

Chapter One

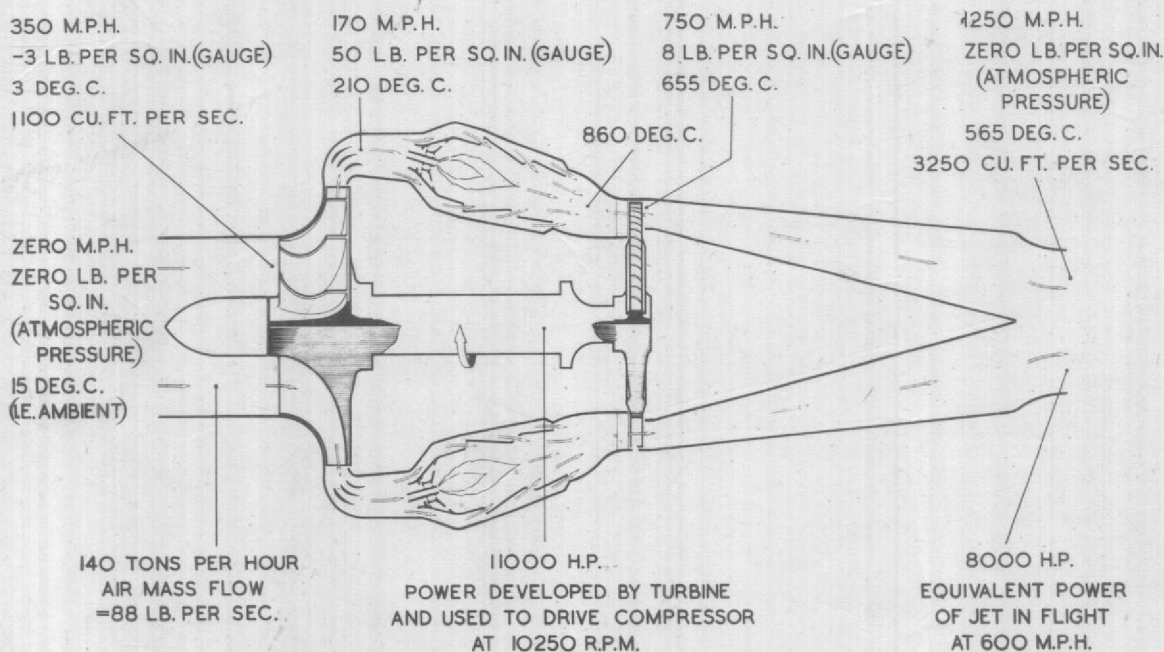
ENGINE

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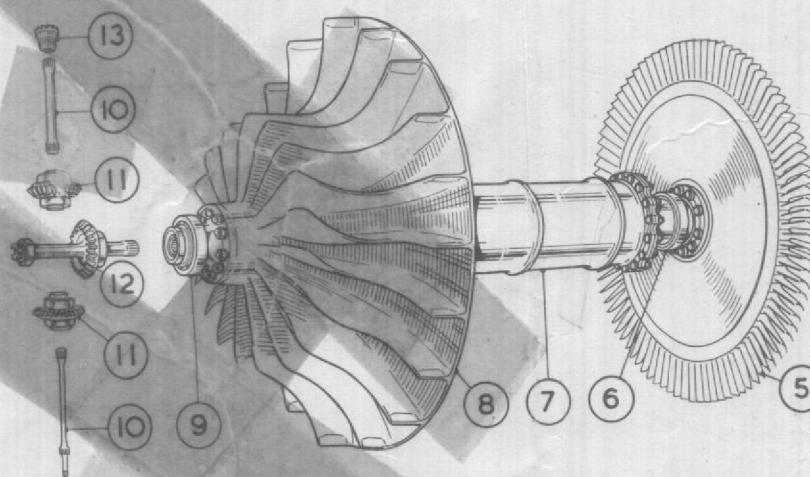
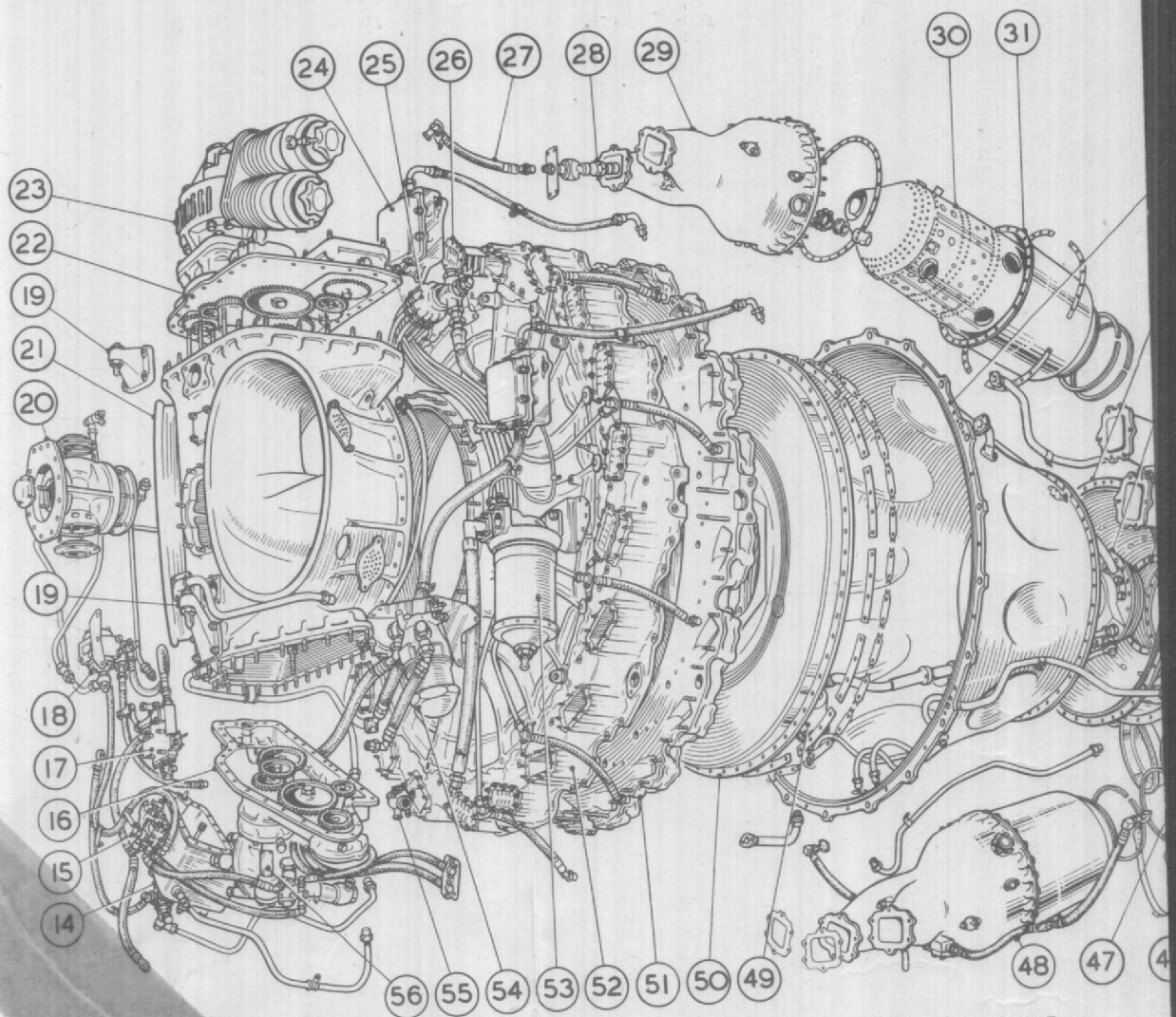
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NOTE: THE FIGURES QUOTED ARE APPROXIMATIONS FOR EXPLANATORY PURPOSES ONLY, AND ASSUME THE ENGINE TO HAVE NO FORWARD SPEED. ALL PRESSURES AND TEMPERATURES QUOTED ARE STATIC. TOTAL TEMPERATURE = STATIC TEMPERATURE PLUS $[(\text{GAS SPEED})^2 \times \text{A FACTOR WHICH VARIES ACCORDING TO THE SPECIFIC HEAT OF THE GAS}]$. TOTAL TEMPERATURE AT THE PROPELLING NOZZLE IS APPROXIMATELY 700 DEG. C.

Fig. 1. Gas flow, or working cycle diagram



MAIN SHAFT ASSEMBLY

- 1 JET THERMOCOUPLE
- 2 FIREGUARD
- 3 OUTER EXHAUST CONE
- 4 INNER EXHAUST CONE
- 5 TURBINE WHEEL
- 6 REAR BEARING
- 7 CENTRE SHAFT
- 8 IMPELLER
- 9 FRONT BEARING
- 10 VERTICAL DRIVE SHAFT
- 11 VERTICAL DRIVE GEAR
- 12 HORIZONTAL DRIVING GEAR
- 13 STARTER DOG
- 14 OIL SUMP
- 15 BAROMETRIC PRESSURE CONTROL
- 16 BOTTOM WHEELCASE
- 17 CONTROL VALVE ASSEMBLY
- 18 AIR-FUEL RATIO CONTROL
- 19 MOUNTING BRACKET
- 20 CENTRE HOUSING
- 21 AIR-INTAKE
- 22 TOP WHEELCASE
- 23 TURBO STARTER
- 24 HIGH ENERGY IGNITION UNIT
- 25 FUEL DISTRIBUTOR
- 26 DEFLECTOR ASSEMBLY
- 27 BURNER FEED PIPE
- 28 BURNER
- 29
- 30
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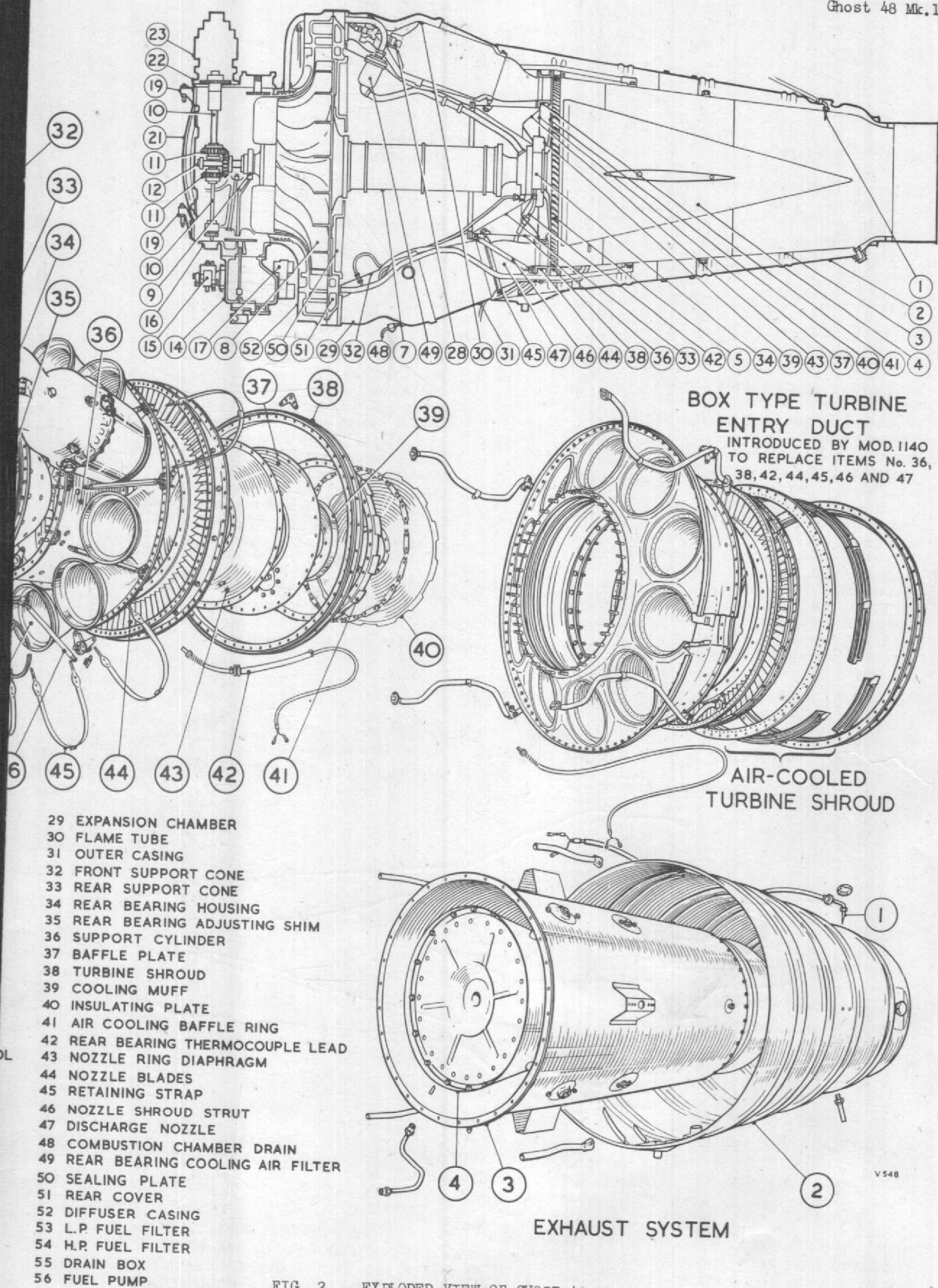
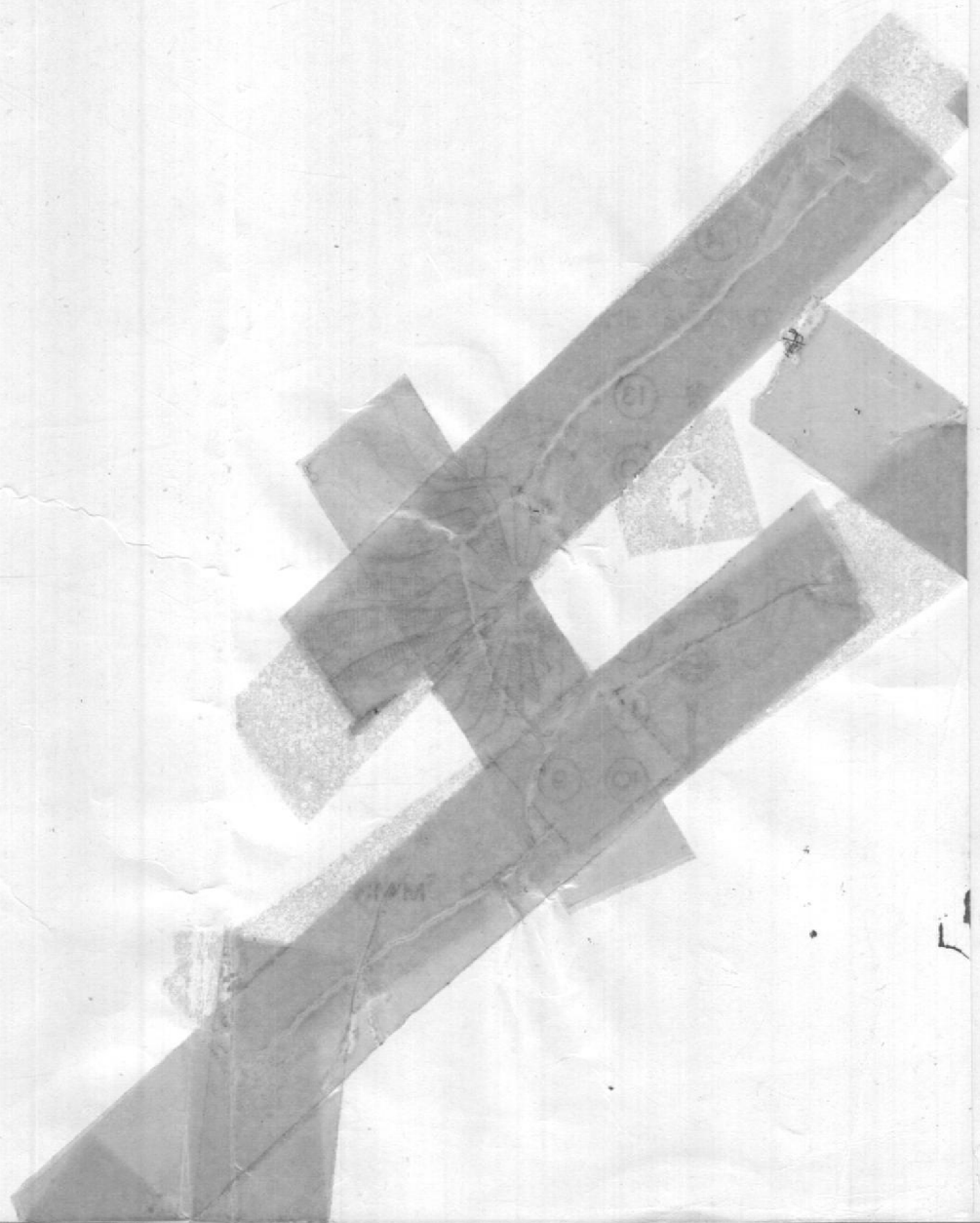


FIG. 2. EXPLODED VIEW OF GHOST 48 Mk. 1.



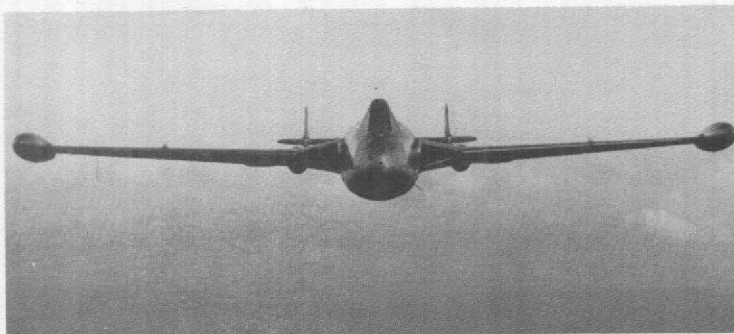


Fig. 3. Air-intakes in the leading edges of the Venom wings.

THIS CHAPTER contains a brief description of the engine under its main sub-assemblies. The lubrication and fuel systems are dealt with in Chapters 2 and 3 respectively. The ignition system which is only necessary to effect ignition of the fuel discharging from the burners during starting, is described separately in Chapter 4. Similarly, the principle of oil-cooling the rear bearing has been included with the lubrication system in Chapter 2. An exploded drawing of the complete engine is given on the facing page.

WORKING CYCLE.

Fig.1 illustrates diagrammatically the main gas flow or working cycle, the figures quoted being approximations and for explanatory purposes only. Air entering through apertures in the leading edges of the Venom aircraft main planes is ducted to the bifurcated air-intake of the single-entry compressor where it is picked up by the impeller. At maximum speed the impeller rotates at more than 10000 r.p.m. and the air compressed to about 50 lb. per sq. in., is delivered to the ten combustion chambers. Fuel burners spray fuel into the combustion chambers where a mixing process, described later, takes place before the products of combustion are admitted to the turbine.

The energy of the gases, now greatly increased, expand with high velocity through the fixed nozzle blades on to the rotating blades of the turbine. The power developed by the turbine at maximum speed exceeds 11000 horse-power. This power is transmitted by the centre shaft to the impeller and represents the work done in compressing approximately 140 tons of air per hour to the pressure attained at the entry to the combustion chambers.

After passing the turbine blades the gases which still possess considerable energy, are led by the converging exhaust cone to the propelling nozzle (fig.4) where they are ejected at a velocity in the order of 1250 miles per hour. The ejection of approximately 140 tons of air per hour at this velocity results in a forward thrust of 4850 lb.

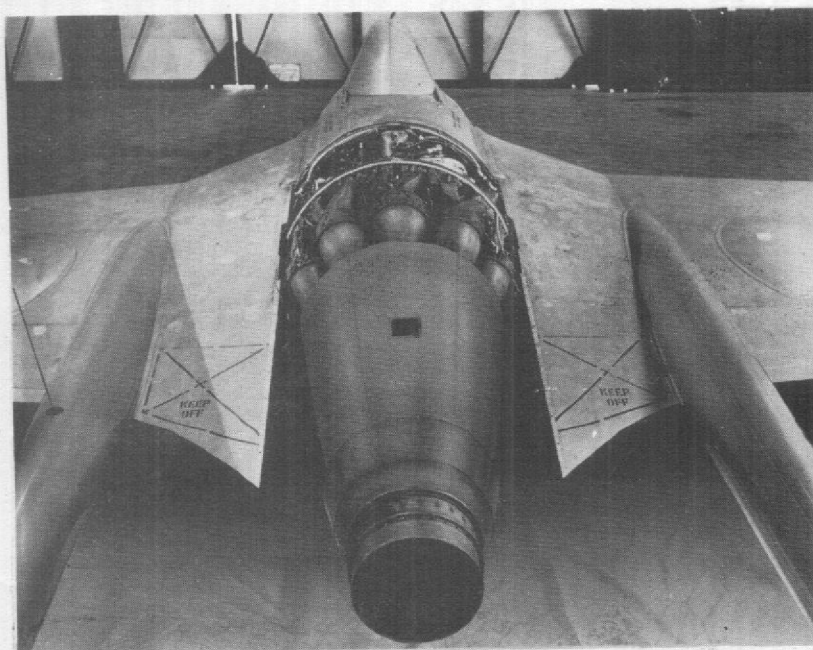


Fig. 4. Ghost installed in Venom fighter showing exhaust system and propelling nozzle.

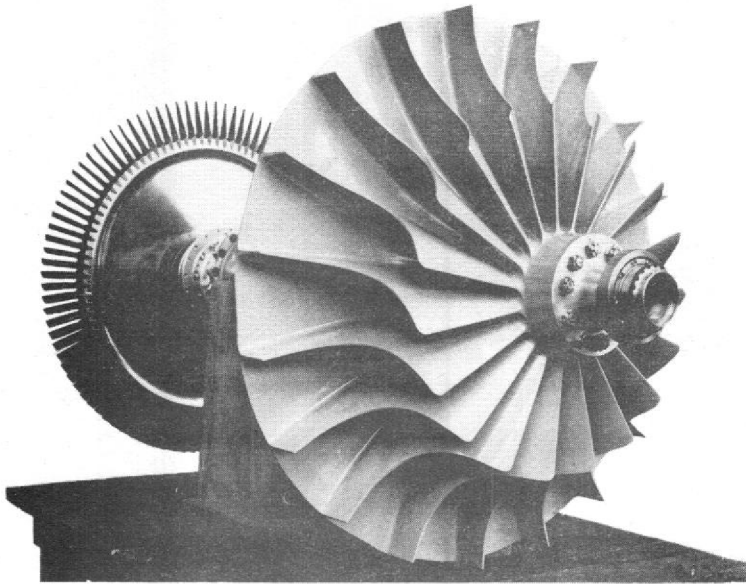


Fig. 5. Front view of main shaft rotor assembly

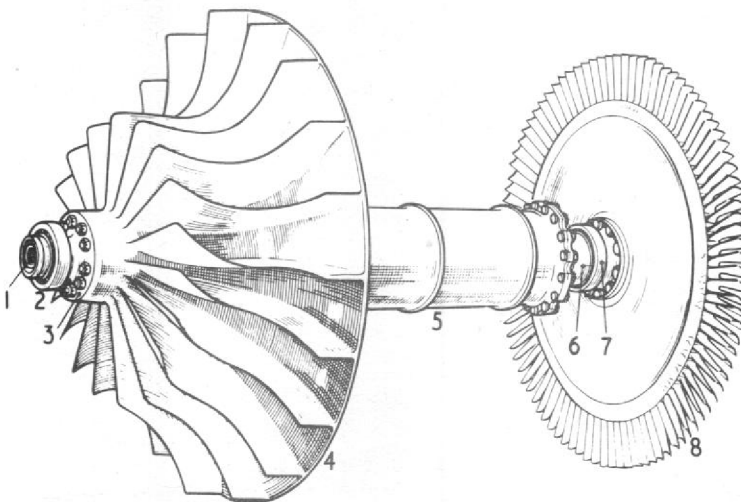


Fig. 7. Main shaft rotor assembly

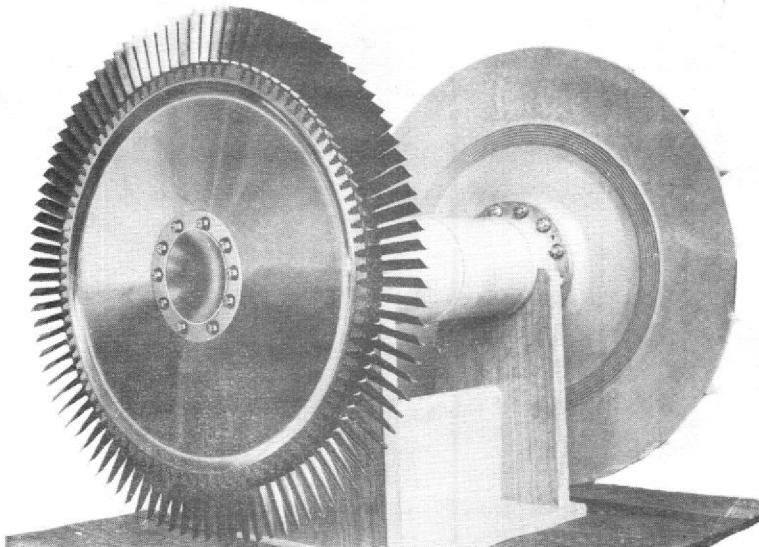
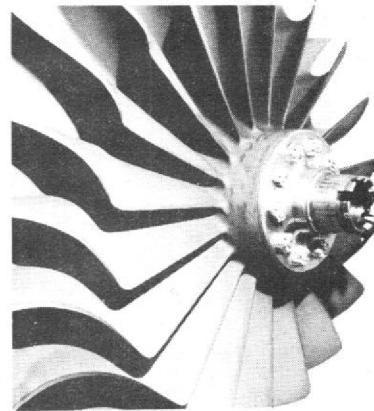


Fig. 8. Rear view of mainshaft rotor assembly

Fig. 6. Impeller with pivot attached



1. Accessory drive shaft.
2. Front bearing.
3. Impeller pivot.
4. Impeller.
5. Centre shaft.
6. Extension shaft.
7. Rear bearing.
8. Bladed turbine disc.

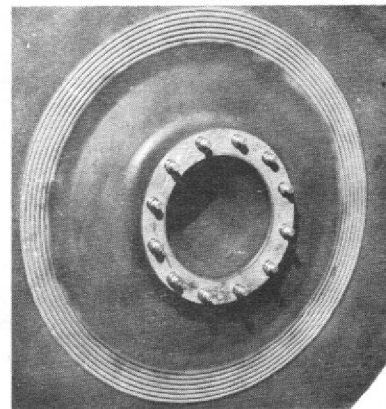
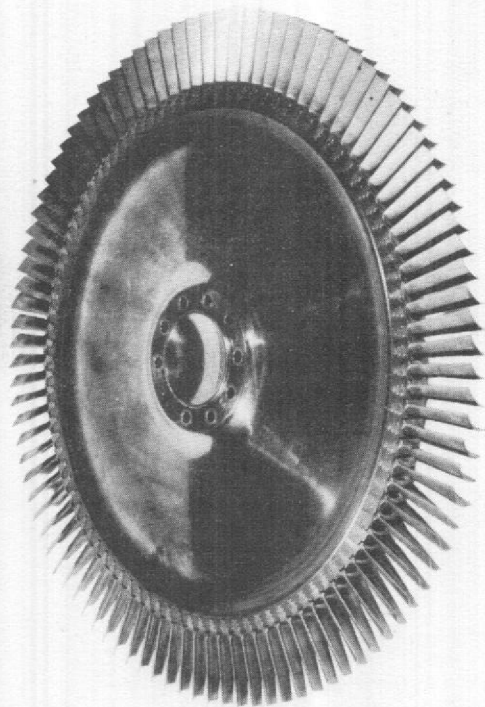
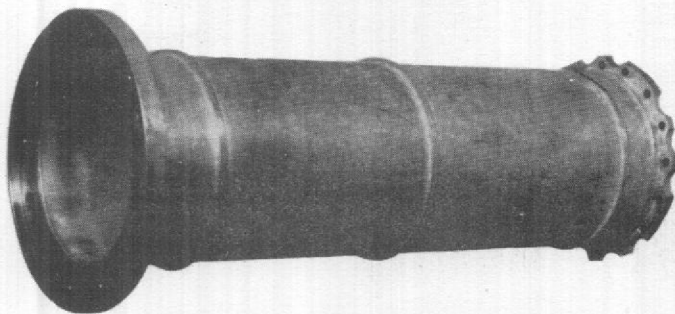


Fig. 9. Rear of impeller, showing labyrinth sealing grooves

Fig. 10. Bladed Turbine Disc.

Fig. 11 Centre Shaft.



COMPRESSOR, TURBINE AND WHEELCASES

MAINSHAFT

The mainshaft, or rotor, assembly (fig. 5, 7, and 8) consisting of the impeller, the centre shaft, and the bladed turbine disc, forms a simple robust assembly which is supported at the front in a ball bearing and at the rear in a roller bearing. The ball bearing provides the axial location, while the roller bearing permits some axial movement to accommodate the effects of differential thermal expansion. Air pressure on the back of the impeller tends to produce a forward thrust on the rotor assembly, while the pressure drop across the turbine produces a rearward thrust. By careful selection of the position of the labyrinth sealing grooves on the back of the impeller the two effects have been balanced so that only a small residual thrust is carried by the locating ball bearing.

IMPELLER

The impeller (fig. 6 and 9) which is of single entry design, is machined from a one piece forging and secured to the forward end of the centre shaft by twelve studs and nuts. A short pivot, which is secured to the front of the impeller by ten studs, carries the inner race of the front bearing. The gently curved intake blades of the impeller are formed without bending and being truly radial, eliminate the risk of secondary distortions when rotating at speed. The problems of vibration and fretting of the impeller face associated with inducer vanes are avoided by the single-piece construction, and toroidal guide vanes are rendered unnecessary by the direct ducting employed with the single-sided impeller. A high efficiency at tip speeds in the order of 1500 feet per second is obtained with this type of impeller, which is also well suited to the variations in flow experienced in flight.

TURBINE

For a given output in terms of mass flow, the single-sided impeller tends to be larger in diameter than the double-entry impeller. Since pressure ratio depends on tip speed, it follows that a single-entry compressor rotates more slowly than a double-entry compressor of equivalent pressure ratio and capacity. These considerations demand a larger turbine wheel to suit the lower speed of rotation and yet maintain an adequate peripheral speed for the blades. As the turbine annulus is determined by the rate of mass flow, it follows that the single-entry design, rotating more slowly, will have a larger turbine disc and shorter blades with a consequent reduction of stresses and improved heat dissipation characteristics. It has, therefore, been possible to use a ferritic turbine disc with consequent reduction in weight and improved thermal conductivity. Ninety seven turbine blades are secured in the rim of the turbine disc (fig. 10) by 'fir tree' roots and peening. The turbine disc is bolted at its centre to a hub shaft by ten bolts and nuts. The hub shaft passes through an extension shaft which is secured to the rear end of the centre shaft (fig. 11) by sixteen bolts and nuts; it is retained in the extension shaft by a special nut at the forward end of the hub shaft (fig. 12). The extension shaft carries the inner race of the rear bearing.

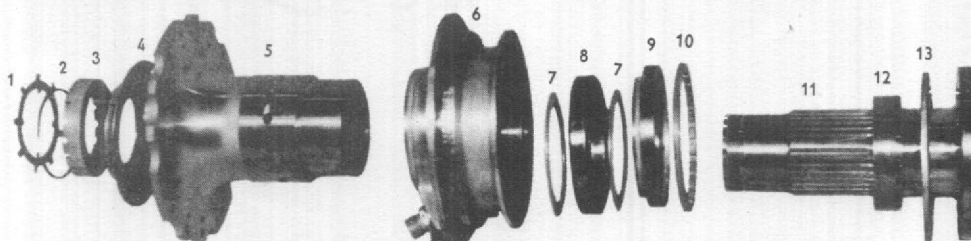


Fig. 12. Hub shaft, rear bearing, and extension shaft

- | | | | |
|------------------------|------------------------------------|------------------------------------|---------------------|
| 1. Tab locking washer. | 5. Extension shaft. | 8. Rear bearing. | 11. Hub shaft. |
| 2. Circlip. | 6. Rear bearing housing. | 9. Sealing bearing housing. | 12. Distance piece. |
| 3. Hub shaft nut. | 7. Rear bearing shielding washers. | 10. Sealing housing retaining nut. | 13. Locking ring. |
| 4. Pressure plate. | | | |

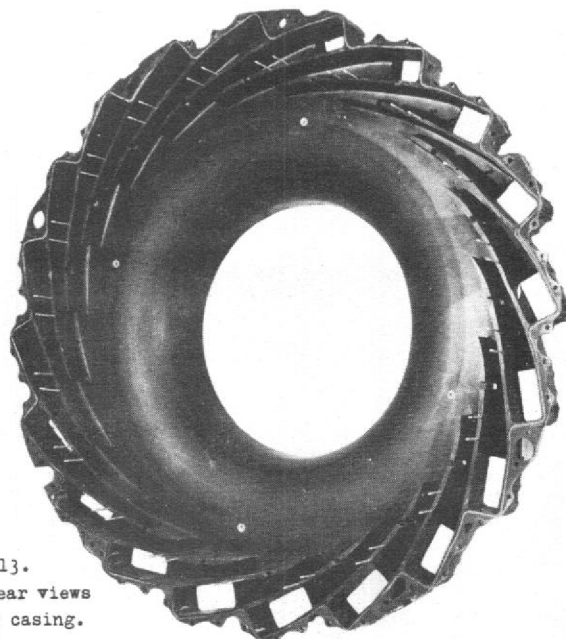
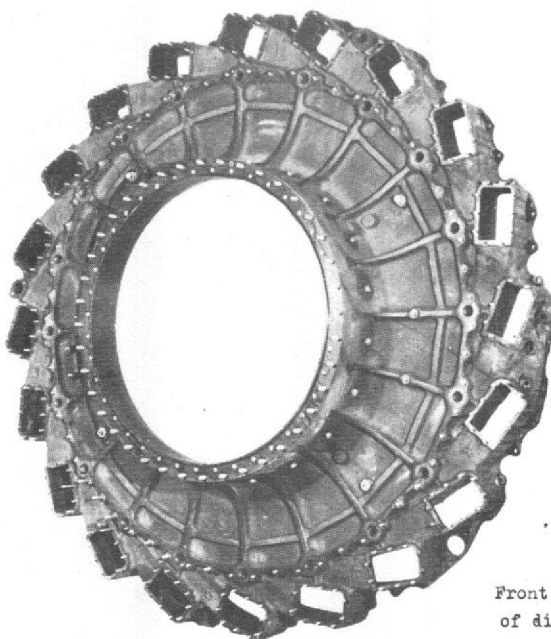


Fig. 13.
Front and rear views
of diffuser casing.

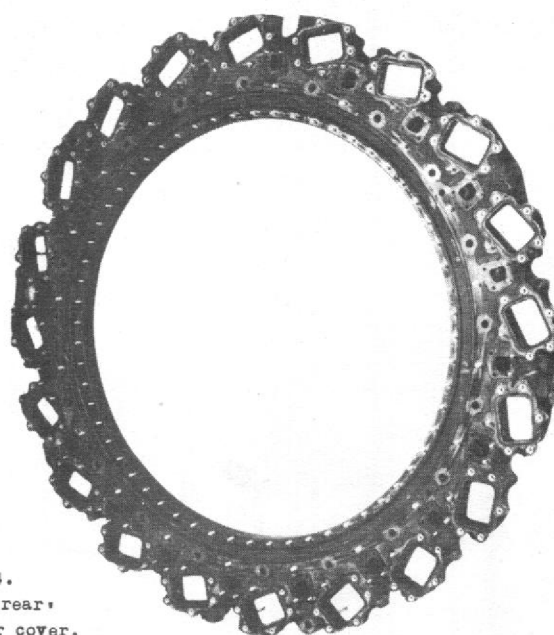
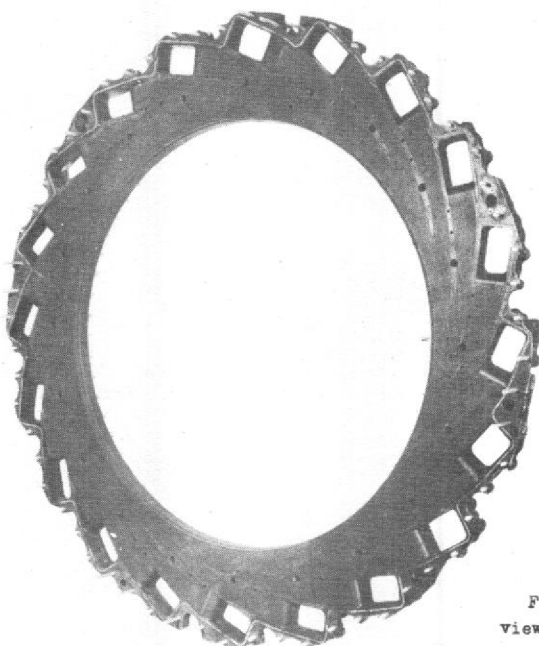


Fig. 14.
Front and rear
views of rear cover.

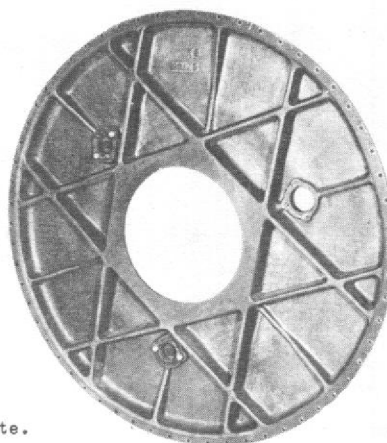
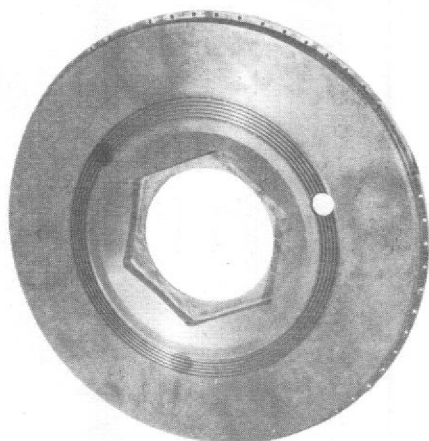


Fig. 15.
Front and rear
views of sealing plate.

DIFFUSER CASING

The diffuser casing assembly consists of a front portion termed the diffuser casing (fig.13), a rear cover (fig.14) and the sealing plate (fig.15). The rear cover is secured to the rear face of the diffuser casing and the sealing plate fills the aperture in the rear cover through which the impeller is assembled.

The diffuser casing assembly is part of the main stationary structure and, in addition to containing the impeller, supports the front ends of the ten combustion chambers and the front end of the centre casing. Twenty discharge passages are cast in the diffuser casing, where the velocity energy of the air delivered radially from the impeller is converted into pressure energy and turned through 90 deg. to flow into the combustion chambers. Twenty deflector assemblies, which are also referred to as cascades, are fitted into the diffuser casing (fig.13). The deflector vanes are of aerofoil section and ensure a smooth air-flow while the air changes direction.

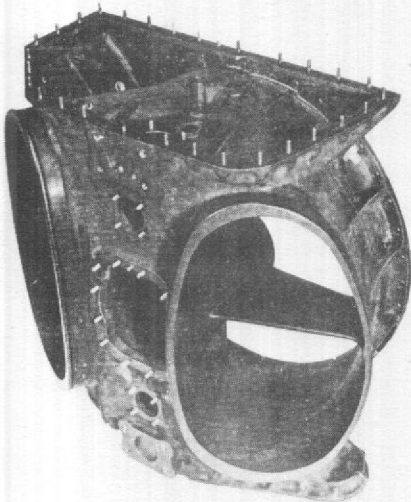


Fig. 16. Air-intake.

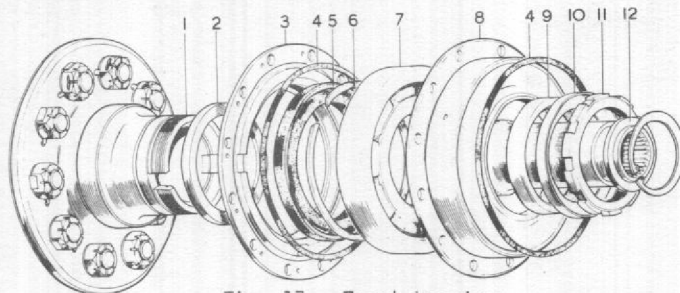


Fig. 17. Front bearing.

- | | |
|--------------------------------------|---------------------------|
| 1. Pivot fasted to front of impeller | 7. Ball bearing |
| 2. Adjusting washer | 8. Bearing housing |
| 3. Bearing retaining plate | 9. Spacer |
| 4. Sealing ring | 10. Cup washer |
| 5. Oil seal | 11. Retaining nut |
| 6. Retaining ring | 12. Accessory drive shaft |

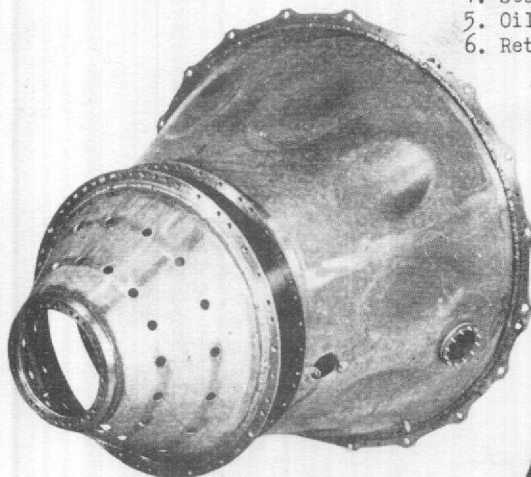


Fig. 18. Centre casing components.

AIR-INTAKE

The bifurcated air-intake (fig. 16) is attached to the front of the diffuser casing by studs and nuts and connects the compressor with the two air-intake ducts. It houses the front bearing (fig.17) which carries the front end of the main shaft rotor assembly and provides the mountings for the top and bottom wheelcases. The centre housing and the gear trains through which the engine-driven accessories are driven are also contained in the air-intake.

CENTRE CASING

The centre casing (fig.18) which may be regarded as forming the primary structure of the engine, consists of the front and rear support cones (fig.19) which are fastened together by flanges slightly to the rear of the centre of the assembly. The front support cone is secured at its front end to the diffuser casing rear cover by studs and nuts. The rear end of the rear support cone carries the rear bearing housing and thus the centre casing completes the structure which supports the front bearing, which is housed in the air-intake, and the rear bearing.

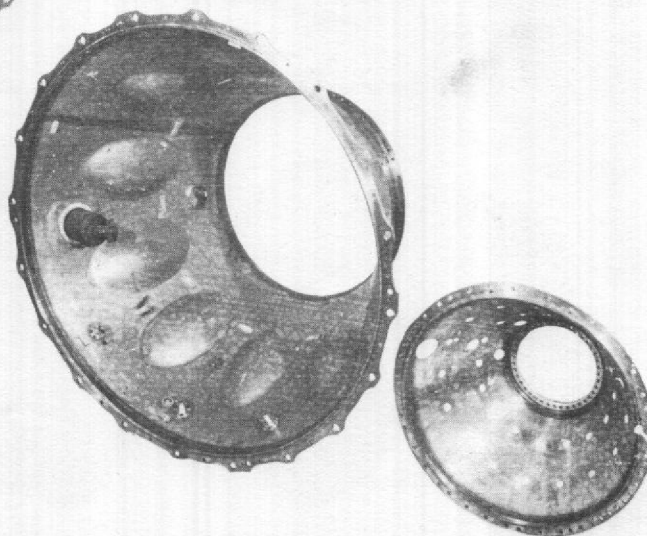


Fig. 19. Front and rear support cones.

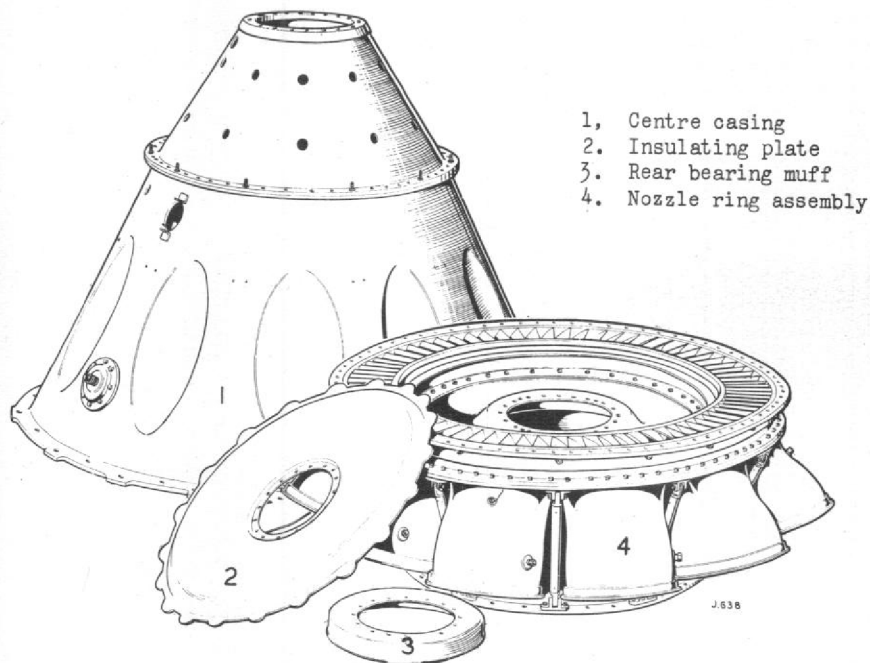


Fig. 20. Centre casing and nozzle ring assembly

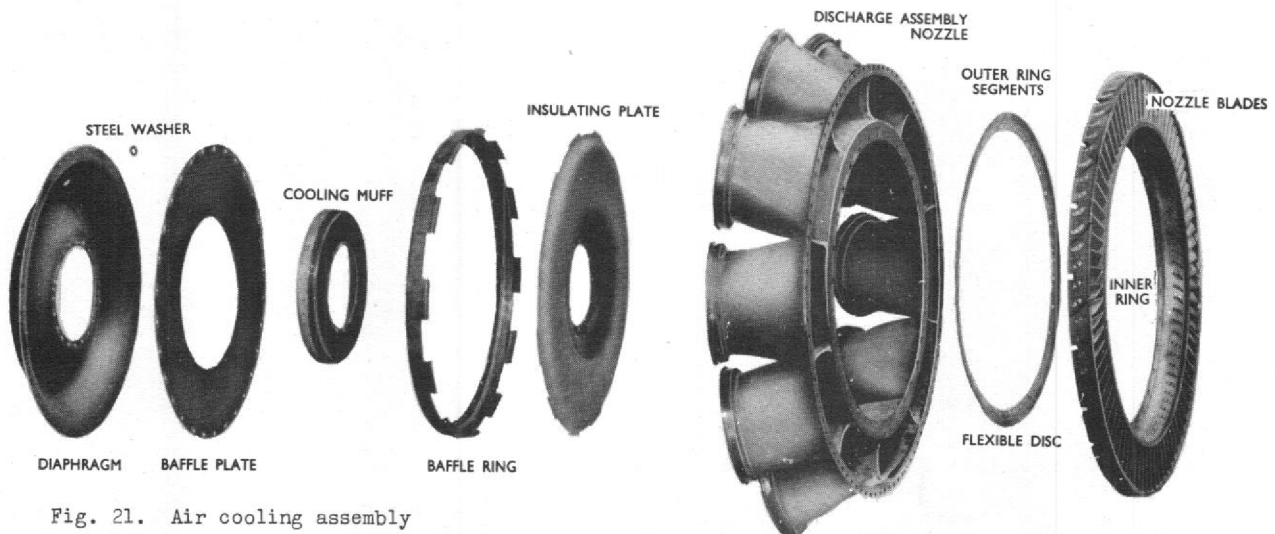


Fig. 21. Air cooling assembly

Fig. 22. Discharge nozzle and nozzle blade assembly

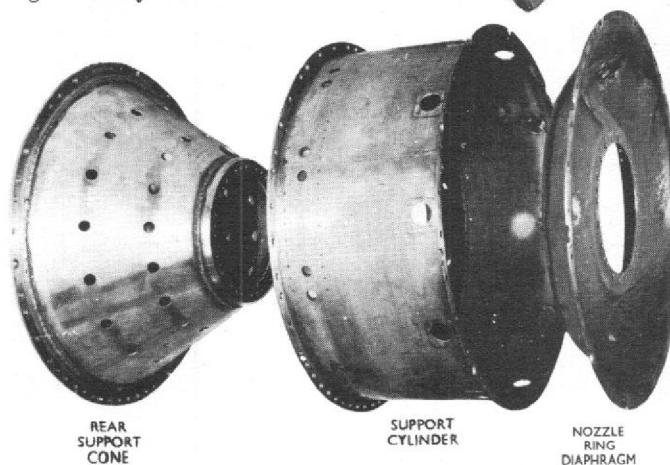


Fig. 23. Support cylinder assembly

NOZZLE RING

The nozzle ring assembly (fig. 20) is comprised of the discharge nozzle assembly, the nozzle shroud which surrounds the nozzle blades between the inner and outer segmented nozzle rings (fig. 22) the turbine shroud, and the support cylinder. The nozzle ring, or turbine entry duct (fig. 20), is supported by a diaphragm mounted on the rear bearing housing and acts as a collector of the combustion gases before they are guided by the static nozzle blades on to the rotating turbine blades. An insulating plate (fig. 21) bolted to the rear bearing housing shields the bearing from the heat contained in the turbine and deflects cooling air escaping from the rear bearing over the front face of the turbine disc. The position of the assembly is stabilized by the support cylinder (fig. 23) which bolts onto the flange of the rear support cone (centre casing).

CENTRE HOUSING

The centre housing (fig. 24) consists of a machined light-alloy casting which is housed in the centre of the air-intake immediately forward of the front bearing. It contains the horizontal driving gear and the top and bottom vertical gears through which the accessories are driven and the drive taken from the turbo-starter. A short accessory drive shaft couples the horizontal driving gear to the pivot attached to the front of the impeller. The bevel gears in the centre housing are carried in the ball and roller bearings.

WHEELCASES AND DRIVES

Fig. 25 shows the accessories mounted on the top wheelcase, and fig. 26 is a diagram of the accessory drives. The bottom wheelcase carries the oil sump, which is described in chapter 2 the two fuel pumps and the hydraulic pump.

The accessories are driven from the front of the mainshaft rotor assembly and the turbo-starter

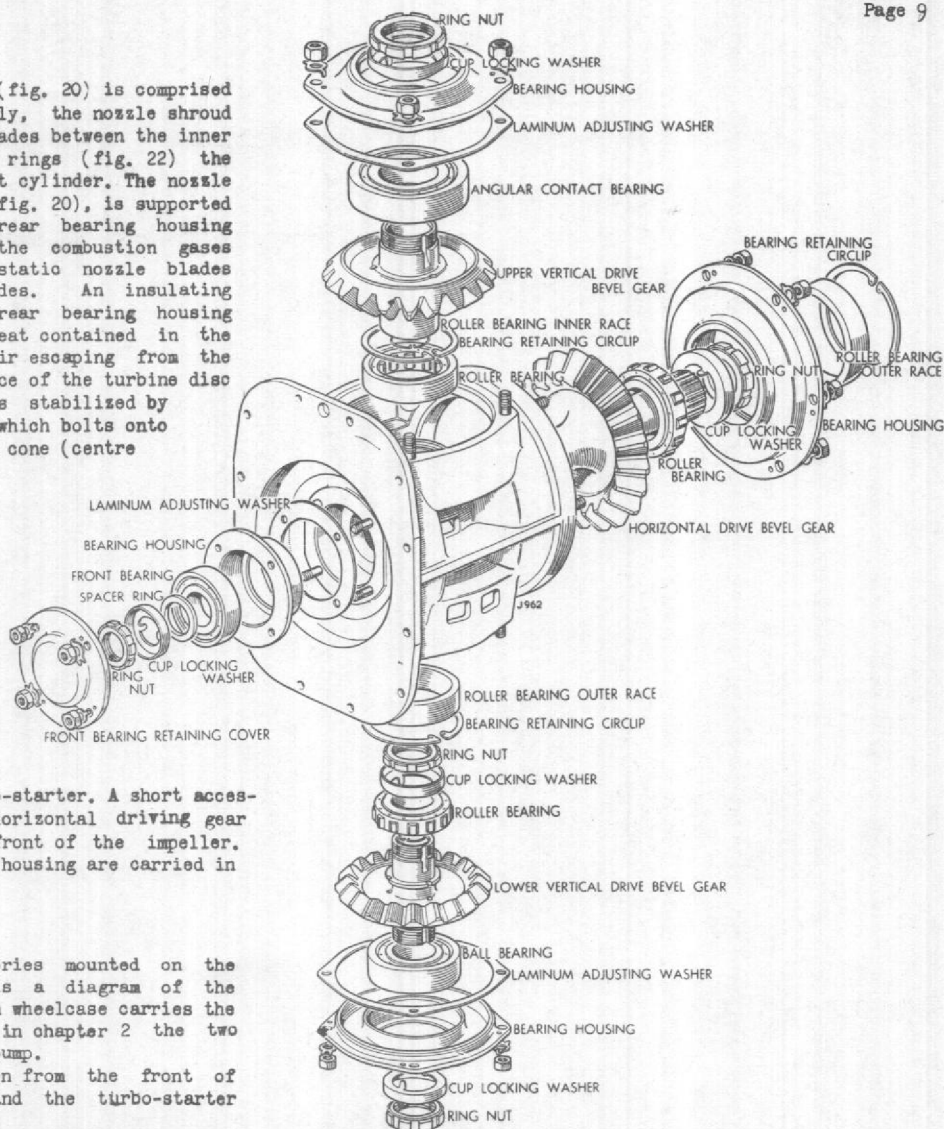


Fig. 24. Centre housing assembly.

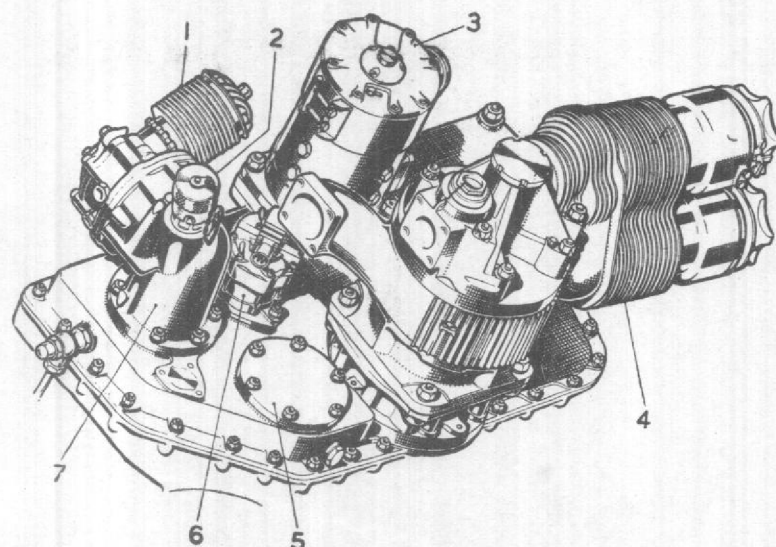


Fig. 25. Accessories mounted on top wheelcase.

1. Air compressor.
2. Oil filler.
3. Generator.
4. Turbo starter.
5. Spare (vacuum pump) mounting face.
6. Tachometer generator.
7. Air compressor drive adapter.

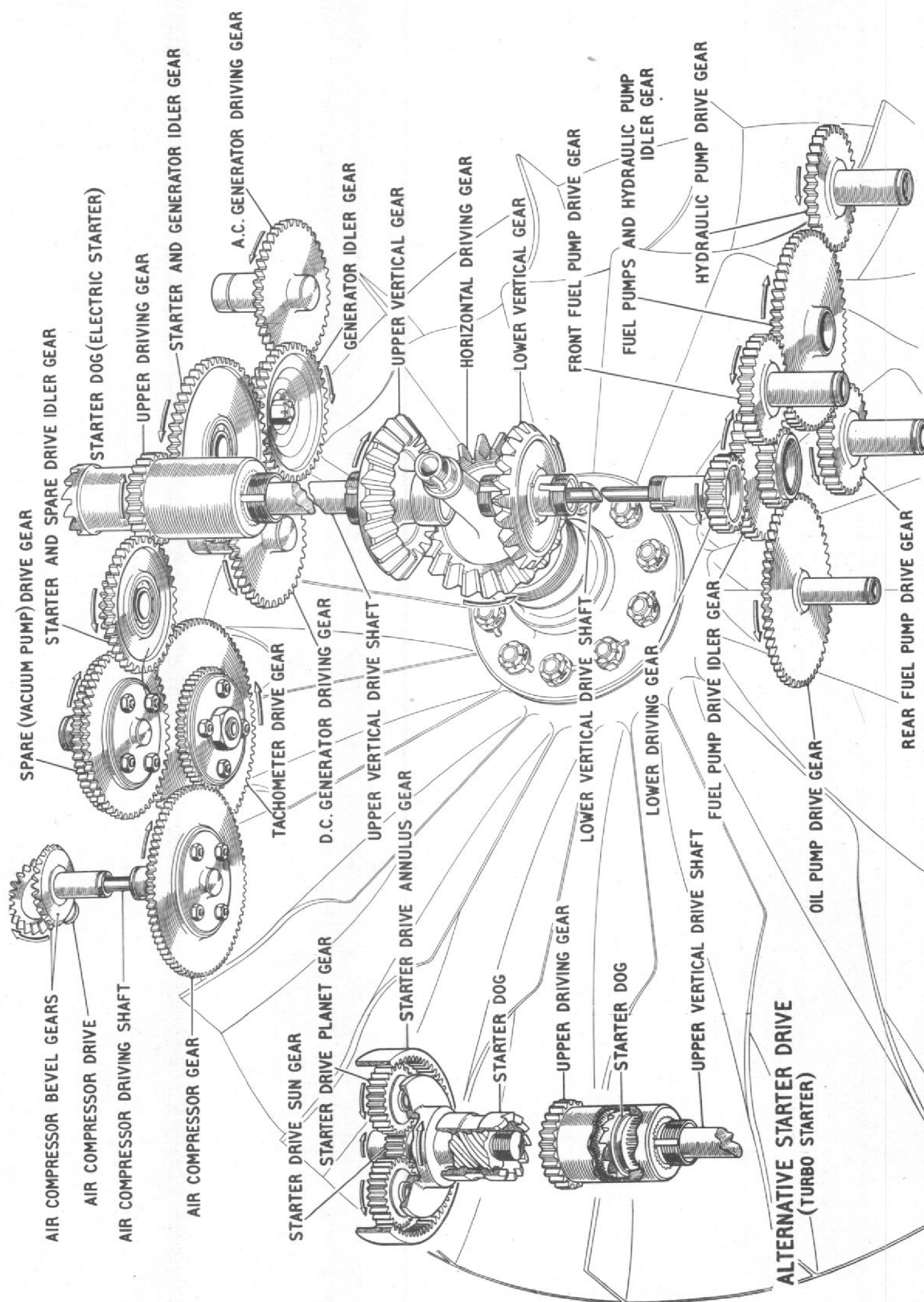


Fig. 26. Arrangement of wheelcase gear drives when electric starter is fitted with inset showing starter drive when turbo starter is fitted.

rotates the engine (at starting) through the same system of shafts and gears. As will be seen from fig. 26, spur gears have been employed as far as possible. A bevel gear, referred to under Centre housing as the horizontal driving gear, is driven from the front of the mainshaft assembly and meshes with bevels on the two vertical shafts. These bevels transmit the drive to the gear trains in the top and bottom wheelcases which are mounted on the top and bottom air-intake facings. The two wheelcases (fig. 25 and 27) take the form of covers and provide the mounting faces on which the turbo-starter, engine accessories and engine-driven aircraft accessories are mounted. The turbo-starter which is mounted on the top wheelcase, is provided with the usual arrangement of dog clutches through which engagement is made with the engine and which throws out once the engine has reached its self-sustaining speed. The fuel pumps and the oil and metering pumps (fig.29) are driven by the gear train in the bottom wheelcase, the metering pumps being actuated by an eccentric formed on the lower extremity of the oil pump driving gear spindle.

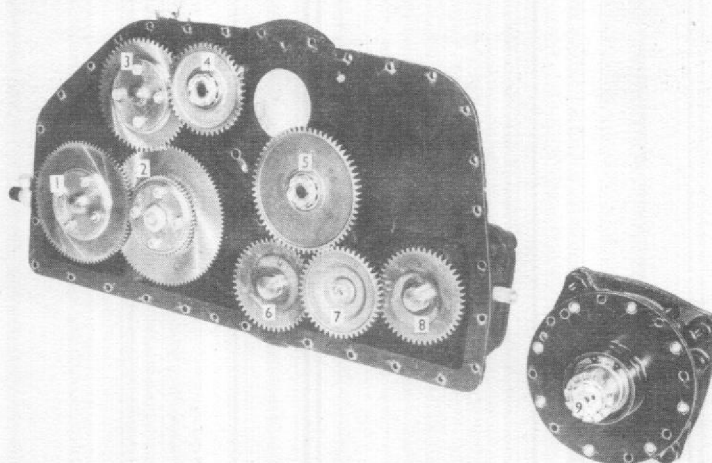


Fig. 27. Interior of top wheelcase and turbo-starter adapter.

1. Air compressor gear.
2. Tachometer drive gear.
3. Spare (vacuum pump) drive gear.
4. Spare drive idler gear.
5. Starter and generator idler gear.
6. Generator driving gear.
7. Generator idler gear.
8. Generator driving gear.
9. Starter dog.

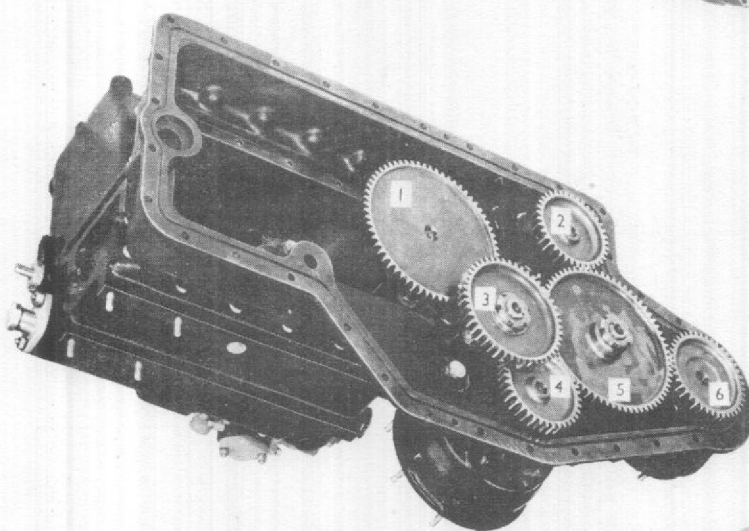
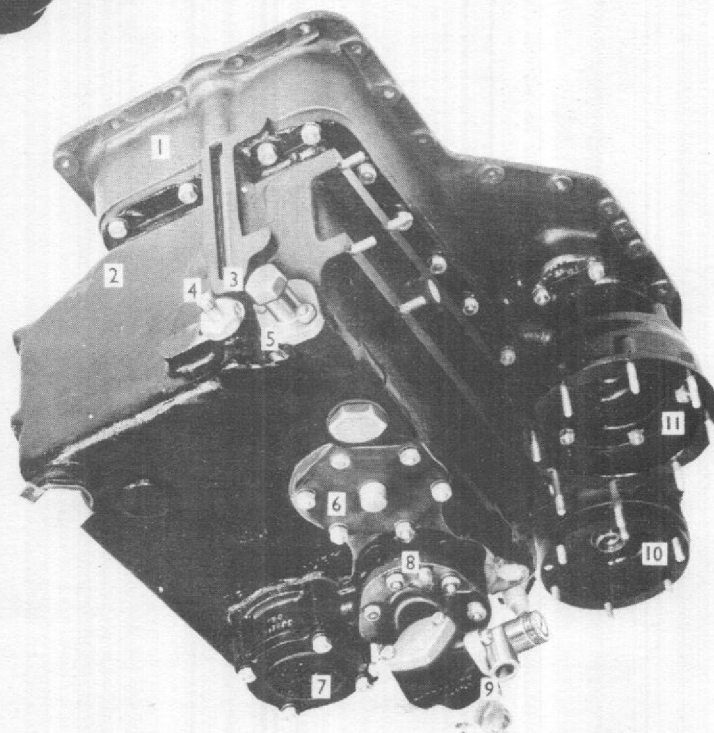


Fig. 28. Interior of bottom wheelcase and oil sump.

1. Oil pump drive gear.
2. Rear fuel pump drive gear.
3. Fuel pump drive idler gear.
4. Front fuel pump drive gear.
5. Hydraulic pump and fuel pump idler gear.
6. Hydraulic pump drive gear.

Fig. 29. Exterior of oil sump and bottom wheelcase.

1. Bottom wheelcase.
2. Oil sump.
3. Oil level sightglass.
4. Oil level plunger.
5. Relief valve.
6. Pressure filter.
7. Suction filter.
8. Oil sump.
9. Metering pumps.
10. Hydraulic pump mounting.
11. Front fuel pump mounting.



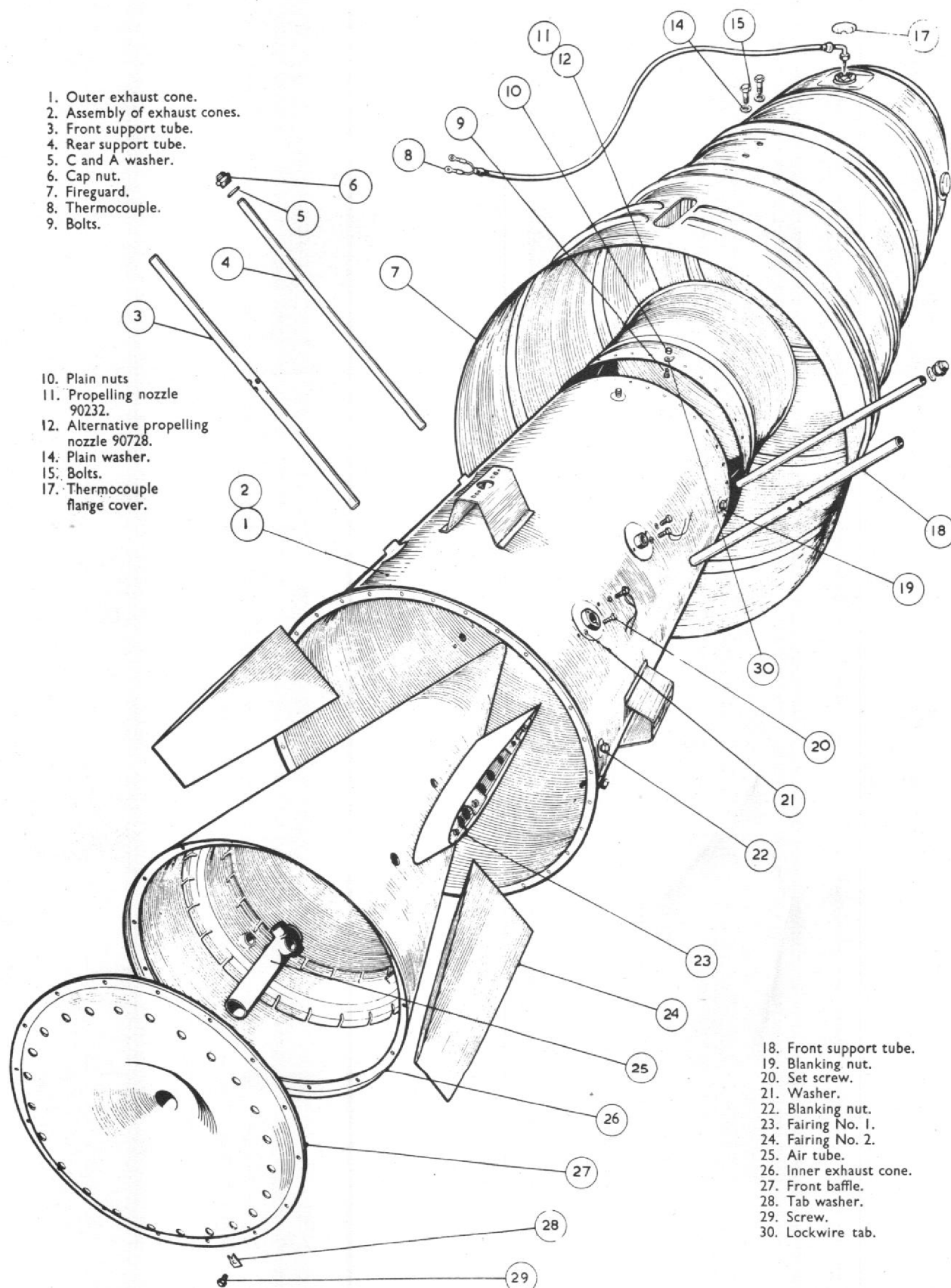


Fig. 32. Exhaust cone and fireguard assembly.

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COMBUSTION CHAMBERS

Ten combustion chambers are mounted between the rear face of the diffuser casing assembly and the nozzle ring assembly. Each consists of a twin-entry expansion chamber, an outer casing, and a flame tube assembly (fig. 30 and 31). A 'Duplex 2' type burner is incorporated in each combustion chamber but for the purpose of this description the burners are considered as forming part of the fuel system. Each flame tube is centralized in its expansion chamber on four guide blocks and is restrained from endwise movement by a locating plug. The flame tube can expand radially and axially from these points. The rear end of the flame tube is located by a sleeve which bears on the inside diameter of the rear outer casing. Two of the combustion chambers accommodate the two igniter plugs and all are interconnected so that pressures are equalized round the engine, and the flame is able to spread to all the burners after initial ignition.

Air enters the combustic chambers from the diffuser passages through the twin air ducts in the expansion chambers. A proportion of the air passes through the scoop on the flame tube head which meters the air required for primary combustion. The burner is held in the centre of the flame tube head and a device for swirling the air surrounds the burner in order to induce turbulence in the primary combustion zone. Most of the air delivered from the diffuser flows, however, over the flame tube head and through the gap between the flame tube and the outer casing, entering the flame tube through secondary holes and diluting the gases to keep the temperature within the necessary limits. A small proportion of the air continues to the annular gap at the rear and joins the main stream immediately after the gases leave the flame tube. A heat insulating layer of relatively cold air is thus maintained throughout the length of the combustion chamber. The rear end of each combustion chamber fits into the discharge nozzle assembly (the turbine entry duct) and an expansion joint is formed by a pair of split sealing rings which are similar to conventional piston rings.

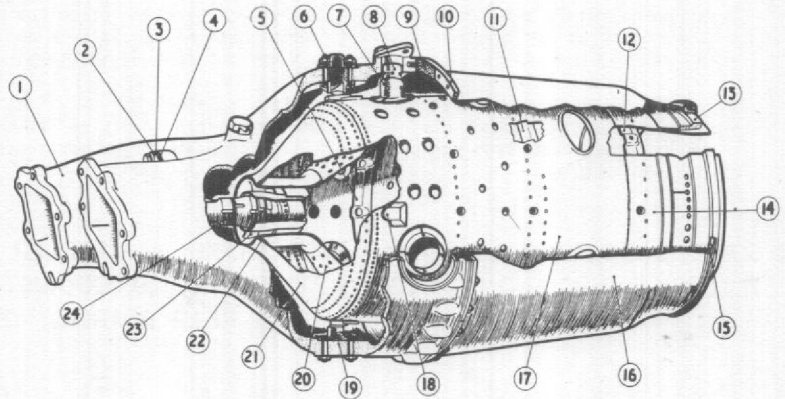


Fig. 30. Type 5D (Mod.437) Combustion chamber components.

- | | |
|-----------------------------------|-----------------------------------|
| 1. Expansion chamber. | 13. Locating muff. |
| 2. Burner diaphragm cover. | 14. Rear section of flame tube. |
| 3. Burner diaphragm. | 15. Sealing rings. |
| 4. Adjusting washers. | 16. Outer casing. |
| 5. Front cooling skirt. | 17. Front section of flame tube. |
| 6. Plunger assembly (2 off). | 18. Mounting pad (4 off). |
| 7. Suspension sleeve. | 19. Support pad assembly (2 off). |
| 8. Locating plug. | 20. Scoop. |
| 9. Klingerit sealing washer. | 21. Flame tube head. |
| 10. Front flange (Four segments). | 22. Snout ring. |
| 11. Centre cooling skirt. | 23. Swirler vane. |
| 12. Cooling skirt. | 24. Burner. |

EXHAUST SYSTEM

The exhaust cone assembly (fig. 32) which is made of stainless steel, is bolted to the turbine shroud and consists of an inner cone and an outer cone to the rear end of which is attached the propelling nozzle. At the forward end of the inner cone a baffle (or diaphragm) is fitted to deflect the cooling air which is piped from the diffuser casing over the rear face of the turbine disc. A heater muff which was welded to the exterior of the outer cone, is deleted when mod. 362 is embodied. Four support tubes locate the inner cone relative to the outer cone and four streamline fairings surround these support tubes where they are exposed between the inner and outer cones. The front support tubes also convey the cooling air to the rear of the turbine disc. The exhaust cone assembly is surrounded by a sheet-metal fireguard.

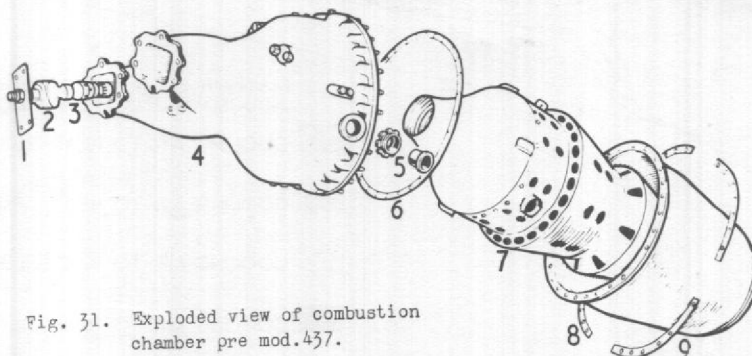


Fig. 31. Exploded view of combustion chamber pre mod.437.

- | | |
|---------------------------|---|
| 1. Diaphragm. | 6. Sealing washer. |
| 2. Burner locating block. | 7. Flame tube and head. |
| 3. Burner. | 8. Outer casing front flange (four segments). |
| 4. Expansion chamber. | 9. Outer casing. |
| 5. Interconnector. | |

ENGINE COOLING

External cooling and ventilation of the engine and its nacelle are effected by surrounding the exhaust cone assembly by an outer cone which is known as the fireguard. The rear end of the fireguard fits snugly round a venturi cuff on the propelling nozzle and the extractor (ejector) action of the propulsive jet draws cold air through the space between the fireguard and the exhaust cone and thus maintains a flow of cold air over the combustion chambers and the exhaust cone. The temperatures developed in those parts of the engine forward of the diffuser casing, including that of the front bearing, are not high enough to necessitate special cooling arrangements.

As described in chapter 2, the rear bearing is partially cooled by the circulation of lubricating oil through an annulus which surrounds the outer race of the bearing. Air from the compressor is passed through an annular cooling ring which forms part of the diffuser casing and thence through an air filter to the rear bearing. This cooling air passes underneath the inner race of the rear bearing between the extension shaft and the hub shaft, forming a barrier of cold air which shields the bearing from heat conducted from the turbine disc to the hub shaft and assists in cooling these parts. The air escapes from the rear of the bearing and flows over the front face of the turbine disc.

The rear face of the turbine disc is also cooled by air taken from the compressor. Pipes from the diffuser casing connect directly with the outer extremities of the cross-tubes which support the inner exhaust cone, and from the centre of these cross-tubes a horizontal tube carries air to the rear face of the turbine disc.

- 1 OIL SUMP. 2 COOLING OIL SPRAY. 3 AIR-INTAKE. 4 IMPELLER. 5 DIFFUSER. 6 NOZZLE GUIDE BLADES. 7 TURBINE DISC AND BLADES. 8 FIREGUARD. 9 EXHAUST CONE. 10 PROPELLING NOZZLE. 11 VENTURI CUFF. 12 REAR BEARING. 13 AIR FILTER.

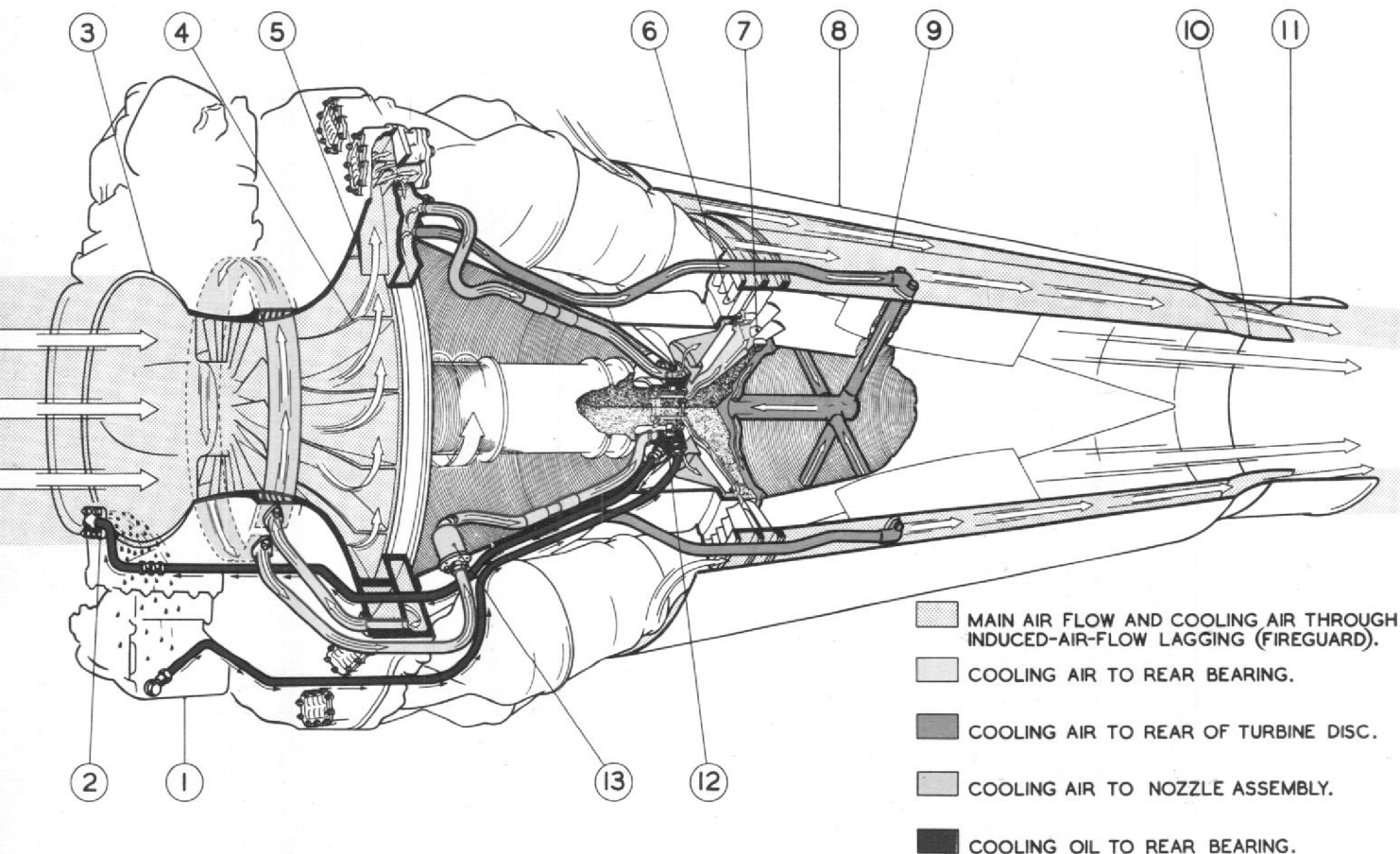


Fig. 33. Diagram of cooling systems

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