur, the automatic (clockwork) time switch is electrically wound, and the slow-engagement relay is energised; pressure must be maintained on the starter button for about two seconds to ensure that the time switch is wound fully. Energising the slow-engagement relay causes the contacts therein to close so that current flows to the starter motor through the slow-engagement and speed limiting resistances and to the ignition equipment relay. Thus the starter motor commences to rotate sufficiently slowly to permit the starter dog jaws to engage without shock and so prevent damage to the drives within the engine, and the ignition equipment commences to operate.

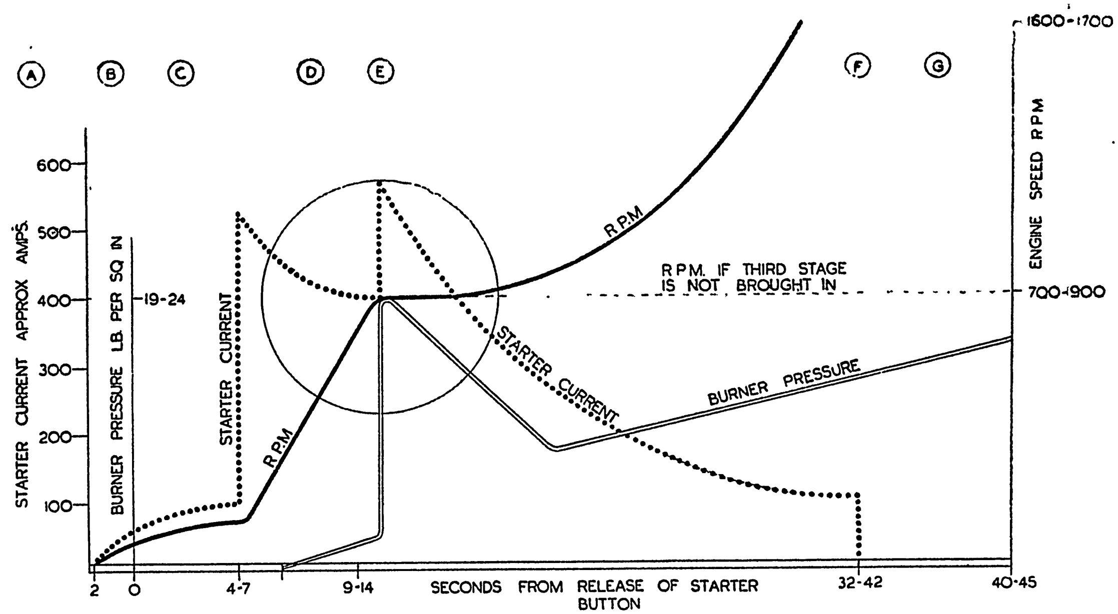
18. After releasing the starter button, current is supplied to the starter motor through speed-limiting resistances in three stages as shown diagrammatically in fig. 2. First stage, with both resistances in circuit, for 4—7 seconds, second stage with one resistance in circuit, for 5—7 seconds when the full current third stage is introduced making a total operating period of 32—42 seconds. The suitable "light-up" speed is approximately 700-900 r.p.m. This varies slightly according to the operating conditions, i.e., it will take longer and more current will be required from the starter battery to attain the requisite engine r.p.m. under very cold conditions than when warm.

19. Under warm conditions the Mk. 2 will attain a high engine r.p.m. more quickly, which assisted by the third stage of the cycle, could give an air flow which might be sufficient to extinguish the flame before a satisfactory "light-sound" occurs. This indicates the desirability of controlling more closely the introduction of the third stage than is provided by the fixed interval of an automatic time switch. For this purpose the auxiliary starting switch (Vampire Mod. 489) was introduced, permitting the third stage of the starting cycle to be brought into use by the pilot either when the jet pipe temperature gauge indicates that "light-up" had occurred or when the familiar sound of "light-up" is evident. The too early use of the auxiliary starting switch will probably result in a poor or even a "wet" start as explained above; if the switch is not switched ON during the starting cycle, the engine will not receive its full-current assistance from the starter motor, i.e., the starter motor will be on the second stage for the remainder of the cycle. This latter condition will result in "labouring" of the engine with long flame in the exhaust, high temperature, and failure to accelerate.

20. The starting procedure detailed in Vol. 2, Part 3, Sect. 2, Chap. 2 of this Air Publication should be closely followed. It is most important that no attempt is made to re-start the engine until it has ceased rotating, otherwise shock engagement of the starter dogs will occur and serious internal damage may result.

Low temperature lubrication

21. The lowest oil temperature for starting or opening up Mk. 2 and Mk. 3 engines is minus 10 deg.C. when using OM-71 or OEP-71. Oil OM-31 (Stores Ref. 34A/200) is approved for Mk. 3 engines only, and in this case, operation can be at temperatures down



A GROUND STARTER BATTERY PLUGGED IN-CONTROLS AND SWITCHES SET IN ACCORDANCE WITH THE STARTING DRILL

B STARTER BUTTON PRESSED FOR ABOUT TWO SECONDS AND RELEASED, TIME SWITCH WOUND, SLOW-ENGAGEMENT PERIOD STARTED

C SLOW-ENGAGEMENT PERIOD CONTROLLED BY TIME SWITCH

D TIME SWITCH CUTS-OUT SLOW-ENGAGEMENT RESISTANCE, STARTER MOTOR ACCELERATES ENGINE TO R.P.M. SUITABLE FOR LIGHT-UP

E FUEL ACCUMULATOR DISCHARGES, IGNITER PLUGS LIGHT FUEL, TIME SW.TCH CUTS-OUT SPEED-LIMITING RESISTANCE, STARTER MOTOR ASSISTS ACCELERATION TO SELF-SUSTAINING SPEED

F TIME SWITCH SWITCHES OFF STARTING CIRCUIT

G ENGINE ACCELERATES UNDER OWN POWER TO IDLING SPEED

Fig. 2. Diagram of starting cycle

to minus 20 deg.C. To ensure a satisfactory rate of oil circulation on starting, the oil temperature should be at least to these values.

22. The viscosity of the oil below the minimum temperature specified is such that the oil spray lubrication in the accessory boxes may be affected. Increased back pressure on the metering pumps may also cause sluggish lubrication of the main bearings. Therefore protection of the engine or pre-heating of the oil under severe conditions is necessary; oil temperatures in flight will be satisfactory owing to the warmth generated by the operation of the engine.

Acceleration and deceleration

23. The thrust of a turbo-jet engine is almost directly proportional to the total quantity of fuel consumed. Excess power for acceleration is provided by over-fuelling which temporarily increases the temperature and energy of the gases entering the turbine. Up to a point, some rise of temperature is inevitable during acceleration and this is reflected in the reading of the jet pipe temperature gauge. Violent accelerations, however, may involve temperatures that are definitely destructive.

24. It will be appreciated that if the throttle is suddenly opened at some intermediate speed, the temperature throughout the combustion system will rise rapidly before the maximum governed speed is reached and the fuel flow automatically regulated to its proper value. A turbo-jet engine will accelerate more readily in the upper speed range than in the lower range and it is particularly important to handle the throttle gently when accelerating from idling r.p.m. Conversely excessive temperatures will not normally be experienced in accelerating fairly quickly from say cruising speed to operational necessity r.p.m. This is apparent from the Operating Limitations which quote two minimum speeds, " Idling " (ground level), and " Idling " (approach minimum). Acceleration from the approach minimum r.p.m. to take-off, or operational necessity (maximum) r.p.m. should take at least five seconds but acceleration from " Idling " (ground level) to maximum r.p.m. should be more leisurely and take at least ten seconds.

25. Apart from the obvious dangers of high turbine temperatures, there are other objections to a too rapid movement of the throttle. Every combustion chamber has both " weak " and " rich " " blow-out " limits beyond which the flame is unstable and may become extinguished. Since the airflow through an engine cannot change instantaneously, sudden throttle movements may so effect the air/fuel ratio that " blow-out " or roughness occurs. This applies particularly at altitude where the reduced air density narrows the limits of combustion stability.

26. Moreover, sudden changes of temperature in any mechanism may involve distortion and stresses which would not occur if the variations were more gradually applied. This consideration applies particularly to such parts as the flame tubes, junction pipe and nozzle blade assembly. Improved service can be obtained from these parts when temperature changes are reasonably regulated. The quenching process on shutting down from high duty to idling speed is, in this sense, just as important as the heating process during acceleration.

27. These limitations must be observed except in the event of extreme operational necessity. Movement of the throttle should be smooth and progressive both when opening up and shutting down the engine. Under steady operating conditions, the temperature appropriate to the particular flying conditions given in the Operating Limitations should not be exceeded, but if as the result of a sudden change of altitude or too rapid opening of the throttle, the temperature is taken too high, it should return to normal as soon as conditions are again stable. The jet temperature must be frequently observed therefore, and too vigorous use of the throttle avoided, particularly at altitude where the response is even greater than at sea level. Except when accelerating, a sudden rise in temperature is a definite indication of trouble and the engine should be throttled back at once.

Taxying

28. It is advisable to run the engine with the aircraft headed into wind whenever the aircraft is stationary. When taxying, care must be taken to open the throttle gently and evenly, otherwise the jet temperature may rise above the maximum permissible.

29. If the jet temperature has risen to any great extent above the normal idling temperature, the aircraft should be headed into wind and the engine throttled back and allowed to cool before take-off is attempted. Every effort should be made to prevent the engine being run with the aircraft headed out of wind, otherwise a mixture of hot exhaust gas and air may be drawn into the air-intakes and cause high jet temperatures and overheating.

General flying

30. Approved flight operating instructions are given in the relevant aircraft Pilot's Notes and the information which follows is intended for ground personnel only as an indication of the conditions to which the engine is subjected in flight. The Operating Limitations specified must be strictly observed and a frequent check should be made of the jet pipe temperature and r.p.m. so that if necessary remedial action can be taken as quickly as possible. From reference to the information contained in para. 23 to 28, it will be understood that coarse movement of the throttle which will produce excessive temperatures in the engine during acceleration must be avoided.

Take-off and climb

31. The aircraft should be headed in the direction of take-off and with the brakes applied, the throttle opened smoothly until the take-off r.p.m. has been reached. *Mk. 3 only.*—Move the fuel pump isolating switch to the ON position ; there will be a slight r.p.m. variation when the isolating valve is operated when the engine is running on the governor. Make a quick check to ensure that the r.p.m. is correct and that the jet temperature is normal. If everything is satisfactory, the aircraft brakes can be released.

Note . . .

The correct functioning of the fuel pump isolating valve will have been checked during the normal ground running but if it is desired to recheck this proceed as described in Vol. 2, Part 3, Sect. 2, Chap. 2.

32. As the efficiency of this method of propulsion improves with forward speed, and the maximum rate of climb is only obtainable at high air speeds, no attempt should be made to climb more steeply than at the recommended indicated air speed for the aircraft. If for any reason maximum power cannot be used without exceeding the jet pipe temperature limit, the r.p.m. should be reduced or the forward speed increased, or both adjusted accordingly. This is particularly important if a climb is continued above 25,000 feet altitude. Except when accelerating, a sudden rise in temperature is a definite indication of trouble and the engine should be throttled back at once. *Mk. 3 only.* As soon as the aircraft has attained its correct climbing speed and a safe height, and before attempting to throttle back, the fuel pump isolating switch should be returned to the OFF position. Immediately the switch has been operated, the throttle should be set to give the desired r.p.m.

Note...

In the event of the switch being left inadvertently in the ON *position and the throttle returned to a position below full throttle, the throttle should be moved slowly to the full-open position and the switch moved to the* OFF *position. To avoid overheating which may occur particularly at high altitude, the throttle should be returned to its original position as soon as possible after the movement of the switch.*

33. Where Goblin Mod. 404 which repositions the jet pipe thermocouple is not embodied, it is recommended that a climb at maximum r.p.m. (take-off and operational necessity) should not be carried out above 25,000 feet. If it is desired to climb beyond this altitude, then the engine should be throttled back to a speed of 10,000 r.p.m. Mk. 2 or 10,500 r.p.m. Mk. 3. This limitation is recommended because, although the jet pipe temperature recording when the thermocouple is fitted in the pre-mod. 404 (three o'clock) position may be within the Operating Limitations, the uneven temperature spread may result in the temperature limitation being exceeded in another region of the jet pipe.

Operational necessity

34. It is important that the duration, r.p.m. and temperatures specified in the Operating Limitations are not exceeded during periods of operational necessity.

Diving

35. High-speed diving increases the airflow through the engine and if performed with the throttle shut, may result in extinguishing combustion.

Cruising

36. To reduce the stresses on the engine as much as possible when cruising, the r.p.m. and jet temperature must be kept within the limits quoted in the Operating Limitations for the maximum continuous condition.

Gliding, landing, and stopping

37. When gliding with the throttle closed, the jet pipe temperature should be kept under observation, and the throttle opened slightly to increase the temperature if it falls lower than usual.

38. To minimise the risk of damage to the engine if it is necessary to accelerate rapidly in the event of a baulked landing, the engine should not be throttled back to a speed less than the "approach idling" specified in the Operating Limitations. *Mk. 3 only.* In the event of a baulked landing, or as soon as it is apparent that a second circuit is necessary, move the fuel pump isolating switch to the ON position as a safeguard against the possibility of fuel system failure at a critical moment. When a safe height is reached, return the fuel pump isolating switch to the OFF position. If an attempt is made to land with the fuel pump isolating switch in the ON position, the resultant higher idling speed which, even with the throttle hard back in the slow-running position, may be as high as 5,000 r.p.m., will involve a longer landing run, and it might be necessary to move the cut-off valve to the OFF position at touch-down and so stop the engine.

39. The correct procedure for stopping the engine is detailed in Vol. 2, Part 3, Sect. 2, Chap. 2. After taxying in and turning into wind, throttle down to idling r.p.m. and allow the engine to run for about 30 seconds to stabilise temperature conditions before stopping the engine. Do not move the L.P. fuel cock lever to the OFF position or switch OFF the tank booster pump until the engine has stopped, as the engine-driven fuel pump relies on the circulation of fuel through the pump for its lubrication. Finally move the master switch to GROUND and replace the air-intake and propelling nozzle covers.

Fuel system failure in flight (Mk. 3 only)

40. Failure of a fuel system component in flight will normally be indicated by an unexpected and progressive decrease in r.p.m. This may be the result of failure of either fuel pump (dual pump systems), the B.P.C. or the servo pipes. The immediate action should be to close the throttle and then move the fuel pump isolating switch to the ON position. The throttle should then be opened to the required r.p.m. and the switch kept ON until the aircraft has landed. Also ensure that neither the H.P. cut-off valve nor the L.P. fuel cock levers have been inadvertently moved to the OFF position, and that there is still fuel in the tanks. At altitude, if the throttle is not closed before moving the fuel pump isolating switch to the ON position, the engine may suffer a rich extinction.

Fire or other emergency

41. In the event of fire in the engine bay or an emergency such as a forced landing or failure during take-off, the following action should be taken.

(1) Close the L.P. fuel cock.

(2) Close the H.P. fuel cut-off valve.

(3) Switch OFF the booster pump and close the throttle fully.

(4) Reduce air speed as far as practicable before operating the fire extinguisher.

Note . . .

These operations should be carried out as rapidly as possible.

Relighting in flight

42. Relighting in flight is permitted without restriction, provided that high energy ignition equipment (Mk. 3 Mod. No. 830, Mk. 2 Mod. No. 984) and Mod. No. 903 (improved fuel drainage system), together with the associated aircraft modifications, are embodied. Where the drainage modifications are not embodied, relighting should be restricted to one attempt only.

43. (*Mk. 2 and Mk. 3*). When a rich extinction occurs in flight due to a too rapid opening of the throttle, the fuel should be cut off immediately by closing the throttle and H.P. fuel cut-off valve, to prevent an accumulation of fuel in the engine.

44. (*Mk. 3 only*). In the event of a combustion failure in flight resulting from a fuel system defect (fuel pump, B.P.C., or servo pipes), the fuel should be cut off immediately by closing the throttle and H.P. fuel cut-off valve, and the fuel pump isolating switch should be moved to the ON position, where it should be left for the remainder of the flight; during the subsequent landing, the higher idling speed resulting from the fuel pump isolating switch being ON, must be borne in mind (see also para. 38).

45. An immediate relight may be attempted, but if required the engine speed may be permitted to fall until a windmilling speed is reached. In the event of a combustion failure at altitudes above 30,000 ft. it is preferable to glide down to 30,000 ft. before attempting to relight. Relighting is more positive below this height and prevents excessive flooding of the engine with fuel. The indicated air speed should be maintained at or above 150 knots, otherwise the engine tends to overheat during the process of relighting, particularly at high altitudes. Where sufficient altitude permits, the aircraft should be dived to assist the engine to accelerate in the event of excessive jet pipe temperature being observed.

46. The relight is made with the throttle closed, by operating the ignition switch and, as nearly simultaneously as possible, opening the H.P. fuel cut-off valve. A light-up should occur within the time setting of the switch (aircraft not fitted with push-button on the H.P. cock lever), but if the engine fails to light within this time, the H.P. fuel cut-off valve should be closed and a further attempt made after a delay of not less than 30 seconds; whenever possible 60 seconds should be allowed. This will enable the engine to dry out before a second attempt is made. In the event of a number of unsuccessful attempts, the throttle may be fully opened and the starting drill repeated, returning the throttle to the slow-running stop when combustion has taken place. While attempting to relight, to give every assurance of a satisfactory current supply to the high energy condenser units, all non-essential electrical loading such as R.T. etc., should be switched OFF, but the fuel tank booster pump should remain switched ON.

47. The most likely cause of failure to relight in flight is insufficient voltage at the high energy condenser units as a result of partially discharged aircraft batteries. It is to reduce this likelihood that the switching OFF of all non-essential electrical loading has been recommended; if discharged batteries are thought to be the cause of failure to relight in flight, all auxiliary electrical loads should be turned OFF before attempting a further relight.

Cold weather operation

48. Reports of loss of r.p.m. under cold weather conditions have in some instances resulted in accessories such as the barostat, overspeed governor, tachometer, etc., being changed unnecessarily.

49. In a turbo-jet engine the power of the turbine is entirely absorbed in driving the compressor. The residual energy of the gases after passing the turbine is used to propel the aircraft. As atmospheric temperature falls in cold climates, the density of the air inhaled at the air-intake increases and the power required to drive the compressor at a given r.p.m. rises proportionately. Similarly, as the speed of flight increases there is an increase in density at the air-intakes due to "ram" and an increased rate of air flow through the engine. This effect also increases the power required to drive the compressor at a given speed of rotation.

50. Thus, low air temperature and increased speed of flight both require increased turbine power to maintain compressor revolutions. This extra power can only be obtained by an increase in the rate of fuel flow. Obviously, there comes a time when, due to low ambient temperatures or high aircraft performance, the fuel flow available is limited by the pump capacity or by the setting of the automatic control mechanism. When this limiting condition is reached, there is a fall of r.p.m. from the maximum obtained under normal conditions. This loss of r.p.m., provided it is neither excessive nor accompanied by high jet temperatures, does not indicate any imperfection in the operation of the engine; in fact, thrust, being roughly proportionate to fuel flow, will be more than normal on a standard day. True air speed will be practically unaffected. From the foregoing, it will be appreciated that loss of r.p.m. is most likely to occur when the demands on fuel flow are a maximum, i.e., under conditions of full throttle at low altitude, high speed flight, and cold atmospheric temperatures.

SECTION 2

DESCRIPTION

LIST OF CHAPTERS

Note.—A list of contents appears at the beginning of each chapter

CHAPTER

ENGINE

ENGINE

RESTRICTED

Chapter 1

ENGINE

Note.—*This chapter applies to Goblin Mk. 2 and 3 aero-engines*

LIST OF CONTENTS

TABLE

LIST OF ILLUSTRATIONS

General

1. The Goblin is a turbo-jet engine, incorporating a single-stage single-sided centrifugal compressor, sixteen straight flow combustion chambers, and a single-stage axial-flow turbine with direct exhaust ejection. Air enters the engine at the front, and after passing through the compressor, combustion chambers, turbine, and exhaust system, is expelled at high velocity through the propelling nozzle to form the propulsive jet. The resultant reaction, expressed in pounds static thrust, is the power rating of the engine.

KEY TO FIG. 1

1 AIR-INTAKE
2 IMPELLER
3 DIFFUSER CASING
4 BURNER
5 FLAME TUBE
6 COMBUSTION CHAMBER OUTER CASING
7 COOLING AIR TO TURBINE BLADE ROOTS
8 JUNCTION PIPE
9 NOZZLE BLADES
10 TURBINE BLADES
11 TURBINE DISC
12 FIREGUARD
13 OUTER EXHAUST CONE
14 INNER EXHAUST CONE
15 PROPELLING NOZZLE
16 FAIRING
17 REAR BEARING
18 CENTRE SHAFT
19 AIR FILTER
20 SEALING PLATE
21 COOLING AIR TO REAR OF TURBINE DISC
22 COOLING AIR TO REAR BEARING

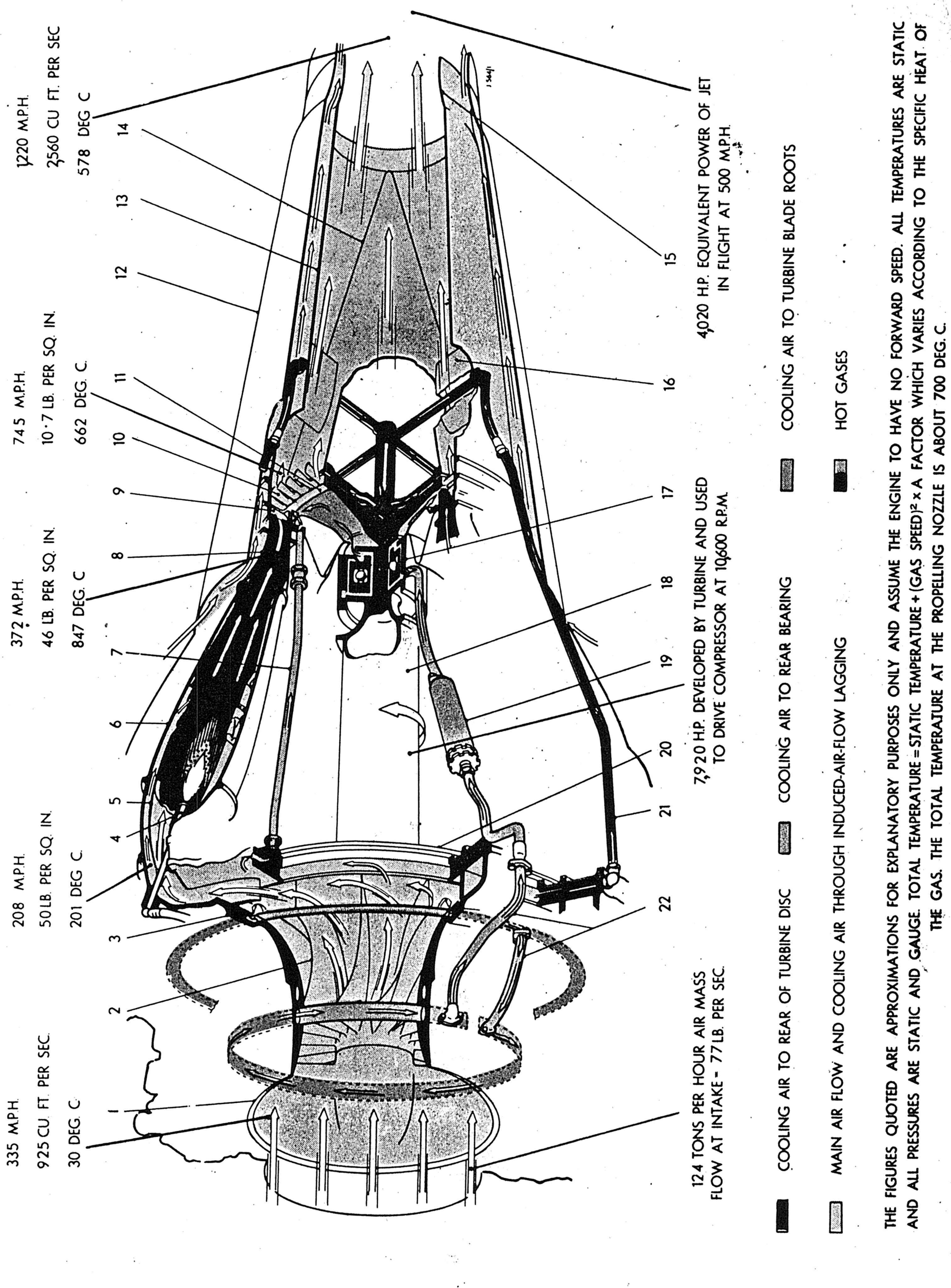


Fig. 1 Simplified diagram of gas flow and cooling air system

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2. The volume of gas expelled through the propelling nozzle depends upon the quantity of air entering the engine, and therefore on the speed at which the impeller rotates. The rotational speed of the impeller depends, in turn, upon the power developed in the turbine which drives it, and this is governed by the amount of fuel burnt in the combustion chambers. Any change in the rate of fuel flow to the burners causes an increase or decrease in the rate of air expansion, with a corresponding change in the rotational speed of the impeller. Therefore, by regulating the fuel flow, the thrust produced by the engine can be controlled. The component parts, and operation, of the fuel system are described in Chap. 2.

3. The two current variants of the Goblin are the Mk. 2 and the Mk. 3. The Mk. 2 is a direct development of the original Mk. 1 and may be recognised by the single Dowty pump fuel system and other minor external differences. The Mk. 3 is more powerful than the Mk. 2, and has a Lucas pump fuel system ; the differences between the fuel systems is shown clearly in the diagrams in Sect. 2, Chap. 2. One of the design changes which contribute to the increased power output is the introduction of deflector assemblies to smooth the air flow between the compressor and the combustion chambers. Mk. 3 engines in which mod. 820 has been embodied are fitted with an improved type of combustion chamber. Although this chapter describes the current Mk. 3 the description is also largely applicable to the Mk. 2, differences between the engines being mentioned where necessary.

COMPONENT DESCRIPTION

4. The engine sub-divisions used in Vol. 3 have, as far as possible, been followed throughout this Volume, and with the exception of the lubrication, fuel and ignition systems, which are dealt with individually in Chap. 2, 3 and 4, the following component description is sub-divided similarly. To avoid confusing the main text, the materials and finishes of the principal components are tabulated at the end of this chapter. It is not practicable to list every detail part, and for a complete list of detail parts reference must be made to the Vol. 3 of this Air Publication. The illustrations at the beginning of this Volume show the general arrangement of the engine components. Reference to these illustrations will enable identification of the majority of parts referred to in the following pages.

Main shaft assembly (*fig. 2*)

5. The main shaft assembly is the principal rotating component in the engine. Consisting of the impeller, centre shaft, extension and hub shafts, and the bladed turbine disc, it forms a simple robust rotor which is supported in ball bearings. The front bearing locates the assembly, the rear bearing assembly permitting sufficient axial movement to accommodate the effects of thermal expansion. In fig. 2 the rear bearing assembly is shown in position on the extension shaft, as it is when the main shaft is withdrawn from the engine. This is a departure from the engine sub-division used in the Vol. 3. A few similar cases will be found in the illustrations throughout this chapter.

Impeller and pivot

6. The impeller is machined from a one-piece forging and is of single-entry design. The seventeen gently curved vanes are truly radial and formed without bending. A short pivot is mounted on the front face of the impeller, as shown in fig. 3. The rear spigot of this pivot is an interference fit in the impeller, and the pivot is further secured by eight studs which pass through a flange on the pivot, and nuts. The inner race of the ball bearing which supports the main shaft assembly at the forward end is mounted on this pivot.

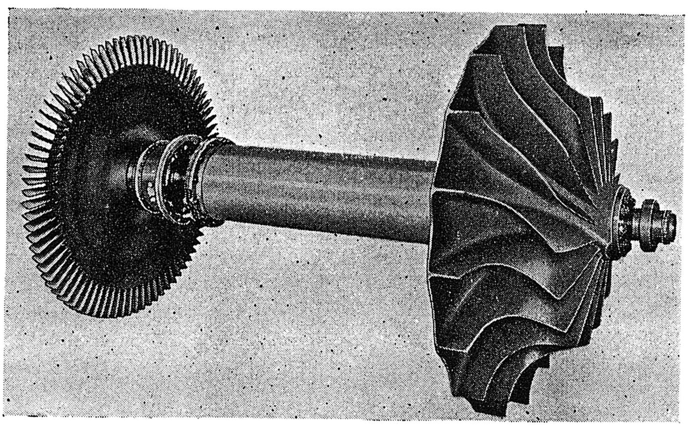


Fig. 2. Main shaft sssembly

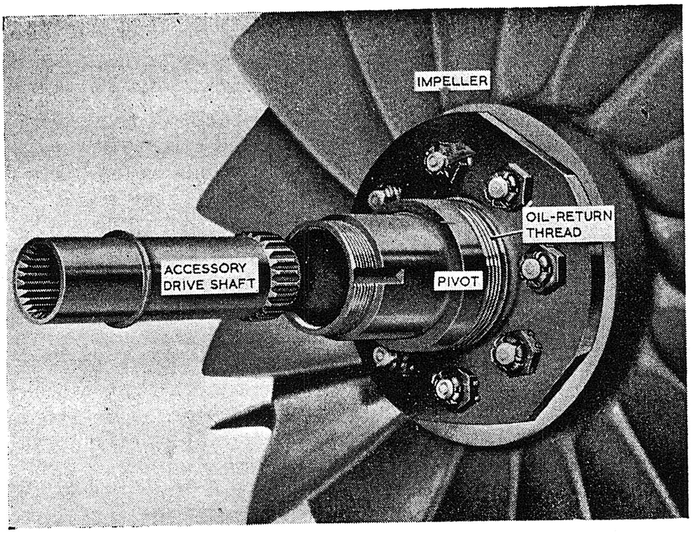


Fig. 3. Pivot, impeller and accessory drive shaft

The flats on pivot flange are where metal has been removed for balancing purposes

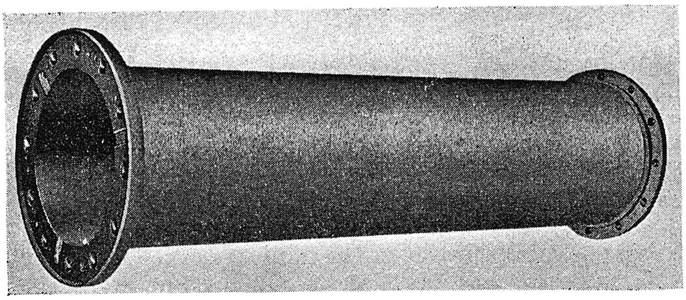


Fig. 4. Centre shaft

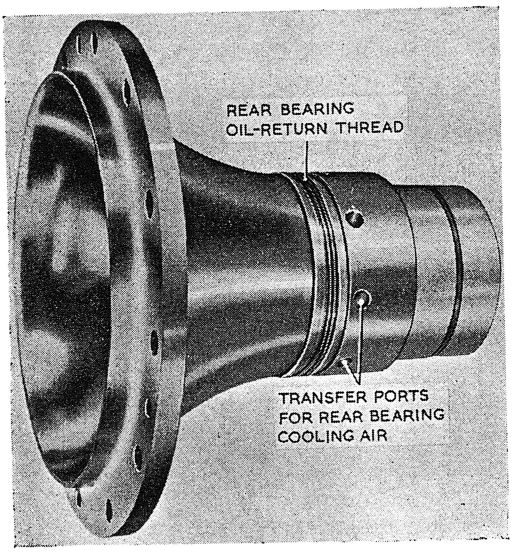


Fig. 5. Extension shaft

7. The impeller and pivot are secured to the forward end of the centre shaft by twelve studs and nuts. Tubular dowels, fitted over each of these studs, transmit the torque loads between the centre shaft and impeller.

Centre shaft (*fig. 4*)

8. The centre shaft is a large-diameter hollow shaft having a flange at each end for attachment to the impeller and extension shaft. The three radial slots (*fig.* 4) in the front flange communicate with holes through the flange, and thus serve to vent the interior of the main shaft assembly.

Extension shaft and hub shaft (*fig. 5 and 6*)

9. The extension shaft is secured to the rear flange of the centre shaft by twelve bolts and nuts; this extension shaft carries the inner race of the ball bearing which supports the main shaft assembly at the rear end. The hub shaft is secured to the turbine disc by ten bolts and passes through the inside of the extension shaft, torque loads being transmitted by serrations. The hub shaft is secured in the extension shaft by a special nut at its forward end. Thus, these two shafts form the attachment between the centre shaft and the turbine disc.

Turbine disc

10. The turbine disc, as shown in fig. 7 has serrated slots broached in its periphery, and eighty-three turbine blades, having corresponding 'fir tree' serrations formed on their roots, are fitted. Each blade root is retained in its slot by peening the front and rear faces of the root. With the object of obtaining the smallest possible turbine unit, consistent with providing a substantially axial discharge from the moving blades, the turbine blades are designed as impulse blades at the root, blending into impulse-reaction blades at the tip. Two eccentric nuts provide a means by which the combined extractor and lifting fixture is able to be used to release the turbine disc from the hub shaft and to lift the disc.

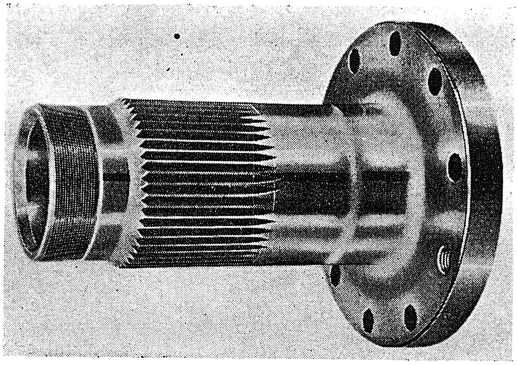


Fig. 6. **Hub shaft**

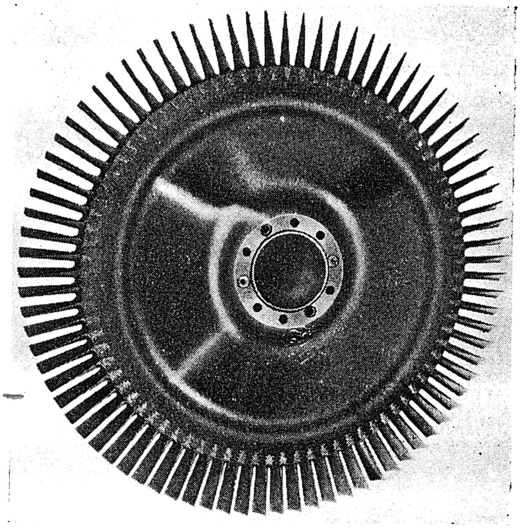


Fig. 7. Turbine disc and blades

Front bearing (*fig. 8*)

11. The front bearing is immediately in front of the impeller, in the front casing. The outer race of this bearing is surrounded by a steel housing located in the front casing. The bearing is retained in its housing by a retaining plate, and both the steel housing and the retaining plate are secured in the front casing by the same six studs and nuts. The rear portion of the bearing housing is lined with white metal to form an emergency bearing capable of supporting the rotating assembly for a sufficient time for the engine to be stopped in the event of the ball bearing failing, thus minimising the consequential damage. Under normal running conditions there is a radial clearance between the two surfaces and no wear occurs between the white metal and the rotating assembly.

12. The inner race of this ball bearing is mounted on the pivot which projects from the front of the impeller. The assembly consists of a distance piece, the ball bearing, and a spacer which are clamped in position against a shoulder formed on the pivot. During assembly the relationship of the impeller to the diffuser casing can be adjusted by varying the width of the distant piece. An oil-return thread to the rear of the ball bearing prevents the leakage of oil into the compressor.

13. To ensure adequate lubrication at all times, a metering pump supplies oil to the bearing independently of the engine main lubrication system. The lubricating oil is piped from the metering pump to a union in the retaining plate

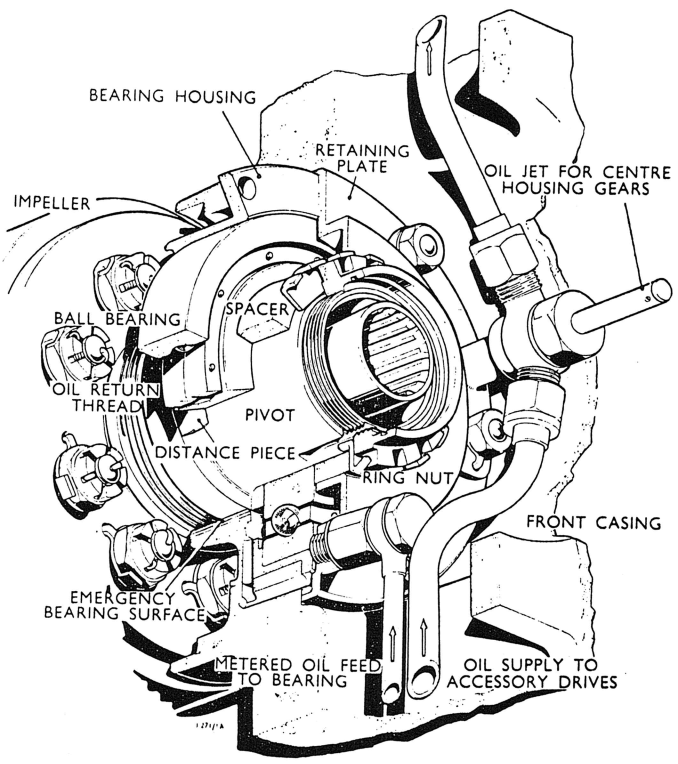


Fig. 8. Front bearing assembly

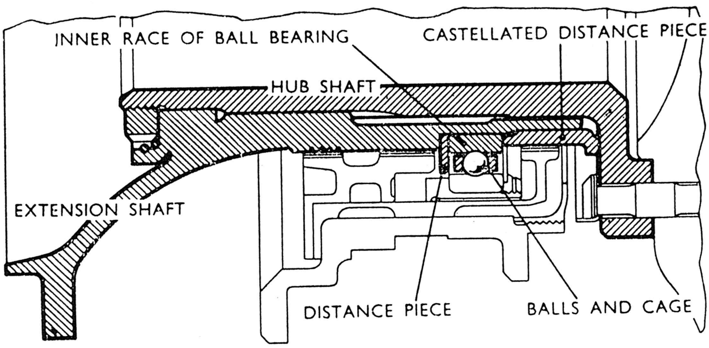
and escapes into the front casing after lubricating the bearing.

Rear bearing (*fig. 9 and 10*)

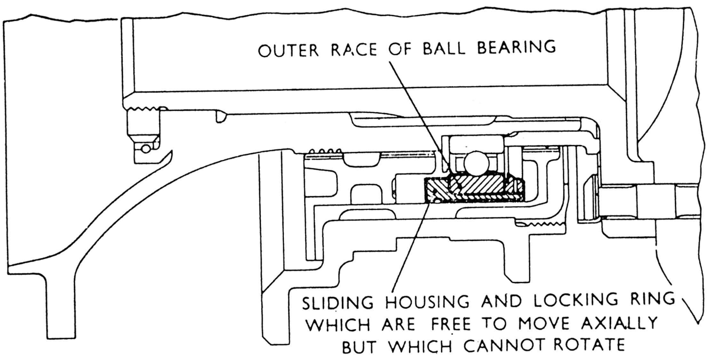
14. The rear bearing is immediately in front of the turbine disc, at the rear of the main shaft. The inner race of the ball bearing is held between distance pieces on the extension shaft, and is prevented from moving axially on the shaft by a shoulder on the extension shaft and the flange of the hub shaft—the whole being secured by the hub shaft nut. These parts form the rotating portion of the rear bearing assembly.

15. The outer race of the ball bearing is secured in a sliding housing by a threaded locking ring. The sliding housing is enclosed within a bearing housing, which is closed at its forward end by a sealing housing. The sliding housing has sufficient free axial movement within the bearing housing to accommodate the effects of thermal expansion in the length of the engine casing, but is prevented from revolving by a square peg formed in its front edge, which engages with a slot in the sealing housing. The bearing housing and the sealing housing are both flanged at their front ends and secured within a casing by studs and nuts. The casing is flanged at both ends for attachment by bolts to the engine centre casing and, at the rear, to the diaphragm and the support ring.

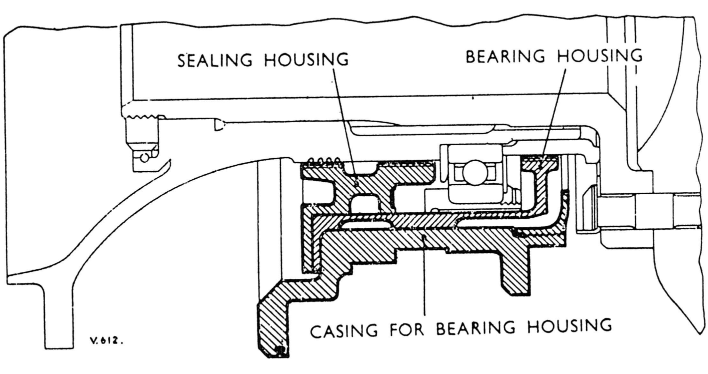
16. Lubricating oil is piped from a metering pump to a union in the bottom of the casing, and flows through a hole in the bearing housing into a groove encircling the sliding housing, and rearward through the slots in the sliding housing. Returning forward through the ball bearing, the



PARTS WHICH ROTATE WITH THE MAIN SHAFT ASSEMBLY



NON-ROTATING PARTS WHICH PERMIT AXIAL MOVEMENT TO ACCOMMODATE THE EFFECTS OF THERMAL EXPANSION



PARTS WHICH ARE POSITIVELY ATTACHED TO THE PRIMARY STRUCTURE

Fig. 10. Simplified sections through rear bearing

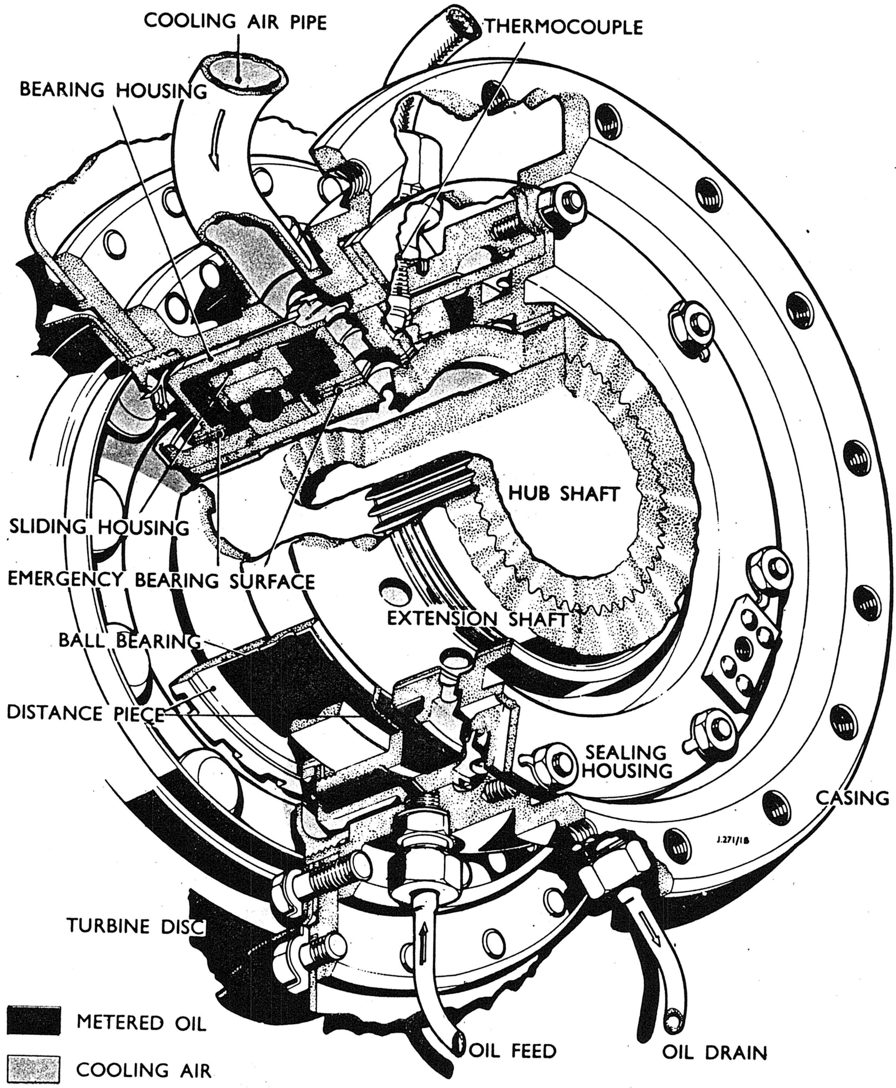


Fig.9 Rear bearing assembled

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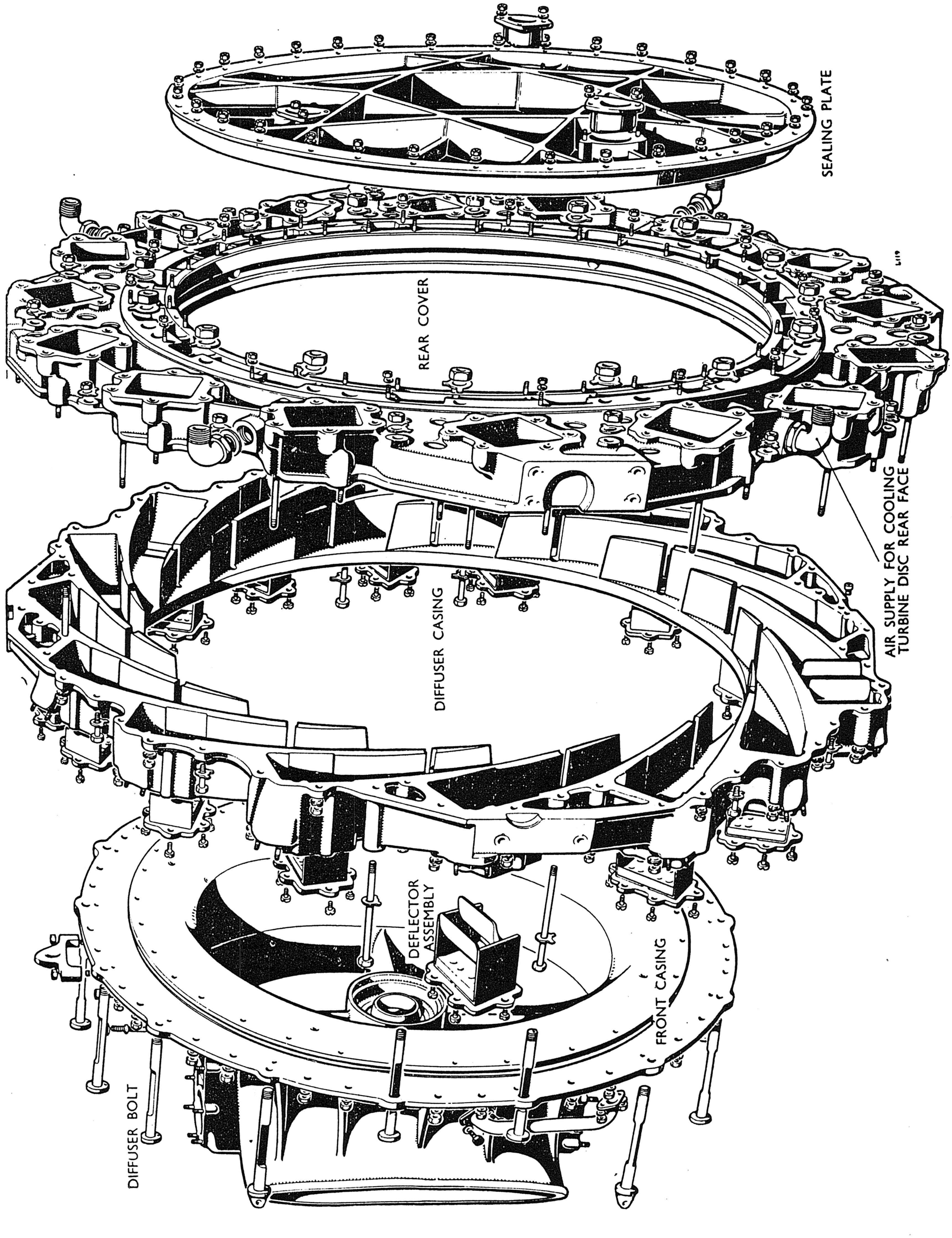

Fig. 11. Compressor casing

oil drains through a hole in the bearing housing and is piped to the common drain box. The position of the drain hole in the bearing housing ensures that a quantity of lubricating oil is retained in the bearing housing. An oil-return thread on the extension shaft prevents the leakage of oil into the engine centre casing.

17. An emergency bearing surface, similar to that for the front bearing, is provided in the rear of the bearing housing and in the sealing housing.

18. Air from the cooling ring spaces (*described* in *para.* 19) in the engine front casing is filtered and piped to two ports in the rear bearing casing, through which it is admitted to a channel which encircles the bearing housing. Some of this air flows rearward through slots in the housing and an annular space between housing and casing, and is exhausted through the open rear end of the casing. The rest of the air flows inward through holes in the bearing housing and sealing housing, and tangential transfer ports in the rotating extension

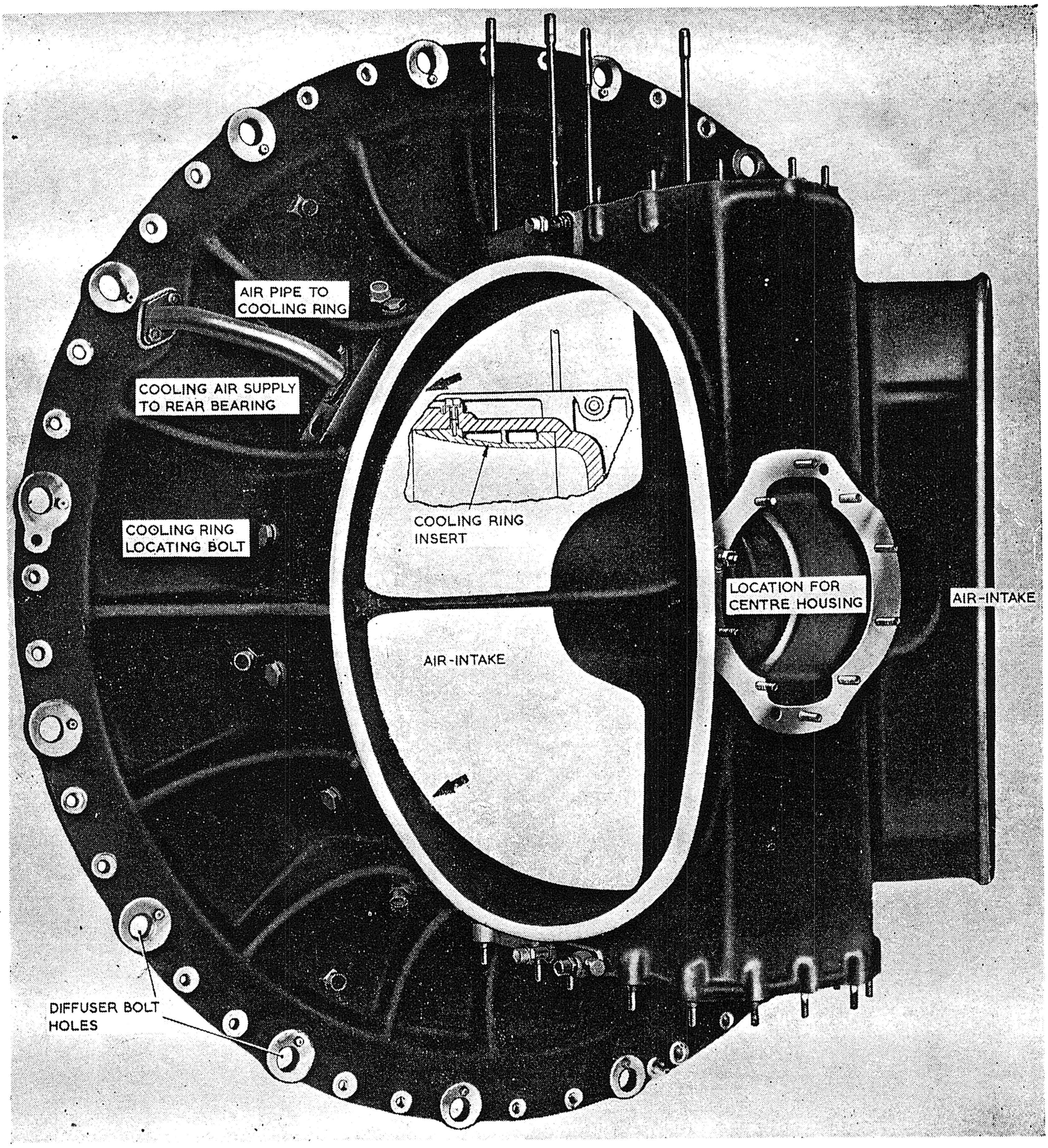

Fig. 12. Front view of front casing

shaft, and travels rearward through an annular space and slots between the extension shaft and hub shaft, finally discharging through slots in the end of the rear distance piece. The bearing, in its housing, is thus surrounded by an insulating layer of cool air. The cooling air, having left the bearing, flows outward over the front face of the turbine disc and is drawn into the main exhaust system through a clearance between the rear edge of the inner support ring and the turbine disc.

Front casing (*fig. 12 and 13*)

19. The compressor casing (*fig.* 11) forms part of the main stationary structure and is in four parts: the front casing, diffuser casing, rear cover, and sealing plate. The front casing is attached to the diffuser casing by thirty-two studs and nuts, as well as by the sixteen diffuser bolts which pass through the diffuser casing and vanes, rear cover, and centre casing front flange. The front of the component forms the bifurcated air-intake, and a housing is provided for the front bearing, which carries the front end of the main shaft assembly. The centre housing, and part of the gear trains through which the engine-driven accessories are driven, are also contained in the front casing.

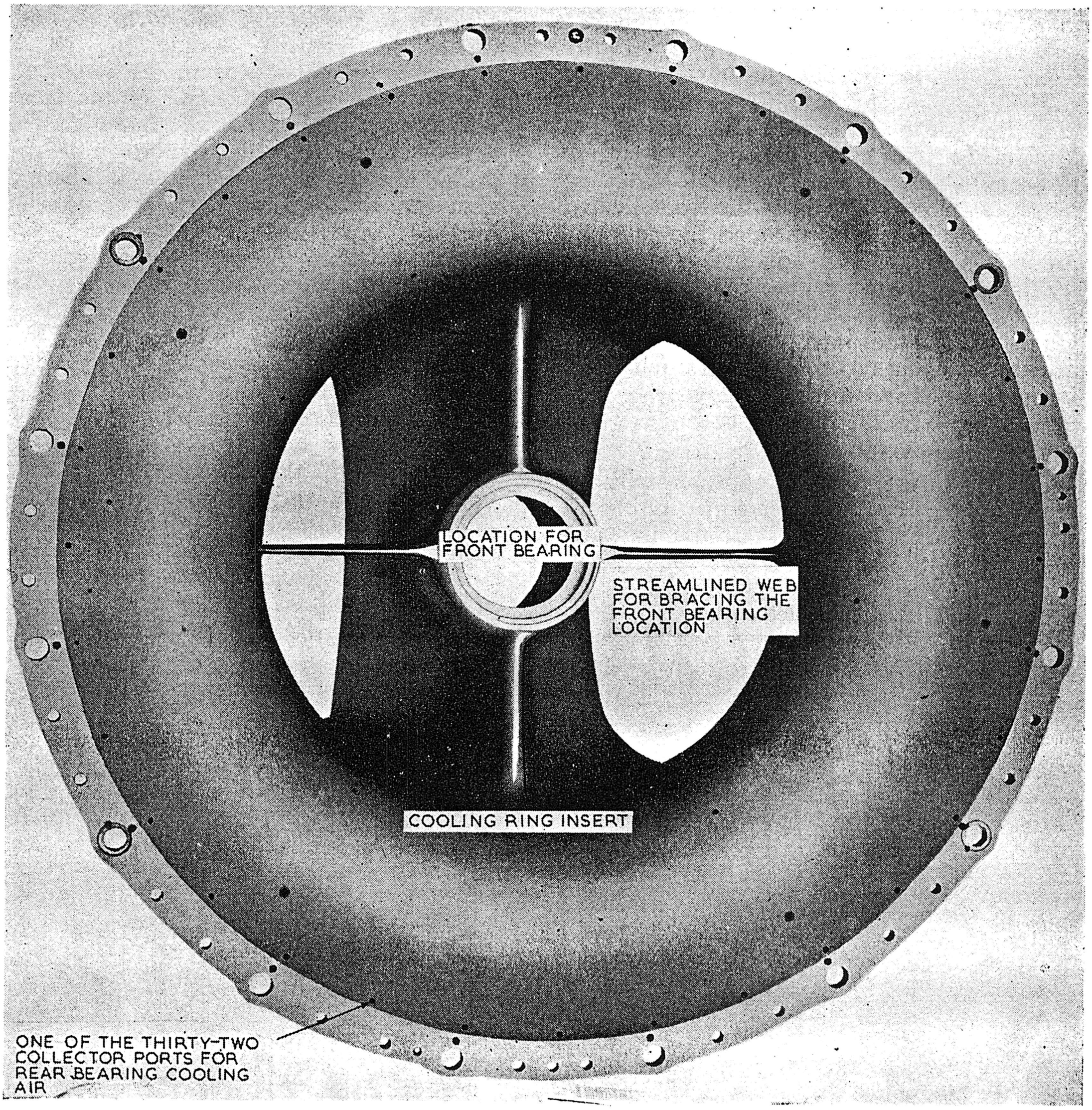

Fig. 13. Rear view of front casing

The front bearing is housed in a large boss which extends rearwards from between the air-intakes. The centre housing is immediately forward of the front bearing, between the air-intakes, and vertical shafts which transmit the drive to accessory boxes mounted top and bottom, are housed above and below the centre housing. Thirty-two holes near the periphery of the front casing admit a small quantity of air from the delivery side of the impeller to an air annulus which is formed by a groove in the face of the front casing which mates with the diffuser casing. This air is piped at two diametrically opposite points to two separate passages which encircle the rear of the air-intake. These passages, or annular spaces, are formed during manufacture by inserting a ring, having circumferential channels machined in its outer face, into the front casing, forward of the impeller. The ring is an interference fit in the casing and the surfaces inside the casing are afterwards carefully blended to give smooth, even contours : thus the ring becomes an integral part of the front casing. The air, while flowing through the passages around the rear of the air-intake, is cooled by the main air-flow to the compressor, and is used for keeping the rear bearing cool. On Mk. 3 engines each air-intake has two anti-resonance holes ; these are indicated in fig. 12 by the two large arrows.

Diffuser casing and rear cover *fig. 11*)

20. The diffuser casing, together with its rear cover, contains sixteen discharge passages (*fig.* 15 *and* 17) ; these passages

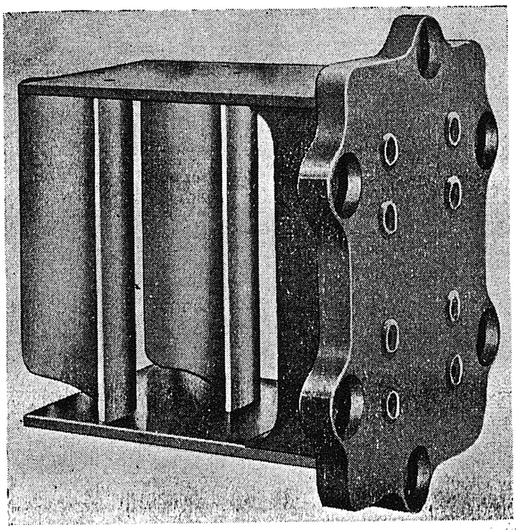

Fig. 14. Deflector assembly

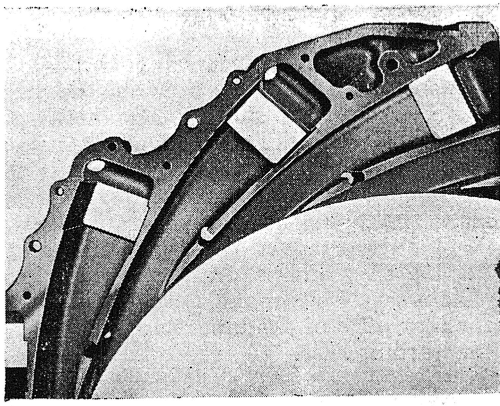

Fig. 15. Rear view of segment of diffuser casing

are cast in the casing, and form volutes in which the velocity energy of the air, delivered tangentially from the impeller, is converted into pressure energy and turned through 90 degrees to flow rearwards into the combustion chambers. Sixteen deflector assemblies are fitted at the points where the airstream is turned through 90 degrees ; this does not apply to Mk. 2 engines. Each deflector assembly (*fig.* 14) consists of a casing containing two aerofoil section vanes which ensure a smooth air-flow while the flow changes direction. The sixteen diffuser bolts, mentioned in the previous paragraph, which carry the main structural load from the rear of the engine, pass through the diffuser vanes and, as their diameter is greater than the thickness of the vanes, have two flats machined on them to reduce their diameter to the vane thickness. As a result of this, these diffuser bolts are not fully interchangeable. The head of each bolt is dowelled to prevent it from turning. Four of the bolts incorporate eye-ends for

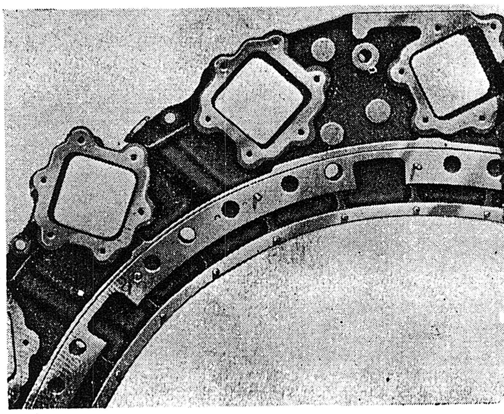

Fig. 16. Rear view of segment of rear cover

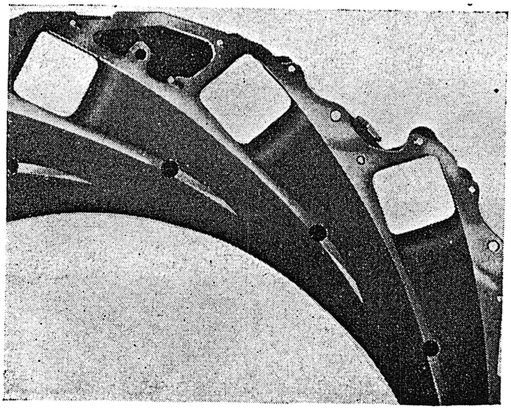

Fig. 17. Front view of segment of rear cover

mounting the engine in the airframe. Alternative mountings, which are used for mounting the engine in assembly and transport stands, and test benches, are provided by bolting suitable trunnions to faces on the circumference of the diffuser casing and rear cover.

21. The diffuser casing rear cover (*fig.* 16 *and* 17) is fastened to the diffuser casing by forty-eight studs and nuts, and sixteen special bolts and nuts, in addition to the sixteen diffuser bolts. Air under pressure, bled from ten points around the rear cover, is collected by a pipe (*fig.* 32) and is used for pressurising or ventilating the cockpit, and for other airframe services.

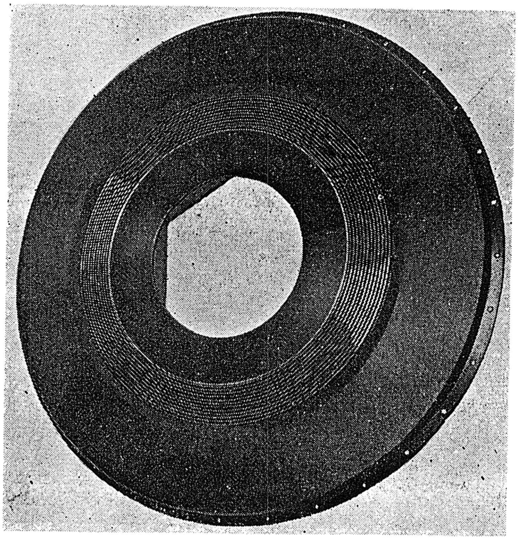

Fig. 18. Front view of sealing plate

Sealing plate (*fig. 18*)

22. The sealing plate is fastened to the rear cover by thirty-two studs and nuts. Twelve grooves on the front face of the sealing plate match up with grooves on the rear of the impeller, forming a labyrinth seal (*fig.* 19). The clearance between the impeller and sealing plate labyrinth groove is adjusted by fitting shims under the flange of the sealing plate. Most of the air which leaks rearwards past the periphery of the impeller is bled off at four points (*shown in fig.* 11) in the diffuser casing rear cover and is used for cooling the rear face of the turbine disc.

Centre casing (*fig. 20*)

23. The centre casing consists of a sheet-metal cone and support cylinder. The cone is secured at its front end to the diffuser casing rear cover by sixteen studs and nuts, and by the sixteen diffuser bolts and nuts. The rear end of the cone carries the casing which contains the rear bearing, and thus completes the structure which supports the rear bearing and the front bearing housed in the front casing. The rear of the cone is attached to the rear bearing casing by sixteen set-screws screwed into threaded holes in the rear bearing casing. The support cylinder is secured at its front end to the cone by thirty-two bolts, which screw into anchor nuts. The rear end of the support cylinder is fastened to the nozzle ring assembly by eighteen bolts and nuts, and additional bracing of the nozzle ring assembly to the centre casing is given by sixteen diagonal struts which are fastened at one end to a bracket and stiffening hoop on the support cylinder and at the

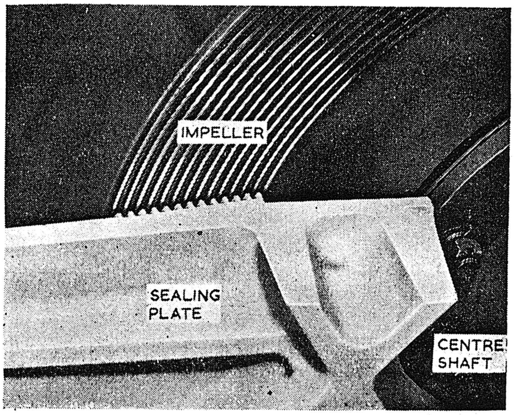

Fig. 19. Labyrinth seal

other end to the nozzle shroud. The support cylinder and diagonal strut are included with the nozzle ring assembly in fig. 21, to show the usual point of separation when dismantling the engine.

Nozzle ring *(fig. 21 and 22)*

24. The nozzle ring assembly is the stationary component of the turbine. The assembly consists of: the junction pipes and supports assembly, the nozzle shroud which surrounds the nozzle blades and rings assembly, and the turbine shroud. The assembly is attached to a flange at the rear end of the support cylinder of the centre casing, and to a diaphragm which is mounted on the rear bearing casing. The

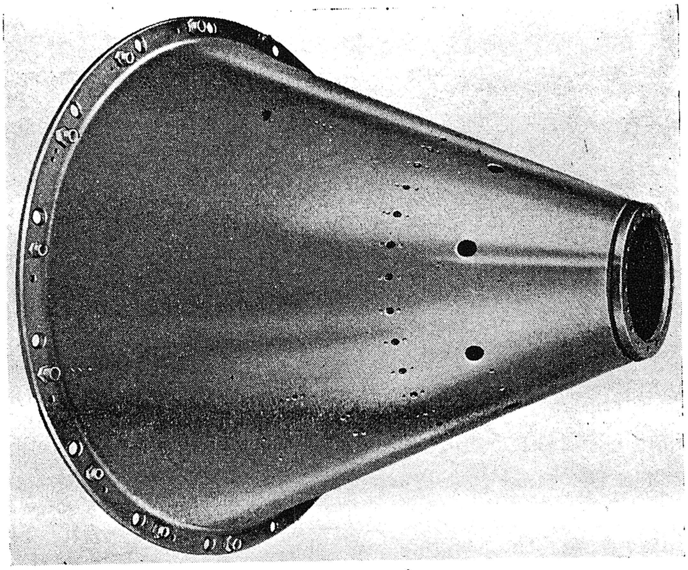

Fig. 20. Centre casing cone

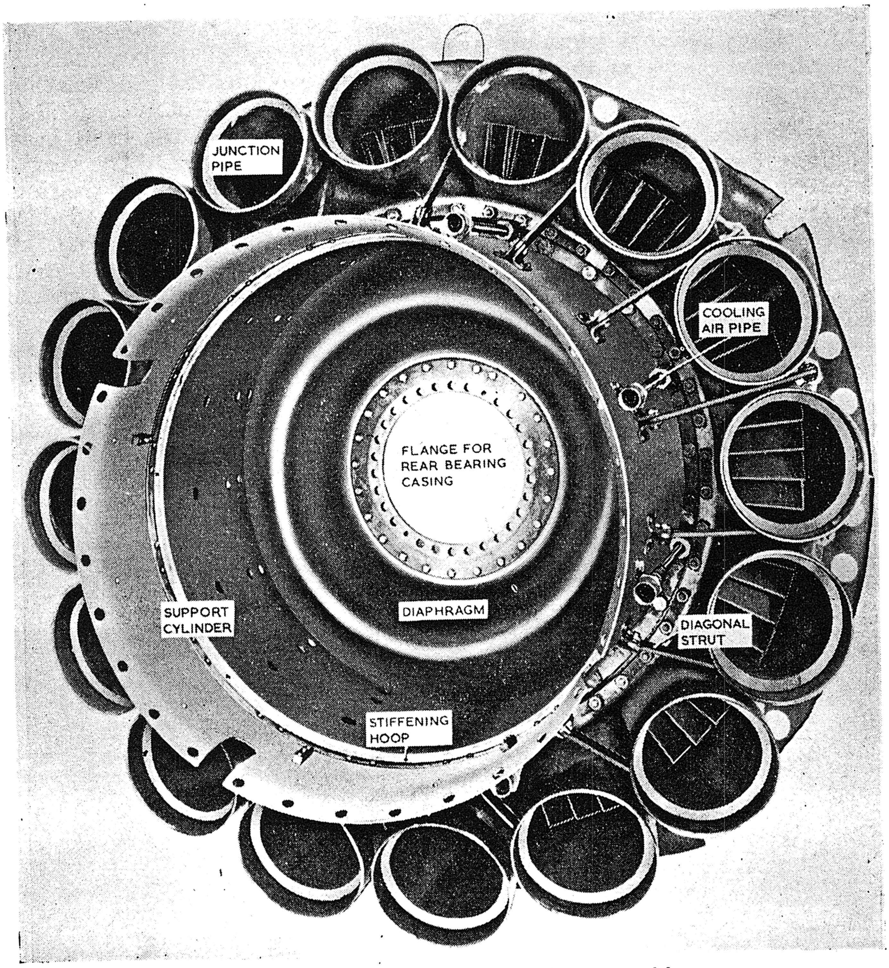

Fig. 21. Front view of nozzle ring assembly

junction pipes collect the combustion gases before they are guided by the stationary nozzle blades on to the moving turbine blades, as shown in fig. 23. Cooling air is piped from the diffuser casing and introduced between the diaphragm and the insulating plate. The junction pipes and supports assembly provides support for the rear end of the combustion chambers and consists of sixteen junction pipes evenly spaced between inner and outer support rings, to which they are welded, the inner support ring being bolted to the support cylinder and the diaphragm. The outer support ring is braced by the sixteen diagonal struts to the support cylinder.

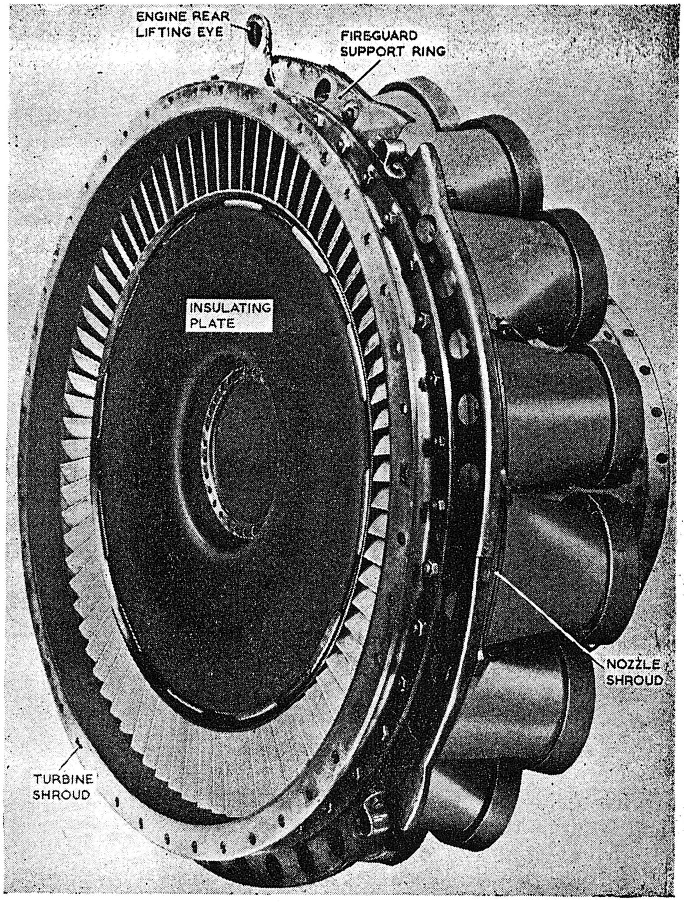

Fig. 22. Rear view of nozzle ring assembly

25. The seventy-seven nozzle blades are mounted between inner and outer rings, as shown in fig. 24. The outer ring is divided into eleven segments. Each nozzle blade has a tongue at each end which passes through a corresponding slot in the inner or outer ring and which is peened over to retain the blade in position. This assembly of nozzle blades and rings fits into the nozzle shroud, which is bolted to the support ring of the junction pipes and supports assembly, the inner blade ring being bolted to the inner support ring and, therefore, to the support cylinder and the diaphragm. This segmented assembly of the nozzle blade ring permits the nozzle blades an appreciable movement to accommodate the effects of thermal expansion. Movement in a forward direction is limited by a shoulder on the inner surface of the nozzle shroud ; circumferential movement is controlled by locating bolts fitted in the shroud, which engage with rectangular slots in the segmented outer ring ; and rearward movement is limited by the clearance between the segmented outer ring and the turbine shroud.

26. The turbine shroud is a simple ring having two flanges on its outer diameter by which it is attached to the nozzle shroud, and to which the exhaust system is attached.

Centre housing and accessory boxes

27. As already mentioned, the centre housing is contained in the front casing, but in order to preserve a rational continuity of the description of the accessory drives, it has been included in this part of the chapter. Similarly, the accessory drive shaft, which is included with the main shaft assembly in the Vol. 3, has been dealt with in this part of this chapter. The drive from the electric starter to the main shaft, and from the main shaft to the oil pumps, essential engine accessories, and engine-driven aircraft accesssories, are clearly illustrated in fig. 25.

28. The centre housing consists of a machined casting, illustrated in fig. 26, which is housed in the centre of the front casing between the two air-intakes and immediately forward of the front bearing. The centre housing contains the horizontal

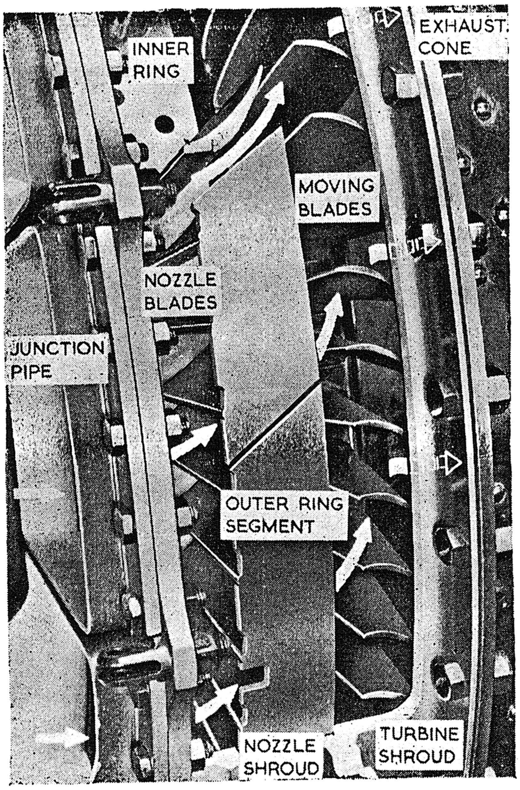

Fig. 23. Arrangement of turbine

driving gear and the top and bottom vertical gears, through which the accessories are driven and the drive taken from the electric starter; a short accessory drive shaft couples the horizontal driving gear to the pivot which is attached to the front of the impeller.

29. The accessory drive shaft (*fig.* 3) is a short tube with external serrations at its rear end and internal serrations at its front. The external serrations mate with corresponding female serrations within the impeller pivot, and the internal serrations mate with corresponding male serrations on the rear end of the centre housing horizontal driving gear spindle. This drive shaft is entirely enclosed within the impeller pivot; at the rear the shaft is retained by a plug, fitted within the impeller pivot, and a circlip, and at the front by a shoulder on the engaging horizontal spindle.

30. The horizontal driving gear is a bevel gear and is integral with its spindle. This gear is carried in two ball bearings fitted in housings which are secured to the centre housing by three studs and nuts each.

31. Meshing with the horizontal driving gear are the two vertical driving gears through which the drive is transmitted from the horizontal drive shaft to the vertical drive shafts. Each vertical gear assembly is similar and consists of a bevel gear which is carried in two ball bearings held apart by a spacing collar on the bevel gear. The bearings are axially located in a housing by shoulders on the inner diameter of the housing. A ring nut secures the bevel gear within the bearings and spacing collar assembly.

Accessory boxes and drives

32. The two accessory boxes are mounted above and below the air-intakes and provide the mounting faces on which the electric starter, the engine accessories, and the engine-driven aircraft accessories are mounted. The top accessory box carries the air compressor, vacuum pump, cabin supercharger, generator, and the tachometer generator; an alternator may be fitted in place of the cabin supercharger. The bottom accessory box carries the electric starter, fuel pump, hydraulic pump, and

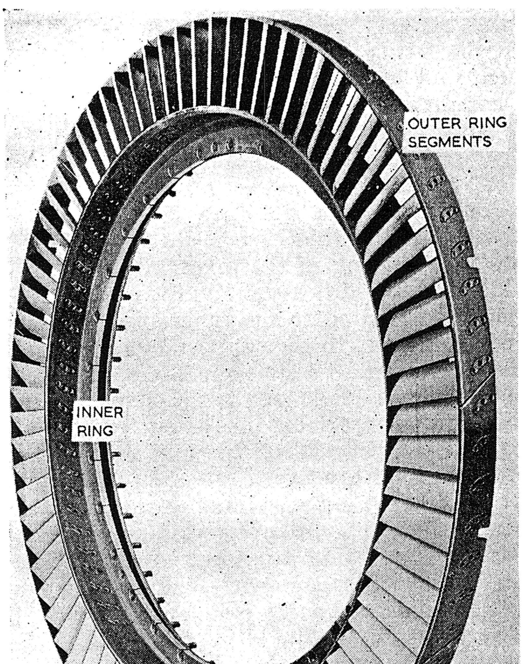

Fig. 24. Nozzle blades and rings

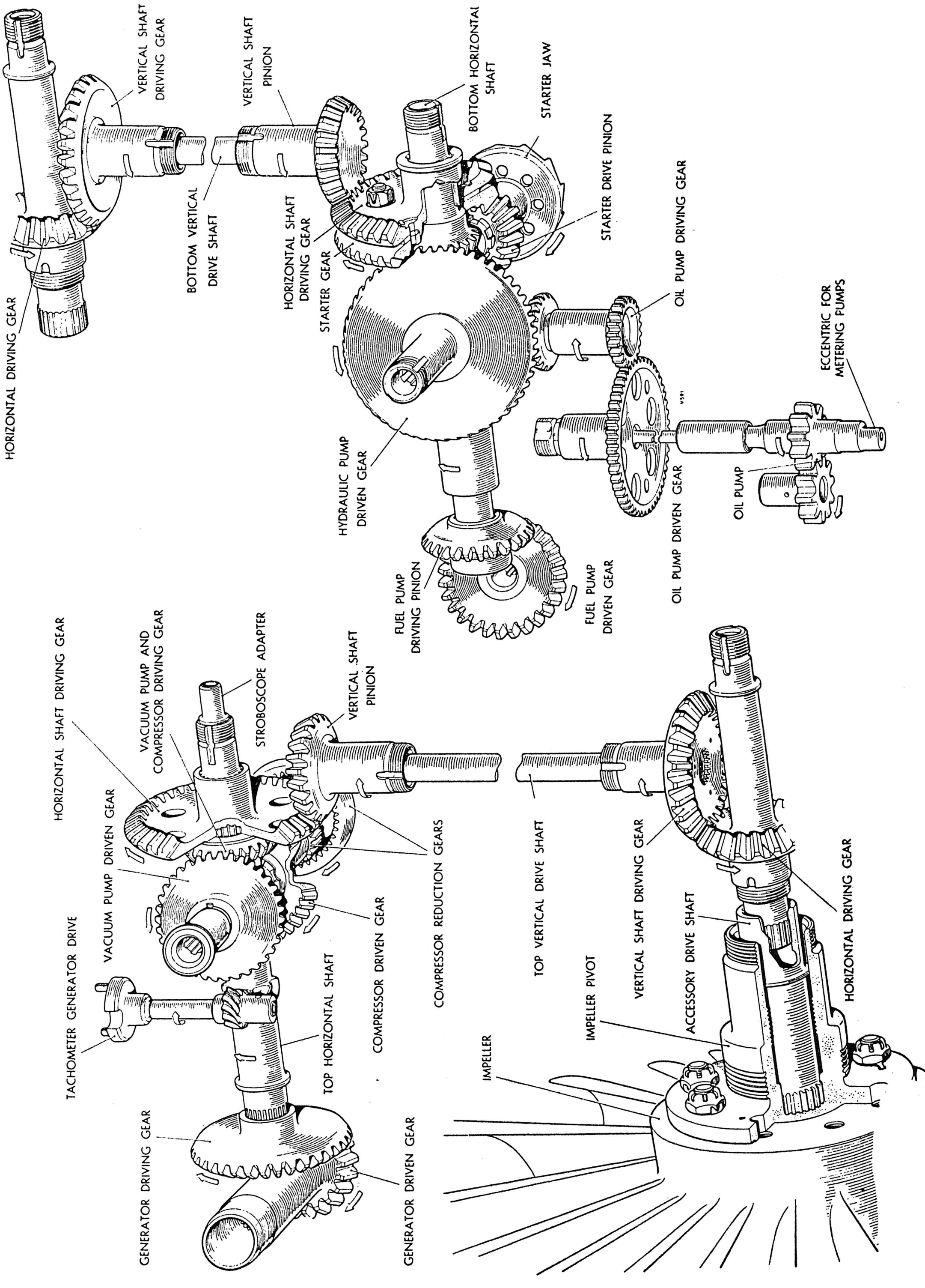

Fig. 25. Accessory drives and gears

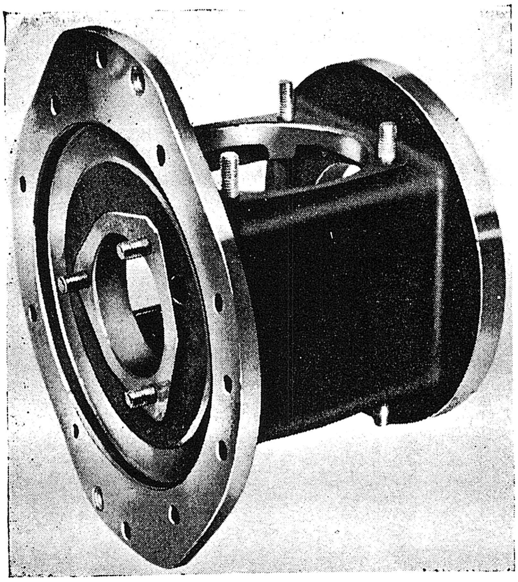

Fig. 26. Centre housing

the oil sump on which is mounted the oil pump. These accessories are driven from the front of the main shaft assembly, through the centre housing gears and the vertical drive shafts described in para. 30 and 31, through bevel gears and horizontal top and bottom shafts which are parallel to the main shaft, and bevel gears having drives at the individual faces. The electric starter rotates the engine through the same system of shafts and gears, and is provided with the usual arrangement of dog clutches through which engagement is made with the engine when starting, and which disengage automatically once the engine has reached its self-sustaining speed. The fuel pump, the oil and metering pumps, and the hydraulic pump are driven by the gear train in the bottom accessory box, the metering pumps being actuated by an eccentric formed on the lower extremity of the oil pump driving gear spindle. The fuel pump is fitted at the port rear drive position, and the starboard drive is not used, except in Mk. 2 engines which have the overspeed governor fitted at this position.

Top accessory box (*fig. 27*)

33. The top accessory box, which is roughly rectangular in shape, consists of two connected chambers and is attached to the top of the front casing by four long studs at the rear and seven short studs at the front. The long studs extend through the depth of the box, and the rear pair take the front lifting eye of the engine. Mounting faces are provided for two accessories on each side of the box, and for a tachometer generator on the top.

34. All the gears which drive the accessories mounted on the top accessory box are housed within the box. The top vertical drive shaft (*fig.* 25) transmits the drive from the centre housing to the top accessory box and is splined into the vertical shaft pinion, which drives the top horizontal shaft through bevel gearing. Bevel gears transmit the drive to short horizontal cross shafts at the two forward accessory mounting faces, and to a single horizontal cross-shaft at the two rear faces. An adapter fitted between the port side short horizontal cross-shaft and the compressor contains a reduction gear comprising a pinion and an internal gear. With this gear arrangement the line of the compressor drive is off-set from the short horizontal cross-shaft. An adapter is fitted to the

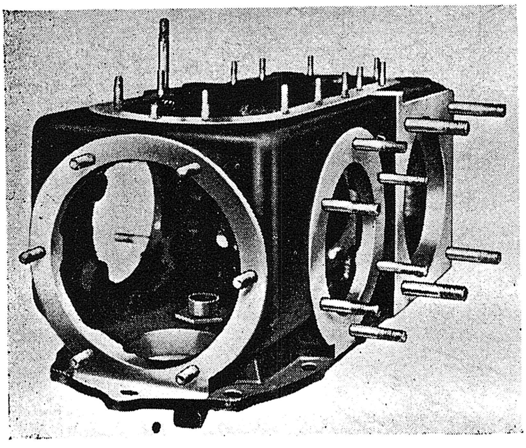

Fig. 27. Top accessory box

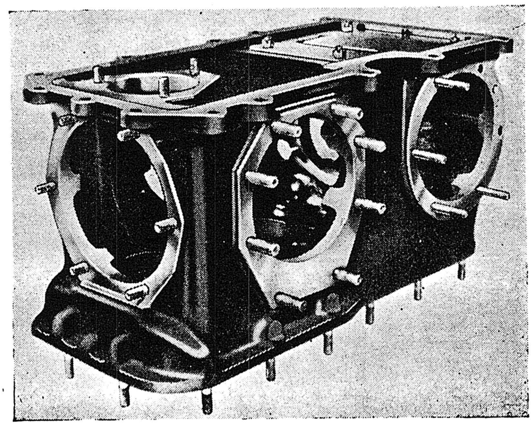

Fig. 28. Bottom accessory box

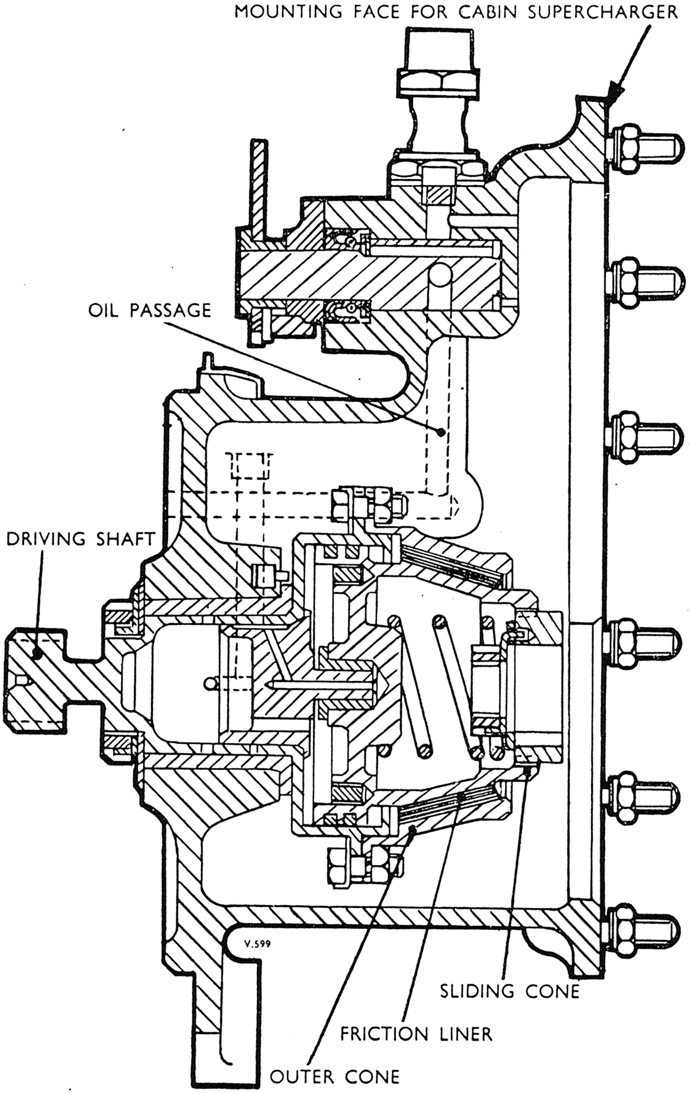

Fig. 29. Cabin supercharger clutch

forward end of the horizontal shaft to provide a drive for a stroboscope, which is used during engine testing. A skew gear integral with the main horizontal shaft drives a mating skew gear and a short vertical shaft to provide a drive for the tachometer generator, which is mounted on the top of the accessory box.

35. A conical clutch (*fig.* 29), operated by oil pressure, is accommodated between the cabin supercharger drive and the cabin supercharger. Oil under pressure is supplied from the top accessory box to a union in the top of the clutch housing, and controlled by an OFF-ON cock, within the housing, which is operated by a lever in the cockpit. The clutch comprises an outer cone and a sliding inner cone; the outer cone is driven by the extension shaft from the accessory box, and the sliding cone drives the cabin supercharger. In the disengaged position, when the operating oil is being returned through holes in the mounting face of the housing to the accessory box, the sliding cone is held out of engagement with the outer cone by a spring. Under oil pressure, the sliding cone is forced against the spring pressure into engagement with the outer cone, and the drive is transmitted through friction liners to the inner cone and cabin supercharger.

36. The vertical shaft pinion is supported by two ball bearings which are pressed into a housing attached to the bottom of the accessory box by three studs and nuts. The front end of the horizontal shaft is supported in a ball bearing located in a housing which is attached to the front of the accessory box by six studs and nuts: the drive for the stroboscope is normally covered by a plate which is secured to this bearing housing by six studs and nuts. The rear end of the horizontal shaft is supported in a ball bearing pressed into a housing which is attached within the rear of the accessory box by four studs and nuts. The three horizontal cross-shafts are each supported in two ball bearings pressed into housings which are secured to the accessory box by studs and nuts. The vertical shaft for the tachometer generator drive revolves in a plain bearing, which is pressed into a housing secured to the top cover of the accessory box by four studs and nuts. The top cover of the accessory box is located in position by two dowels and secured by thirteen studs and nuts. The oil filler cap and a breather cap are situated in the top cover, and provision is made for an oil thermometer pocket and for an oil pressure gauge connection. An oil gallery carries oil to four jets which play continuously upon the gears. An oil drain allows oil to drain into the centre housing, but projects into the top accessory box for about half an inch, to ensure that a sufficient level of oil is always maintained in the box.

Bottom accessory box (*fig. 28*)

37. The bottom accessory box is also roughly rectangular in shape and is similar to the top accessory box ; it is attached to the bottom of the front casing by fourteen studs and nuts. As with the top box, there are mounting faces for four accessories, and on the underside a large mounting face is provided for attachment of the oil sump.

38. The arrangement of the gears in the bottom accessory box is similar to that described for the top accessory box (*para.* 33). The horizontal shaft, which is of stronger construction than its counterpart in the top accessory box, carries four bevel gears. The front bevel gear transmits the drive from the vertical shaft pinion to the horizontal shaft—except during starting when conditions are reversed. Bolted to the back of this gear is another bevel gear which, during starting, transmits drive from the starter coupling to the front bevel gear. A smaller bevel gear, integral with the horizontal shaft, drives the hydraulic pump and, through a further bevel and spur gear train, the oil and metering pumps. At the rear end of the horizontal shaft another bevel gear drives the fuel pump and, in Mk. 2 engines, the governor. With the exception of the oil pump spur gears, which run in plain bearings, each of the drives is supported by two ball bearings.

39. A fuel pump driving gear meshes with the bevel gear at the rear end of the horizontal shaft. In Mk. 2 engines this driving gear is bolted to the flange of a cross shaft, which traverses the width of the accessory box to drive the governor mounted on the starboard side. The port mounting face carries an adapter assembly for the fuel pump. This assembly consists of an engine part which carries the driving gear extension shaft, and an engine part which is bolted to, and supplied with, the fuel pump. The function of the adapter is to simplify assembly, as the fuel pump is immediately behind the starter motor. In Mk. 3 engines a blanking plate is fitted to the starboard drive face.

40. The starter coupling assembly consists of a starter jaw, integral with a short shaft splined into a bevel gear pinion, which is supported by two ball bearings in a housing. The coupling assembly is secured to the front, port face of the accessory box by studs and nuts, and a face is provided on the coupling assembly for mounting the starter motor.

Combustion chambers

41. Sixteen combustion chambers are mounted between the rear face of the diffuser casing assembly and the nozzle ring assembly ; the chambers are numbered in a clockwise direction, when the engine is viewed from the front, No. 1 being at twelve o'clock. Each combustion chamber consists of a flame tube assembly enclosed within a casing, and a 'Simplex' type burner (*A.P.*4282*A*, *Vol.* 1) is mounted in each combustion chamber. All the combustion chambers are interconnected, thereby ensuring that pressures are equalised round the engine, and also permitting the flame to spread from one combustion chamber to the next after initial ignition.

42. All sixteen combustion chambers are not identical. The casings, which are formed in two halves (*fig.* 30 *and* 31), have alternate long and short front halves which pair with corresponding short and long rear halves, so that, although the overall lengths of complete casings are the same, the centre joint flanges of adjacent casings clear one another when in position on the engine. Combustion chambers No. 8, 9 and 10, which are the lower three on the engine, are each equipped with a drain point for connection to a common drain valve, and

Fig. 30. Combustion chamber rear casing

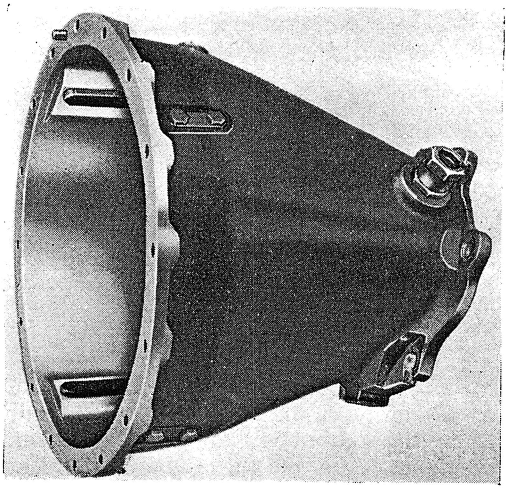

Fig. 31. Combustion chamber front casing

No. 2 and 14 are adapted to accommodate an igniter plug.

43. The combustion chamber front casing is connected to the diffuser casing by six bolts which screw into the diffuser casing rear cover. The drain connection, and the support pads which support the flame tube within the casing are contained in the front casing. The rear casing is flanged at its forward end for attachment to the rear of the front casing by bolts and nuts. The rear casing flange is stiffened by a segmented joint ring, and a composition joint ring between the flanges ensures a gas-tight joint. The rear casing contains flanges for the locating pin which locates the flame tube within the casing, as well as the interconnectors and the igniter plugs. To maintain the annular clearance between the casing and the flame tube as constant as practicable, thus promoting a uniform air velocity throughout the length of the combustion chamber, the rear casing is tapered from front to rear. A groove is machined in the rear end of the casing and two cast iron sealing rings are fitted into this groove to form a gas-tight sliding joint between the rear end of the combustion chamber and the nozzle ring.

44. Combustion takes place inside the flame tube assembly, which is enclosed within the front and rear casings, and the design of the flame tube plays a decisive part in determining the performance of the

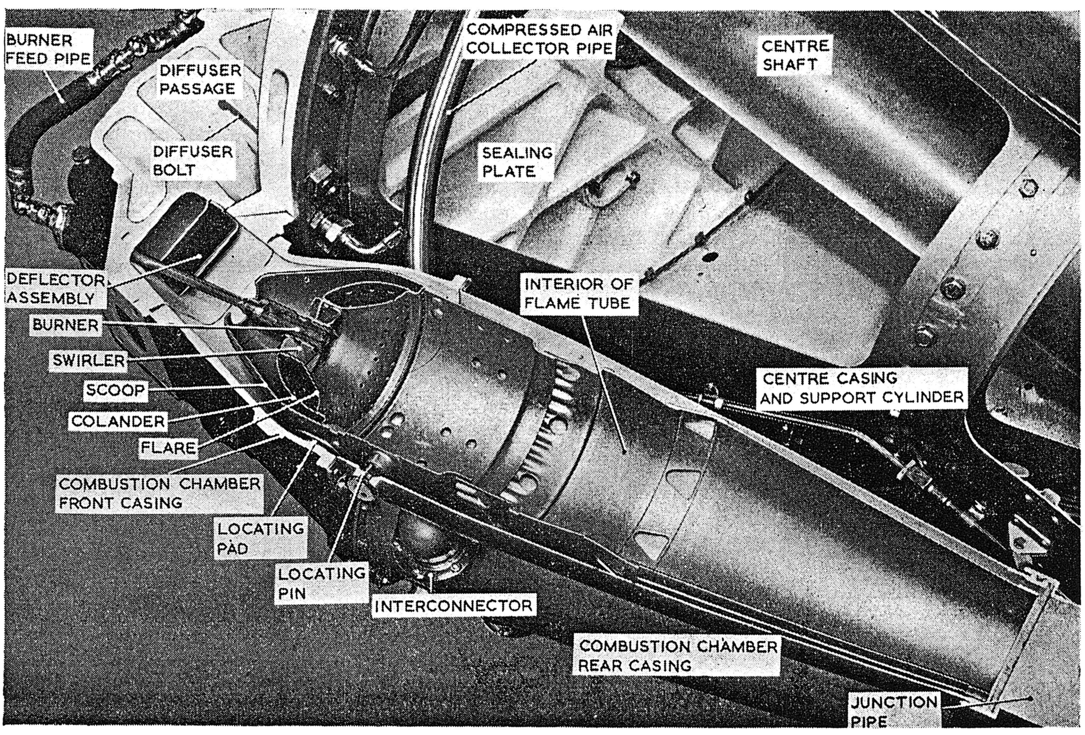

Fig. 32. Arrangement of combustion chamber components

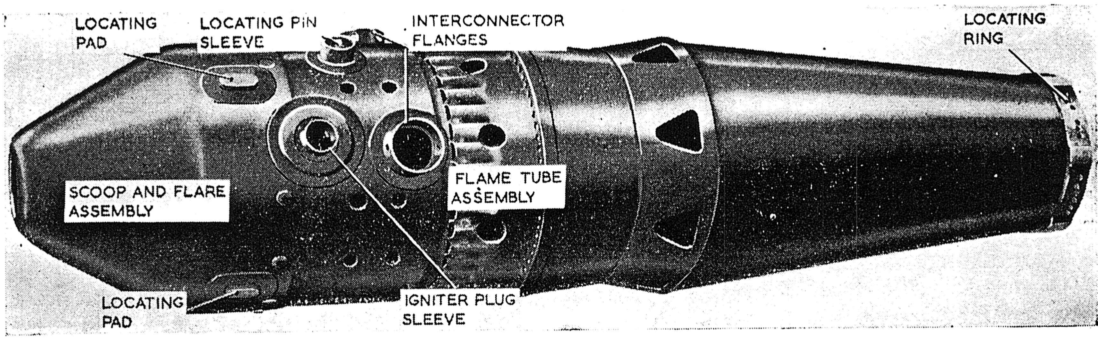

Fig. 33. Flame tube assembly fitted to Goblin 3, (Mod. 820)

complete combustion chamber. It is emphasized that the description which follows applies to the type of flame tube assembly fitted to Mk. 3 engines post-mod. 820 ; there being some difference between this and the pre-mod. 820 type (*compare fig.* 33 *and* 34).

45. The flame tube assembly consists of two main portions, the scoop and flare, and the flame tube. The scoop and flare assembly consists of a cone-shaped portion, containing the colander, flare, and swirler (*fig.* 32). These parts are welded together to form one unit. Most of the air which enters the front casing flows over the exterior of the scoop and flare assembly, but about a quarter of the quantity passes through an annular metering orifice around the burner at the forward end of the scoop into an annular space formed between the colander and the interior of the scoop. The dome-shaped colander is welded at its centre to the flare, and at its periphery to the skirt of the scoop. The flare, which is funnel-shaped, is welded at its periphery to the colander and at its centre to the swirl vanes, and has three rings of holes in it through which air is admitted to the outer radius of the combustion zone. Eight swirl vanes, welded at the centre of the colander and flare assembly, induce a swirl in the air entering the combustion zone through them. The inner edges of the swirl vanes are welded to a short sleeve which surrounds the atomiser end of the burner.

46. The flame tube is manufactured in three main parts, which are welded together, and is riveted to the rear end of the scoop and flare assembly. A series of holes and passages in the forward half of the flame tube control the distribution and quantity of air flowing into the combustion and mixing zones, while maintaining a constant flow of air along the inner surface of the flame tube to control temperature and reduce the formation of carbon. Cooling air is permitted to flow through the annular space between flame tube and rear casing to the rear end of the combustion chamber and out between six pads formed on a locating ring welded on to the outside of the rear end of the flame tube.

47. The complete flame tube assembly is centralised within the outer casing by four support pads welded on to the outside of the scoop and is supported by the support

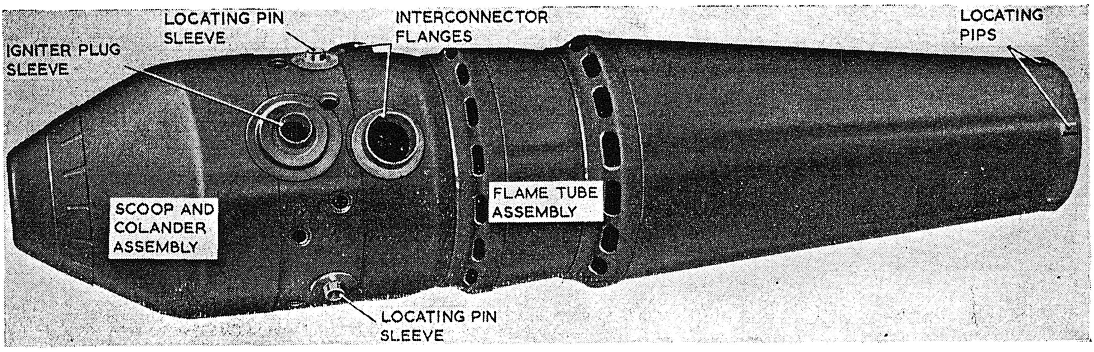

Fig. 34. Flame tube assembly fitted to Goblin Mk. 2 and Mk. 3 pre-mod 820

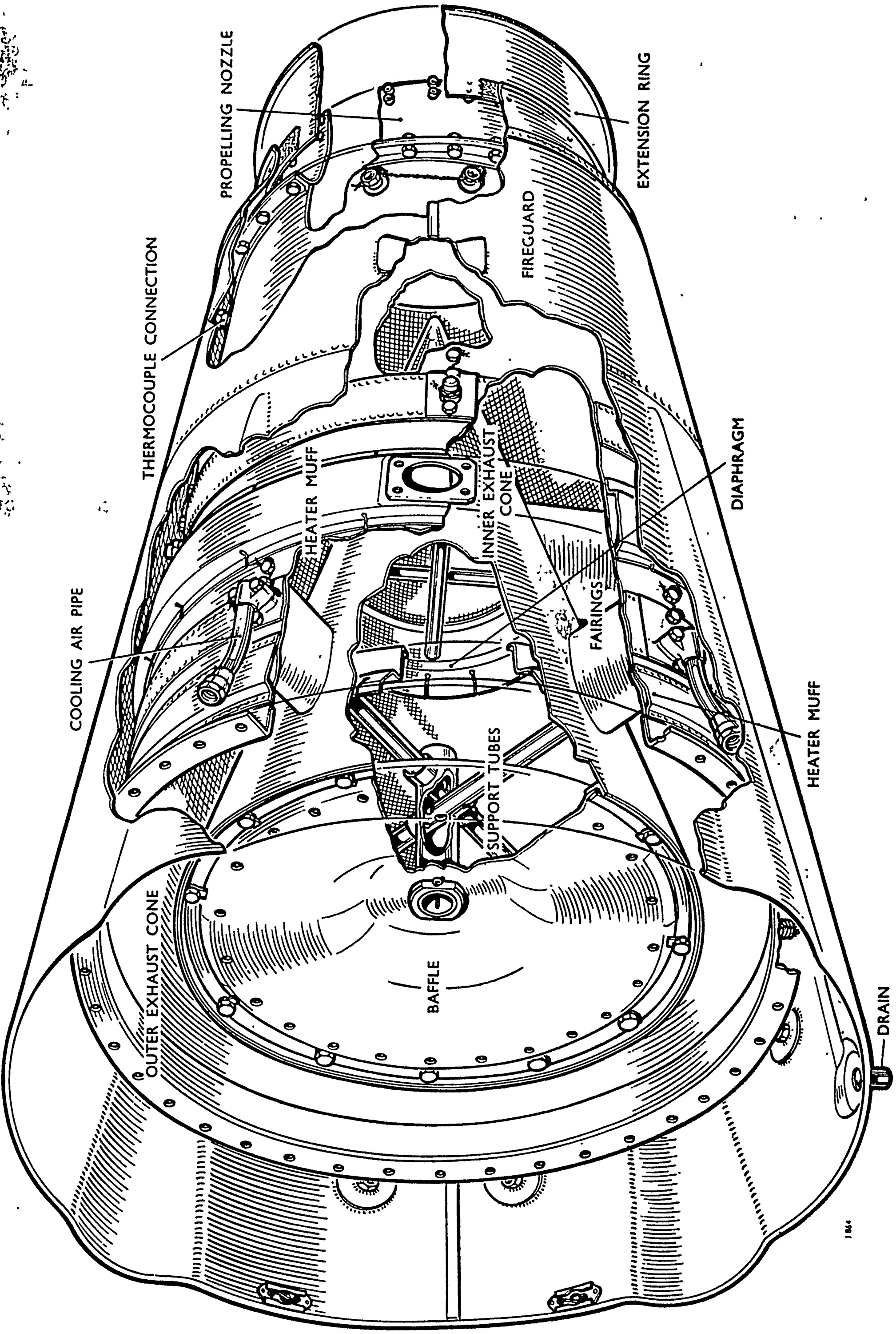

Fig. 35. Exhaust cones, propelling nozzle and fireguard assemblies.

pads inside the front casing, and by the segmented locating ring at the rear end of the flame tube, which is a sliding fit within the rear casing. Circumferential and longitudinal movement of the flame tube assembly is prevented by a locating pin which screws into a boss welded to the rear casing and locates a sleeve welded to the flame tube assembly.

48. Two interconnector stubs are welded to each flame tube. Each interconnector assembly consists of a pair of inner interconnector tubes within a pair of outer interconnector sleeves. The inner tubes are centralised within the interconnector stubs of the flame tubes. The other ends of the tubes are held in alignment with each other by two spherical connections, which are bolted together by six bolts and nuts. Cast iron sealing rings, fitted into grooves in the spherical connection, ensure a gas-tight joint between the spherical connection and the outer interconnector sleeve which is welded to the rear casing; eighteen holes in the spherical connections allow air to flow between the outer annular spaces of adjacent combustion chambers. The inner interconnector tubes provide the passage through which the flame spreads from one combustion chamber to the next after initial ignition; two only of the combustion chambers are fitted with igniter plugs. This sympathetic flame propagation only occurs during 'light-up'; once the engine is running the pressure balance is restored and no further flame flow takes place.

49. The flame tube assemblies fitted to Mk. 2 engines, and to Mk. 3 engines pre-mod. 820, differ from the combustion chamber which has been described, and which is illustrated in fig. 33. These flame tube assemblies (*fig.* 34) have three smaller locating pins, no locating pads, and a different system of holes for admitting air to the combustion zone. The scoop and colander assembly is not riveted to the flame tube assembly, the two components being located within the combustion chamber casing by the same three locating pins.

Exhaust cone (*fig. 35*)

50. The exhaust cone assembly, which collects the gases discharged from the moving turbine blades and directs them to the propelling nozzle, consists of an outer and inner cone, with fairings in between, and a propelling nozzle.

51. The outer cone takes the form of a sheet-metal truncated cone with its smaller end to the rear. At the front end a flange is welded for attachment to the turbine shroud by bolts and nuts. A second flange is welded to its rear end for attaching the propelling nozzle. At the smaller end of the outer cone, four thermocouple connection points are provided: only one point is fitted with a thermocouple for use in flight, the others, which are used on the test bench, being blanked. Sheet-metal sections welded over the cone form two muffs, which provide an air passage for air drawn from an external source; this air is heated through contact with the cone and is used for heating the aircraft cabin or guns. Drain connections are situated at the bottom, front and rear, of the outer cone, through which any excess fuel—due to 'wet starts' or other causes—can escape. Two reinforcement bands are welded to the outside of the outer cone, and four boss plate assemblies are welded to each reinforcement band to provide location for the support tubes of the inner cone.

52. The sheet metal inner cone fairs off the rear face of the turbine disc and also serves to maintain a smooth gas flow to the propelling nozzle. The cone is stiffened internally by two flexible diaphragms, which take the form of shaped sheet-metal hoops, welded to it, and the front end is closed by a dished disc of metal, known as the baffle. The inner cone is held in position in the centre of the outer cone by two pairs of crossed support tubes; these tubes are located in the boss plate assemblies of the outer cone, and pass through bosses welded into the inner cone at the points where it is stiffened by the large and small diaphragms. The rear support tubes are retained by cap nuts at each end. The front tubes are retained by the cooling air pipes which connect their open ends to pipes delivering air from the diffuser casing. At the centre, these two tubes pass through an air tube which projects forwards through the baffle. Cooling air from the diffuser casing is therefore delivered at the centre of the rear face of the turbine disc and, flowing outwards between the turbine disc and the baffle, is drawn into the main exhaust system through a clearance between the front end of the inner cone and baffle, and the turbine disc.

53. Two pairs of fairings enclose the support tubes where they pass between the outer and inner cones, thereby providing a smooth gas flow past the tubes. Each fairing is secured to the outer cone by three set-bolts and is just clear of the inner cone to allow for expansion of the fairings and of the inner cone.

54. The propelling nozzle assembly consists of the nozzle and the extension ring. The nozzle is shaped to form a venturi and is flanged at its larger, forward end for attachment to the outer cone. The extension ring is cylindrical, with a small lip at its rearward end, and is of larger diameter than the rear end of the nozzle. It is flush-riveted to the nozzle with packing pieces in between so that the exhaust gases leaving the nozzle can induce a flow of air through the annular space formed. This flow of air is used to ventilate the engine bay.

55. The size of propelling nozzle fitted to each individual engine is decided whilst the engine is being bench tested, alternative nozzles being fitted, where necessary, to correct the jet pipe temperature. Mod. No. 938 introduced a propelling nozzle which may be adjusted in size by varying the number of trimming strips which are fitted inside at the point where the extension sleeve is riveted to it. Each detachable trimming strip takes the form of a segment one-eighth of the circumference of the nozzle in length, and is secured by counter-sunk socket screws, and nuts ; the screws are fitted with the heads inside the propelling nozzle. From the foregoing, it will be realized that once an engine has been passed for service, a different size of propelling nozzle must not be fitted, nor must any alteration be made to the number of trimming strips, except as a result of subsequent bench testing.

Fireguard *(fig. 35)*

56. The fireguard, when assembled on an engine, forms a conical covering which surrounds the nozzle ring and exhaust cone assemblies. It consists of two halves, which separate longitudinally at the sides, and a support ring assembly. The support ring is secured to the rear flange of the nozzle shroud by the same bolts which attach this shroud to the turbine shroud. The top and bottom halves of the fireguard are assembled over the support ring and are drawn together by clip and pinch-bolt assemblies. The rear end of the fireguard is tightened, by the same method, over the front end of the extension sleeve of the propelling nozzle assembly. Air entering the engine bay is drawn rearward through the annular space between the fireguard and outer exhaust cone, and is expelled rearward through the propelling nozzle extension sleeve with the engine exhaust gases. The top half of the fireguard has a slot through which the engine rear lifting eye projects. The bottom half has a longitudinal gutter, which terminates at its forward end in a circular well having a central drain. Provision is made for connecting the air pipes from the heater muff, and the forward half of the assembly is flared at four points to obviate fouling with the pipes carrying cooling air to the rear of the turbine disc.

TABLE 1

MATERIALS AND FINISHES OF PRINCIPAL COMPONENTS

Note.—*For a complete list of detail parts, reference must be made to the Volume 3 of this publication.*

Main assembly	Component	Material	Surface finish
Bottom accessory box	Accessory box	Heat treated magnesium alloy	Chromate and black lacquer
	Gears	High tensile air hardening, or case hardening steel	None
Centre casing	Centre cone	Dead mild steel	Nickel plated
	Supporting cylinder	' 20 ' carbon steel	Nickel plated
Combustion chamber	Flame tube assembly	Nickel chrome alloy	None
	Front casing	Heat treated magnesium alloy casting	Chromate and black lacquer

Table I—*continued*

Main assembly	Component	Material	Surface finish
Combustion chambers *cont.*	Rear casing	Dead mild steel	Nickel plated
	Sealing rings	Cast iron	None
Compressor casing	Centre housing	Heat treated magnesium alloy casting	Chromate
	Diffuser casing	Heat treated magnesium alloy casting	Chromate and black lacquer
	Front casing	Heat treated aluminium alloy casting	Chromate and black lacquer
	Rear cover	Heat treated magnesium alloy casting	Chromate and black lacquer
	Sealing plate	Heat treated magnesium alloy casting	Chromate and black lacquer
Exhaust cone	Extension ring	Austenitic stainless steel sheet	None
	Fairings	Austenitic stainless steel sheet	None
	Front baffle	Austenitic stainless steel sheet	None
	Inner exhaust cone	Austenitic stainless steel sheet	None
	Nozzle	Austenitic stainless steel sheet	None
	Outer exhaust cone	Austenitic stainless steel sheet	None
	Support tubes	Stainless steel tube	None
Fireguard	Fireguard	Austenitic stainless steel sheet	None
	Support ring	Austenitic stainless steel sheet	None
Main shaft	Centre shaft	Mild steel forging	Cadmium plated
	Extension shaft	Mild steel forging	Cadmium plated
	Hub shaft	High tensile steel	None
	Impeller	Heat treated aluminium alloy forging	Anodised and Rockhard lacquer
	Pivot	High tensile steel	Cadmium plated under flange
	Turbine blades	Nickel chrome alloy	None
	Turbine disc	Ferritic high tensile steel forging	None
Nozzle ring	Inner nozzle ring	Austenitic high tensile steel casting	None
	Junction pipes	Austenitic stainless steel sheet	None

Table 1—*continued*

Main assembly	Component	Material	Surface finish
Nozzle ring *cont.*	Nozzle blades	Nickel chrome alloy	None
	Nozzle shroud	Austenitic high tensile steel casting	None
	Nozzle shroud struts	Stainless steel tube or austenitic stainless steel sheet	None
	Outer nozzle ring segments	Austenitic high tensile steel casting	None
	Turbine shroud	Austenitic high tensile steel casting	None
Oil sump	Sump	Heat treated magnesium alloy casting	Chromate and black lacquer
Top accessory box	Accessory box	Heat treated magnesium alloy	Chromate and black lacquer
	Gears	Case hardening steel and high tensile air hardening steel	None

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CHAPTER [illegible]

FUEL SYSTEM

Chapter 2

FUEL SYSTEM

Note.—*This chapter applies to Goblin Mk. 2 and 3 aero-engines*

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

GENERAL

1. Para. 2 to 26 of this chapter contain a general description of the Goblin Mk. 2 fuel system and para. 27 to 53 contain a general description of the Goblin Mk. 3 fuel system. Further details of the individual fuel system components are given in A.P.4282A, A.P.4282B and A.P.4282E.

GOBLIN Mk. 2 FUEL SYSTEM

FUEL SYSTEM COMPONENTS

2. Fig. 1 and 2 show the external appearance of the fuel system components and their location on the front of the engine.

Fuel pump

3. The fuel pump is mounted on the port side of the bottom accessory box immediately behind the starter motor. An adapter converts the four-hole type mounting on the pump cover to a standard RDE14/33 mounting flange to suit the mounting face on the engine. The fuel pump, which is driven at one-third engine speed through a train of bevel gears, is of the uni-directional, self-priming, rotary, piston type.

4. The fuel pump delivery is proportional to engine speed and the pump has ample capacity for all normal engine requirements with an adequate margin for acceleration.

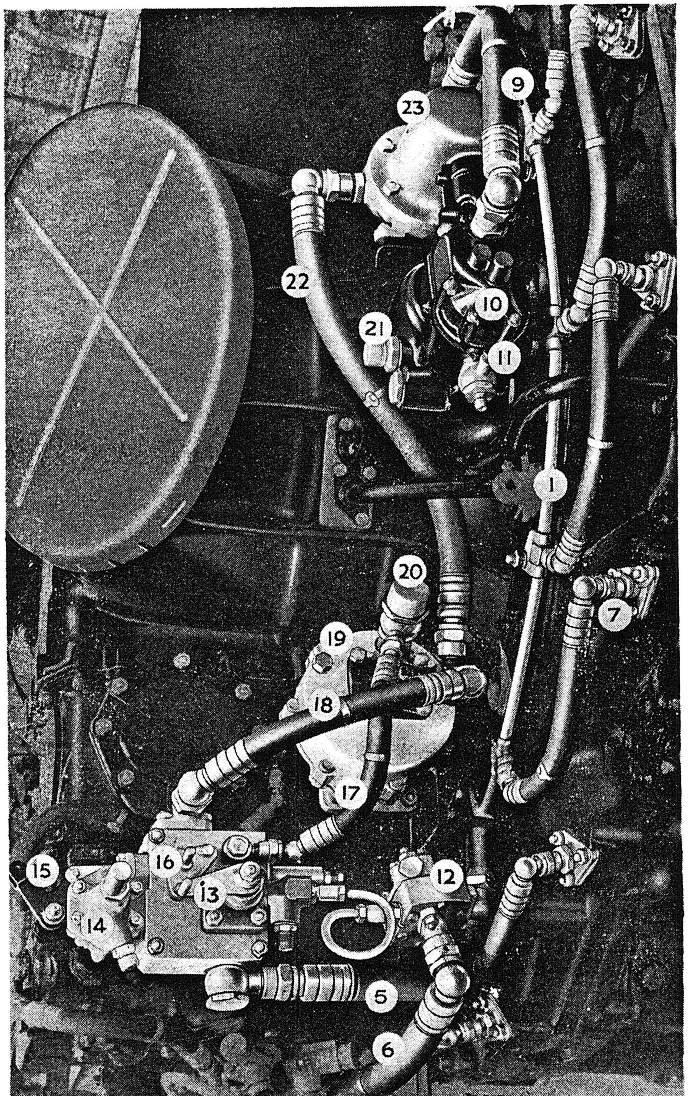

Fig. 1. Fuel system components on port side of Mk. 2 engine

KEY TO FIG. 1 AND 2

1 BURNER, OR FUEL, RING ASSEMBLY
2 OVERSPEED GOVERNOR
3 PIPE FROM MAIN FUEL SUPPLY LINE TO ACCUMULATOR
4 FUEL ACCUMULATOR
5 PIPE FROM CONTROL BOX TO GOVERNOR
6 PIPE FROM GOVERNOR TO STARTING VALVE
7 ONE OF THE BURNERS
8 BURNER FEED PIPE
9 PIPE FROM H.P. FILTER TO BAROSTAT
10 BAROSTAT
11 TOTAL HEAD (AIR PRESSURE) CONNECTION
12 STARTING VALVE
13 H.P. FUEL CUT-OFF LEVER
14 PRESSURE LIMITING VALVE
15 THROTTLE CONTROL PICK-UP
16 CONTROL BOX
17 ANTI-HAMMER PIPE FROM CONTROL BOX TO FUEL PUMP INLET
18 DELIVERY PIPE FROM FUEL PUMP TO CONTROL BOX
19 FUEL PUMP
20 FUEL PUMP INLET CONNECTION
21 FUEL RETURN, OR SPILL CONNECTION
22 PIPE FROM PUMP TO H.P. FILTER
23 HIGH PRESSURE FUEL FILTER

Barostat

5. The delivery to the burners is controlled by the barostat, which is mounted on the port side of the front casing just below the high-pressure fuel filter. The barostat is essentially a fuel pump pressure relief valve designed to by-pass fuel in excess of engine requirements back to the fuel tank. An exhausted capsule stack incorporated in the unit varies the amount of fuel by-passed to suit engine requirements, as determined by the pressure existing in the air-intake.

Control box

6. The control box is mounted on the port side of the sump and contains a graduated metering needle or plunger, which is connected to the pilot's throttle lever. The h.p. fuel shut-off valve is also incorporated in the control box and is connected to the h.p. shut-off lever in the cockpit.

7. The control box plunger is the throttle control and it is calibrated to meter the requisite fuel flow proportional to thrust; for equal increments of travel.

8. The h.p. fuel shut-off valve enables the pilot to stop the engine positively by shutting off the fuel supply to the burners when shutting down normally and in an emergency. To avoid the risk of hydraulic

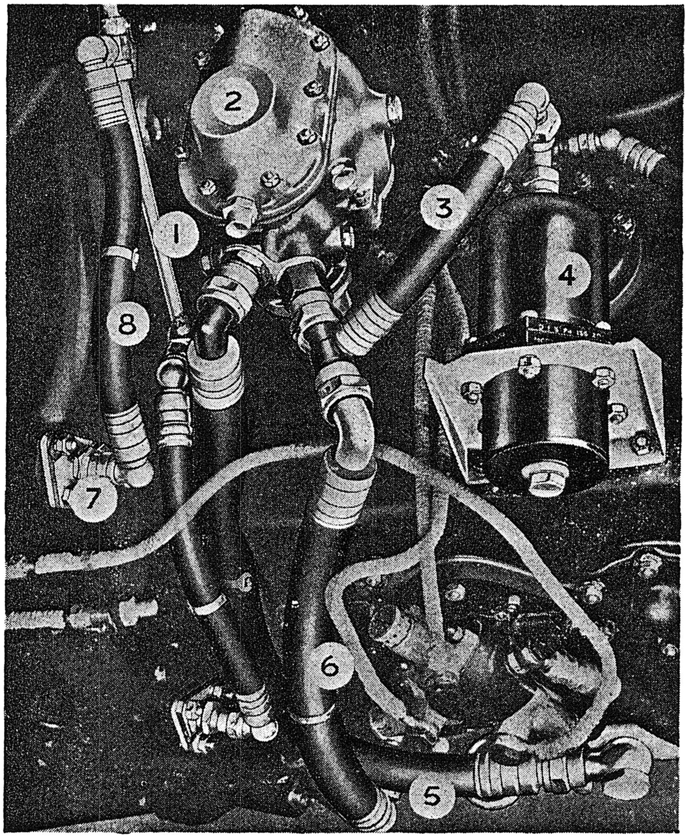

Fig. 2. Fuel system components on starboard side of Mk. 2 engine

in the burner ring does not fall below the safe minimum, thereby providing a safeguard against the possibility of the flame being extinguished if the throttle is closed at extreme altitude. The valve operates in conjunction with the throttle control box and functions only when the pressure in the burner manifold falls below a specified pressure. In this event a by-pass valve in the unit is opened by spring pressure, thus permitting a sufficient amount of fuel to by-pass the throttle control needle to enable the appropriate idling speed for that altitude to be maintained. By this means a safe minimum fuel pressure at the burners is ensured irrespective of the position of the needle which, in effect, is the throttle control.

Overspeed governor

10. The overspeed governor is mounted on the starboard side of the bottom accessory box and is driven by the opposite end of the cross-shaft which drives the fuel pump. It is of the centrifugal type and is designed to prevent overspeeding of the engine. The governor is situated in the main fuel path from the control box to the starting valve and the whole of the engine's fuel supply passes through the governor piston valve. As maximum engine speed is reached, centrifugal force acting on rotating weights in the governor moves the piston valve so that it throttles the engine's fuel supply and limits the maximum rev/min attainable.

hammer due to the sudden closing of the delivery passage to the burners, the fuel shut-off valve is arranged, when it is in the off position, to divert the fuel delivery back to the fuel pump inlet. A dump valve is attached to the side of the control box and may be regarded, for all practical purposes, as a part of the control box. The dump valve consists of a spring-loaded poppet valve, the stem of which engages a cam groove in the cut-off valve spindle. When the cut-off valve is moved to the off position, the dump valve is opened. One side of the dump valve is connected by a pipe to the starting valve and thus to the burner ring and the other side is piped to waste.

Pressure limiting valve

9. The pressure limiting valve (14, *fig.* 1) is attached to the front of the control box. Its purpose is to ensure that the fuel pressure

Fuel accumulator

11. The fuel accumulator is mounted on the starboard side of the sump and is connected to the main fuel supply pipe between the overspeed governor and the starting valve. Its function is to provide the initial boost of fuel to the burners during the motoring period when the starting valve opens and the engine speed is too low to provide a well atomized fuel spray.

Starting valve

12. The starting valve is situated just behind the control box on the port side of the engine and is connected directly to the burner ring. When the engine is not running a spring-loaded diaphragm seals the inlet port and prevents fuel passing to the burners. This permits the fuel accumulator to be charged during the initial motoring period until the pressure in the supply pipe reaches the value necessary for an efficient start and overcomes the starting valve spring pressure. During all normal running the starting valve is held open by the fuel pressure on the diaphragm.

Pressure switch

13. The pressure switch is mounted on a bracket attached to the front of the diffuser casing near the centre towards the top of the engine. It is connected to the burner ring, by a flexible pipe, to a point immediately before the flexible pipe leading to No. 15 burner. This pressure switch is wired into the starting circuit and when the contacts are open the relays controlling the final stage of the starting cycle cannot be energized. The pressure switch is operated by the fuel pressure in the burner ring and thus, since the contacts in the switch do not close until the burner pressure reaches a predetermined value, prevents the final stage of the starting cycle commencing too early and at the same time ensures that it commences immediately there is sufficient fuel pressure at the burners.

Burners

14. The sixteen burners are inserted into their respective combustion chambers through bosses cast in the diffuser casing and are connected by flexible pipes to the burner ring. They are of the fixed orifice simplex type and provide a conical spray giving atomization over the working flow range.

High-pressure fuel filter

15. The high-pressure fuel filter is mounted on the port side of the front casing. It is of the Purolator type and is situated in the fuel pipe between the fuel pump and the barostat, in order to protect the fine working clearances of this unit.

OPERATION OF THE FUEL SYSTEM

16. Fuel is supplied to the fuel pump on the engine by normal fuel tank booster pumps, through the low-pressure fuel shut-off or main fuel cock and a low-pressure fuel filter. These are airframe components, the engine part of the fuel system commencing at the engine-driven fuel pump.

17. Fig. 3, which is coloured to indicate the fuel flow, shows the general arrangement of the fuel system as mounted on the engine. The diagram does not illustrate the principle of operation of each fuel system component, for which reference should be made to the individual diagrams in the relevant Air Publications listed in para. 1.

Starting

18. The engine is started with the throttle needle in the slow-running position, and the h.p. fuel shut-off valve in the ON position, the starting valve being held closed by its spring. Since there is no fuel pressure in the burner ring, the contacts in the pressure switch are open.

19. As soon as the starter motor begins to turn the engine and the fuel pump begins to pump fuel through the control box, the fuel accumulator commences to fill, the piston therein being forced down and the spring compressed. When the fuel accumulator spring is fully compressed, the fuel pressure, together with the small pressure already built up in the burner ring, is sufficient to overcome the spring load on the starting valve. As the total area of the diaphragm in the starting valve is greater than the area of the valve closing the inlet port, the load on the diaphragm increases considerably immediately the valve commences to open, thus causing the valve to open fully almost instantaneously, and the fuel pressure in the burner ring to operate the pressure switch. Fuel then flows to the burners, the discharge of the fuel accumulator ensuring a good initial burst of spray.

20. The fuel accumulator is fully charged in approximately a quarter of a minute; the starting valve then opens to allow the accumulator to discharge through the burners into the combustion chambers. During this time the starter motor working with speed limiting resistances in circuit will have accelerated the engine to approximately 700 to 900 r.p.m. The spray of fuel discharging into No. 2 and 14 combustion chambers is lit by the igniter plugs, the flame rapidly spreading to the other combustion chambers. The ensuing pressure in the burner ring operates the pressure switch thus enabling a time switch in the starting panel to cut out the speed limiting resistances immediately after light-up. Full power of the starter motor is then available to assist the engine to its self-sustaining speed. A description of the electrical cycle during starting is given in Section 1 of this Volume.

Normal running

21. The thrust developed by the engine depends on the quantity of fuel being burnt. Thus, at a constant barometric pressure, opening the throttle calls for an increased flow of fuel to the burners. At altitude however, due to the reduced density of the air and the consequent lower weight of oxygen per cubic unit of air inhaled by the compressor, less fuel is required for any given throttle setting than at sea level.

22. When the aircraft is flying at a constant altitude or more correctly at a constant barometric pressure, the barostat acts as a simple fuel pump pressure relief valve and by-passes to the fuel tank all fuel in excess of that metered by the throttle setting. If however, the aircraft is climbing at a constant throttle setting, the decreasing barometric pressure reacts on the barometric capsule stack within the barostat so that the effective spring-loading on this relief valve is reduced. Thus a greater quantity of fuel is by-passed to the fuel tank and the fuel flow to the burners is reduced. Similarly with decreasing altitude the reverse action takes place.

23. To compensate for changes in the ram effect on the engine air-intake due to forward speed, the barostat capsule chamber is connected to a pressure point which faces forwards and receives the total head effect of flight. As flying speed increases, the pressure in the capsule chamber rises slightly and the fuel flow to the burners is increased to take advantage of the increased mass air flow due to ram effect.

24. If the throttle is closed quickly at extreme altitude, the very low resultant pressure in the burners might cause the flame to be extinguished. To prevent this the pressure limiting valve is connected across the throttle plunger metering orifice so that its spring-loaded diaphragm is subject to burner pressure. Normally, the burner pressure acting in the diaphragm is sufficient to overcome the spring pressure and to prevent the valve opening. Whenever the burner pressure falls below a pre-set value, the spring opens the pressure limiting valve and permits sufficient fuel to by-pass the throttle needle to maintain combustion.

Overspeeding

25. The whole of the fuel supply passes through the piston valve in the overspeed governor. So long as the engine speed is below the permitted maximum the fuel flow is unimpeded. The overspeed governor therefore, controls maximum r.p.m. only and not intermediate engine speeds. When the engine speed reaches a predetermined value the spring-loaded governor weights move outwards under centrifugal force and move the piston valve until sufficient restriction is offered to the fuel flow to limit the r.p.m. to the maximum permitted.

Stopping

26. When the H.P. fuel shut-off valve is moved to the off position by movement of the control in the cockpit, an anti-hammer passage in the control box is connected to the delivery side of the throttle needle and allows all the fuel delivered by the fuel pump to return to the pump inlet so that excessive fuel pressure is prevented; simultaneously the cam groove in the cut-off valve spindle opens the dump valve so that any unburnt residue of fuel in the burner ring can drain to waste. As soon as the burner pressure falls below that necessary to overcome the spring load on the diaphragm in the starting valve, the starting valve closes and the contacts in the pressure switch open ready for the next start.

GOBLIN Mk. 3 FUEL SYSTEM

FUEL SYSTEM COMPONENTS

27. The Goblin Mk. 3 may have either a dual or single pump fuel system according to the modification standard of the engine. The dual pump system is described and illustrated in this chapter. This description, however, can be applied to the single pump system if the following points are borne in mind. When a single fuel pump is used the pump is fitted on the port side of the engine and the mounting face on the starboard side is blanked off. The single pump is of larger capacity than either of the pumps used in the dual pump system, and is fitted with a fuel pump isolating valve. The piping, of course, is re-arranged slightly but remains fundamentally the same. Therefore, the fuel system diagram (*Fig.* 6) can be used if the following alterations are imagined:—Delete port pump (*item* 6) and its attendant piping. Regard starboard pump (*item* 5), which has the fuel pump isolating valve, as being the single pump and mounted on the port side of the engine.

Fuel Pump

28. The fuel pumps are mounted on either side of the bottom accessory box; the port pump immediately behind the starter motor and the starboard pump immediately behind the hydraulic pump, where it occupies the mounting face used for the overspeed governor on the Goblin Mk. 2. There is a cylindrical adapter between each fuel pump and the mounting face on the engine. These fuel pumps are of the positive displacement,

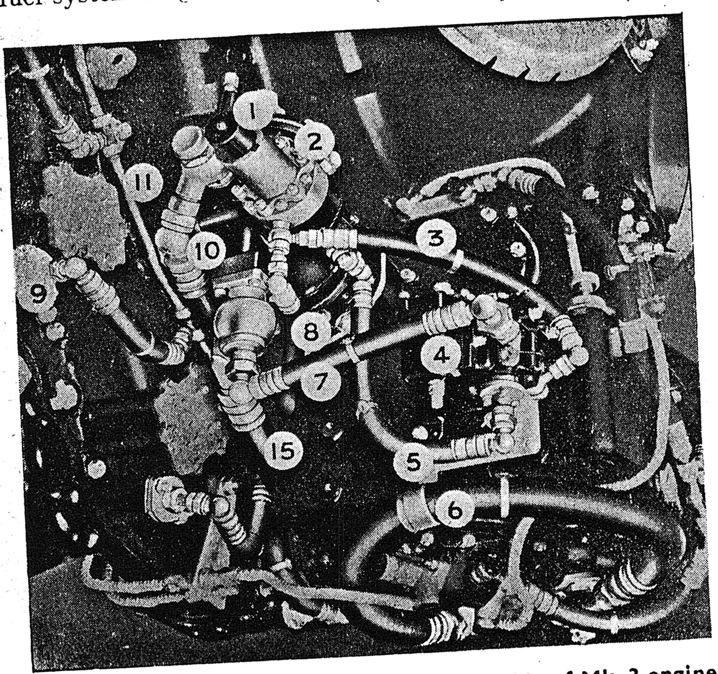

Fig. 4. Fuel system components on port side of Mk. 3 engine

KEY TO FIG. 4 AND 5

1 FUEL PUMP ISOLATING SOLENOID TERMINALS
2 STARBOARD FUEL PUMP
3 SERVO PIPE FROM STARBOARD PUMP TO B.P.C.
4 BAROMETRIC PRESSURE CONTROL
5 PUMP-DELIVERY PRESSURE PIPE FROM STARBOARD PUMP TO B.P.C.
6 PIPE FROM CONTROL BOX TO STARTING VALVE
7 PIPE FROM B.P.C. TO STARBOARD PUMP INLET
8 SERVO PIPE CONNECTING PORT PUMP TO STARBOARD PUMP
9 ONE OF THE SIXTEEN BURNERS
10 PUMP-DELIVERY PIPE FROM STARBOARD PUMP TO PORT PUMP
11 BURNER, OR FUEL, RING ASSEMBLY
12 REMOTE BLEED VALVE CONNECTED TO PORT PUMP
13 FUEL ACCUMULATOR
14 PIPE FROM ACCMULATOR TO STARTING VALVE
15 FUEL SUPPLY PIPE FROM TANK TO STARBOARD FUEL PUMP
16 STARTING VALVE
17 H.P. FUEL CUT-OFF LEVER
18 CONTROL BOX
19 PRESSURE LIMITING VALVE
20 THROTTLE CONTROL PICK-UP
21 PUMP-DELIVERY PIPE FROM PORT PUMP TO CONTROL BOX
22 ANTI-HAMMER PIPE FROM CONTROL BOX TO FUEL PUMP INLET
23 PORT FUEL PUMP INLET CONNECTION

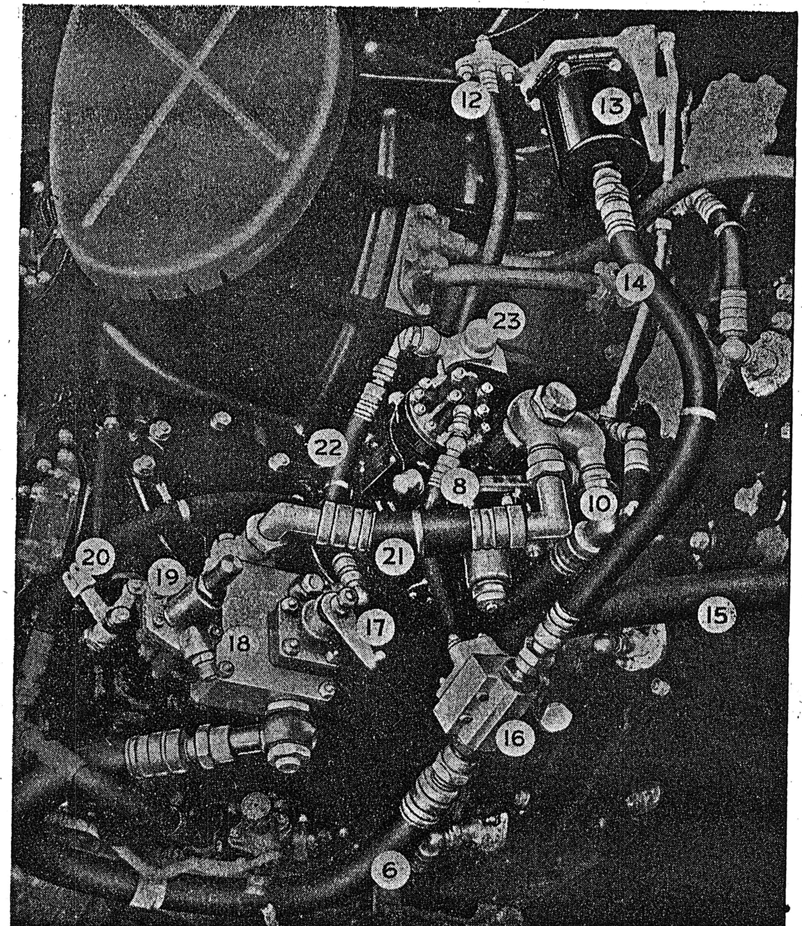

Fig. 5. Fuel system components on starboard side of Mk. 3 engine

variable stroke, multi-plunger type, and each incorporates a servo control, an overspeed governor, and relief valve mechanism. Each pump is driven at one third engine speed through a train of bevel gears. A solenoid operated, servo isolating valve is fitted to the starboard pump to provide an additional safety factor during take-off or in emergency conditions. Each pump is fitted with a non-return valve in its outlet connection so that fuel at high pressure cannot be pumped back into a failed pump thus causing it to motor and reduce the effective delivery pressure of the working pump. As already stated, each pump incorporates its own overspeed governor mechanism, and it is customary to set the starboard pump governor mechamism to control at an engine speed 50 r.p.m. higher than the port, so that the maximum r.p.m. can be reached without a conflict for control. When the ambient air temperature is above approximately eight degrees centigrade, either pump is capable of supplying sufficient fuel to enable the engine to attain its maximum r.p.m.

29. The pump delivery pressure is controlled by the Barometric Pressure Control through the pump servo mechanism. This mechanism contains a spring-loaded piston which is responsive to the servo pressure regulated by the Barometric Pressure Control, the pump delivery pressure, and the governor pressure. Movement of the piston alters the stroke, and hence the delivery, of the pump in response to the varying requirements of the engine as a result of changes in the throttle setting, altitude or barometric pressure, ram pressure on the engine air-intake due to the forward speed of the aircraft, attempts to overspeed, and excessive pressure in the delivery line such as might be caused by an obstruction in a pipe or orifice.

Barometric pressure control

30. The Barometric Pressure Control is mounted on the starboard side of the sump in the position occupied by the fuel accumulator on the Goblin Mk. 2, and is generally referred to as the B.P.C. It is connected, by flexible pipes, to the servo outlet on the port and starboard fuel pump, to the inlet (low pressure) side of the starboard fuel pump, and to the delivery (high pressure) side of the same pump. The two fuel pumps are connected in parallel and, as long as they are functioning normally, the B.P.C. is in communication with both.

31. When the engine is running, a small intermittent escape of fuel through the servo pipe and the B.P.C. to the fuel pump inlet, balances the quantity of fuel entering the servo system from the delivery side of the pump through a calibrated orifice. A filter in the servo connection of the B.P.C. prevents the entry of any foreign matter. There is no flow in the high pressure pipe (fuel pump delivery to B.P.C.) which simply acts as a pressure transmitter.

32. The B.P.C. contains an evacuated capsule stack which is subjected to the variations of air pressure at the engine air-intake. This evacuated capsule stack, in conjunction with a piston subjected to fuel pump delivery pressure via the fuel pump delivery to B.P.C. pipe, varies the size of the orifice through which fuel escapes from the servo system through the B.P.C. to the fuel pump inlet and thus regulates the servo pressure. Thus the B.P.C. is able to adjust the fuel pump delivery pressure so that the pressure is always proportional to the total air pressure in the engine air-intake. By this means the fuel pump delivery pressure, and consequently the pump stroke and actual delivery, is varied to meet changes in the engine speed or throttle setting, altitude or barometric pressure, and forward speed or ram effect, and the fuel pumps deliver only the exact quantity of fuel required by the engine.

Control box

33. The principal difference between the control box described in para. 6, 7, and 8 and that fitted on the Goblin Mk. 3 lies in the fitment of special fuel inlet and outlet connections to suit their different fuel systems. As this necessitates the fitment of different studs and similar small parts, the body assemblies are not interchangeable. A dump valve is not fitted to the Goblin Mk. 3.

Pressure limiting valve

34. The pressure limiting valve is virtually identical with that described in para. 9.

Overspeed governor

35. The overspeed governor is integral with each fuel pump.

Fuel accumulator

36. The fuel accumulator is mounted, with its fuel connection at the bottom, on the port side of the engine, occupying approximately the position of the barostat on the Goblin Mk. 2. It is connected directly to the inlet side of the starting valve, and its function and general construction is identical with that described in para. 11.

Starting valve

37. Although there are detail differences in the design of the starting valves fitted to the Goblin Mk. 3 their purpose and functioning are identical with those fitted to the Goblin Mk. 2.

Burners

38. The burners are similar to those used in the Goblin Mk. 2 but each is secured by two studs and nuts instead of three.

OPERATION OF THE FUEL SYSTEM

39. Fuel is supplied to the engine-driven fuel pumps by a normal fuel tank booster pump through a low pressure fuel shut-off valve, or main fuel cock, and a low pressure fuel filter. These are airframe components, the engine portion of the fuel system commencing at the engine-driven fuel pumps. The fuel is pumped, at a comparatively high pressure, through the control box, and the starting valve to the burner ring and the sixteen burners.

Starting

40. The engine is started with the control valve plunger in the slow-running position and the H.P. fuel cut-off valve in the ON position ; the starting valve is held closed by its springs, and the fuel accumulator is discharged.

41. As soon as the starter motor begins to rotate the engine, fuel is pumped through the control box, and the fuel accumulator commences to fill ; the piston therein is forced up and the spring compressed. When the fuel accumulator spring has been fully compressed the spring load on the starting valve is overcome by the fuel pressure, assisted by the small fuel pressure that calibrated leakage past the starting valve has built up in the burner ring. As the total area of the diaphragm in the starting valve is much greater than the area of the valve closing the inlet port, the load on the diaphragm increases considerably immediately the valve commences to open, thus causing the valve to open fully almost instantaneously. Fuel then flows to the burners, the discharge of the fuel accumulator ensuring a good initial burst of spray.

42. Approximately a quarter of a minute is taken to charge the fuel accumulator, by which time the starter motor, working with speed limiting resistances in circuit, will have accelerated the engine to between 700 and 900 r.p.m. The igniter plugs light the spray of fuel issuing from the burners, the flame spreads to the other combustion chambers through the interconnecting passages, and a time switch in the starting panel cuts out the speed limiting resistances so that the full power of the starter motor is available to assist the engine to accelerate to its self-sustaining speed.

Normal running

43. The thrust developed by the engine depends on the quantity of fuel being burnt. Thus, at a constant barometric pressure, opening the throttle calls for an increased flow of fuel to the burners. At altitude, however, due to the reduced density of the air and the consequent lower weight of oxygen per cubic unit of air inhaled by the compressor, less fuel is required for any given throttle setting than at sea level. Thus when climbing at a constant throttle setting a diminishing amount of fuel is required.

44. The Barometric Pressure Control, in conjunction with the servo piston mechanism in each fuel pump, automatically adjusts the fuel pump delivery pressure, and thus the fuel flow, to meet changes in throttle setting, altitude or barometric pressure, and forward speed. When the aircraft is flying at a constant altitude, or more correctly at a constant barometric pressure, as long as the throttle setting remains unchanged, the escape of fuel through the B.P.C. controls the pressure in the servo system so that the forces acting on the servo piston are in equilibrium, with a very small flow of fuel through the servo pipe and the B.P.C. back to the inlet side of the pump. The pressure in the servo system is less than pump delivery pressure by approximately the value of the spring loading on the servo piston. The fuel pump delivery pressure, the fuel pressure on the inlet side of the control box, is automatically maintained at a pressure sufficient to maintain this equilibrium. If, under these conditions, the throttle is opened further the consequent momentary reduction in the fuel pump delivery pressure below that pressure required to maintain the equilibrium, causes the servo orifice in the B.P.C. to be closed. The fuel pressure on either side of the servo piston in each fuel pump becomes balanced and the spring-loaded servo pistons move so that the pump stroke is increased, and hence the delivery and pressure, until the forces are once again in equilibrium. Conversely any rise in pump delivery pressure such as will occur momentarily when the throttle is closed, causes the servo orifice to be opened further and the decreased fuel pressure in the pump servo system permits the servo pistons to move so as to decrease the pump stroke, delivery and pressure, until normal operating conditions are restored.

45. If, however, the aircraft is climbing at a constant throttle setting, the decreasing barometric pressure, due to the increasing altitude, reacts on the evacuated capsule stack within the Barometric Pressure Control so that the equilibrium of the servo pistons is upset; the servo orifice in the B.P.C. is opened and the pump servo mechanisms decrease the pump stroke delivery and pressure, until equilibrium is restored at the new air-intake pressure. Thus the fuel pressure on the inlet side of the control box is reduced and the flow to the burners reduced correspondingly. Similarly with decreasing altitude, or increasing barometric pressure, the reverse action takes place.

46. To compensate for changes in the ram effect on the engine air-intake, due to changes in the forward speed of the aircraft, the evacuated capsule chamber in the B.P.C. is connected to a pressure point, or total head, which faces forward and receives the full effect of the speed of flight. As flying speed increases the pressure in the capsule chamber rises slightly and the fuel flow to the burners is increased to take advantage of the increased air mass flow due to ram effect.

47. If the throttle is closed quickly at extreme altitude, or if for any other reason, the pressure in the burner ring falls below a critical value, the very low resultant pressure at the burners might cause the flame to be extinguished. To prevent this the Pressure Limiting Valve is connected in parallel with the control valve, or throttle, so that its spring-loaded diaphragm is subjected to burner pressure. Normally the burner pressure acting on the diaphragm is sufficient to overcome the spring loading and to prevent the valve opening. Whenever the burner pressure falls below a pre-set value, the spring opens the Pressure Limiting Valve and permits sufficient fuel to by-pass the control valve to maintain combustion.

Overspeeding

48. In the Goblin Mk. 3 fuel system there is no separate overspeed governor as each fuel pump contains its own integral overspeed governor mechanism. Radial ports in the pump rotor create, when the pump is running, a centrifugal fuel pressure within the pump casing. This fuel pressure, which increases with increasing r.p.m., acts on a diaphragm in the pump and at a predetermined engine speed, opens an orifice which permits fuel from the pump servo system to escape to the inlet side of the pump, thus allowing the servo piston in the pump to decrease the pump stroke, delivery and pressure, and so prevent any further increase in engine speed.

Stopping

49. When the high pressure fuel cut-off valve is moved to the OFF position by operation of the control in the cockpit, an anti-hammer passage in the control box is connected to the delivery side of the control valve, or throttle, the delivery passage to the burners is closed, and all the fuel delivered by the fuel pumps is diverted back to the inlet side of the pumps so that any build up of excessive fuel pressure between the fuel pumps and the control box during the slowing down of the engine is prevented. As soon as the burner pressure falls below that necessary to overcome the spring load on the diaphragm in the starting valve, the starting valve closes ready for the next start.

Fuel pump isolating control

50. In the dual pump system fitted to the Goblin Mk. 3 both pumps are normally subject to the same degree of control and thus contribute an equal share of the engine's fuel requirements. In the event of failure of either pump, or of the B.P.C., or of the connecting servo pipes, the delivery of the serviceable pump would be related to that of the defective one. Therefore, both pumps would tend to be moved by their servo-mechanisms to the zero delivery position. To safeguard against this occuring during take-off, the pilot operates the fuel pump isolating switch before attempting to take off; energising the solenoid on the starboard fuel pump and closing the isolating valve.

51. As long as both pumps are functioning normally, and the delivery of fuel from each holds open the non-return valves in their delivery outlets, both pumps are controlled by the B.P.C. Under these conditions, when the isolating valve is closed the starboard fuel pump servo mechanism is cut off from the B.P.C. and the pump operates at maximum delivery, subject to the limit imposed by the relief valve and governor mechanism. The servo mechanism of the port fuel pump, being still controlled by the B.P.C., automatically reduces the delivery of this pump until it is supplying only the difference between the engine's fuel requirements and the delivery of the starboard pump. When the ambient air temperature is above about eight degrees centigrade, or when below this temperature the engine is operating at less than its maximum speed, the port fuel pump will be at zero delivery as under these conditions one pump is capable of supplying the engine's full requirements.

52. With the isolating valve already in the closed position, if a failure should occur in the port fuel pump, the B.P.C. or the servo pipes, the starboard pump continues to operate at full delivery, as described in the preceding paragraph. Failure of the starboard pump would, however, cause a drop in the pump delivery pressure transmitted to the B.P.C. which will then be isolated from the effect of port fuel pump delivery pressure by the non-return valve in the starboard pump outlet. Therefore, the servo mechanism in the port fuel pump will automatically bring that pump to full delivery and ensure the continued delivery of fuel to the burners.

53. In the single pump system, the isolating valve is fitted to the pump and provides a safeguard against failure of the B.P.C. and servo pipes in a similar manner to that described in para. 52.

A SYSTEM UNDER NORMAL RUNNING CONDITIONS

1 FUEL INLET
2 OVERSPEED GOVERNOR DIAPHRAGM
3 PISTON
4 CENTRIFUGAL PASSAGE
5 STARBOARD PUMP
6 PORT PUMP
7 PUMP SERVO OUTLET
8 BURNER
9 BURNER MANIFOLD
10 ACCUMULATOR
11 STARTING VALVE
12 PORT PUMP BLEED VALVE
13 H.P. COCK
14 MINIMUM PRESSURE VALVE
15 INLET TO ENGINE CONTROL BOX
16 ENGINE CONTROL BOX
17 THROTTLE NEEDLE
18 HALF BALL VALVE
19 SERVO INLET FROM PUMPS
20 PRESSURE TRANSMITTING PLUNGER
21 FLEXIBLE PIVOT PLATE
22 VALVE LEVER
23 CAPSULE STACK
24 PRESSURE TRANSMITTING LINE
25 PUMP ROTOR
26 B.P.C. OUTLET
27 B.P.C. UNIT
28 SWASH PLATE
29 LINK
30 CAPSULE CHAMBER SUBJECTED TO NACELLE PRESSURE
31 SERVO PISTON
32 INLET AND OUTLET PORTS INSERT
33 SOLENOID OPERATED ISOLATING VALVE
34 NON-RETURN VALVE
35 RESTRICTING ORIFICE TO SERVO CYLINDER
36 RELIEF VALVE

B. CONDITIONS IMMEDIATELY AFTER CLOSING HP COCK

37 ANTI-HAMMER PASSAGE
38 TO ACCUMULATOR
39 FROM BURNER MANIFOLD
40 RETURN TO PORT PUMP INLET

C. POSITIONS OF COMPONENTS ON ENGINE

- PUMP INLET PRESSURE
- PUMP DELIVERY PRESSURE
- BURNER OR METERED PRESSURE
- SERVO PRESSURE
- CENTRIFUGAL PRESSURE
- DRAIN
- COMPRESSOR INTAKE PRESSURE

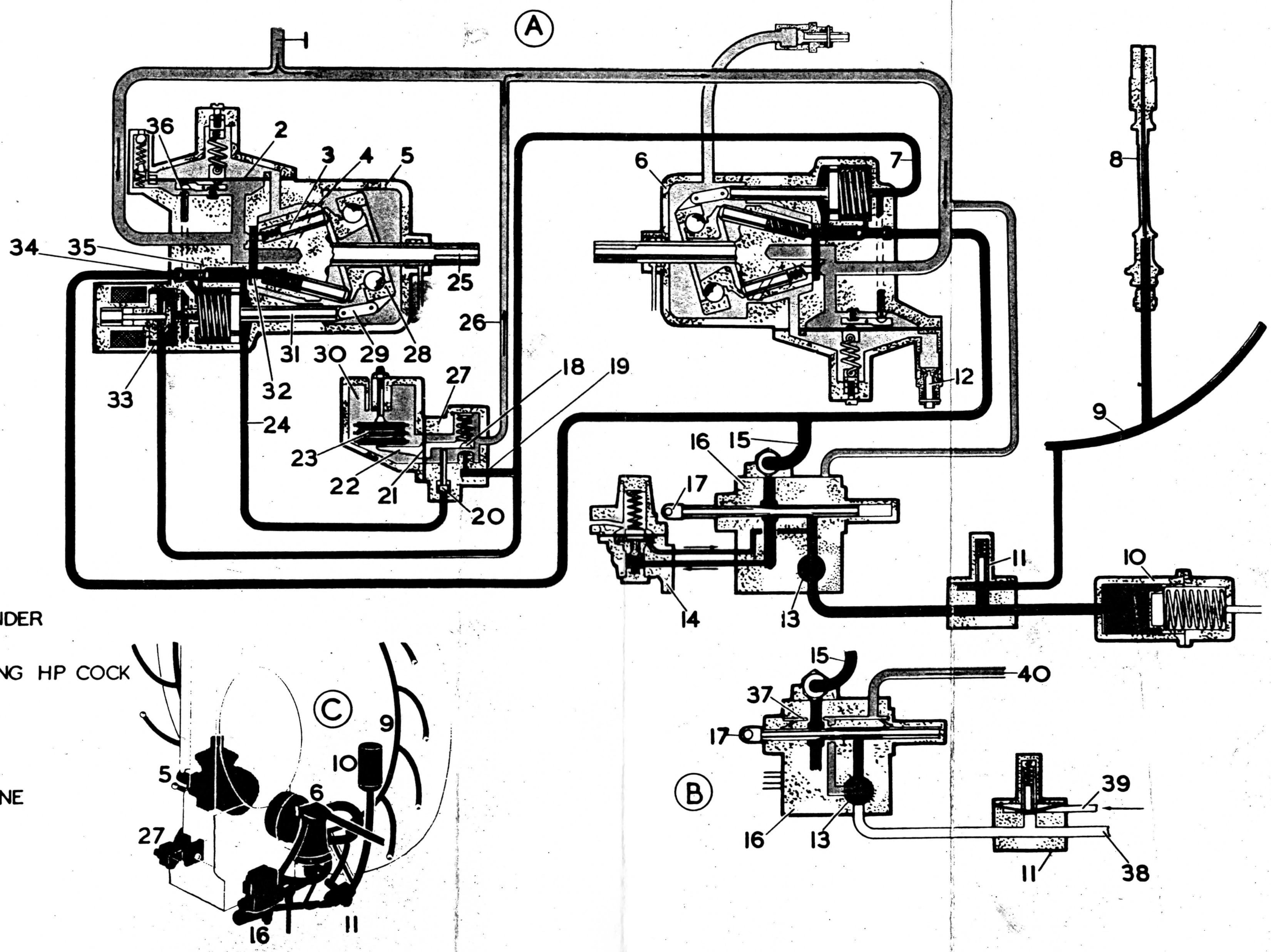

FIG. 6 - DIAGRAM OF GOBLIN MK. 3 FUEL SYSTEM

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1. BAROSTAT SPILL RETURN TO TANK.
2. BAROSTAT.
3. TOTAL HEAD AIR-INTAKE PRESSURE.
4. HIGH PRESSURE FUEL FILTER.
5. BURNER RING.
6. BURNER PRESSURE SWITCH.
7. FUEL PRESSURE GAUGE CONNECTION.
8. BURNERS.
9. FUEL ACCUMULATOR.
10. STARTING VALVE.
11. DUMP VALVE.
12. HIGH PRESSURE FUEL CUT-OFF VALVE.
13. CONTROL VALVE PLUNGER THROTTLE.
14. ANTI-HAMMER PIPE RETURN TO PUMP INLET
15. CONTROL BOX.
16. PRESSURE LIMITING VALVE.
17. ENGINE DRIVEN FUEL PUMP.
18. FUEL INLET FROM TANK.
19. OVERSPEED GOVERNOR.

- PUMP INLET PRESSURE
- CENTRIFUGE FLOW
- PUMP DELIVERY PRESSURE
- METERED OR BURNER PRESSURE
- BAROSTAT SERVO PRESSURE
- BAROSTAT SPILL RETURN TO TANK
- COMPRESSOR INTAKE PRESSURE
- DRAIN

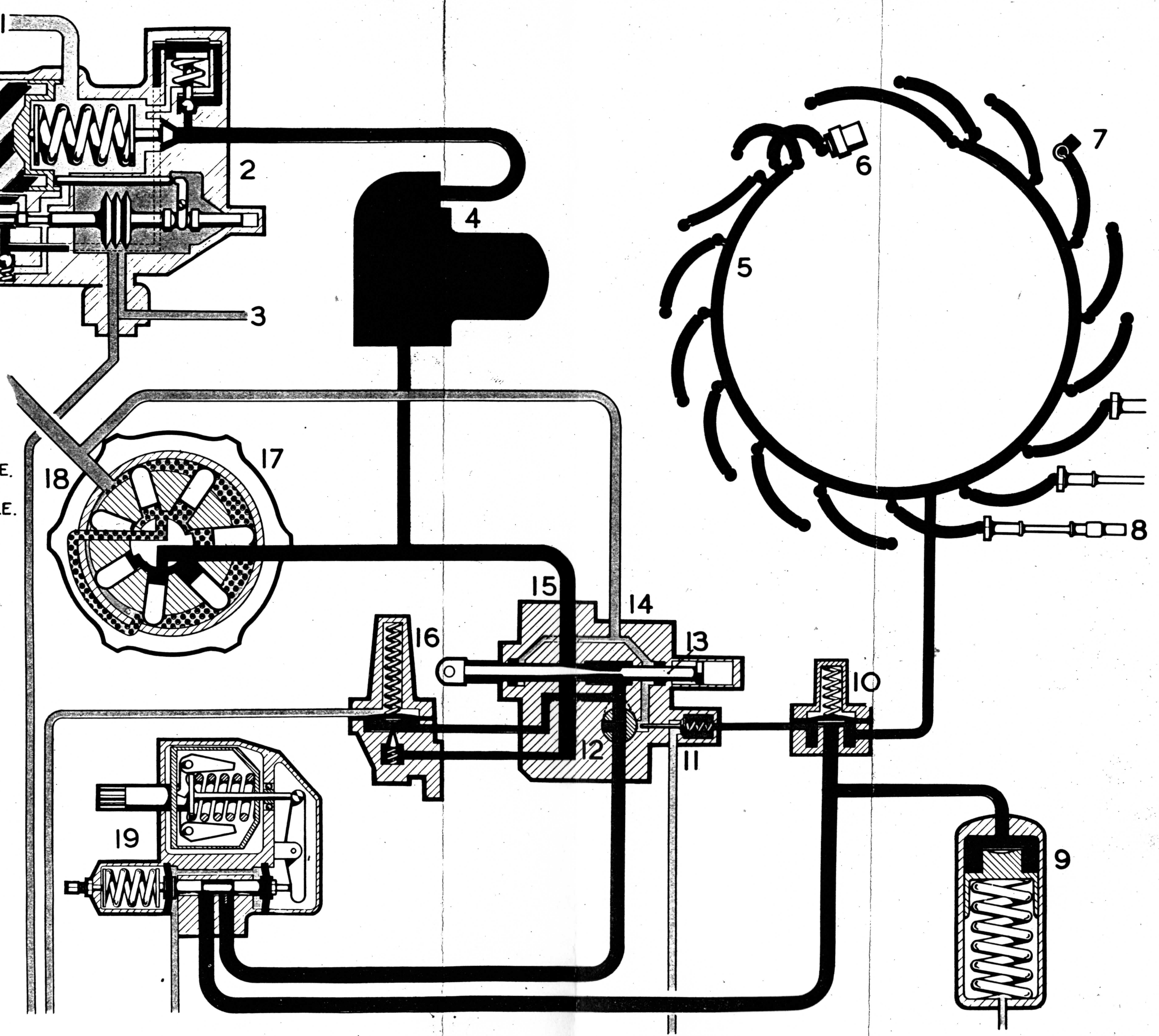


FIG. 3. DIAGRAM OF GOBLIN MK.2 FUEL SYSTEM

RESTRICTED

CHAPTER [illegible]

LUBRICATION

RESTRICTED

Chapter 3

LUBRICATION

Note.—*This chapter applies to Goblin Mk. 2 aero-engines*

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

GENERAL

1. The entire lubrication system of the engine is self-contained; the oil is carried in a sump directly attached by studs to the base of the bottom accessory box. The sump contains a gear-type pressure pump, suction and pressure filters, an oil pressure relief valve and a dip-stick for measuring the depth of the oil; the filler cap is situated on the top accessory box. Small metering pumps are also mounted externally on the base of the sump and are driven from the extension shaft of the pressure pump.

Oil circulation

2. The general scheme of lubrication is to supply pressure oil to a number of jets which spray on to the driving gears and other points of loading; drain oil from the accessory boxes falling back to the sump lubricates all parts by splash. In the sump, the oil passes through the suction filter to the gear-type pressure pump and from the pump direct to the pressure filter. The high pressure filtered oil then passes through pipes leading from the front of the sump to engine and aircraft accessories mounted on the bottom and top boxes respectively. The high pressure filtered oil is also supplied to the metering pumps mounted on the bottom of the sump. There are two metering pumps supplying oil to the front and rear bearings by external pipe lines and a third metering pump supplies the governor (para. 18).

3. The high pressure line to the accessory boxes leaves the front of the sump and crosses to the starboard side. One branch follows the contour of the sump to the port side of the bottom accessory box where it supplies a jet for the starter motor gears and reduction gears; this jet is bolted to the housing of the extension drive of the starter motor. Another branch follows up the starboard side of the bottom accessory box, passes into the front casing, emerges at the top and is continued at the top of the upper accessory box; this long pipe is in two parts, coupled together at the front bearing, by a fitting which incorporates an oil jet to feed the centre housing driving gears. On the top of the upper box there are unions on an external oil gallery, from which there are connections to :—the pressure transmitter, transferring the pressure to the pressure gauge; the oil thermometer; the pipe lines to the vacuum pump; the cabin supercharger; and the air compressor. There is also an internal gallery to the oil jets for the top accessory drives, three jets in one block supplying the front drives and one jet supplying the rear.

4. Oil is supplied to the front bearing by a pipe from one of the metering pumps. This pipe is on the starboard side of the accessory box, and, entering the front casing, is carried inside the longer pipe which supplies pressure oil to the top accessory box. Metered oil for the rear bearing is supplied through an external pipe carried on the starboard side of the engine. The metered oil to the front bearing returns to the sump and the rear bearing oil drains to waste. The front and rear bearing housings are so arranged that when the engine is stopped, sufficient oil is retained to ensure lubrication at starting.

Oil sump

5. The sump is a flat rectangular magnesium-alloy casting and the casings for the suction and pressure filters, the dip-stick container, and the housing of the pressure relief valve, are integral with the sump. The pipe connecting the sump with the bottom accessory box, into which it protrudes approximately one inch, extends to within one inch of the bottom of the sump to prevent the oil accumulated in the sump from flooding the accessory boxes during aerobatics.

Oil sump filters

Suction filter

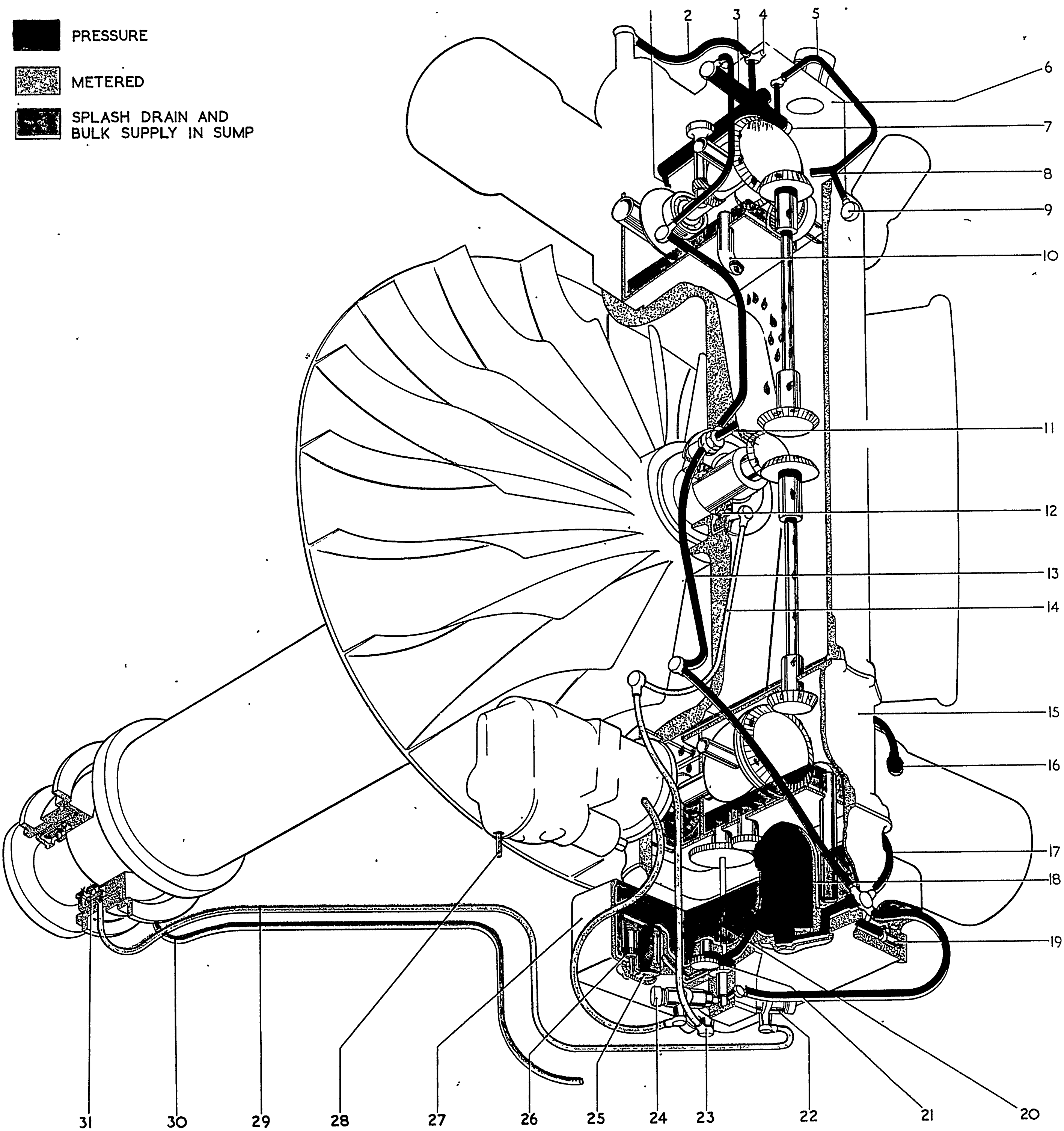
6. This filter is composed of a wide-mesh copper gauze which seats directly into the sump and is held in position by a cast cover with five studs. Alongside the filter, a spring-loaded valve is carried in a guide which is formed integrally with the casting; the valve seat is screwed into the casting. When the cover of the suction filter is bolted down, it opens the valve by pressing on the stem of the valve and oil can pass through the filter. When the cover is removed, the spring closes the valve thus preventing the sump from being drained.

KEY TO FIG. 1

1 SINGLE JET LUBRICATING BEVEL GEARS AT REAR OF TOP ACCESSORY BOX
2 OIL SUPPLY TO VACUUM PUMP
3 TRIPLE JET LUBRICATING BEVEL GEARS AT FRONT OF TOP ACCESSORY BOX
4 OIL PRESSURE GAUGE CONNECTION
5 OIL FILLER CAP
6 TOP ACCESSORY BOX
7 THERMOMETER POCKET
8 OIL SUPPLY TO CABIN SUPERCHARGER
9 OIL SUPPLY TO AIR COMPRESSOR
10 TOP ACCESSORY BOX OIL DRAIN PIPE
11 JET SPRAYING OIL ON TO BEVEL GEARS IN CENTRE HOUSING
12 FRONT BEARING
13 OIL SUPPLY TO CENTRE HOUSING JET AND TO TOP ACCESSORY BOX
14 METERED OIL SUPPLY TO FRONT BEARING
15 BOTTOM ACCESSORY BOX
16 OIL SUPPLY TO STARTER COUPLING
17 OIL SUPPLY TO OIL JET (NOT SHOWN) WHICH LUBRICATES THE BEVEL GEAR AT FRONT OF BOTTOM ACCESSORY BOX, AND THE STARTER COUPLING
18 PRESSURE FILTER
19 OIL PRESSURE RELIEF VALVE
20 OIL PUMP DRIVE SHAFT
21 OIL PUMP
22 REAR BEARING METERING PUMP
23 FRONT BEARING METERING PUMP
24 OVERSPEED GOVERNOR METERING PUMP
25 SUCTION FILTER
26 OIL DRAIN VALVE
27 SUMP (MAIN OIL CONTAINER)
28 OVERSPEED GOVERNOR DRAIN
29 METERED OIL SUPPLY TO REAR BEARING
30 REAR BEARING OIL DRAIN
31 REAR BEARING

Pressure filter

7. The filter seats directly into a bowl cast in the sump and is held in position by a cast cover with six studs. It consists of a cylindrical copper gauze supported by a central tube and surrounded by a felt filter. At either end of the support tube are metal plates which are located on bronze tubes brazed to the support tubes at each end; the inner plate is spring-loaded. The filter incorporates an over-load valve assembly at its inner end, so that if there is an excessive restriction, the oil by-passes the filter and there is no loss of lubrication. The outer casing of the valve is sweated inside the inner end of the support. The valve is retained in position across the top of the



F.S/2

FIG.1.– DIAGRAM OF LUBRICATION SYSTEM

RESTRICTED

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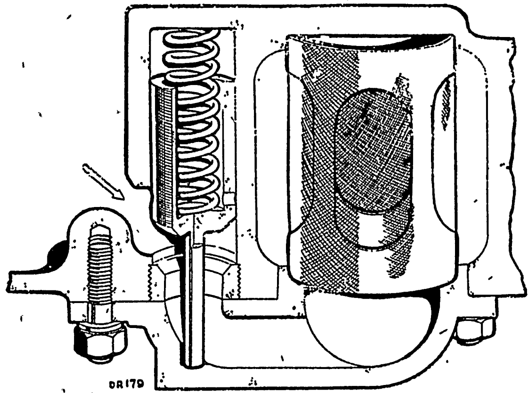
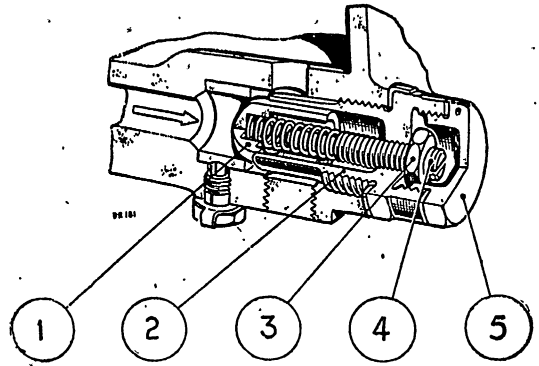


Fig. 2. Suction filter



1 RELIEF VALVE
2 GUIDE
3 LOCK-NUT
4 ADJUSTING SCREW
5 CAP NUT

Fig. 4. Pressure relief valve

support tube by a circlip and is held up by a coil spring centred on a rivet in the bottom of the outer casing. Under normal operation of the filter, the oil flows through the felt to the wire-mesh gauze and then down the centre of the support tube. If the filter becomes choked, however, the pressure on the outside overcomes the overload spring and oil by-passes the felt to flow between the guides of the overload valve down the central support tube.

Relief valve

8. The relief valve is spring-loaded and is carried in a guide which is screwed into a boss in the sump casting. The spring seats between the head of the valve and a shoulder on the adjusting screw which screws into the outside face of the housing where it is locked by a lock-nut. There are also internal threads in the housing to take a cover or cap nut.

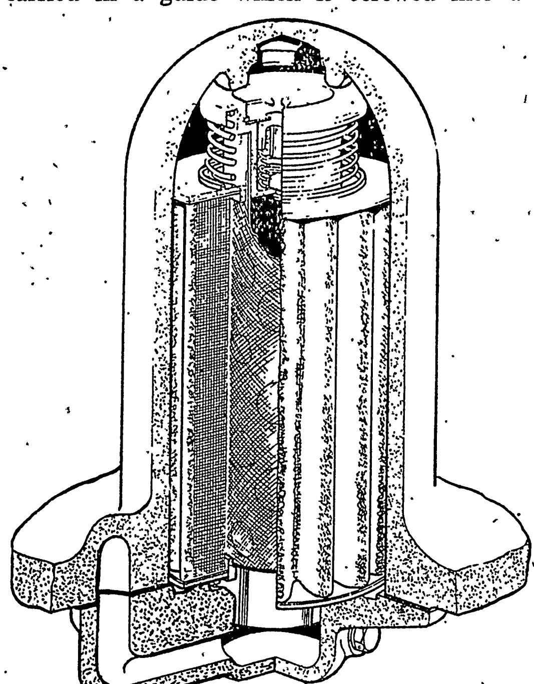


Fig. 3. Pressure filter

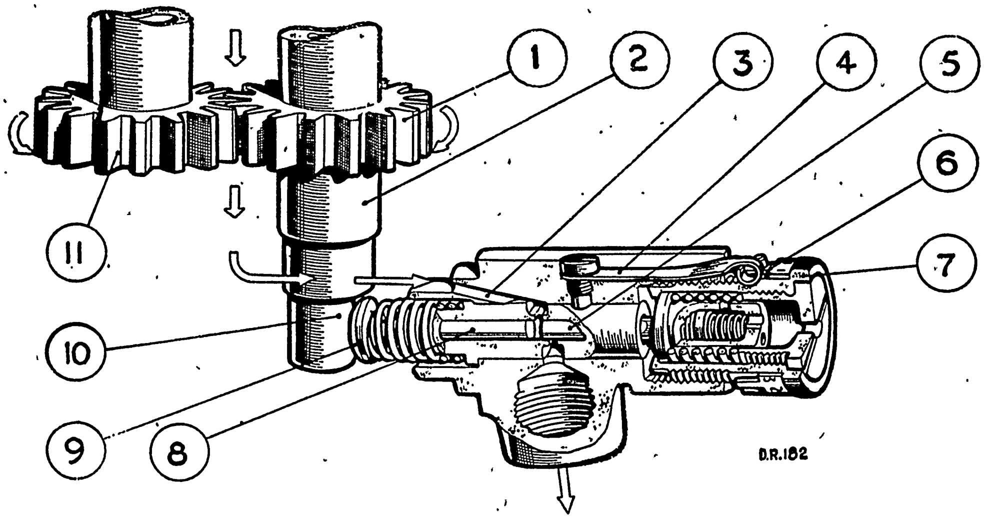
Oil pumps

Pressure pump

9. The speed of the gear-type pump is 0·16 of the impeller speed and the drive is through a vertical shaft and a train of gears from the horizontal shaft in the bottom accessory box. The pump housing comprises two casings; the inner casing is machined to receive the driving and idling gears, and is lined up with the outer casing to which it is reamed and dowelled. The metering pump housings are also mounted on the outer casing. The two casings are held together by two dowel bolts, the whole assembly being secured in the sump by eight studs. When the engine is operating at full duty, the pump delivers oil at a pressure of approximately 50 lb. per sq. in. at 90 gall. per hour.

Metering pumps

10. Each metering pump consists of a light-alloy casting into which is fitted a steel cylinder with a plain bore. The cylinder carries two pistons in opposition to each other. The inner piston contains a tappet head which bears on a cam extension of the oil pump driving shaft. A coil spring, which is fitted under the tappet head and surrounds an extension of the cylinder, ensures that the tappet maintains contact with the cam. The position of the outer piston in relation to the



1 DRIVING GEAR	4 SPRING-STEEL TONGUE	7 KNURLED NUT	10 CAM
2 DRIVING SHAFT	5 PISTON (OUTER)	8 PISTON (INNER)	11 IDLING GEAR
3 OIL PASSAGE	6 NOTCH	9 TAPPET HEAD	

Fig. 5. Gear-type pump and metering pump

inner piston is adjusted by a knurled nut screwed into the end of the cylinder. Eleven equally spaced notches, which are numbered from 0 to 10, are cut in the outer periphery of the knurled nut. A flat spring-steel tongue engages in a notch and locks the nut in a specific position which gives an indication of the quantity of oil that is delivered by the pump.

11. Oil is supplied to the pump from a space arranged under the pump spigot from which a drilling in the pump body communicates with a port in the pump cylinder. A Neoprene sealing ring is fitted round the pump spigot under the flange, to prevent leakage from the supply channel. When replacing the pump, care must be taken that the ring does not block the supply passage. Another port in the cylinder communicates with the outlet port from which the metered oil supply is taken, at right angles to the bore of the cylinder.

12. With the cam in its lowest position, the inner piston uncovers the supply port in the cylinder and the space between the two pistons fills with oil. As the cam rotates, the inner piston moves outwards covering the supply port. The two pistons then move together with a metered quantity of oil between them. Towards the outer extremity of the pump stroke, the outer piston uncovers the outlet port and the continued movement of the inner piston evacuates the pump space against the spring load on the outer piston caused by the collapsing of the springs in the adjustable knurled nut. The quantity of oil delivered depends on the position of the outer piston with reference to the inner piston, as determined by the knurled nut, and only slightly on the oil inlet pressure.

13. The capacity of each pump is 0·60 pints per hour at 1,000 r.p.m., but before installation they are adjusted on a test rig, by means of the knurled nuts at the outer end, to give a delivery of approximately 100 cc. per hour at 3,000 r.p.m. in the instance of metering pumps to the bearings, and of 14 cc. per hour in the instance of the governor metering pump.

Miscellaneous

Oil pressure gauge

14. The pressure gauge connection on the top box is provided at a point in the pressure line remote from the pressure pump. It serves as a connection to the pressure transmitter which is mounted on the firewall of the aircraft and which eliminates the necessity of running the lubricating oil pressure lines direct from the engine to the indicating instruments in the cockpit. By means of a flexible diaphragm, the pressure of the oil on the engine side is transferred to a low viscosity fluid connecting the airframe side to the pressure gauge in the cockpit.

Oil temperature gauge

15. The oil temperature is obtained, at a point remote from the pressure pump, by a resistance thermometer inserted in a pocket in the oil gallery on the top accessory box. The resistance thermometer operates by reason of the increase with temperature in electrical resistance of a wire carrying a current. The two leads from the thermometer are connected to a junction box on the airframe from which the connection is made to the gauge in the pilot's cockpit. The variation in resistance with temperature is translated into degrees centigrade in this instrument; the range of the instrument is from 0-120 deg. C. The operating temperature should lie between the limits of 10 deg. C. and 75 deg. C.

Front bearing

16. The front bearing is contained between its housing at the rear end and the retaining plate for the outer race at the forward end; these two components are held together by studs. The metered oil enters through a banjo connection fitted to an oil pillar screwed into the retaining plate in which there is a groove to ensure that the oil goes to the bearing itself. The oil pressure builds up in the bearing, escapes through a small diameter hole in the retaining plate and is dispersed by the flinger which is rotating with the shaft, and eventually drains back through the front casing to the sump.

Rear bearing

17. The pipe carrying the metered oil for the rear bearing follows the line of the centre casing. The oil feeds into the centre of the outer housing of the rear bearing assembly and passes through a small hole in the inner housing. At a slightly higher point in the housing is the drain hole; the oil that passes through this drain hole forms a small well into which the bearing cage dips; the oil is caught by, and is rotated with the bearing. If the rear bearing temperature reading is high, it is an indication of unsatisfactory lubrication at the rear bearing.

Governor lubrication

18. A cast diaphragm in the governor drive housing carries two oil seals through which the driving shaft passes, forming an annular space round the shaft. Metered oil, from the third pump on the sump, supplies this annular space from which it passes through a radial hole in the shaft to a central bore and thence to the internal parts of the governor. Surplus lubricant is conveyed to the common drain from the union in the end of the governor housing.

CHAPTER 4

STARTING AND IGNITION EQUIPMENT

Chapter 4

STARTING AND IGNITION EQUIPMENT

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

General

1. To start the engine an auxiliary source of power is required to rotate the main shaft assembly, and some form of ignition is necessary to ignite the fuel. The first is provided by a compound-wound electric motor mounted on the bottom accessory box, and ignition is provided by two high energy ignition units and two surface discharge igniter plugs. As the conditions for successful starting are critical, the starting cycle is controlled automatically in three stages. This chapter deals mainly with ignition system components which are mounted on the engine; for details of the airframe wiring and switches, reference must be made to the relevant aircraft Air Publication. Instructions for servicing and overhauling the individual ignition system components are given in A.P.1374, Volume 1.

Starting cycle

2. Before a start can be initiated by pressing the starter push-button, the controls must be set correctly and connection made to a ground starter battery in accordance with the starting procedure detailed in Vol. 2, Part 3, Sect. 2, Chap. 2 of this publication. When the starter button is pressed two things occur; the automatic (*clockwork*) time switch is electrically wound, and the slow-engagement relay is energized; pressure must be maintained on the starter button for about two seconds to ensure that the time switch is wound fully. Energizing the slow-engagement relay causes the relay contacts to close so that current flows to the starter motor through the slow-engagement and speed-limiting resistances, and to the high energy ignition unit relay. With the two resistances in circuit the starter motor rotates slowly, thus allowing the starter dog jaws to engage without shock, and so preventing damage to the drives within the engine; at the same time the high energy ignition units and igniter plugs commence to operate.

3. When the starter button is released the automatic time switch commences to function, and the starter button is isolated so that the starting cycle cannot be interfered with, except by opening the starter switch. Current flows to the starter motor through the two resistances for the duration of the first stage (4-7 *seconds*), then the second stage relay is energized, by operation of the time switch, and the slow-engagement relay is short-circuited.

4. The second stage of the starting cycle, with only the speed-limiting resistance in circuit, lasts for 5-7 seconds, during which time the starter motor accelerates the engine up to approximately 700-900 r.p.m. At about the end of the second stage, an atomized spray of fuel from the burners is ignited by the igniter plugs, in No. 2 and No. 14 combustion chambers, and the flame spreads to the other combustion chambers through the interconnectors.

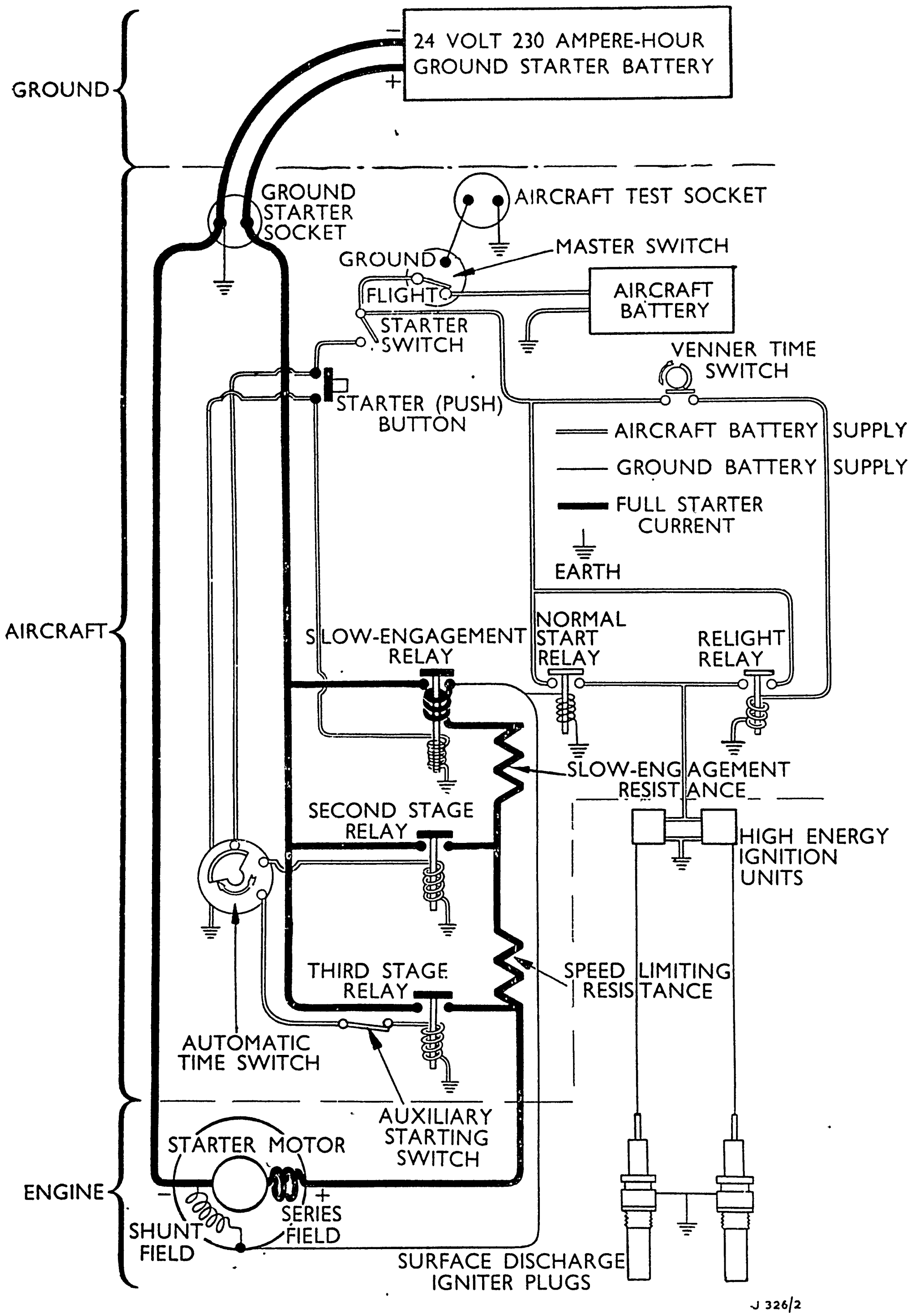
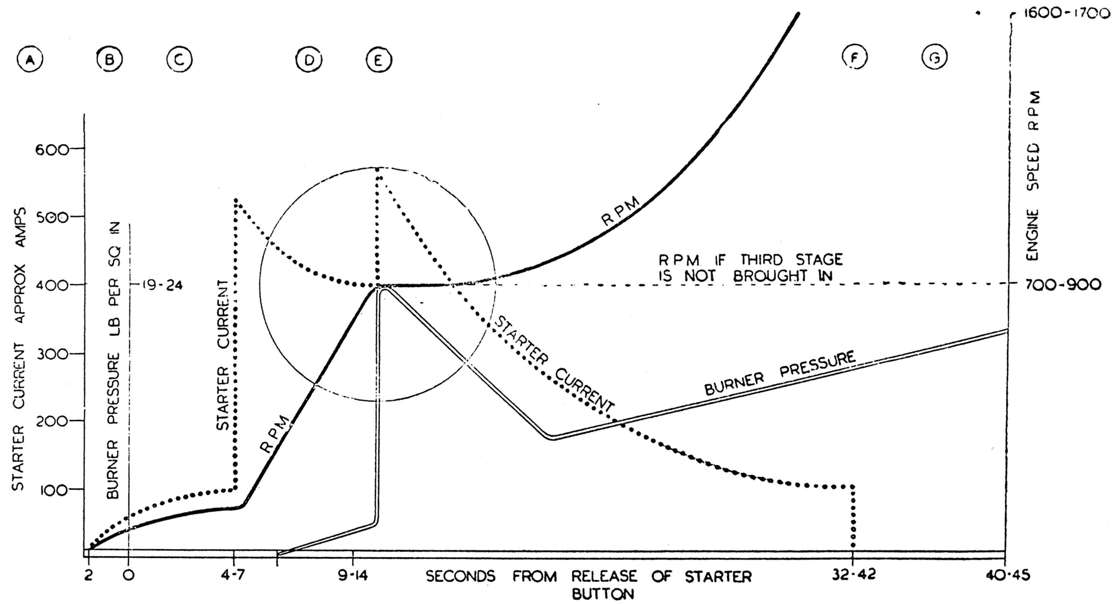


Fig. 1. Diagram of electrical starting equipment



A GROUND STARTER BATTERY PLUGGED IN, CONTROLS AND SWITCHES SET IN ACCORDANCE WITH THE STARTING DRILL

B STARTER BUTTON PRESSED FOR ABOUT TWO SECONDS AND RELEASED, TIME SWITCH WOUND, SLOW-ENGAGEMENT PERIOD STARTED

C SLOW-ENGAGEMENT PERIOD CONTROLLED BY TIME SWITCH

D TIME SWITCH CUT-OUT SLOW-ENGAGEMENT RESISTANCE, STARTER MOTOR ACCELERATES ENGINE TO R.P.M. SUITABLE FOR LIGHT-UP

E FUEL ACCUMULATOR DISCHARGES, IGNITER PLUGS LIGHT FUEL, TIME SWITCH CUTS-OUT SPEED-LIMITING RESISTANCE, STARTER MOTOR ASSISTS ACCELERATION TO SELF-SUSTAINING SPEED

F TIME SWITCH SWITCHES OFF STARTING CIRCUIT

G ENGINE ACCELERATES UNDER OWN POWER TO IDLING SPEED

Fig. 2. Starting cycle

5. The third stage of the starting cycle is then introduced by energizing the third stage relay, which short-circuits the speed-limiting resistance and allows full current to pass to the starter motor. The engine, assisted by the starter motor, will then attain a self-sustaining speed (1,600-1,700 *r.p.m.*), from which it can accelerate under its own power to idling speed (3,000 *r.p.m.*). The starter motor is in operation for a total of 32-42 seconds.

6. The suitable 'light-up' speed is approximately 700-900 r.p.m., and the time taken to reach this speed will vary with the operating conditions, i.e., it will take longer, and will need more current from the starter battery, to attain the required engine r.p.m. under very cold conditions, than when warm.

7. Under normal conditions the Mk. 2 engine will quickly attain high engine r.p.m., and assisted by the third stage of the cycle, this promotes an air flow which may be sufficient to extinguish the flame before a satisfactory 'light-up' can occur. On Mk. 2 engines, therefore, it is necessary to control more closely the introduction of the third stage, and to override the fixed interval of the automatic time switch. For this purpose an auxiliary starting switch is fitted, permitting the third stage of the starting cycle to be brought into use by the pilot when the jet pipe temperature gauge indicates that 'light-up' has occurred, or when the familar sound of 'light-up' is heard. The use of the auxiliary starting switch too soon will probably result in a poor or even a 'wet' start; while if the switch is not switched ON during the starting cycle, the engine will not receive its full assistance from the starter motor, i.e., the starter motor will be on the second stage for the remainder of the cycle. This latter

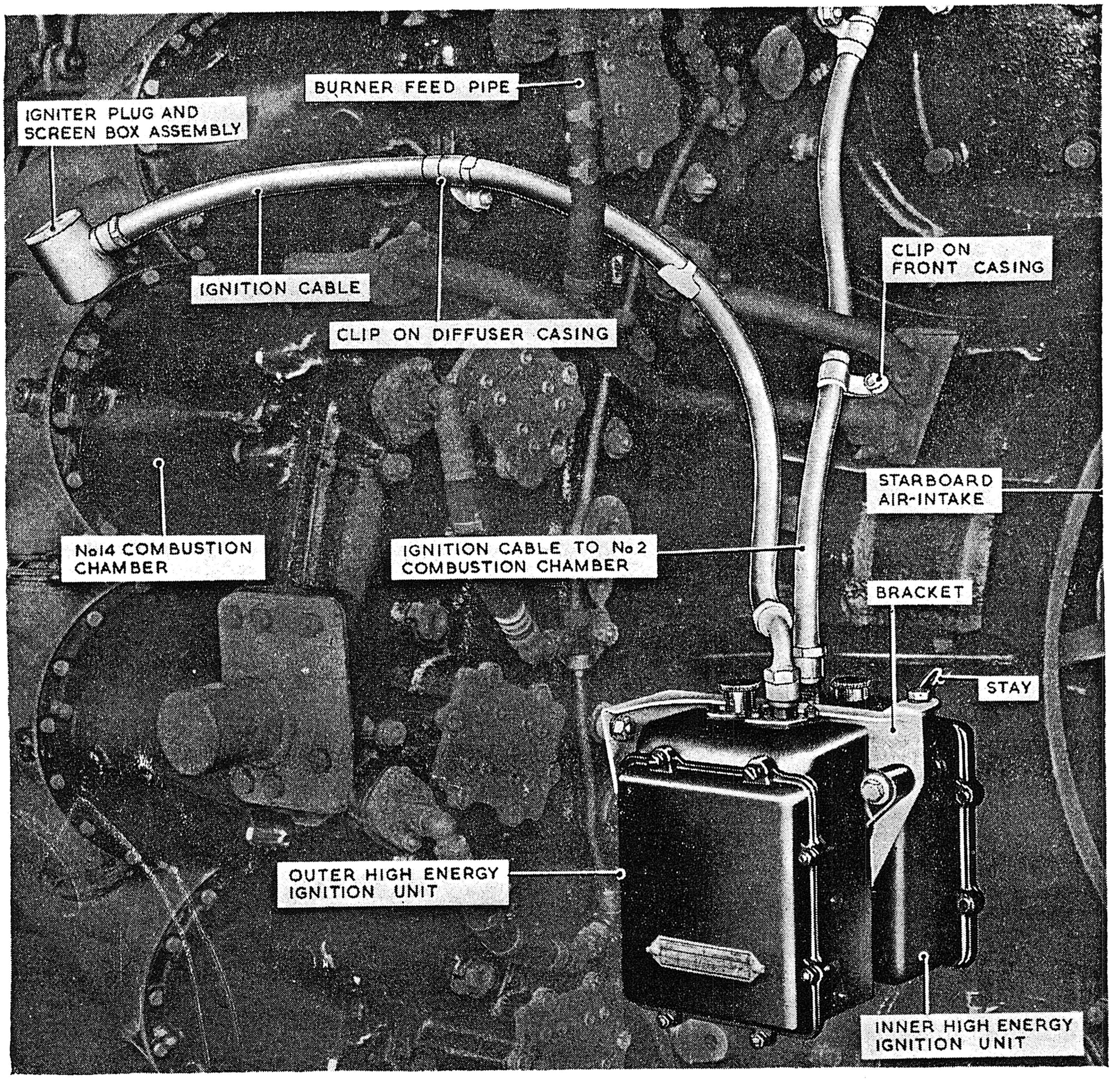


Fig. 3. High energy ignition equipment installed on Goblin engine

condition will result in 'labouring' of the engine with long flame in the tail pipe, high temperatures, and failure to accelerate. If temperatures of minus 20 deg. C. are experienced the auxiliary starting switch should be moved to the ON position, as experience has shown that due to engine sluggishness at these low temperatures, the automatic time switch starting cycle is properly in step with engine r.p.m. and fuel pressure.

8. Owing to the different characteristics of the Lucas fuel system fitted to Mk. 3 engines, only the automatic time switch starting cycle is used, and if an auxiliary starting switch is fitted it is wire-locked in the ON position.

Ignition equipment

9. The high energy ignition equipment consists of two surface-discharge type igniter plugs which are supplied from two high energy ignition units mounted on the starboard side of the engine air-intakes, through individual ignition cable assemblies. The ignition units are supplied with low tension current (16 *to* 29 *volts D.C.*) from the aircraft battery via the engine starter circuit, when starting normally on the ground, or via a Venner time switch when relighting in flight or checking the ignition equipment on the ground. The low tension side of the system is entirely an airframe item, and reference must be made to the relevant Air Publications for a detailed description of the wiring and switching.

10. Each surface-discharge igniter plug consists of an insulated centre electrode and an earth. Unlike the H.T. igniter plug or conventional sparking plug, there is no air gap, and the space between the electrodes is filled by a semi-conductive insulator. The centre electrode is connected to its individual high energy ignition unit, and the earthed electrode is connected to the screen which surrounds the ignition cable assembly.

11. Each high energy ignition unit contains a coil and trembler mechanism, capacitors, a high-voltage selenium type rectifier, sealed discharge spark-gap, and a choke. The electrical discharges produced by this unit are delivered at a much slower repetition rate than those produced by a booster coil, but each discharge is of considerably higher energy. The duration of each discharge is of the order of 50 micro-seconds, and the peak discharge current in the region of 1,500 amp. The stored energy per discharge is approximately 12 joules, with a frequency of about 60 discharges per minute.

12. Each ignition cable is in one piece, and extends from the ignition unit to the igniter plug. The single cable is supported throughout its length by a number of simple clips.

13. When an engine fitted with high energy ignition is being started, 24 volt D.C. (*maximum input* 2·5 *amp. measured on a moving coil instrument*) is supplied to the coil and trembler mechanism in each ignition unit. The induction coil repeatedly charges a reservoir capacitor, through the selenium rectifier, until the capacitor voltage increases to a value at which the sealed discharge gap will 'break down'. The capacitor then discharges through the sealed gap, an inductance, and the surface-discharger igniter plug, which are all connected in series. The capacitor is then recharged and the process repeated at a frequency of not less than one discharge per second. The discharge across the semi-conductive insulator of the surface-discharge igniter plugs ignites the fuel issuing from the burners in No. 2 and No. 14 combustion chambers, and the flame spreads to the other fourteen combustion chambers through the inter-connecting passages.

14. Mod. 1063 introduced the B.T.H. C.10TS/3 high energy ignition unit to supersede the /2. The /3 ignition unit incorporates a miniature spark gap to initiate the first discharge at the correct break-down voltage. With the earlier type of ignition units it was found that when the ignition was switched on after a period of inactivity there could be an appreciable delay before the initial discharge occurred at the igniter plug. This delay impairs engine starting and also results in overloading of the reservoir capacitor in the ignition unit. Although a failure of one of the ignition units might not be detected on the ground, it might result in failure to relight at altitude. In the /3 unit the miniature spark gap is fitted close to the main discharge gap, which triggers off the actual discharge at the igniter plug, and this auxiliary gap ionises the main gap and so ensures an immediate discharge as soon as the voltage reaches 2,000 volts.

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