SECTION 1

DESCRIPTION

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

CHAPTER 1

GENERAL DESCRIPTION

Note.—*This chapter applies to Avon Mk. 10701, 10901, 11301, 11501, 12101 and 12201 Engine Change Units*

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INTRODUCTION

1. The Avon is a turbo-jet aero-engine having a twelve-stage axial flow compressor directly coupled to a two-stage turbine.

2. Fuel is injected through a burner into each of the eight separate combustion chambers and the flow is controlled by a fuel control unit in conjunction with an engine-driven dual pump of variable stroke.

3. Drives for the fuel pump and the tachometer generator are provided on an externally mounted wheelcase driven from an internal wheelcase surrounding the centre main bearing. A coupling flange is provided on the starboard or the port side for driving an accessory gearbox.

4. The oil system is entirely self-contained in the engine and incorporates a fuel-cooled oil cooler and a combined oil tank and sump containing immersed oil pumps.

5. The engine has a cartridge-operated turbo-starter mounted in the central fairing in the air intake.

GAS FLOW

6. The ducts which carry the main gas stream through the engine have smooth internal surfaces to reduce frictional and aerodynamic losses to a minimum.

7. The compressor is designed to operate over a wide range of engine speeds, aircraft speeds and intake air densities, and delivers air to the combustion chambers at a compression ratio of approximately 6.5:1 at maximum engine speed at normal amtospheric temperature; slightly higher ratios are given at lower temperatures.

8. The air entering the compressor passes through an annular intake duct and is directed on to the compressor rotor blades at the correct angle by a ring of intake guide vanes. The angular setting of the intake guide vanes is controlled automatically to suit the engine speed. After each row of rotor blades there is a set of stator blades fixed to the casing, which direct the air at a higher pressure and at a suitable angle on to the next row of rotor blades. The cross-sectional area of of the compressor air duct is reduced at each stage to maintain the velocity of the air under the rising pressure. From the last stage of the compressor the air passes through a ring of outlet guide vanes. The annular duct of the compressor outlet casing then divides into eight separate circular ducts, each supplying air to a combustion chamber.

9. The combustion chambers are designed to facilitate complete and stable burning of the fuel and to enable the heat so generated to expand the main gas flow and accelerate it rearwards. The products of combustion are surrounded by and mixed with cooler air to distribute the heat evenly. This reduces the temperature of the gas before it reaches the turbine, so that critical temperatures within the turbine are not exceeded.

10. The gas is fed to the turbines through nozzles which gradually merge from the individual circular section of each combustion chamber to segments which form a complete annulus at the high pressure nozzle guide vanes.

11. To keep the diameter of the turbine small and yet enable it to extract sufficient power from the gas stream to drive the compressor, two turbine wheels are used and are coupled together to drive through a single shaft. All the gas passes through both the high pressure (front) and the low pressure (rear) turbines, being directed on to each row of blades at a suitable angle by a ring of nozzle guide vanes. These guide vanes produce a considerable increase in the velocity of the gas and a reduction in the pressure and temperature.

12. After leaving the low pressure turbine the gas passes through the exhaust unit and the jet pipe to the propelling nozzle. To avoid frictional losses in the jet pipe the gas velocity is slightly reduced by diffusion between the cone and the walls of the exhaust unit.

13. The reduction to atmospheric pressure and the final acceleration of the gas occurs at the propelling nozzle, whose exit area is designed to suit the maximum gas flow through the engine.

COOLING AIR

14. To counteract the transfer of heat from the gas stream, air is fed under pressure to cool various parts of the engine.

15. Both faces of each turbine disc are cooled by air which is discharged through labyrinth seals into the main gas stream, thus preventing any leakage of hot gases on to the disc faces. To ensure that the pressure of the cooling air exceeds that of the main gas stream at the point of discharge, the front face of the high pressure turbine disc receives air from the twelfth stage of the compressor, the space between the two discs receives air from the eleventh stage, and the rear face of the low pressure disc receives eleventh stage air through a restrictor hole which maintains an adequate pressure between the turbine discs.

16. The twelfth-stage cooling air is collected in an annular space in the compressor outlet casing, and is conveyed through internal pipes to the high pressure turbine.

17. The eleventh-stage air passes through a 'vortex reducer' which reduces the swirl energy ultimately dissipated as heat and thus minimizes the rise in temperature. The air then passes through a further vortex reducer and transfer tubes inside the compressor shaft and through the hollow turbine shaft to the turbine discs.

18. Third-stage air also passes through a vortex reducer into the compressor shaft, but then flows through the intermediate casing, cooling the turbine shaft, the main bearings and those in the internal wheelcase, and pressurizing the main oil seals. From the intermediate casing, the air flows through the rear bearing housing and then outwards through the arms of the nozzle box frame into a shield where it cools the outer casing of the nozzle box before escaping to atmosphere.

19. To counteract the transfer of heat from the engine and jet pipe to the aircraft structure, the spaces surrounding the engine are ventilated and a circulation of air at atmospheric pressure is assured by the ejector action of the main gas stream at the propelling nozzle and by a similar effect at the outlet for air from the centrifugal breather and the compressor rotor vent.

STRUCTURAL FEATURES

20. The main frame of the engine is formed by a number of basically circular casings secured together by flanged joints to form a rigid structure, inside which the main rotating assembly is supported by three bearings. The concentricity of the structure is assured by a series of spigots, dowels, and close-fitting bolts.

21. Each casing is manufactured from the lightest material which will withstand the stresses and temperatures to which it is subjected in service. For example, magnesium alloy is used for the intake casing, the oil sump and the wheelcases, which are the coolest parts of the engine ; steel is used for the nozzle box where the temperature is fairly high and through which the thrust of the engine is transmitted to the airframe ; aluminium alloy is used for those casings subject to intermediate temperatures.

Thermal expansion

22. Due to the wide divergence of temperature and the variety of materials used, expansion is not uniform throughout the engine.

23. To allow for this, sliding joints are used on the combustion chambers, the nozzle guide-vanes have clearance when assembled in the cold nozzle box, and the turbine blades have clearance both at the blade root and at the tip to allow for axial movement.

24. To allow for relative movement without losing the alignment of the drive, the external wheelcase is attached to the compressor outlet casing by two pivots and a swinging link, and the oil feed, drain and vent connections are made by transfer tubes with rubber sealing rings.

Internal stresses

25. Most of the joints between the main casings are in a state of tension, and in the more highly stressed positions the nuts are tightened to a specified torque loading during assembly to ensure adequate tightness of the joints under running conditions. Controlled tightening is also applied to nuts retaining gears and bearings on shafts, and to the bolts on the compressor and turbine shaft flanges.

26. The compressor rotor tends to pull itself forward due to the increase in pressure across each stage of blades ; the effect of air pressure acting on the rear face of the twelfth stage rotor disc is practically eliminated by venting this space to atmosphere. The turbine wheels tend to move rearwards due to the difference in pressure across the turbine discs and blades. The centre coupling connects the turbine to the compressor shaft, and the loading on the shafts is carried by one thrust bearing at the rear end of the compressor shaft.

Gas seals

27. Throughout the engine there are several places where gas must be confined at the junction of a stationary and a rotating member. Due to the high peripheral speeds, the seals used are of the labyrinth type, having a number of pockets between areas of close clearance. These seals are not air-tight but merely form a controlled restriction to the passage of air or gas. Leakage of hot gas on to the turbine discs is prevented by supplying air at a pressure exceeding that of the main gas stream.

28. The seals between the turbine discs are self-clearing if there is a rub due to thermal and centrifugal expansion of the discs. This is achieved by making the outer members of high expansion material so that the heat produced by the rub causes them to expand away from the rotors. A fine groove self-clearing seal (Mod. 1015) is fitted to the twelfth stage rotor on all engines except Mk. 109. By reducing air losses this seal improves the performance of the engine and has the added advantage of being very robust.

Engine mounting

29. Engine thrust is transmitted to the airframe through two trunnions attached to the nozzle box which support the rear of the engine. One trunnion is designed to slide in its housing to allow for lateral expansion of the engine. A ball-jointed framework attached to the compressor casing supports the front of the engine but does not carry any forward thrust. This front suspension permits limited movement to allow for engine expansion, torque reaction and airframe distortion without excessive stress in the compressor casing.

30. For lifting the engine, one or two brackets are attached to the nozzle box and a lifting eye to the top of the compressor casing or to the air intake extension ring.

MECHANICAL FEATURES

Main rotating assembly

31. The turbine and compressor rotors are directly coupled and are supported in three bearings—a roller bearing at each end and a ball thrust bearing at the centre.

32. To accommodate the slight variations in alignment which may occur under running conditions, the centre coupling incorporates a ball and socket joint, and a splined coupling sleeve is used to transmit the torque from the turbine. The coupling is located axially by a collar which is turned to cross the splines after assembly, and the collar itself has a spring-loaded locking plunger.

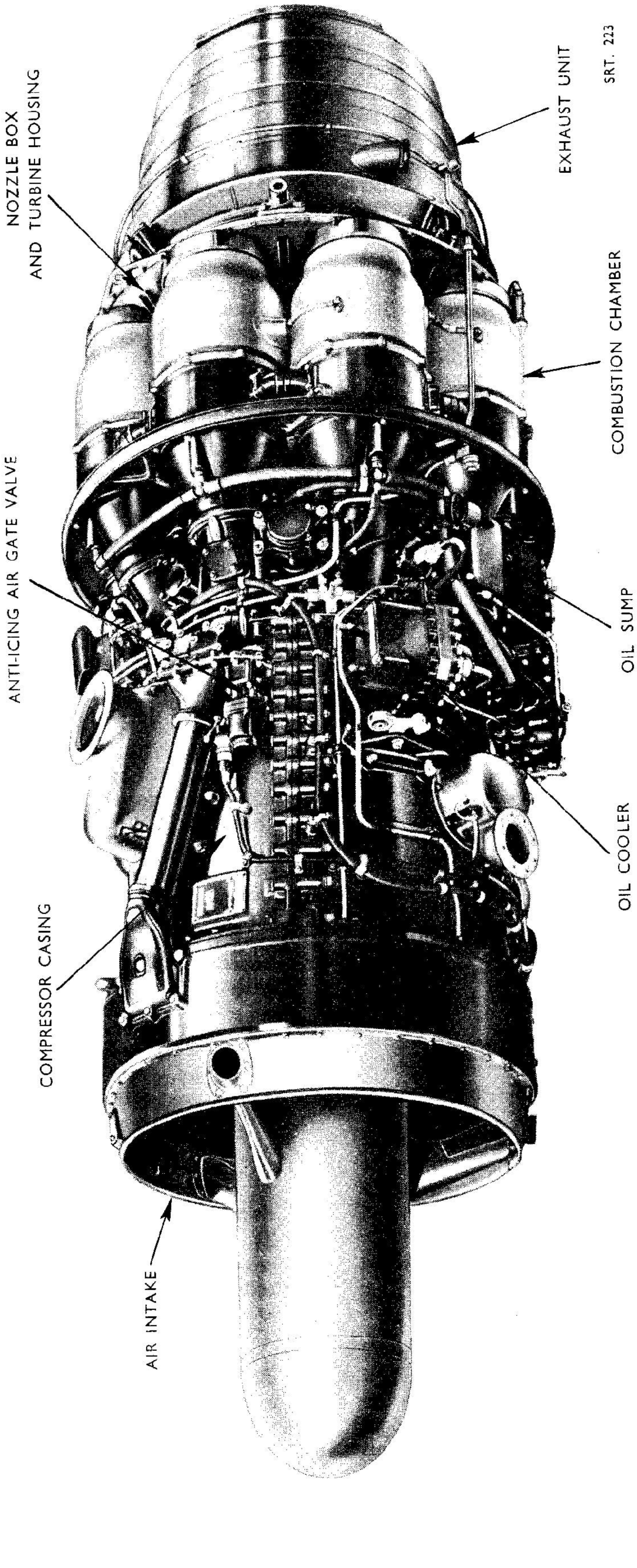

Fig. 1. Location of units (port view)

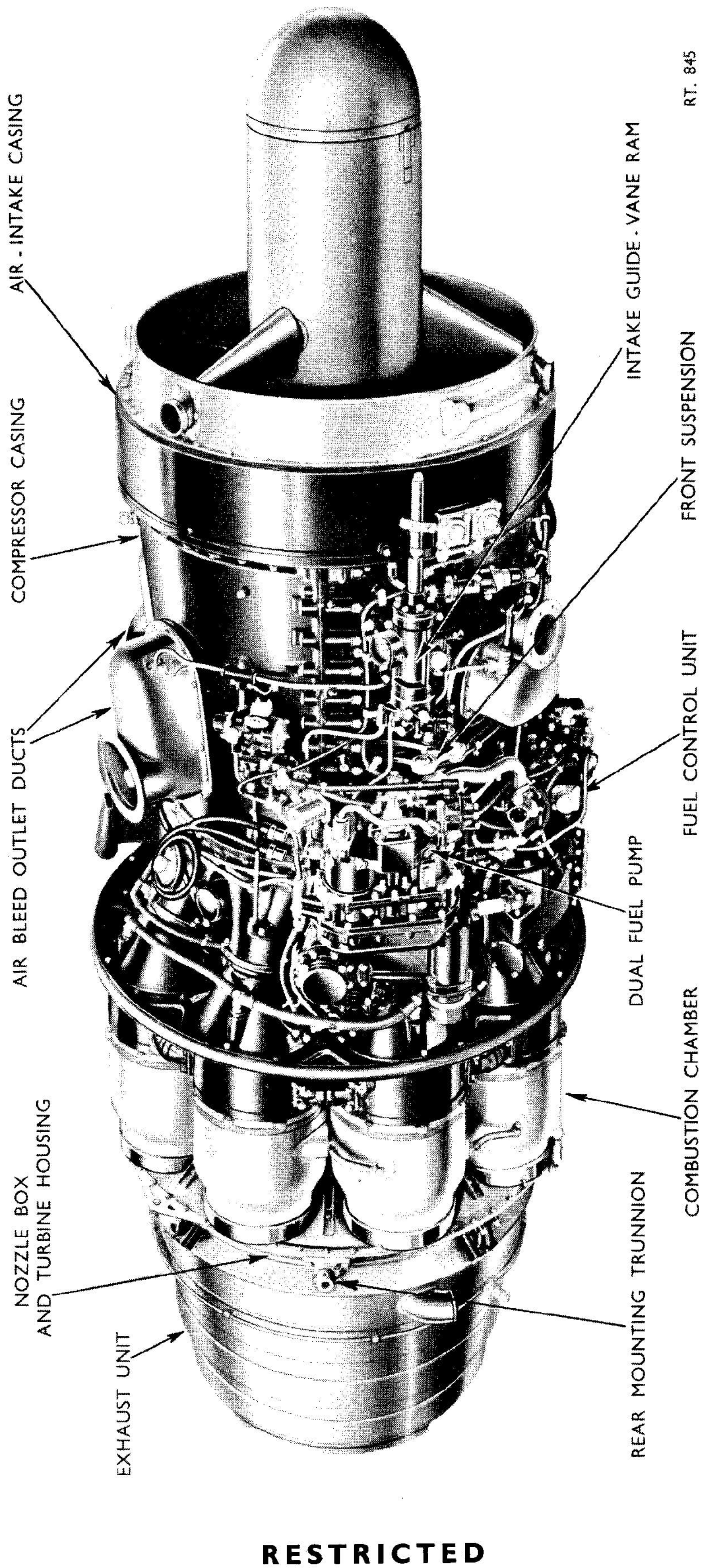

Fig. 2. Location of units (starboard view)

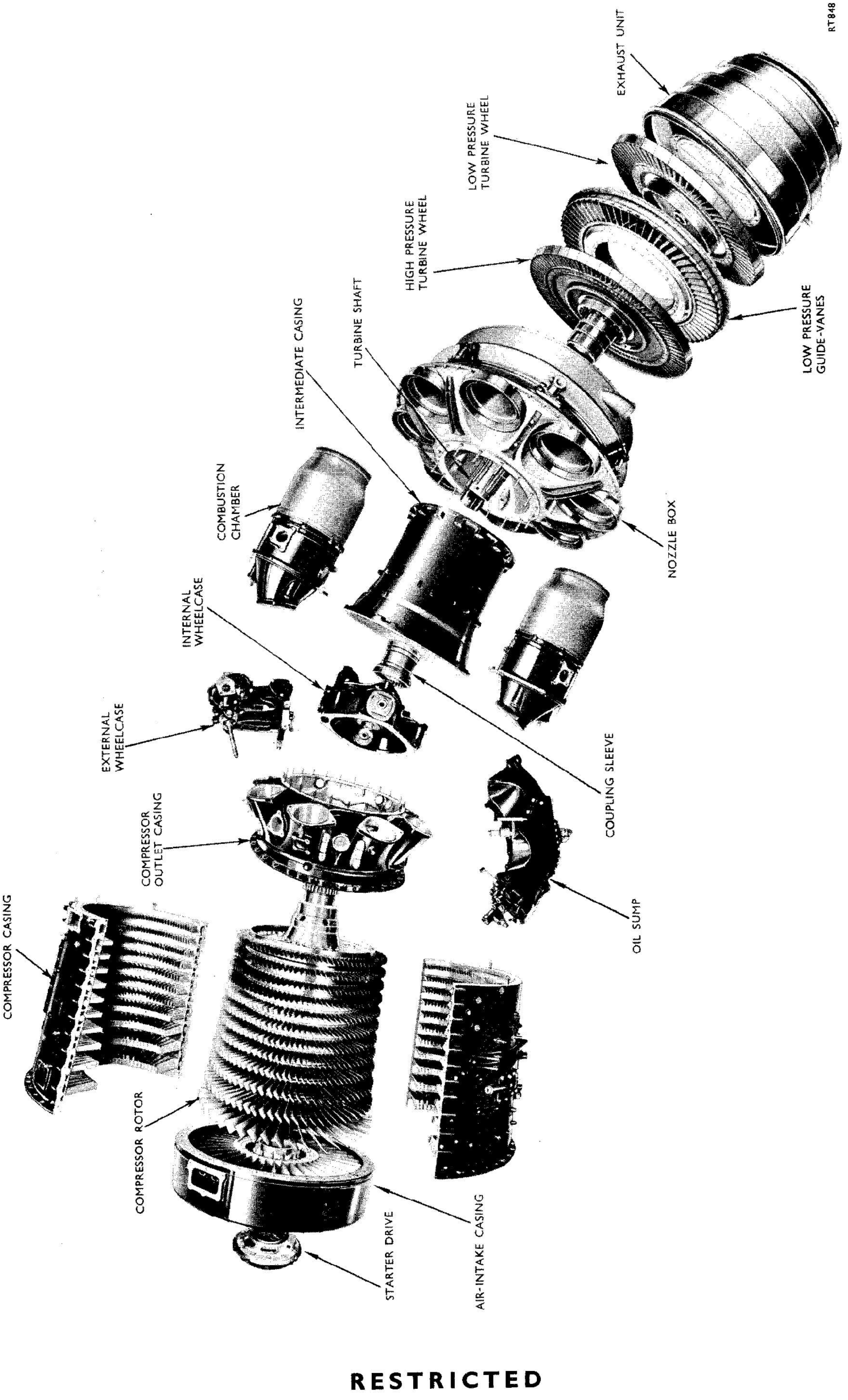

Fig. 3. Main units of engine

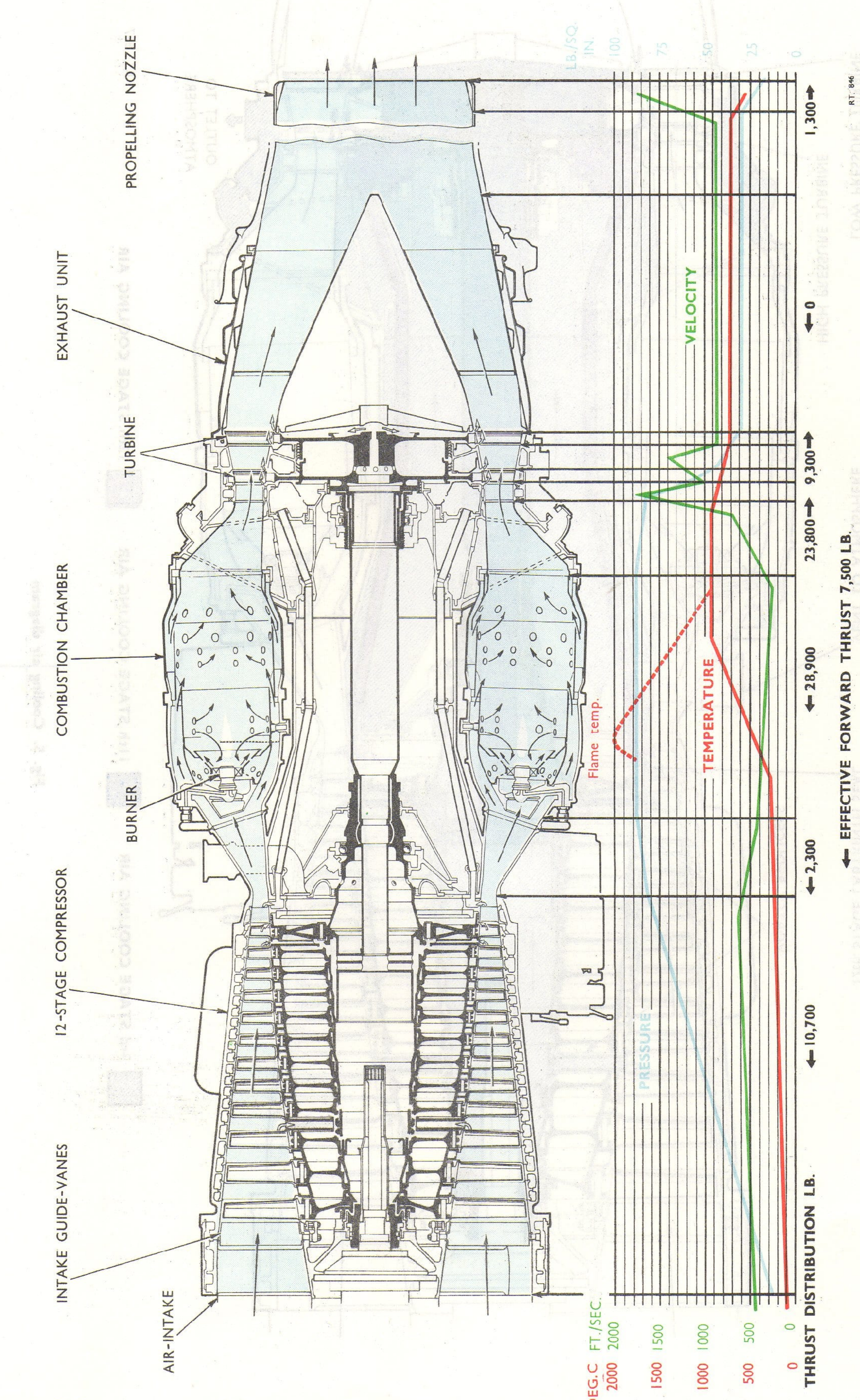

Fig. 4 Typical Gas Flow diagram

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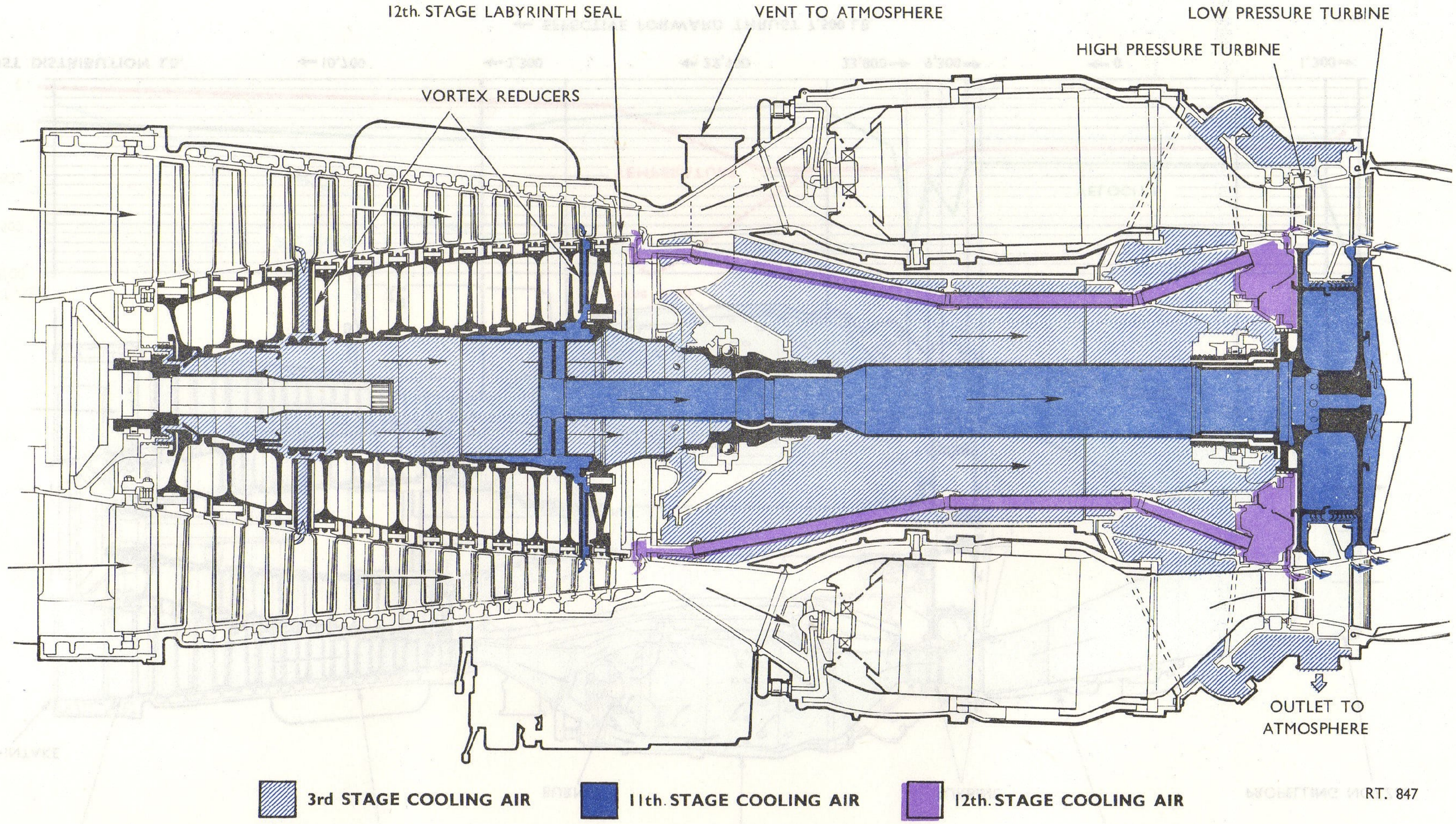

Fig. 5. Cooling air diagram

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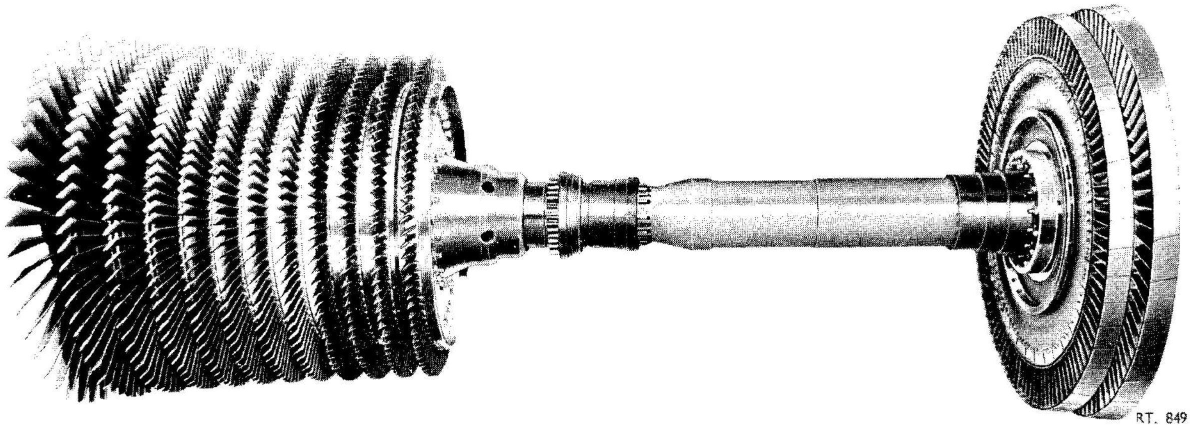

Fig. 6. Main rotating assembly

The axial load of the turbine is transmitted to the compressor shaft through the ball and socket; these have three segments cut away to permit assembly, and a system of baulking pegs and three master splines on the coupling sleeve ensures that the remaining spherical segments are correctly aligned to withstand the axial load.

33. The compressor and turbine rotors are built up from components which are individually balanced, but, to allow final balancing of the assemblies, provision is made for the fitting of balancing plugs on both the compressor and the turbine rotors.

Accessory drives

34. The main drive from the compressor passes through the internal wheelcase in which drives are taken through spur and bevel gears to the centrifugal breather, to the oil pumps, to the external wheelcase, and to the accessory gearbox. The gears in the external wheelcase drive the dual fuel pump, the tachometer generator, and the ram governor pump.

35. In the Avon Mk. 10901 E.C.U., the accessory gearbox may be driven from either side of the engine. On the port side, the drive is taken direct from the internal wheelcase. On the starboard side, the drive is taken from the input gearshaft of the external wheelcase.

36. In the Avon Mk. 10701, 11301, 11501 and 12101 E.C.U., the accessory gearbox drive is on the port side only, and a pair of bevel gears are used to turn the drive through nearly 90 degrees towards the front of the engine.

37. Ball and roller bearings are used throughout the wheelcases, except on the oil pumps and the tachometer generator, which run in plain bearings.

COMPRESSOR

38. The compressor rotor has twelve sets of blades between which are eleven rings of stator blades. The blades in the first eight stages are of aluminium alloy, but the later stages are in bronze alloys to withstand the heat due to compression.

Compressor rotor

39. The rotor blades are secured to discs which are splined to the main shaft. Between the discs are spigoted spacing rings which locate the discs axially and also retain the blade securing pins. The clearance between the spacing rings and the tips and shrouds of the stator blades is kept to a minimum to ensure that as little leakage as possible occurs across each stage.

40. The pins securing the rotor blades to the discs are a free sliding fit and allow the blades to rock slightly; blade root vibration stresses are thus considerably reduced.

41. The compressor shaft is in two parts joined together by flanges with taper bolts. The coupling bolts also secure the two discs which carry the twelfth stage rotor blades. The shorter rear shaft carries the gear from which all the accessory drives are taken.

42. To achieve dynamic balance of the rotor assembly the individual discs and the shaft are balanced, and balancing plugs are inserted at both ends of the rotor.

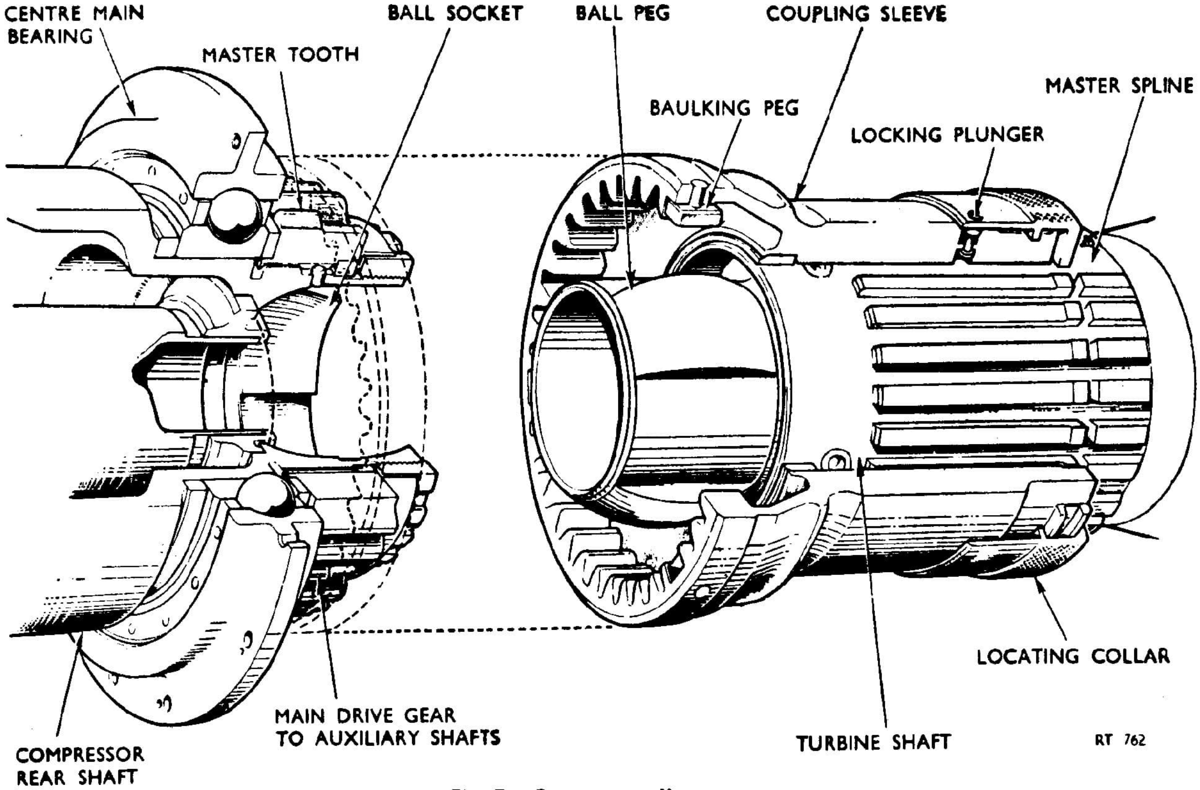

Fig. 7. Centre coupling

Compressor casings

43. The eleven rows of stator blades are housed in two casings which together form a cylinder. Each casing is grooved to hold the blades, and the land between the grooves is just clear of the rotor blade tips. Stops at the casing joints prevent the stator blades from sliding round the grooves when the engine is running.

44. The blades in the first four stages are joined together in groups. The pieces joining the blade tips form a complete inner shroud ring for each of these stages. This minimizes the vibration due to variations in aerodynamic loading, which would otherwise be excessive on the longer blades.

45. The blades in the last two stages are joined together at the root in groups of four and five. These are the smallest and most closely spaced blades, and the grouping maintains correct alignment of the blades.

46. There are facings on the main casings for mounting the oil cooler, acceleration control unit, intake guide-vane operating ram, hot air gate valve, bleed valves, air dip unit and fuel dip unit.

Air-intake casing

47. The air-intake casing has a large hub on which the front main bearing and the starter are mounted. The hub is supported by six spokes which, to allow for expansion, are tangential rather than radial.

48. These spokes are hollow and are used to convey oil to and from the front main bearing and to carry the electrical cables to the starter. Each spoke also conveys hot air for anti-icing purposes.

49. To the rear of the spokes and between the hub and the outer ring are the intake guide-vanes. Each vane has a lever at the inner end engaging with trunnions in an actuating ring to enable the angle of incidence of all the vanes to be altered together. Two vanes have also a lever at the outer end, and through these master vanes a ram operates all the vanes. Internal stops are incorporated to limit the movement of the vanes under compressor surge conditions, and the operating ram is provided with internal limiting stops.

Outlet casing

50. The compressor outlet casing is shaped to divide the air stream into eight ducts, each leading to a combustion chamber. In the annular space immediately after the last stage of rotor blades there are the outlet guide-vanes which remove the swirl from the air as it leaves the compressor. These outlet guide-vanes are retained both axially and circumferentially by a toothed ring which engages with the root of every vane.

51. In the compressor outlet casing there is a ring of holes behind the outlet guide-vanes to supply air at final delivery pressure to cool the front face of the high pressure turbine wheel. Compressed air is also taken through external connections to the acceleration control unit, the air bleed control unit, air-dip unit and valves, and for aircraft services.

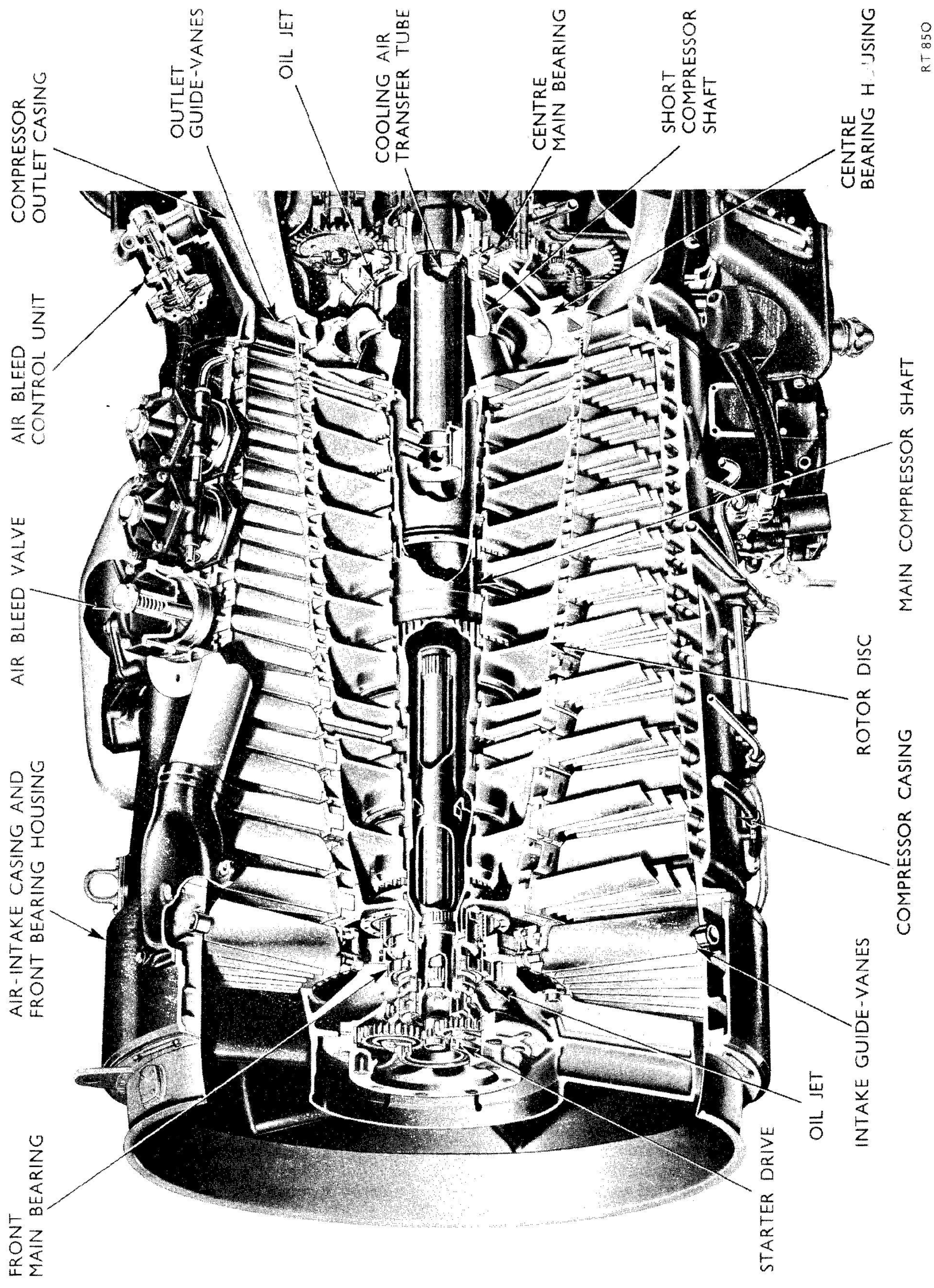

Fig. 8. Compressor

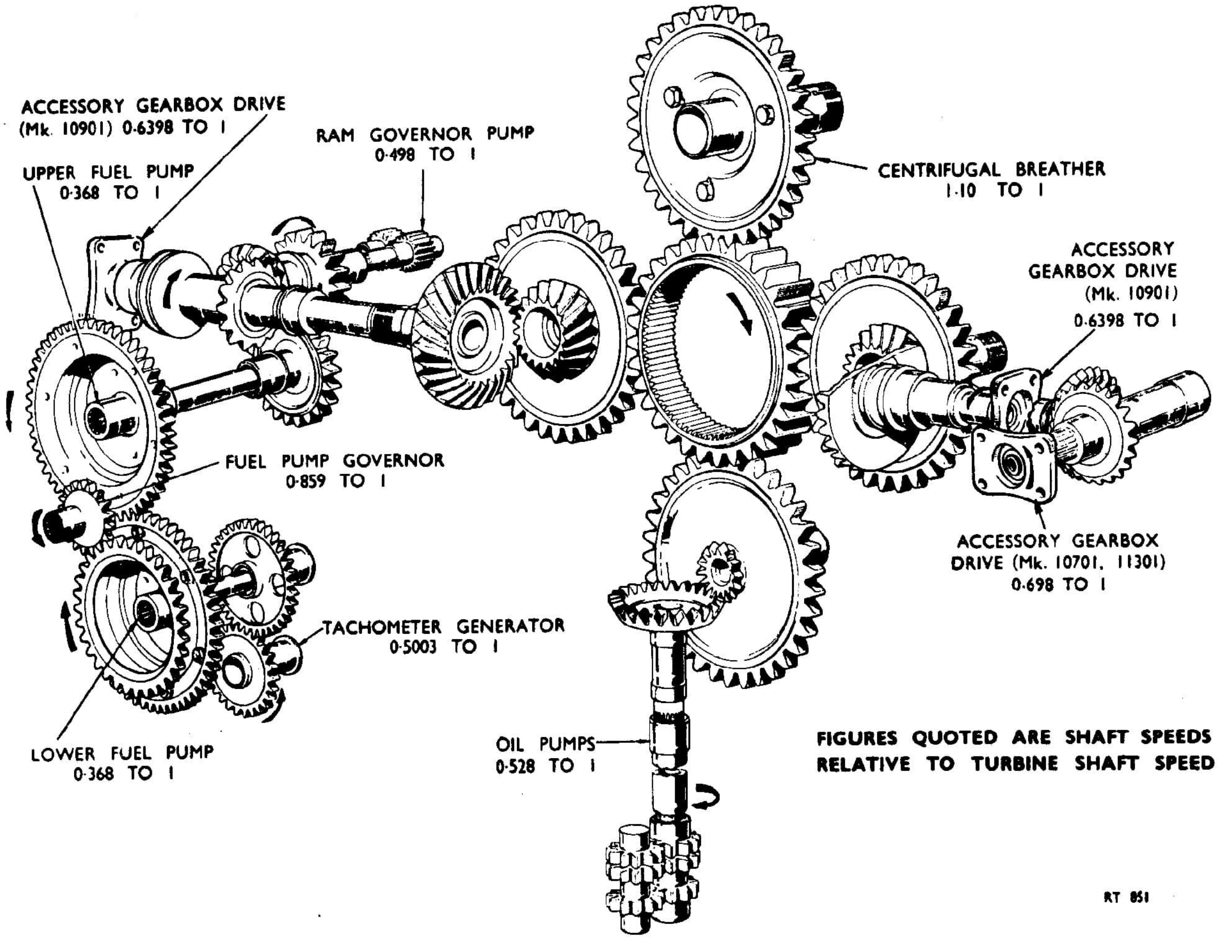

Fig. 9. Gear train diagram

52. The compressor outlet casing also carries the centre bearing housing and the internal wheelcase. Mounted on the outside of the casing are the external wheelcase, the accessory gearbox drive, the oil sump and the air bleed control unit and the air dip bleed valves.

Compressor performance

53. The stages of the compressor are designed for maximum efficiency in the speed range near maximum r.p.m. in which the engine normally operates. However, the engine must run satisfactorily at all speeds, and, to achieve this, variations in the angular setting of the intake guide-vanes and a system of bleed valves, operating automatically, are used to ensure stability of the air flow.

54. At low engine speeds the bleed valves are open and the guide-vanes are at maximum incidence ; at high engine speeds the bleed valves are closed and the guide-vanes are at minimum incidence and produce a minimum of swirl. The vanes are operated by a hydraulic ram which incorporates its own control mechanism.

55. When the air bleed valves are open, i.e. at the lower engine speeds, they allow some of the air from the middle stages of the compressor to escape to atmosphere so that the earlier stages pass more air than the later stages.

Air bleed system

56. A number of bleed valves are connected across the compressor casing at stages four to five, six, and eight to nine. These bleed valves are controlled by a unit which directs air at compressor delivery pressure to the top of the bleed valve pistons so closing the valves above a pre-determined compression ratio (approximately 3 : 1). When the bleed valves are required to open, the control unit shuts off the supply of delivery pressure and vents the top of the piston to atmosphere. A tension spring keeps the valves open when the compressor is stationary.

57. The main parts of the unit are a valve operated by a double-acting piston, and a diaphragm-controlled half-ball valve.

58. The piston-operated valve is spring loaded to close the port that supplies compressed air to the bleed valves, the piston being actuated by air admitted through the main half-ball valve.

59. Two diaphragms of unequal area combine to control the main half-ball valve. The space between the two diaphragms is connected to a venturi through which a small flow of compressor

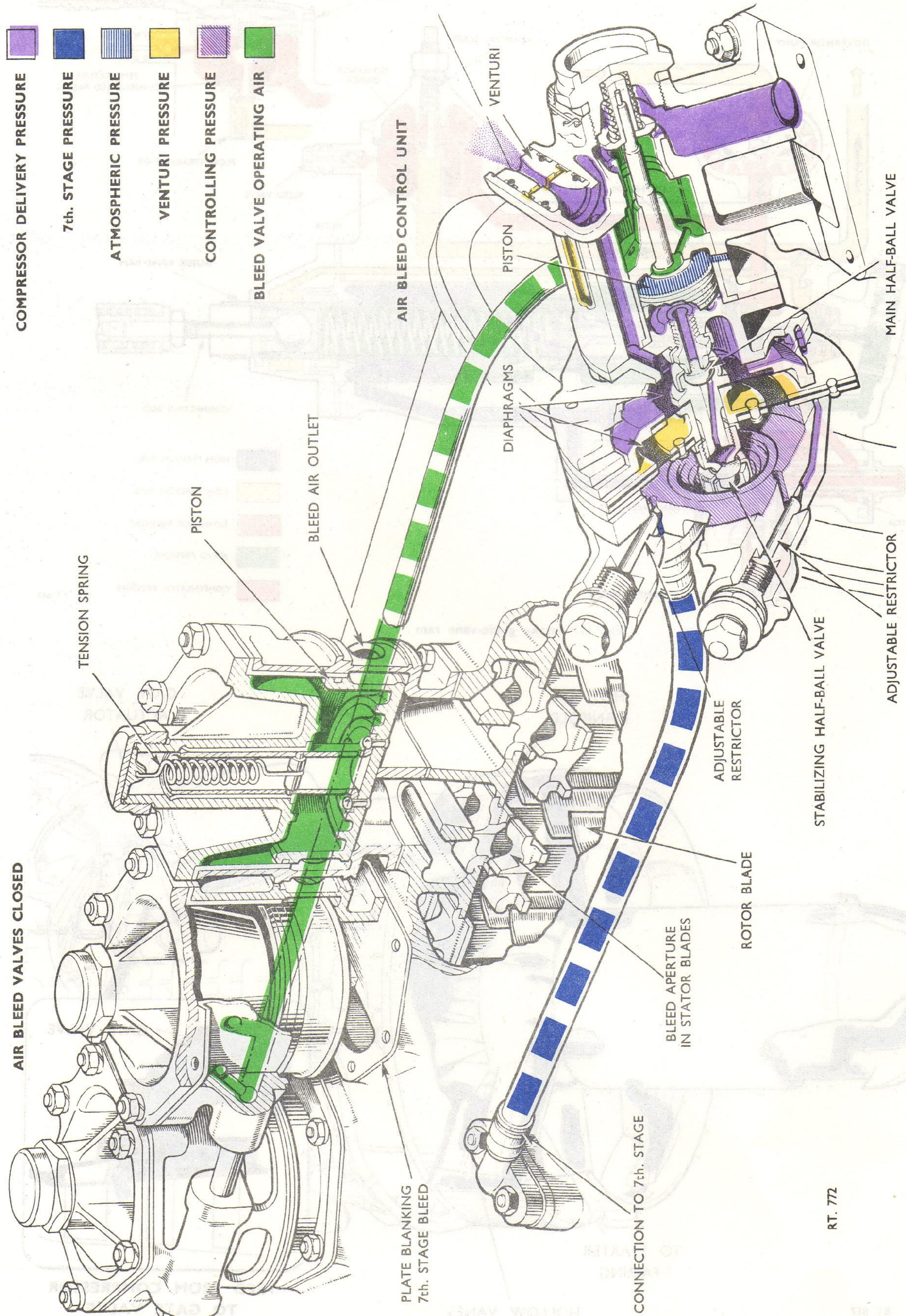

Fig. 10. Air bleed system

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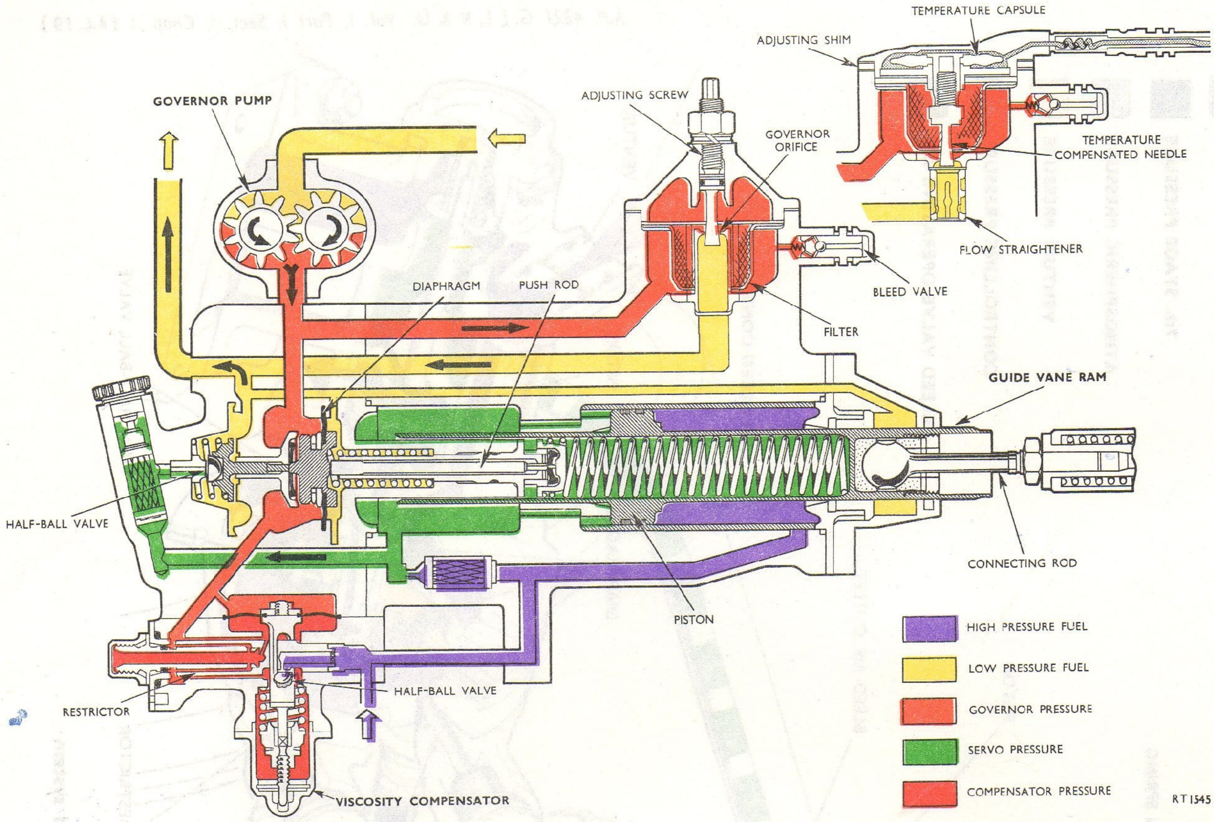

Fig. 11. Intake guide-vane ram

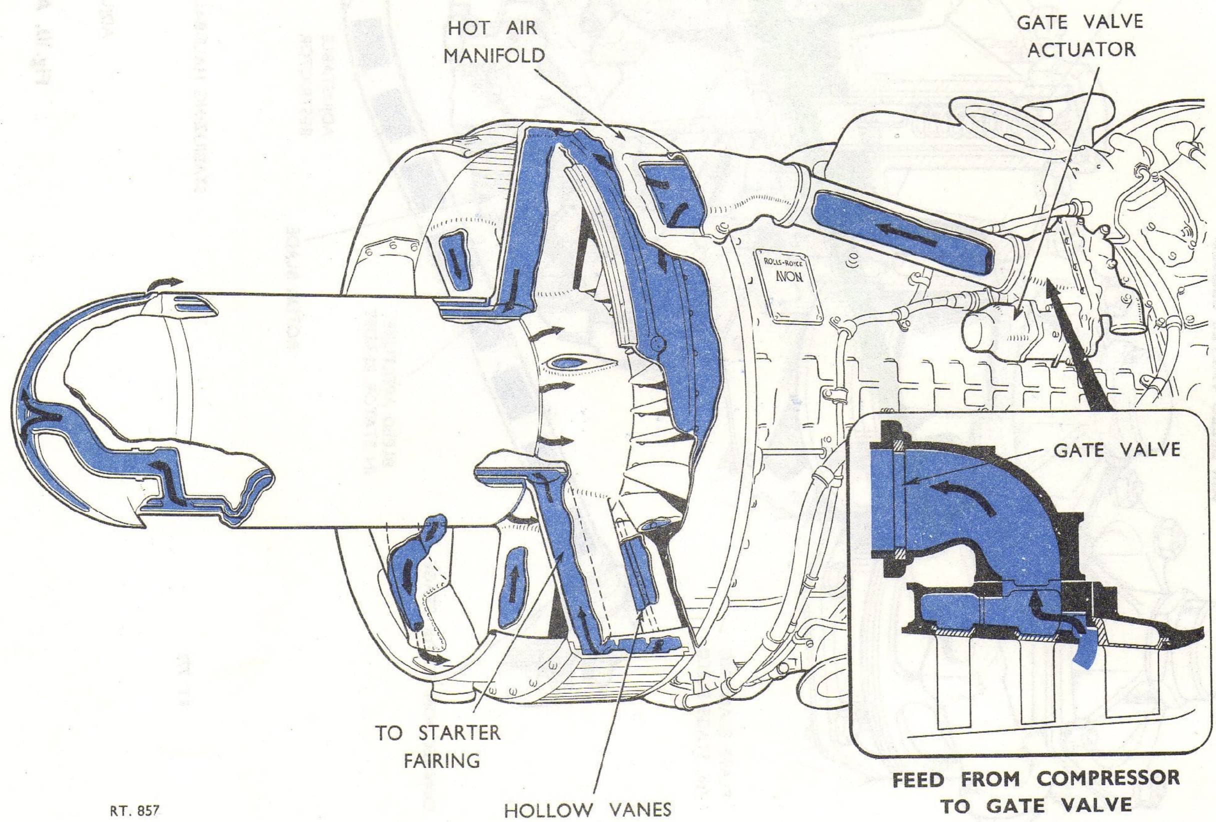

Fig. 12. Anti-icing system

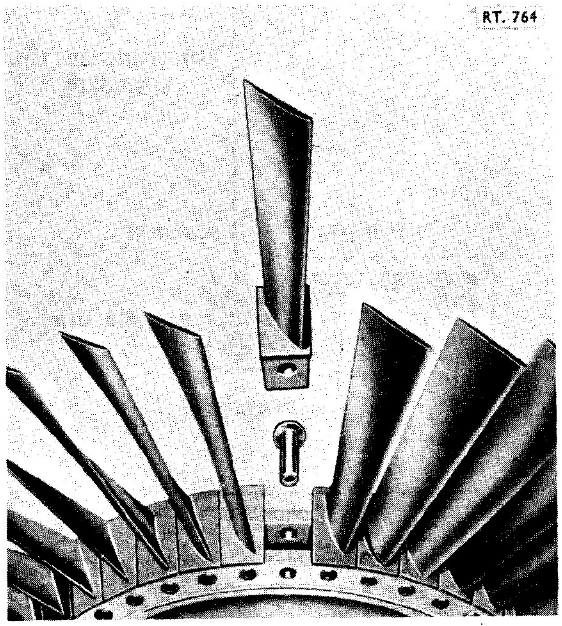

Fig. 13. Compressor blade attachment

delivery air is discharged to atmosphere. As the engine accelerates from idling speed, the air flow in the venturi becomes choked and thereafter the venturi pressure rises rapidly. As the two diaphragms are of unequal area, the venturi pressure exerts a larger force on the larger diaphragm and, at a certain engine speed or compression ratio, opens the main half-ball valve thus directing compressed air to the bleed valves and closing them.

60. The controlling pressure behind the large diaphragm is adjustable and determines the compression ratio or engine speed at which the bleed valves are closed and opened. Air flowing from the twelfth to the seventh stage, through two adjustable restrictors, provides an intermediate pressure which is applied to the diaphragm.

Intake guide-vane ram

61. The hydraulic ram moves the intake guide-vanes progressively over a range of engine speed. As engine speed increases in this range, the ram piston moves rearward and the angle of incidence of the vanes decreases.

62. The position of the ram is related to engine speed, and a measure of this is obtained in terms of a pressure difference from an engine-driven governor pump circulating fuel through an orifice. A profiled needle in the orifice provides a means of adjustment for the range of engine speed over which the ram operates.

63. On some engines the profiled needle is mounted on a capsule connected by capillary tubing to a thermometer bulb in the air-intake extension ring, so that the pressure difference also depends on the intake air temperature. This temperature compensation makes the ram sensitive to 'corrected r.p.m' rather than actual engine speed. On engines post-Mod. 861 or 949, air temperature compensation is deleted and the compensating device is replaced by a screw adjustment to the fixed orifice needle, this improves engine handling at altitude and avoids deceleration surge.

64. The ram incorporates its own servo system and derives its power from the high pressure pumps in the main fuel system and from the governor pump. Both sides of the ram piston are supplied with fuel, but the front of the piston has a smaller effective area than the rear, and the full pump delivery pressure is applied to the front only. The rear of the piston is subject to ram servo pressure and receives fuel through a restrictor from pump delivery pressure, the servo pressure being controlled by a half-ball valve spilling fuel back to the inlet of the high pressure fuel pump.

65. The force tending to close the half-ball valve is decreased by the effect on the diaphragm of the governor orifice pressure drop, and increased by the compression of the spring inside the piston. Thus, within the range of engine speed in which the ram is in an intermediate position, this position is directly related to engine speed. An increase in speed results in a greater pressure drop across the diaphragm, which reduces the servo pressure. This causes the piston to move to the rear until the higher spring pressure balances the higher governor pressure.

66. Movement is limited in both directions by internal stops in the ram, and the connecting-rod incorporates a spring-loaded coupling to avoid imposing excessive stress on the master vanes.

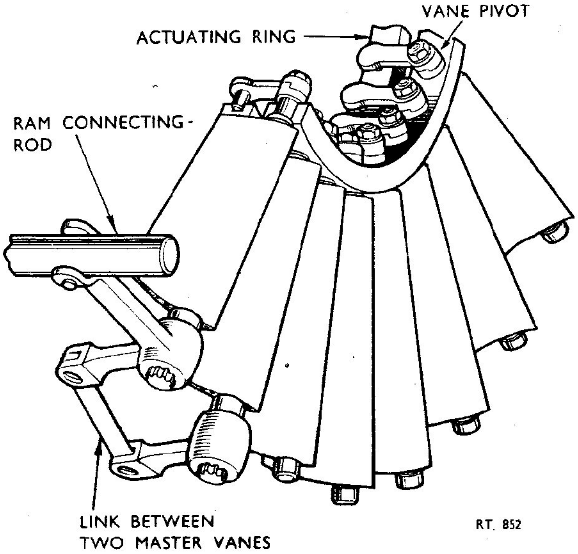

Fig. 14. Intake guide vanes

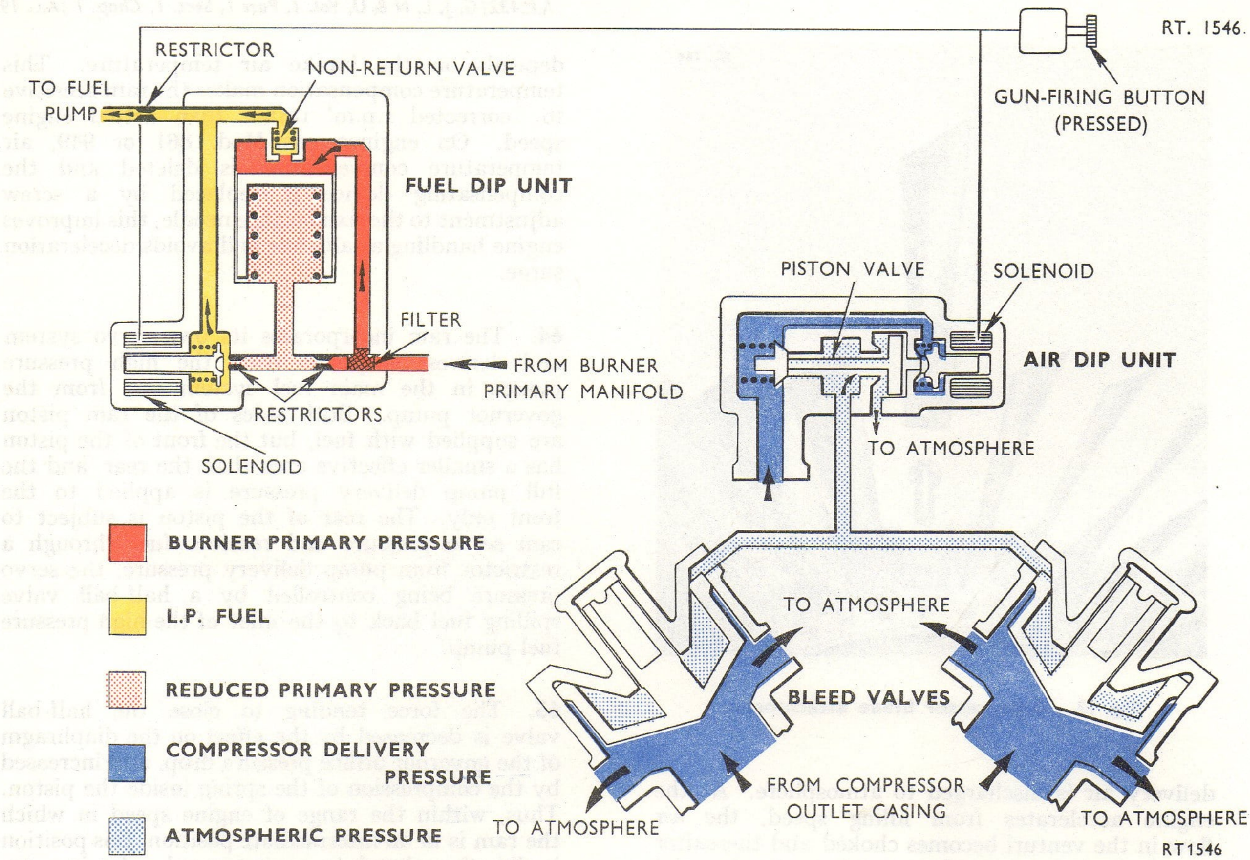

Fig. 15. Fuel and air-dip system

Viscosity compensator

67. The intake guide vane ram governor pump is sensitive to changes in fuel viscosity, i.e., an increase in fuel viscosity will increase the governor pump delivery pressure and vice-versa. The pressure at the ram diaphragm, therefore, varies with viscosity change and the intake guide vane ram will operate earlier or later than the r.p.m. at which it is set. To avoid this, a viscosity compensator has been introduced.

68. The viscosity compensator consists of a viscous restrictor and a diaphragm operated half-ball valve; the half-ball valve being biased towards the open position by a light adjustable spring (*fig*. 11).

69. A supplementary supply of H.P. fuel is admitted past the half-ball valve, through the narrow clearances between two sleeves in the viscous restrictor housing, to the ram diaphragm. The pressure drop across the restrictor is sensed and kept constant by a compensator diaphragm which controls the position of the half-ball valve. The characteristic of the viscous restrictor is such that, with a constant pressure drop across it, the flow through the restrictor is inversely proportional to the viscosity change of the fuel, i.e., a decrease in fuel viscosity causes an increase in fuel flow through the restrictor.

70. The pressure at the ram diaphragm, therefore, is kept as constant as possible within the working range of the restrictor for any given r.p.m. irrespective of fuel viscosity.

FUEL AND AIR DIP SYSTEM

71. To counteract compressor surge when the guns are fired at high altitudes, a fuel and air dip system have been incorporated on Mk. 121 engines.

72. During gun firing, the fuel dip unit reduces the fuel flow and the air dip unit opens two bleed valves to permit some of the air to by-pass the turbine to atmosphere. The combined effect is to lower the compression ratio so that the working point of the compressor is moved away from the surge line.

Fuel dip unit

73. The fuel dip unit is mounted on the port side of the compressor casing forward of the fuel cooled oil cooler. The unit is connected to the burner primary manifold and the L.P. filter, the latter connection being made through a T-piece mounted on the compressor. The unit consists of a spring loaded piston valve and a solenoid operated half-ball valve as shown in fig. 15.

74. When the engine is running normally (without gun firing) the half-ball valve is on its seating, thus the fuel pressure on both sides of the piston valve is the same and the piston is forced upwards on to its seating by spring action. When the gun firing button is pressed, the solenoid is energised and the half ball valve is lifted off its seating, allowing fuel to be bled from the underside of the piston valve and causing it to lift off its seating, and bleed burner primary fuel to the L.P. filter. When the gun firing button is released, the piston valve is returned on to its seating and the fuel flow returns to normal.

Air dip unit and bleed valves

75. The air dip unit is mounted on the top of the compressor casing forward of the bleed valve control unit. Two air dip bleed valves are mounted on top of the compressor outlet casing, one on the port and one on the starboard side. Compressor delivery pressure is tapped from the compressor outlet casing through the air-dip control to the top side of the air dip bleed valves.

76. The air dip control consists of a piston valve and a solenoid operated half-ball valve. When the engine is running normally, the half-ball valve is spring loaded to the open position and this allows compressor delivery pressure to lift the piston valve off its seat against spring pressure; compressor delivery can thus pass to the top side of the bleed valves. Because compressor delivery pressure on top acts over a larger area than the same pressure on the underside the bleed valves are retained in the closed position.

77. When the gun firing button is pressed, the solenoid is energised and the half-ball valve shuts off the supply of compressor delivery pressure to the piston valve; the valve closes, shuts off compressor delivery pressure to the bleed valves and vents the top of the bleed valves to atmosphere. Compressor delivery pressure on the underside of the bleed valves thus forces the valves open and bleeds to atmosphere.

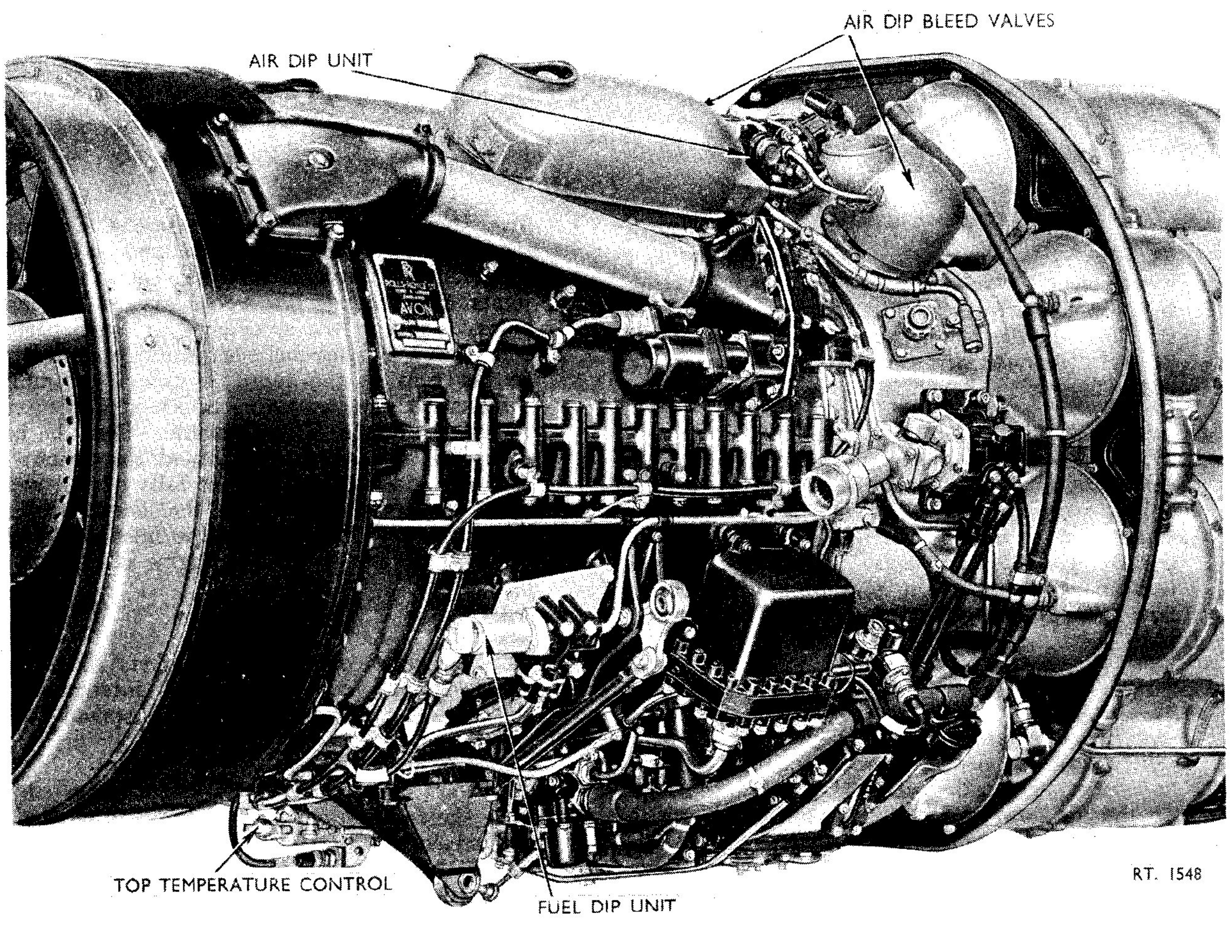

Fig. 16. Location of top-temperature control fuel-dip unit and air-dip units

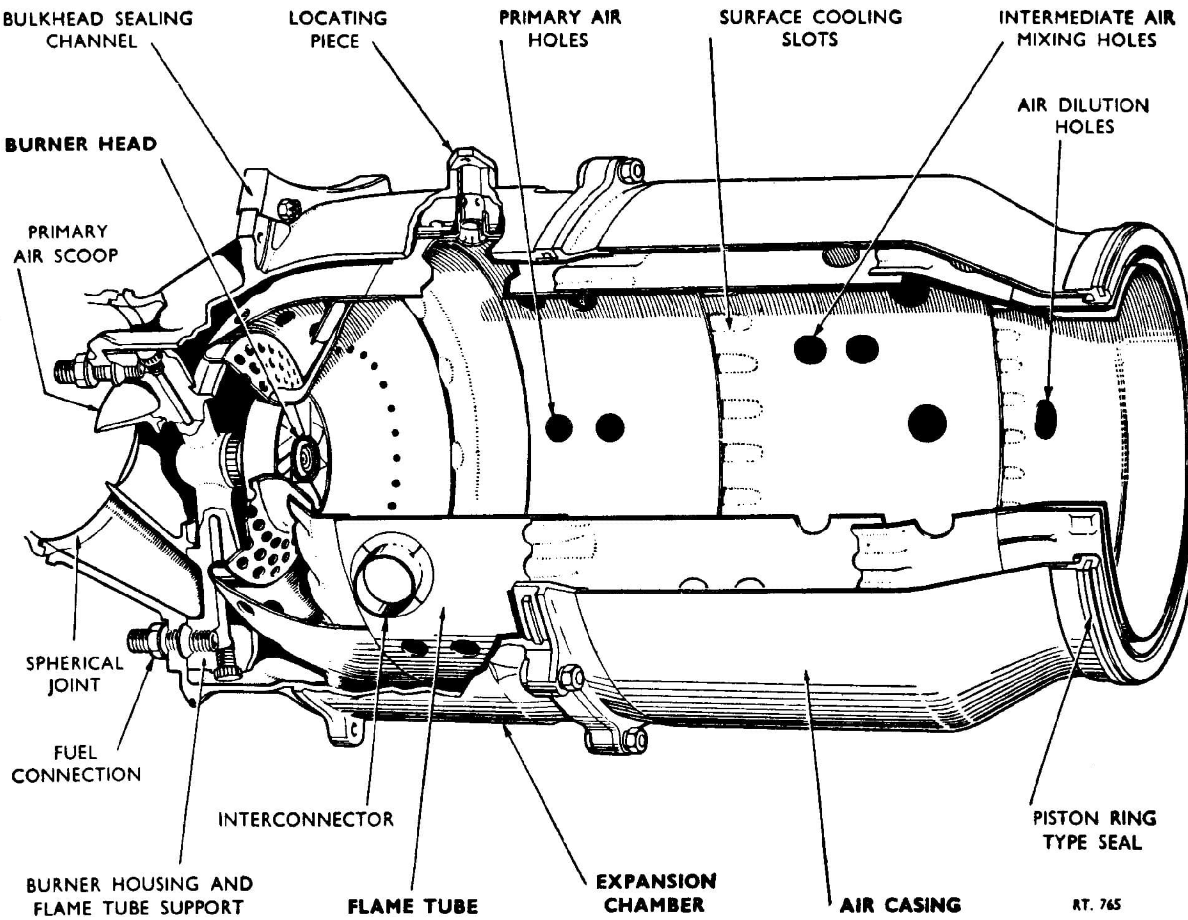

Fig. 17. Combustion chamber

COMBUSTION CHAMBERS

78. In each combustion chamber there is a burner which emits a finely atomized spray of fuel. A flame tube stabilizes the flame, regulates the flow of the outer layer of cooler air, and protects the outer air casing from the direct heat of the flame.

79. To ensure stability and completeness of combustion, the fuel spray is in the form of a hollow wide-angle cone burning in the primary zone of the flame tube where the air flow is comparatively slow. To assist atomization of the fuel and to combat the formation of carbon a flow of air is directed across the face of the burner from passages in the burner head.

80. Approximately 15 per cent of the air entering each combustion chamber flows through the primary air scoop and passes through perforated and corrugated baffles which slow down and even up the air flow, and through swirl vanes which produce a vortex in the primary zone. The depression near the burner head due to the vortex causes a reverse flow in the centre of the chamber, which assists the stabilization of combustion by mixing the fuel and air and helps to reduce the overall length of the flame.

81. The air which passes outside the primary air scoop cools the flame tube and is admitted progressively through corrugation at the welded joints and through the secondary and tertiary holes. Some of the secondary air takes part in combustion, but the fuel needs only approximately 25 per cent of the total air flow for complete combustion. The remaining air is heated by mixing with the products of combustion. Thus the heat energy of the fuel is distributed throughout all the gas, and the temperature falls from a maximum of 2,000 deg. C. in the flame itself to approximately 800 deg. C. at the inlet to the high pressure turbine when the engine is running at full speed.

82. Adjacent combustion chambers have their flame tubes and air casings interconnected by tubes to allow the flame to spread when starting.

83. The combustion chambers expand more than the intermediate casing and, to allow for this, the discharge end is able to slide in the nozzle box, gas leakage being prevented by a piston-ring type seal. The interconnector tubes also have sliding joints or bellows to allow for expansion.


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