THE AVRO ARROW

AVRO CANADA

TO DOUG DOUCETTE
WITH MY BEST
REGARDS

A BOOK BY

Tom Dugelby

THOMAS B DUGELBY

CHAPTER 8

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INTRODUCTION

GENERAL

The Iroquois is a high performance, axial flow, two-spool turbojet engine with integral afterburner, and is specifically designed for operation under super-sonic flight conditions. The engine derives its thrust from the reaction to the increase in momentum of the air mass passing through it. This increase in momentum is produced by burning fuel in the air mass to increase its temperature and volume, and by accelerating the exhaust gases to a high velocity by means of a final nozzle at the rear of the engine.

MECHANICAL ARRANGEMENT

The engine comprises essentially a two-spool compressor, an annular type combustion system, a turbine section, an afterburner-equipped exhaust system, and the necessary support frames and casings.

An inlet frame assembly directs the air flow into the three-stage low pressure compressor, from which it is forced into the seven-stage high pressure compressor. Each compressor is individually coupled to its respective turbine by direct shafting, the HP compressor being driven by a two-stage turbine and the LP compressor by a single stage turbine.

The LP and HP compressor rotor assemblies are mounted in two separate ball thrust bearings supported in the front frame assembly, interposed between the LP and HP compressors. Additional support is provided by a "steadying" roller bearing at the front of the HP rotor assembly. The turbine rotor assemblies are mounted in two separate roller bearings housed in the rear frame assembly located at the rear of the turbine section. In addition to supporting the LP and HP rotors, the front frame and rear frame assemblies distribute the high thrust and tangential flight loadings from the engine casings to the airframe.

The mid-frame assembly is located between the compressor and turbine sections and accommodates an annular combustion chamber in which the main fuel supply is injected and burned by means of 32 walking stick vaporizer type burners.

The afterburner assembly, being an integral part of the engine, is mounted aft of the rear frame assembly. It comprises a casing which houses flame stabilizing equipment and fuel spray rings. A variable area final nozzle is attached to the rear of the afterburner assembly.

Internal gearing located in the hub of the front frame assembly, provides for power take-off points to operate the various accessories necessary to sustain engine operation and meet airframe service requirements. All accessories are mounted around the bottom of the engine forward of the mid-frame. These are enclosed in a sheet metal shroud. Lubrication of internal bearings and gearing, and cooling of the heat producing areas of the engine are provided by self-contained oil and air systems. Protection against the formation of ice at the engine intake under certain operating conditions is by means of a hot air anti-icing system.

The engine has five mounting points. The front mount located on the top of the front frame transmits the net axial thrust load and side loads, while a side mount takes vertical loads only. Two mounts, one on each side of the rear frame, take vertical loads and a rear mount at the top of the rear frame takes only side loads.

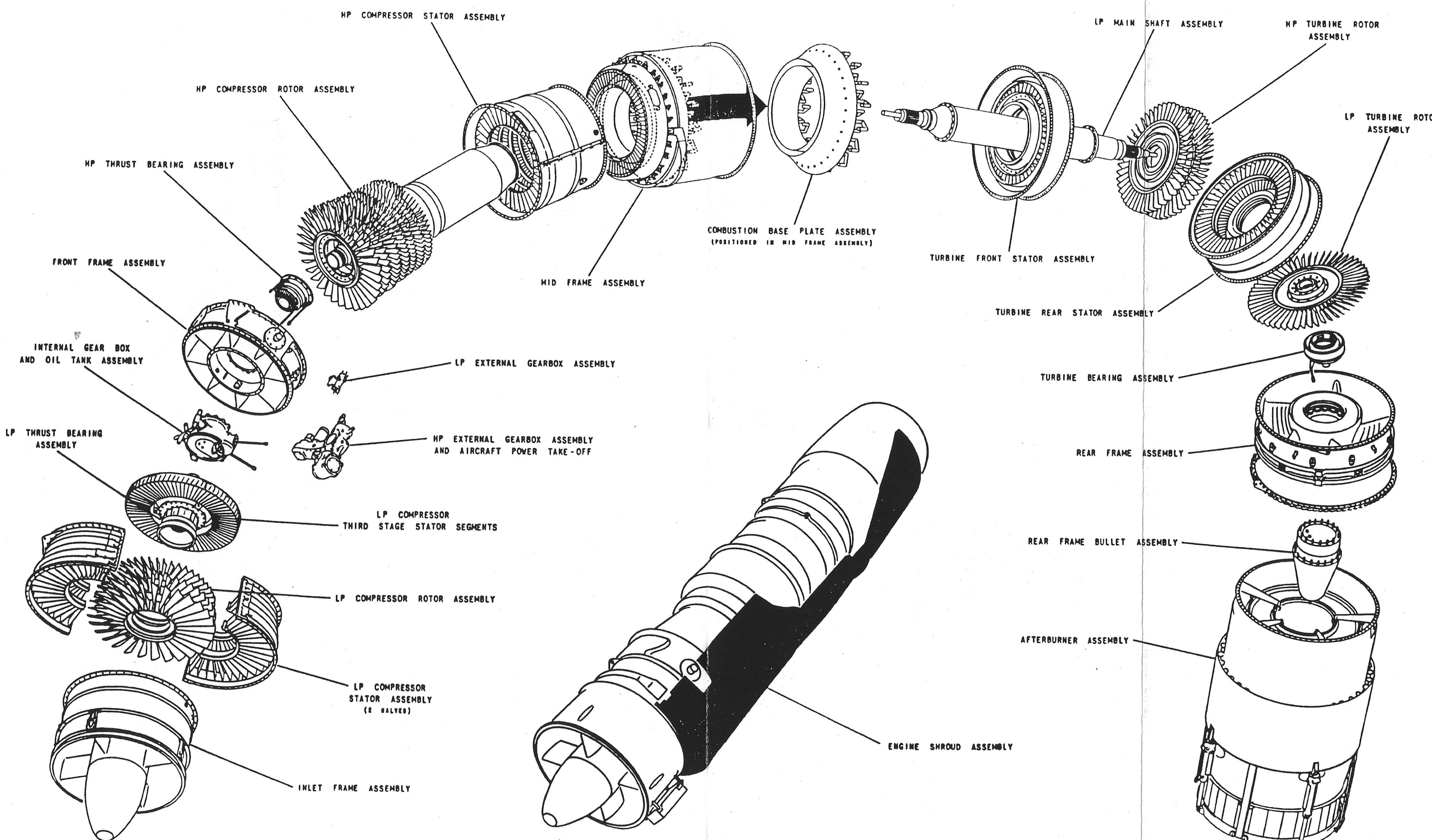
OPERATION

The Iroquois operating cycle is continuous, whereby a steady supply of air is taken in, compressed, heated and expanded, then exhausted.

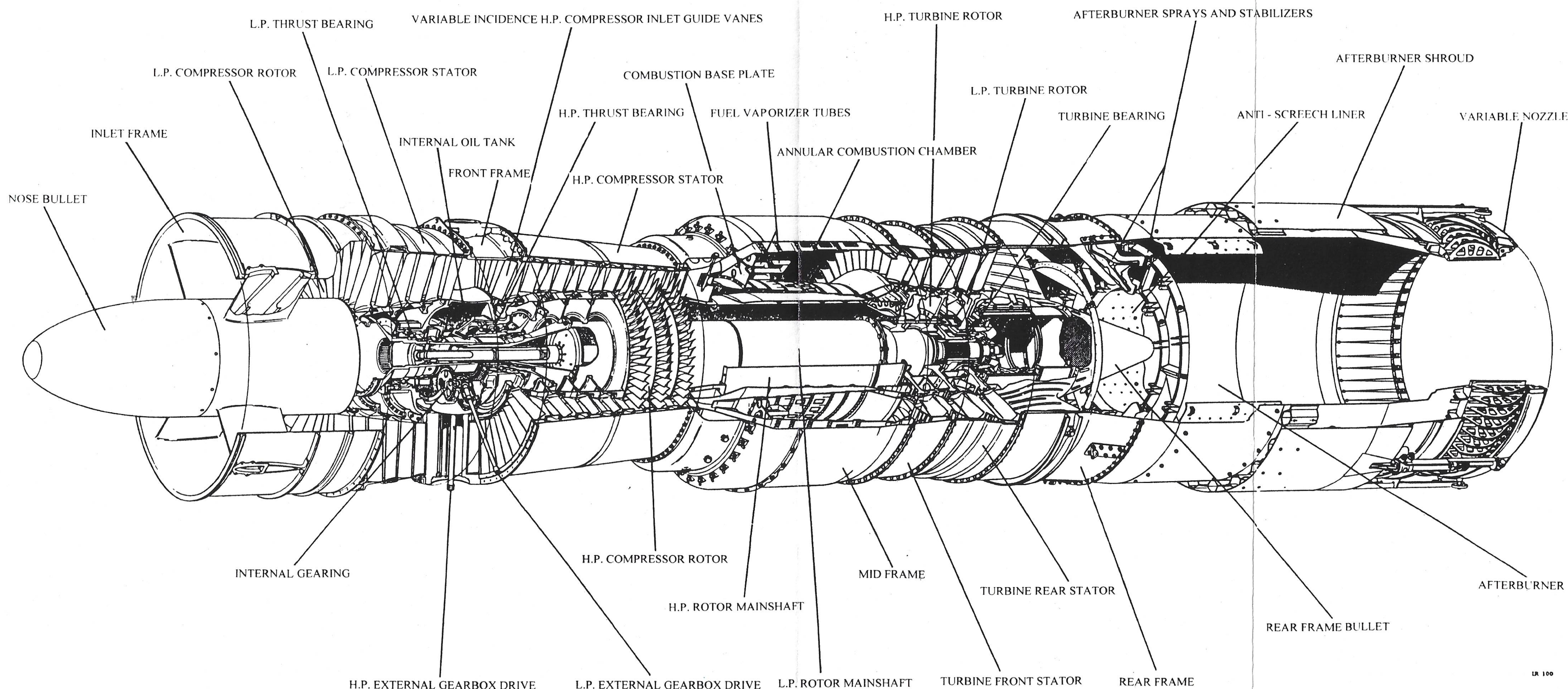
By referring to the gas flow diagram, it will be seen that the air at ambient temperature and pressure is drawn through the inlet frame into the LP compressor where it is progressively compressed at each stage until heated to the temperature indicated on the diagram. The air flow then passes through the annulus provided by the front frame. Struts in the annulus straighten and direct the flow into the HP compressor where further compression takes place until at the compressor outlet, the airflow is heated as indicated. The compressors, being mechanically independent of each other, rotate at speeds up to a maximum of 6000 rpm for the LP rotor and 8150 rpm for the HP rotor. Careful aerodynamic matching of the compressors provides an overall compression ratio of about 8 to 1 in ten stages of compression. To obtain similar qualities in a single compressor would require a longer rotor with a greater number of stages. Variable incidence fourth stage stator blades improve the aerodynamic qualities and efficiency of the compressor over a wider range of operating conditions.

The compressor delivery air is forced into the annular combustion chamber where a proportion of the compressed air is diffused and mixed with vaporized fuel. This mixture burns continuously at extremely high temperatures, and expands the main volume of air considerably. The combustion cycle is essentially one of constant pressure, therefore the air flow leaves the combustion chamber at extremely high temperatures and increased velocity.

In the turbine section, a portion of the total energy instilled in the gases is converted into mechanical work to drive the compressors. Three stages of stator blades increase the velocity of, and direct the gases onto impulse-reaction type

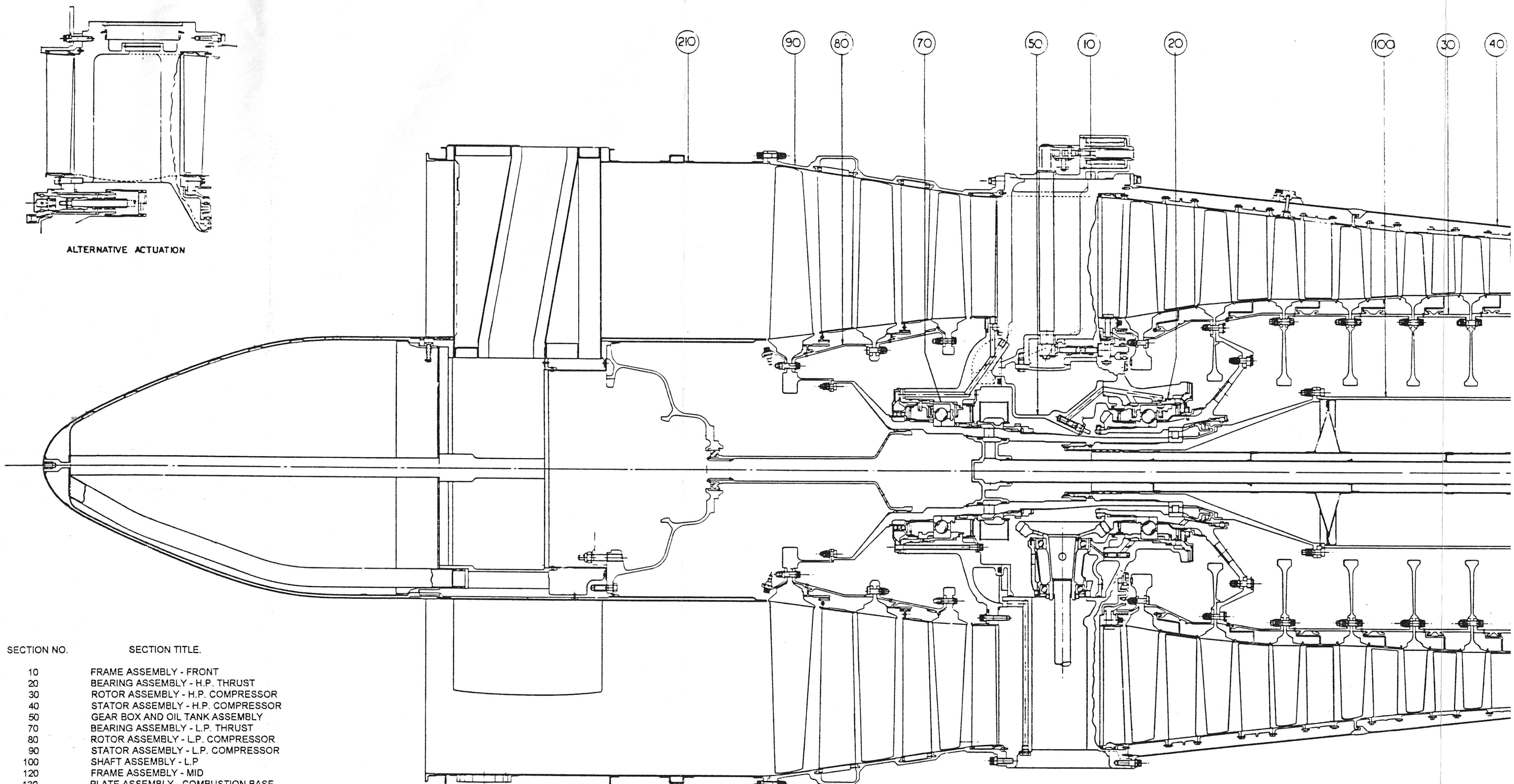


EXPLODED VIEW OF ENGINE

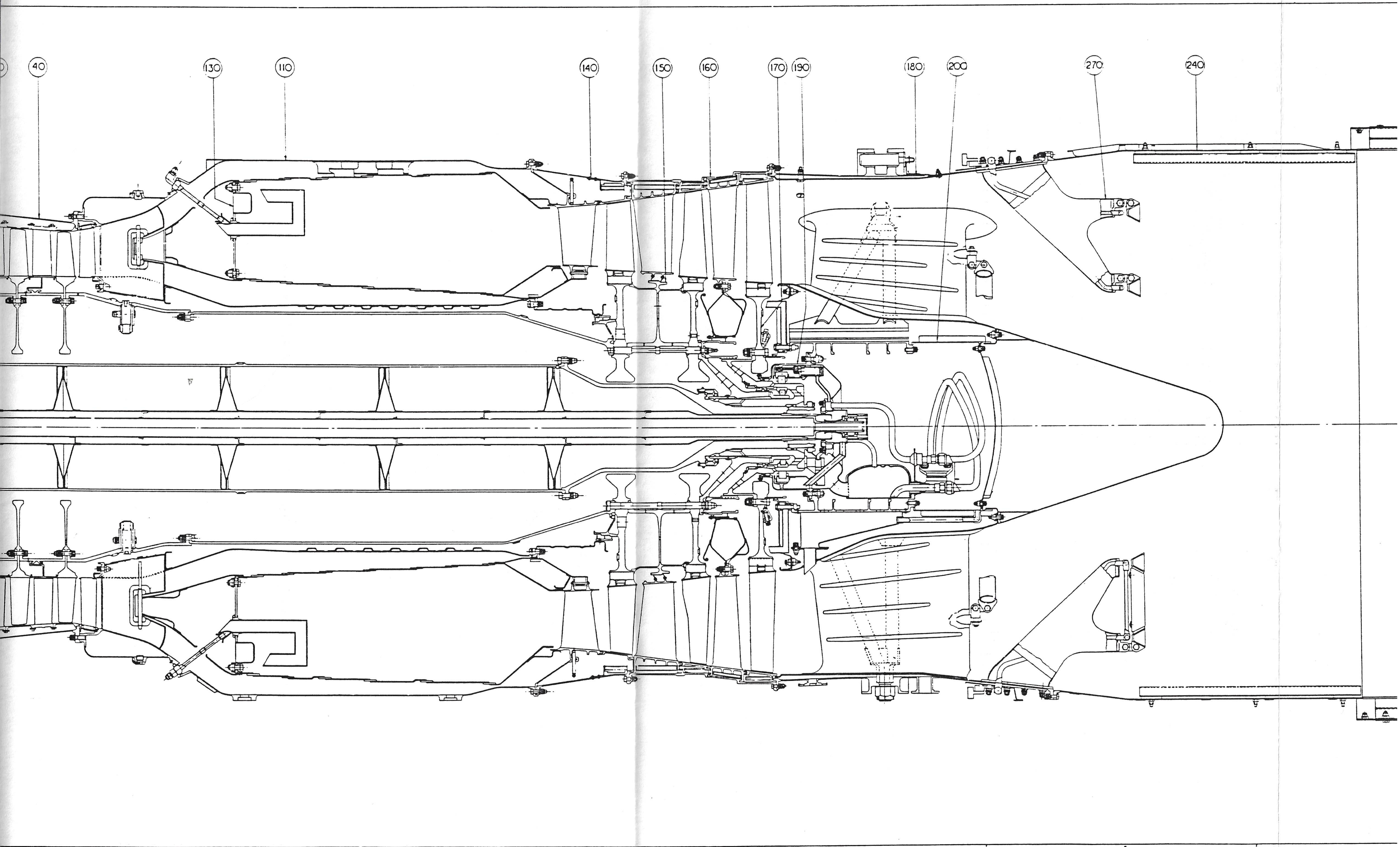


SECTIONED VIEW THROUGH ASSEMBLED ENGINE

ORENDA



SECTION NO.	SECTION TITLE.
10	FRAME ASSEMBLY - FRONT
20	BEARING ASSEMBLY - H.P. THRUST
30	ROTOR ASSEMBLY - H.P. COMPRESSOR
40	STATOR ASSEMBLY - H.P. COMPRESSOR
50	GEAR BOX AND OIL TANK ASSEMBLY
70	BEARING ASSEMBLY - L.P. THRUST
80	ROTOR ASSEMBLY - L.P. COMPRESSOR
90	STATOR ASSEMBLY - L.P. COMPRESSOR
100	SHAFT ASSEMBLY - L.P
120	FRAME ASSEMBLY - MID
130	PLATE ASSEMBLY - COMBUSTION BASE
140	STATOR ASSEMBLY - TURBINE FRONT
150	ROTOR ASSEMBLY - H.P. TURBINE
160	STATOR ASSEMBLY - TURBINE REAR
170	ROTOR ASSEMBLY - L.P. TURBINE
180	FRAME ASSEMBLY - REAR
190	BEARING ASSEMBLY - TURBINE
200	BULLET ASSEMBLY - TURBINE
210	FRAME ASSEMBLY - INLET
240	AFTERBURNER ASSEMBLY
270	AFTERBURNER SPRAY AND STABILIZER GROUP



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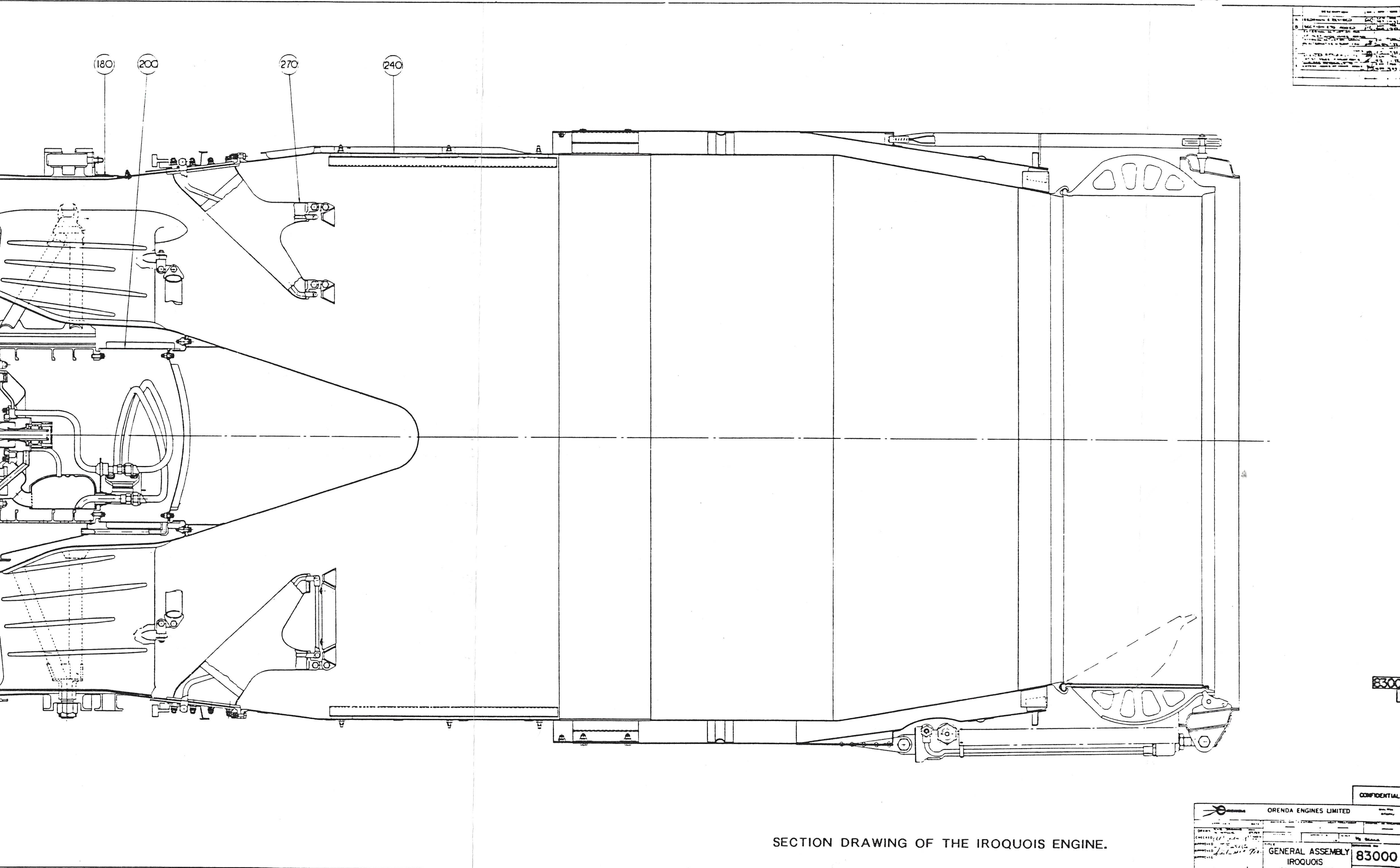
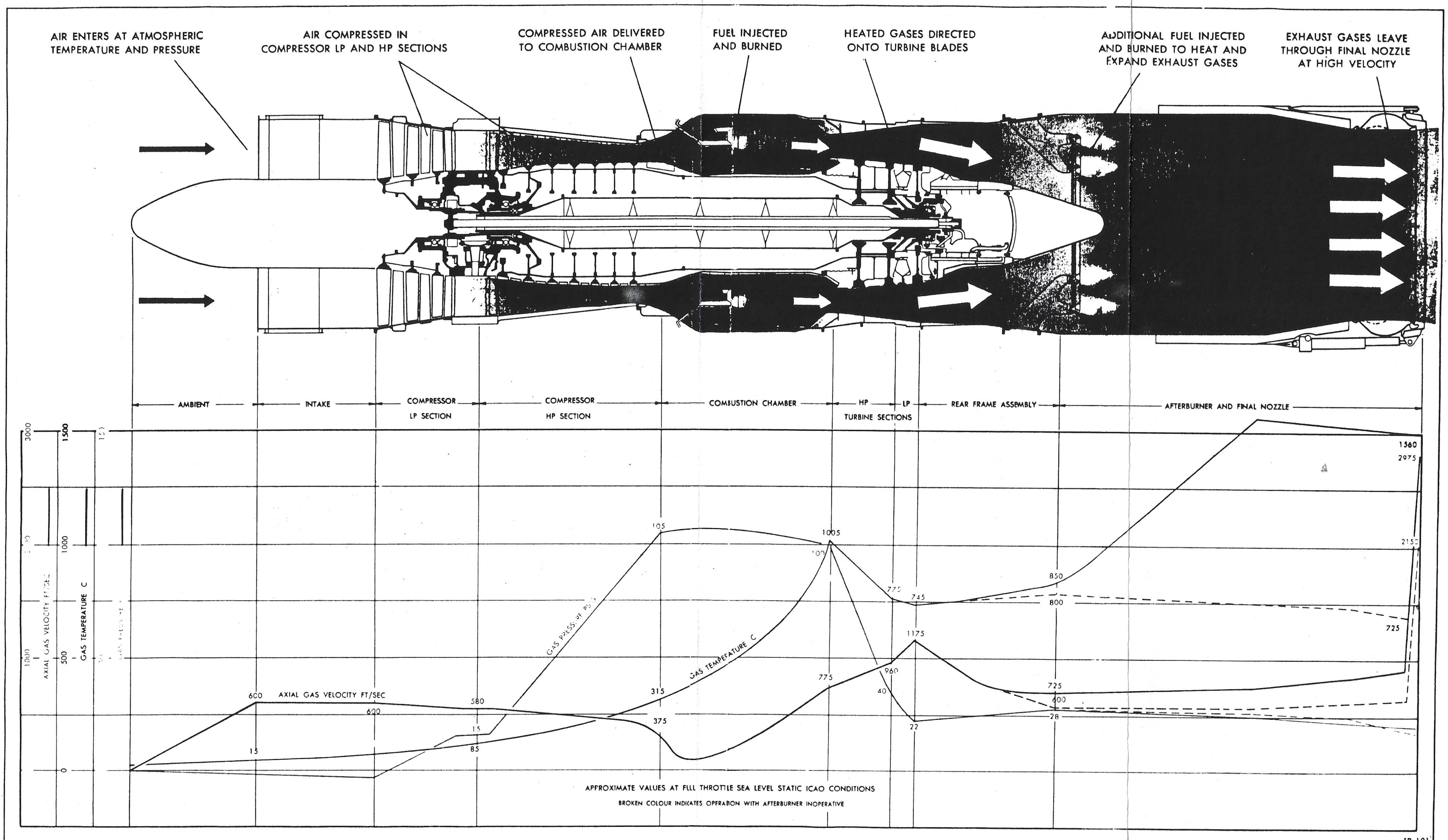


SECTION DRAWING OF THE IROQUOIS ENGINE.



GAS FLOW DIAGRAM

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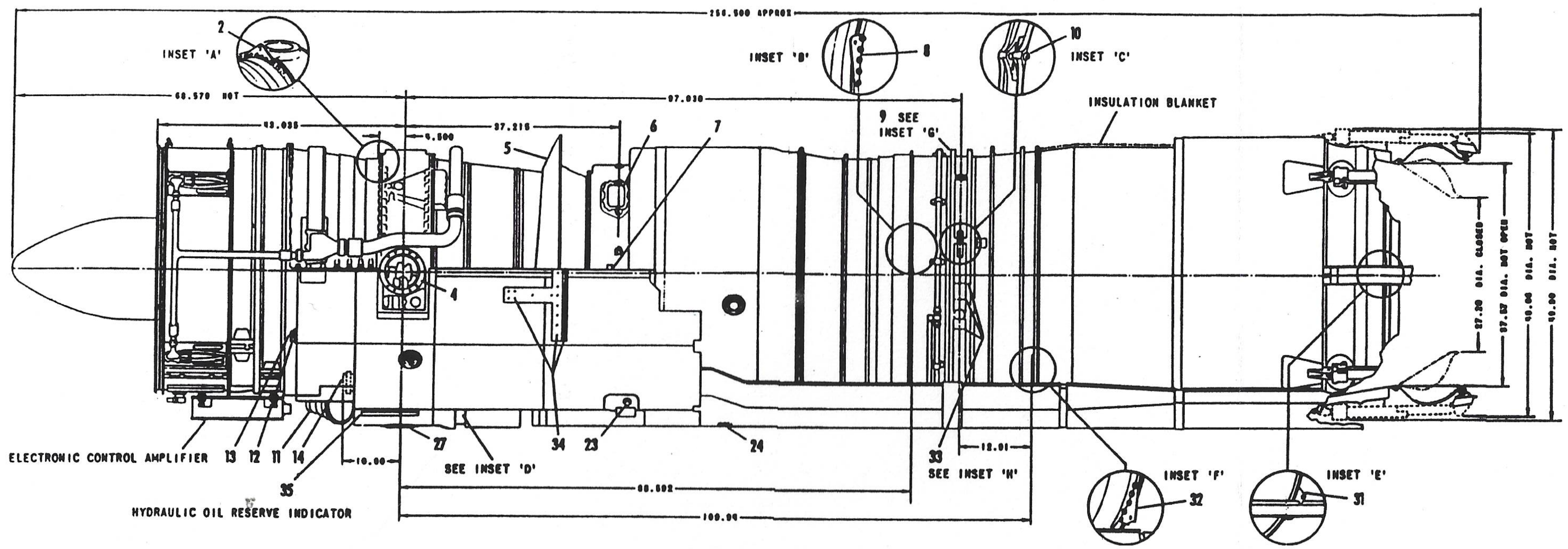
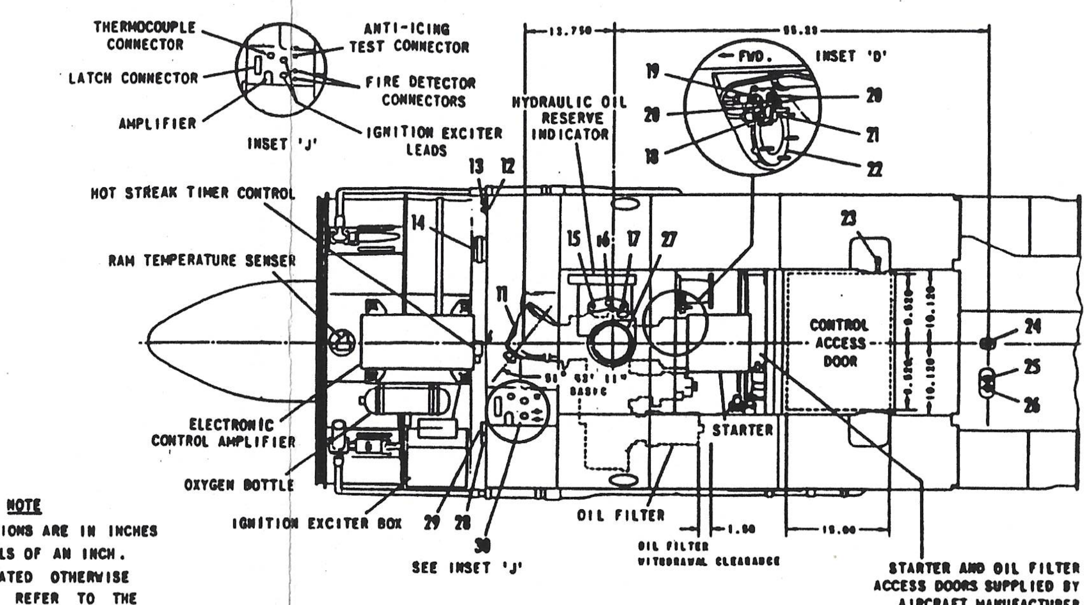


LEFT-HAND SIDE VIEW

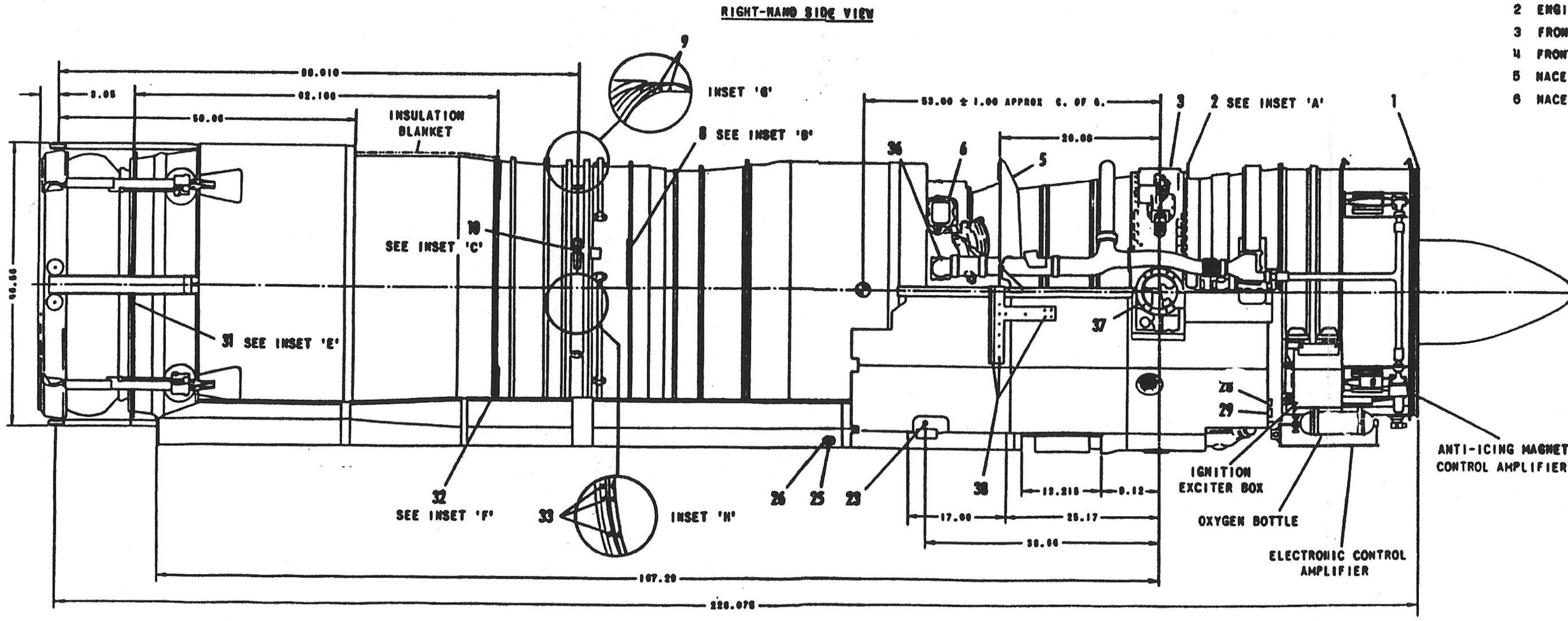


NOTE

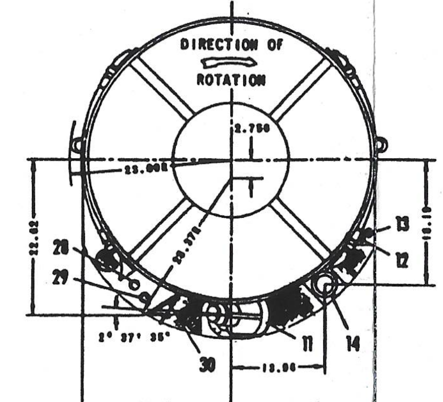
ALL DIMENSIONS ARE IN INCHES AND DECIMALS OF AN INCH. UNLESS STATED OTHERWISE DIMENSIONS REFER TO THE COLD CONDITION AND ARE FOR NOMINAL VALUES ONLY.

BOTTOM VIEW

RIGHT-HAND SIDE VIEW



1 AIR DUCT SEAL ADAPTOR
2 ENGINE FRONT LIFTING BRACKET
3 FRONT MOUNTING TRUNNION PAD (TOP)
4 FRONT MOUNTING TRUNNION PAD (LH SIDE)
5 NACELLE AIR RESTRICTOR
6 NACELLE AIR TAKE-OFF CONNECTION
7 CABIN AIR BLEED VALVE ELECTRICAL CONNECTOR
8 ENGINE REAR LIFTING BRACKETS
9 ENGINE ALIGNMENT CENTRE FITTING ATTACHMENT POINTS
10 REAR MOUNTING PINS
11 AIRCRAFT POWER TAKE-OFF (MAY BE ROTATED TO SUIT INSTALLATION)
12 CONSTANT SPEED UNIT OIL SUPPLY CONNECTION (NOW DELETED)
13 CONSTANT SPEED UNIT OIL RETURN CONNECTION (NOW DELETED)
14 FUEL INLET CONNECTION
15 OIL TANK OVERFLOW DRAIN CONNECTION
16 OIL TANK REFILL COUPLING CONNECTION
17 HYDRAULIC OIL COUPLING CONNECTION
18 HYDRAULIC RESERVOIR BLEED VALVE
19 HYDRAULIC ACCUMULATOR NITROGEN CHARGING VALVE
20 FUEL PUMP AIR BLEED VALVES
21 OIL TANK DRAIN COCK
22 STARTER MOUNTING FLANGE
23 AIRCRAFT POWER CONTROL LINKAGE CONNECTION (MAY BE FITTED TO EITHER SIDE OF THE ENGINE FIREWALL ASSEMBLY)
24 COMBUSTION DRAIN CONNECTION
25 COMBINED DRAINS CONNECTION
26 FIRE EXTINGUISHER CONNECTION
27 GROUND HANDLING JACKING PAD
28 P_0 AIRCRAFT QUICK DISCONNECT
29 P_7 AIRCRAFT QUICK DISCONNECT
30 ELECTRICAL CONNECTIONS
31 AFTERBURNER LIFTING BRACKETS
32 GROUND HANDLING JACKING BRACKETS
33 ENGINE HANDLING FACILITIES
34 AIR RESTRICTOR FLAP INSTALLATION POINT (LH SIDE)
35 HYDRAULIC OIL RESERVE INDICATOR
36 ANTI-ICING AIR TAKE-OFF CONNECTION
37 FRONT MOUNTING TRUNNION PAD (RH SIDE)
38 AIR RESTRICTOR FLAP INSTALLATION POINT (RH SIDE)

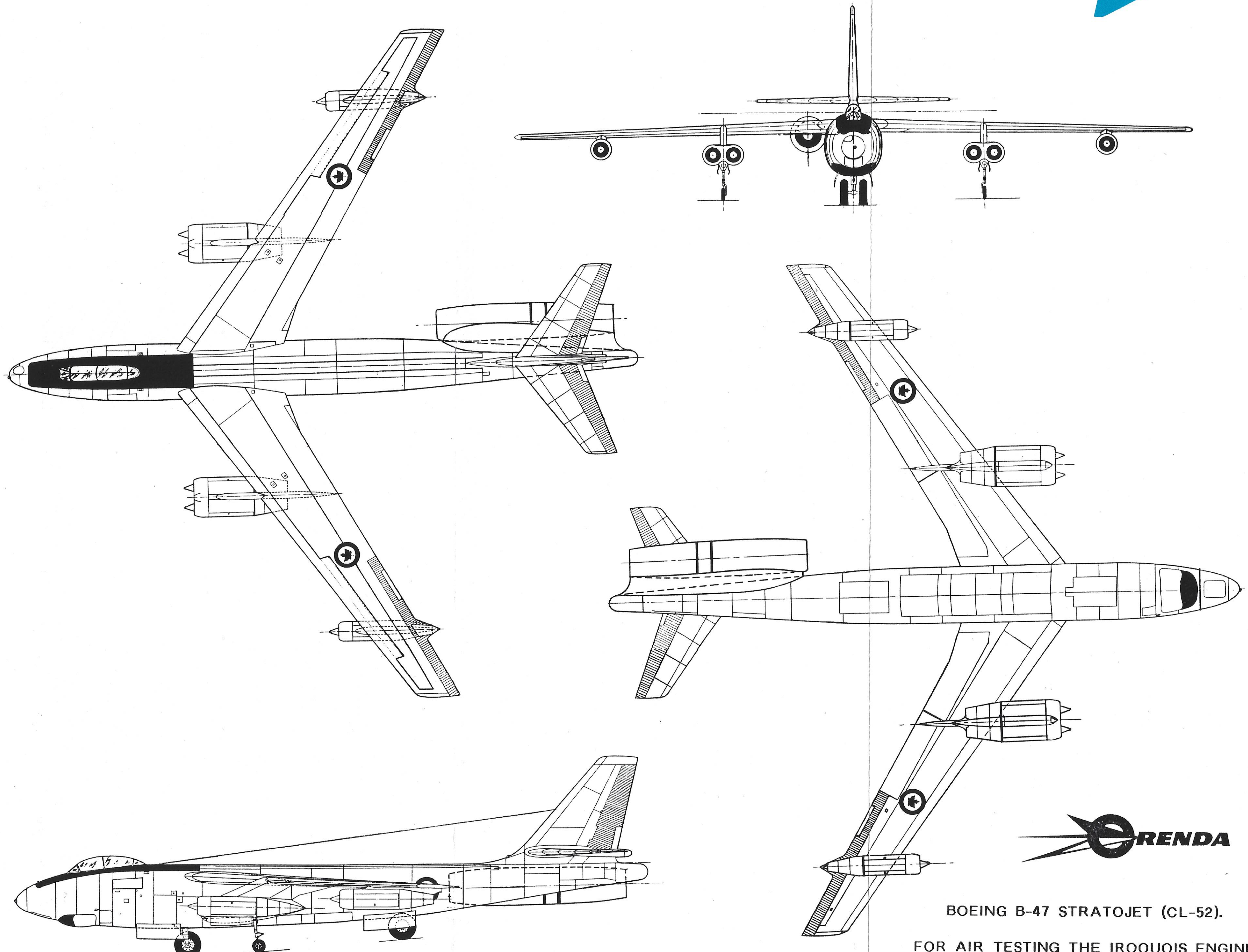


NOTE

ELECTRONIC CONTROL AMPLIFIER, ANTI-ICING MAGNETIC CONTROL AMPLIFIER, OXYGEN BOTTLE AND IGNITION EXCITER BOX OMITTED FROM THIS VIEW FOR CLARITY

FRONT VIEW

INSTALLATION DETAILS



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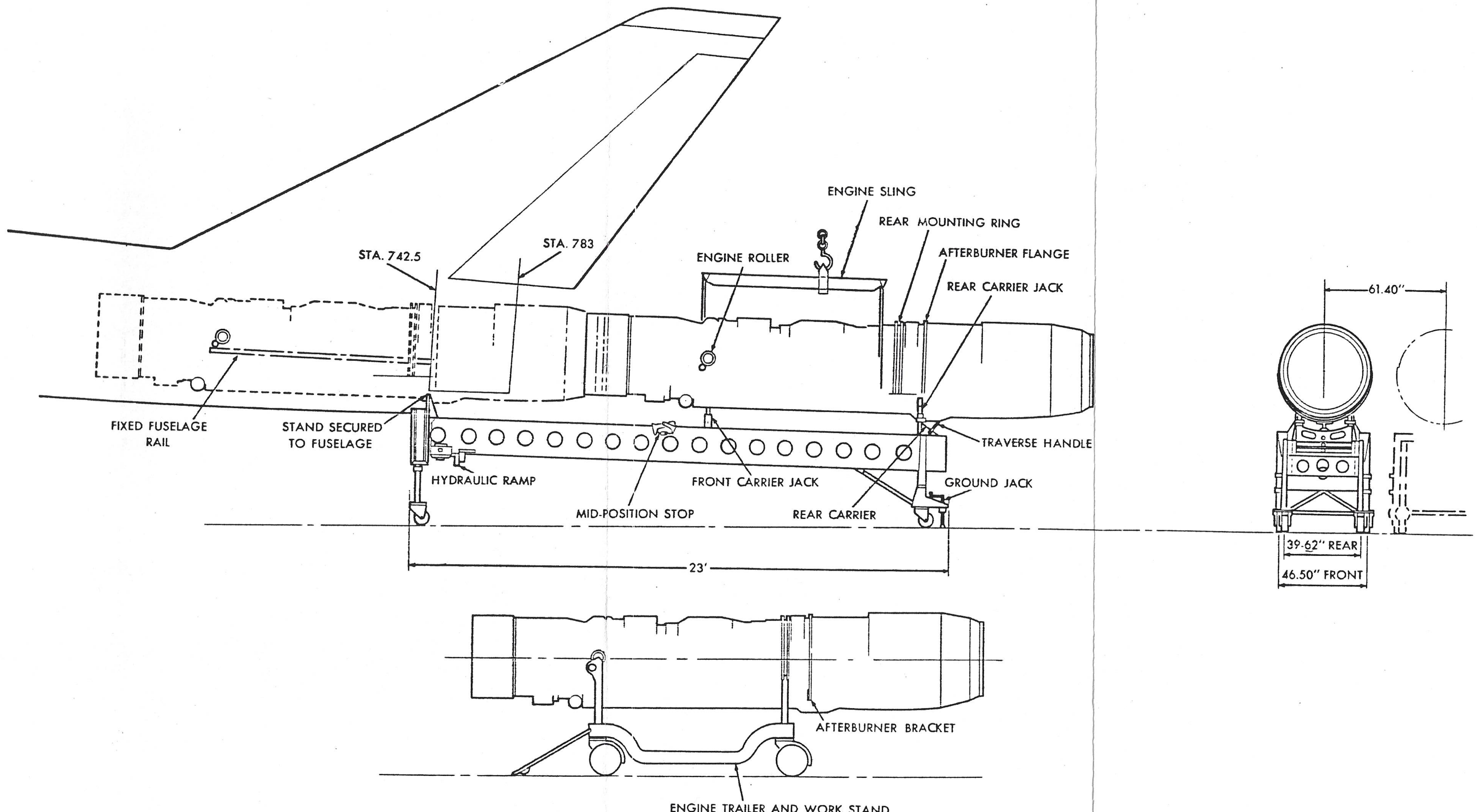
BOEING B-47 STRATOJET (CL-52).

FOR AIR TESTING THE IROQUOIS ENGINE



IROQUOIS HANDLING EQUIPMENT - ARROW 2

blades, which in turn react to the gas loading by causing rotation of the turbine rotors and hence the compressors.

From the turbine, the gas flow passes through the rear frame assembly to the afterburner where additional fuel is injected and burned in a proportion of the remaining unburnt air in the exhaust stream to further accelerate and increase the momentum of the mass air flow. From the afterburner, the gas stream emerges to atmosphere through a variable area final nozzle. The area of the nozzle determines the temperature and hence the velocity of the exhaust gas stream expelled from the engine.

For a given set of operating conditions, the thrust of the engine is proportional to engine speed, which in turn is governed by the quantity of fuel burned and the temperature to which the air flow is heated. Engine speed is selected by a manually operated power control lever in the pilot's cockpit. The engine and afterburner fuel flows and the area of the final nozzle are automatically controlled to provide the desired percentage of the available thrust as determined by the pilot's speed setting.

DESCRIPTION OF ENGINE AND COMPONENTS

GENERAL

This part of the Iroquois Advance Data sheets deals with a physical description of the engine. Although the basic design of the engine was completed at the time these sheets were being prepared, many changes of a minor nature will take place before the engine design is sealed. Preparing these sheets under such conditions means that much detail will have to be omitted and that where detail has been included, it could quite possibly be changed before the production configuration is reached. If the reader keeps this in mind when using these sheets, he will gain a general idea of the engine while his impression of detail will remain flexible, thus making things easier when the final configuration arrives.

In this section, the engine general assembly is divided into major assemblies, these being shown in the order of engine assembly. For the purpose of clarity, the combustion support frame is shown detached in solid outline and in ghost outline in its assembled position within the mid frame assembly. Accessory components have been omitted, these, and the mounting locations of the fuel system and oil system major components will be shown in a later issue.

Detailed descriptions covering individual major assemblies and their sub-assemblies will be issued under separate headings in subsequent advance data sheets. Engine systems, engine mounting and installation details, and the after-burner assembly are described in individual sections.

INLET FRAME ASSEMBLY

The inlet frame assembly is a fabricated structure consisting of a cylindrical outer casing, four aerofoil struts, a cylindrical inner casing, and a nose bullet. The main function of this assembly is to house and support an alternator/constant speed unit combination which is mounted within the inner casing. The drive for these units is provided by, suitable shafting extending forward from the LP compressor rotor.

OUTER CASING

The outer casing is fabricated from aluminum sheet with a machined aluminum flange ring at the rear, which serves as the mounting attachment to the forward flange of the LP compressor stator casing, Two folding lifting eyes are provided at the top of the casing, and at the bottom provision is made for the inclusion of the ram temperature sensing probe. A dual pressure probe is fitted on the outer casing, just below No. 2 strut for obtaining the P1 total pressure and the P1 reverse pressure; these probes are connected into the fuel system.

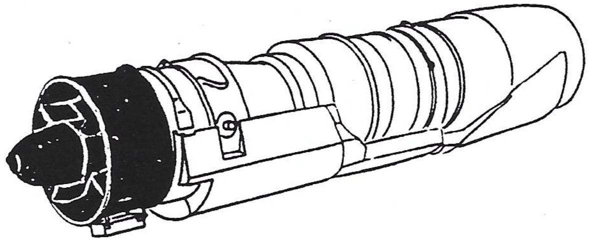
INNER CASING

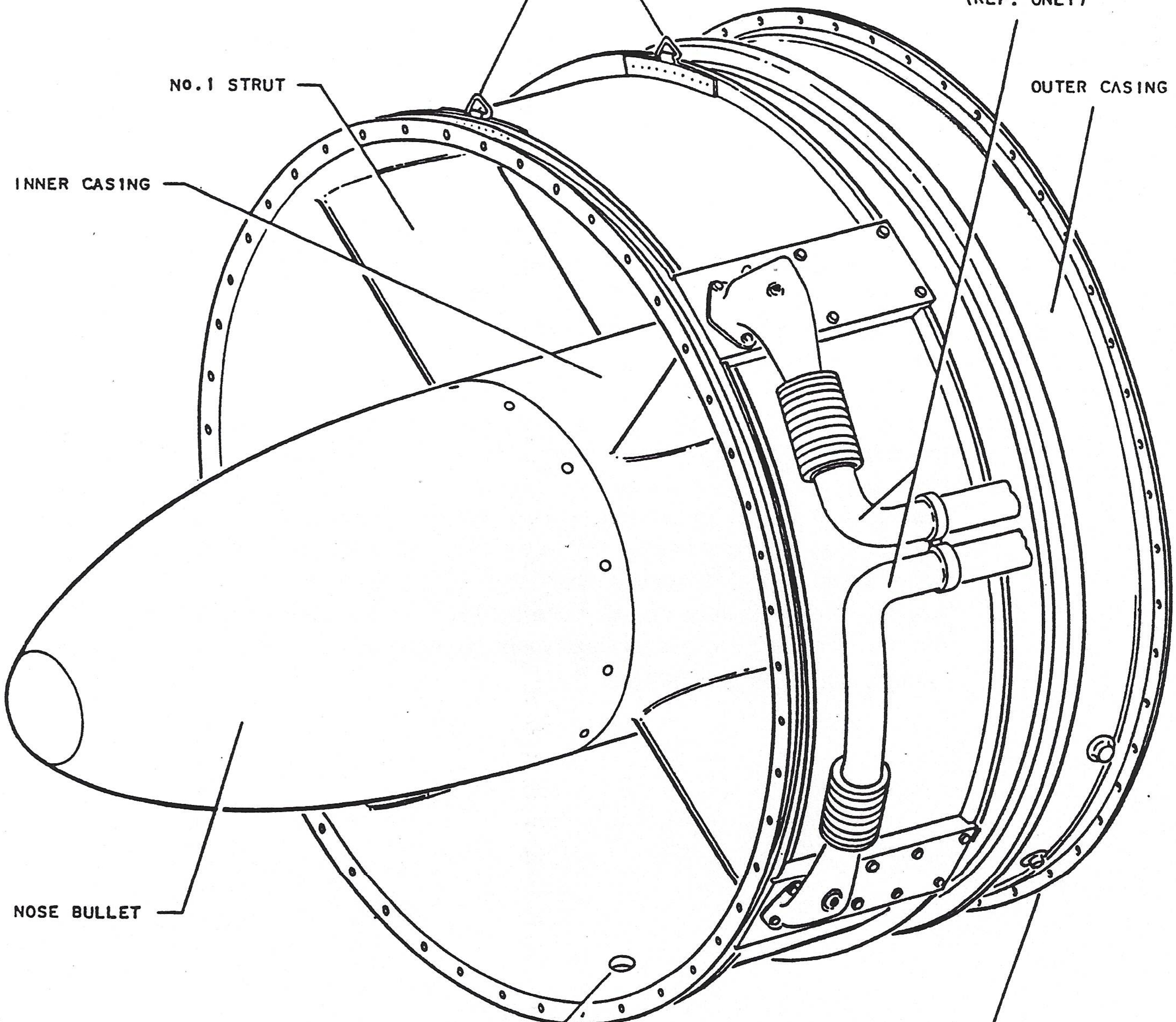
A magnesium casting shrouded by an aluminum sheet casing forms the inner casing, four radial, hollow, equi-spaced struts locate the inner casing in the centre of the outer casing. The struts are numbered anti-clockwise, No.1 strut being at approximately the 10 o'clock position when viewed from the front of the engine. A temperature sensitive thermistor is fitted to the outer skin of the inner casing between No.1 and 4 struts, to sense icing conditions at the engine intake.

NOSE BULLET AND STRUTS.

The nose bullet, fitted to the front of the inner casing, the four struts; and the inner casing are al1 double skinned, thus providing passage for a supply of compressor delivery air for de-icing purposes. The air is piped externally to the outer ends of No. 1 and 4 struts which are interconnected with No: 2 and 3 struts respectively by external manifolds. The warm air passes into the struts, follows a circular path around the inside of the outer skin. and enters four passages in the inner casing. From here it flows forward, spills under the outer skin of the bullet, and then flows in a rearward direction under .the outer akin of the inner casing to join the air intake stream upstream of the LP compressor first stage rotor blades.

The hollow struts also carry electrical and thermocouple leads, the oil supply, return, and vent pipes for the aircraft constant speed unit, together with other aircraft services.





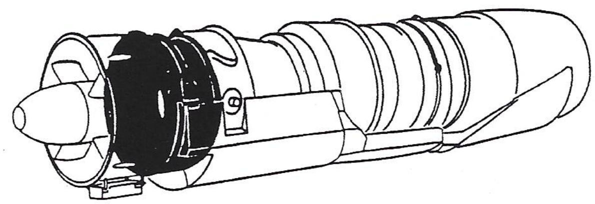
INLET FRAMEASSEMBLY

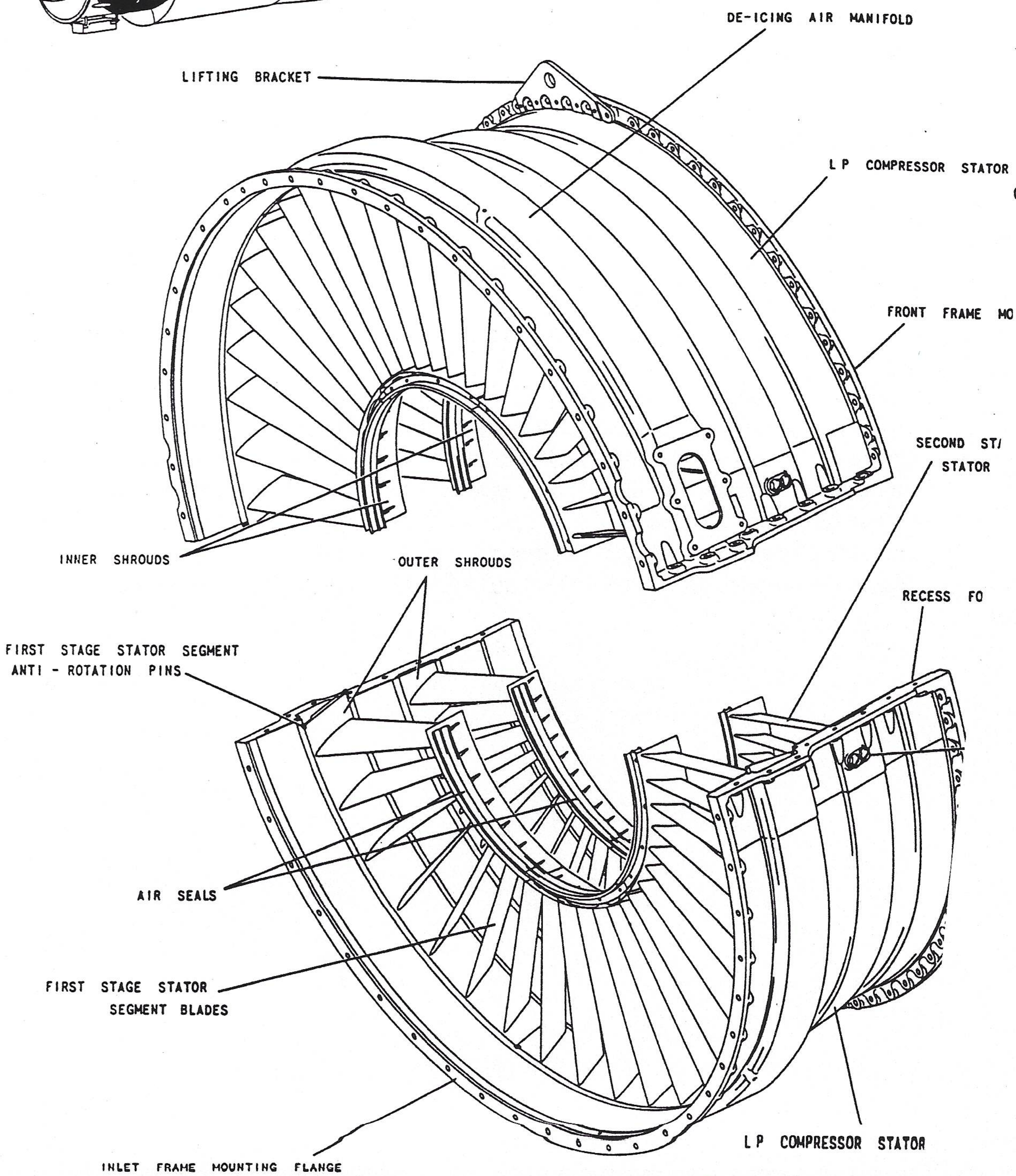
LOW PRESSURE COMPRESSOR STATOR ASSEMBLY

The LP compressor stator assembly is a horizontally split, magnesium casing containing three stages of stator blades. Recesses and T slots are machined around the inside diameter, the front recess being designed to provide a manifold for the distribution of compressor delivery air for blade de-icing purposes. A coating of friable material is applied to the casing inner surfaces opposite the tips of the compressor rotor blades to minimize damage which may occur should a rotor blade tip rub develop. A machined flange at each end of the casing serves as the mounting attachment to the inlet frame and front frame respectively. Nuts, and bolts with externally splined heads, are used at the split line to secure the two halves of the casing. A lifting bracket is centrally located on top of the casing at the front face of the rear flange. The bracket is secured with the casing joint bolts and by shear pins interposed between the bolts.

The stator blades are manufactured from stainless steel sheet, and have stainless steel corrugated stiffeners through each blade core. Inner and outer shrouds of stainless steel are brazed to the blades to form stator segments. Each stage has six segments, the first, second and third stage segments having seven, ten and twelve blades respectively.

The first and second stage stator segments are located in the T slots and are prevented from rotating by anti-rotational pins and lock pins respectively. The third stage segments are mounted on the LP thrust bearing housing outer flange, and are retained and locked against the forward outer and inner flange faces of the front frame by pins and bolts when the LP thrust bearing assembly is installed on the front frame. When the front frame is attached to the stator casing the segments fit into the rear recess in the stator casing. Stainless steel air seals are riveted to the inner shrouds of the first and second stage stator segments and mate with seal sleeves on the LP compressor rotor spacers.





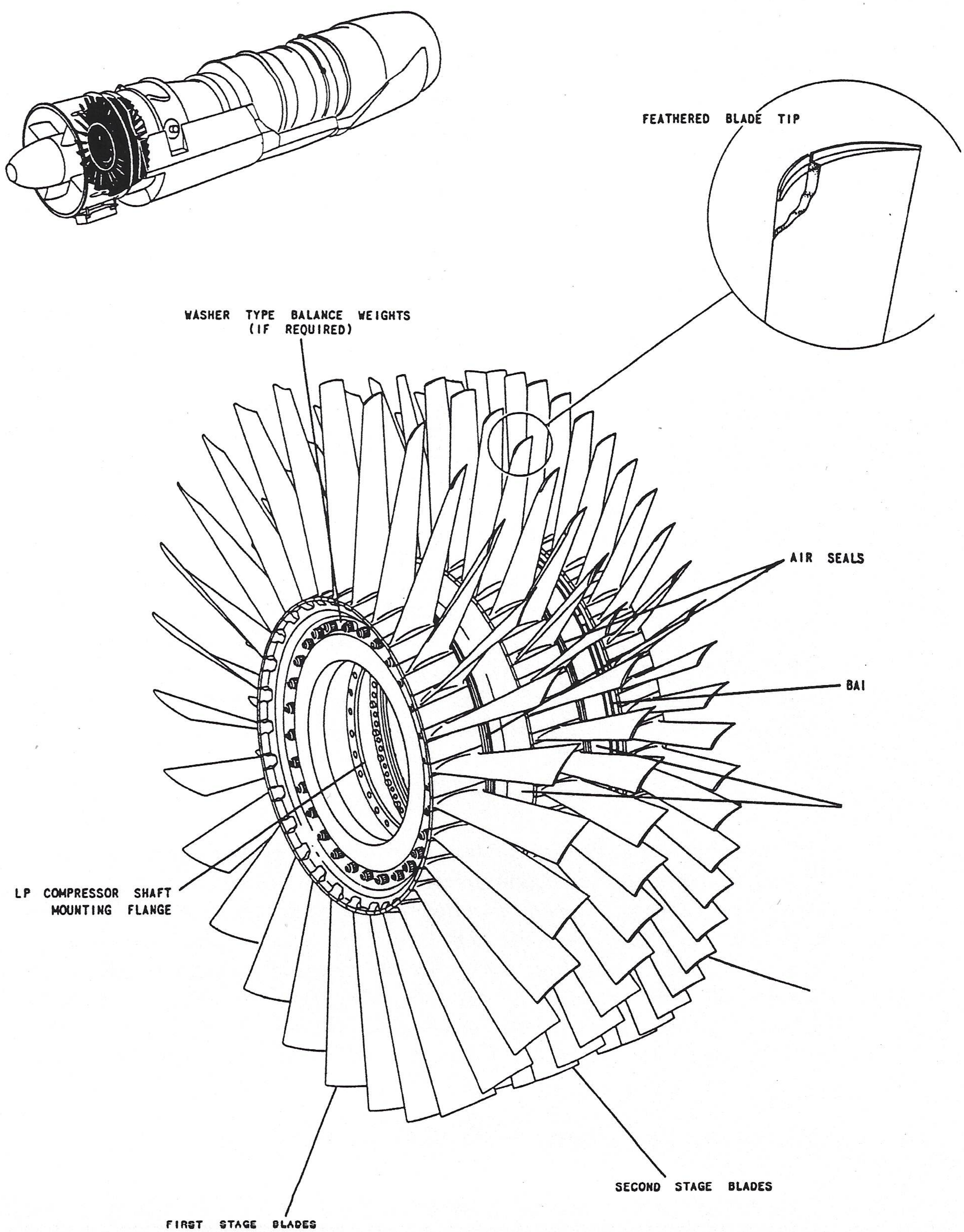
LOW PRESSURE COMPRESSOR STATOR ASSEMBLY

LOW PRESSURE COMPRESSOR ROTOR ASSEMBLY

The low pressure compressor rotor is composed of three stages of blades, three discs, two spacers, and two peripheral seals, all of which are machined from titanium. The driving flange of the first stage disc is remotely positioned to the rear of the disc hub, the cylinder between the driving flange and the disc hub absorbing the differential strains between the LP main shaft and the first stage disc. The remaining stages are cantilevered in a rearward direction, with the spacer rings bolted directly to the discs to form a continuous drum.

A fourteen groove, labyrinth type, peripheral seal is riveted in position in a machined groove in the spacer rings immediately behind the first and second stage blade roots. The mating parts of the seals are fitted to the inner shrouds of the compressor first and second stage stators respectively. Immediately in front of the third stage rotor blades, a machined slot is provided in the spacer ring for the addition of balance weights which may be required during dynamic balancing. At the forward face of the first stage disc, additional weights in the form of strip washers may be added under the disc securing nuts to attain the correct balance.

The rotor blades are machined from forgings, all three stages having feathered edges on their outer extremities to reduce the possibility of damage to the stator casing if a tip rub should develop due to unforeseen mechanical and/or atmospheric conditions. The first and third stage blades are secured to the disc by a two branch fir tree root while the second stage employs a cylindrical seat dovetail fixing. On the rear face of the blades a positive stop is machined into the blade roots to prevent the blades from being knocked loose should a failure occur in a preceding stage.



LOW PRESSURE COMPRESSOR ROTOR ASSEMBLY

LOW PRESSURE THRUST BEARING ASSEMBLY

GENERAL

The LP thrust bearing assembly supports the LP compressor shaft and absorbs the net axial thrust of the LP compressor rotor and LP turbine rotor. The assembly consists of the LP compressor shaft, a bearing housing, a ball thrust bearing, and the LP compressor third stage stator segments.

LP COMPRESSOR SHAFT

The LP compressor shaft is of nickle-plated steel. Internal splines at the front and rear of the shaft provide the drive for the constant speed unit mounted in the inlet frame, and transmit the torque from the LP main shaft to the LP compressor rotor respectively. The shaft is bolted to the driving flange of the LP compressor rotor first stage disc during engine build. A seat and shoulder on the external diameter of the shaft, and located immediately forward of the shaft mid-point, accommodates the LP ball thrust bearing.

BEARING HOUSING

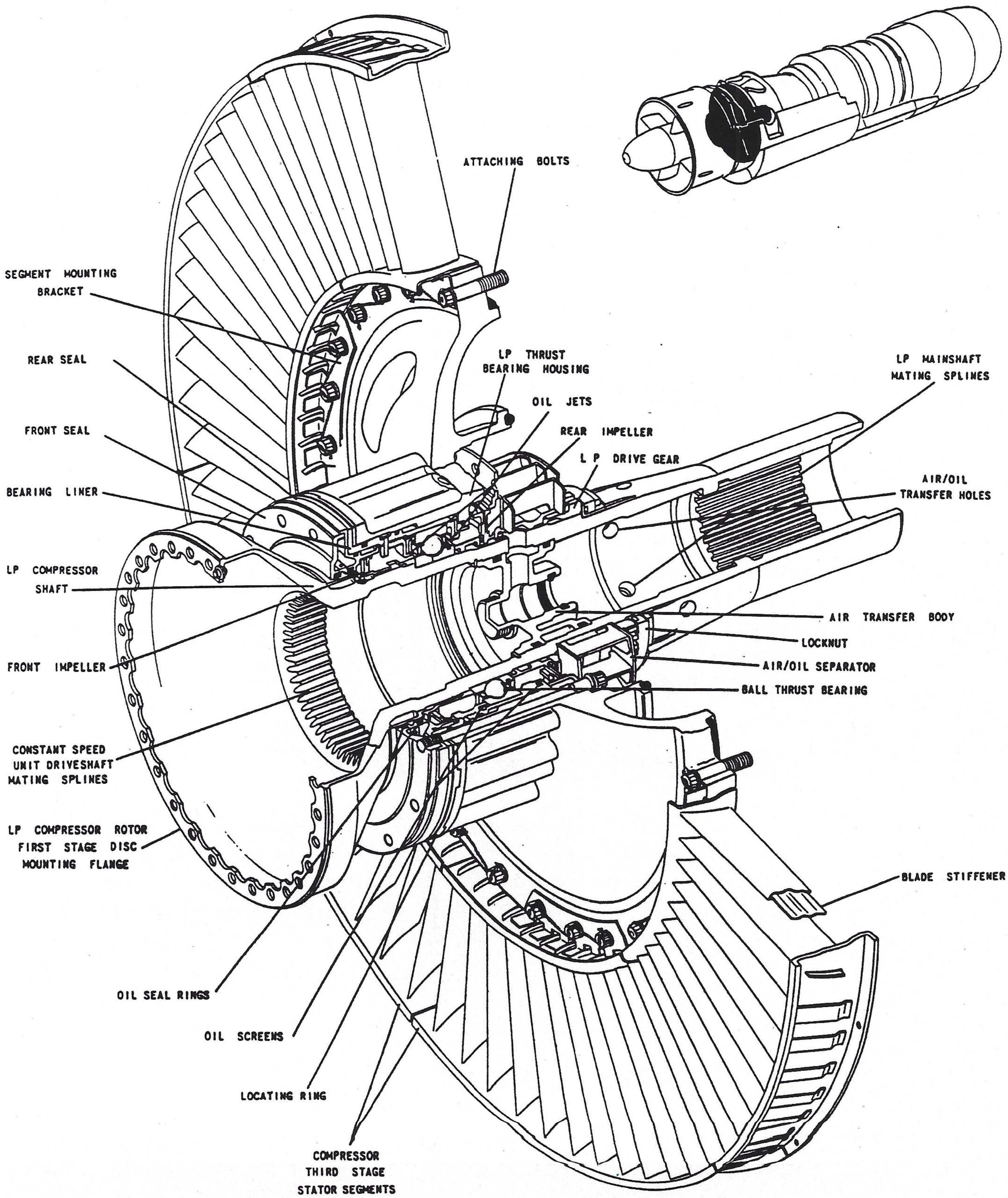
The bearing housing is of magnesium and is mounted on the front inner flange of the front frame. The LP compressor third stage stator segments are mounted on the outer periphery of the housing and are retained by the housing attachment bolts passing through the segment mounting brackets on the inner shrouds. Pins on the front outer flange of the front frame position the outer shrouds of the segments when the bearing assembly ie secured to the front frame.

LP THRUST BEARING AND OIL JETS

The bearing is a single row, ball thrust type with a split inner track. It is installed in a steel liner in the bearing housing and is held in position by a locknut. Three screen protected equidistant oil jete are integrally machined in the bearing locknut and spray lubricating oil on the front face of the bearing. Three similar oil jets, integral with the bearing liner are located at the rear of the bearing. The effect of thermal differential expansion between the housing magnesium casting and the steel bearing liner is counteracted by a locating ring with lugs on its rear face, the ring being located in slots on the front inner face of the bearing housing and secured to the liner, thus centralizing the liner.

AIR TRANSFER BODY

An air transfer body of cast magnesium ie fitted inside the LP compressor shaft



LOW PRESSURE THRUST BEARING ASSEMBLY

at the mid-shaft location. The rear face of the body butts against an internally machined shoulder in the shaft, and is secured at the front by a retaining ring which located in a machined groove in the shaft. The air transfer body seals the forward end of the internal air vent tube and the internal oil return tube, and cored passages in the six webs of the air transfer body permit the transfer of purified seventh stage scavenge air from the front sump to the internal air vent tube. Six equally spaced holes drilled in the LP compressor shaft aft of the air transfer body give access to the front sump for the seventh stage air/oil mixture passing forward from the rear sump through the internal oil return tube.

OIL SEAL

Forward of the bearing a seal sleeve is fitted to the LP compressor shaft, the outer diameter of the sleeve forming a seat for the seal rings. A double floating ring, pressure balance type seal with a spacer between the seal rings, is mounted between the seal front housing and the seal rear cartridge. Compressor seventh stage air is led through drilled passages to pressurize the cavity between the seal rings.

OIL SCAVENGE IMPELLERS

Two radially vaned impellers, one on either side of the bearing, are each secured by a dowel pin, the head of which is located in a slot machined in the LP compressor shaft. The impellers return scavenge oil from the bearing cavity to the internal oil tank via a cored passage in the bearing housing. The front impeller is shrouded by a rearward extended flange on the rear seal cartridge, and the rear impeller rotates within an annulus ring fitted to the rear of the bearing housing and in front of the air/oil separator.

AIR/OIL SEPARATOR AND DRIVE GEAR

The air/oil separator is mounted on the LP compressor shaft immediately aft of the rear impeller and is retained circumferentially by a dowel located in a slot in the shaft. A LP drive gear splined to the shaft butts against the rear inner face of the separator and is retained axially by a locknut and tanged lock washer. The drive gear drives the LP external gearbox gear train.

FRONT FRAME ASSEMBLY

GENERAL

The front frame assembly is the main structural member of the engine and consists basically of a magnesium casing, a single stage of HP compressor variable incidence inlet guide vanes, and hollow struts which are used to carry engine services. The assembly forms the structural connection between the LP and HP compressors and supports the internal gearbox and oil tank assembly, and the LP and HP thrust bearings; the loads of these bearings are transmitted to the airframe through trunnion mounts on the front frame casing.

OUTER CASING

The front frame casing is cast in the form of a cylindrical outer casing joined to an inner casing by eight integrally cast struts. The outer casing is provided with front and rear mounting flanges for attachment of the LP and HP compressor stator casings respectively. A mounting is fitted to a pad machined at the top of the outer casing and transmits the net axial thrust load and tangential side loads from the engine to the airframe. Trunnion mounting pads fitted to the outer ends of the horizontal struts transmit tangential vertical loads only. Dependent upon aircraft installation, either one or both of the trunnion side mounts may be used in conjunction with the thrust mount without imposing any undue strains on the front frame casing. The HP and LP external gearboxes are mounted on machined bosses in the outer casing at the ends of No. 5 and 6 struts respectively.

STRUTS

The eight equi-spaced, hollow struts are aerofoil-shaped and extend radially outwards from the inner casing to the outer casing. Starting with No. 1 strut at the top, the struts are numbered clockwise as viewed from the rear of the engine and carry the following services:

No. 1 Strut - Nil.

No. 2 Strut - Drive from hydraulic actuator to HP compressor variable incidence inlet guide vanes.
- Anti-icing air (If required).

No. 3 Strut - Nil.

No. 4 Strut - Normal flight scavenge oil return and oil tank overflow (Common line),
- Oil tank fill pipe.
- Feed from oil tank to oil pump.

No. 5 Strut - Drive for HP external gearbox.

- Front sump scavenge oil.
- Internal oil tank drain.

No. 6 Strut - Oil feed to bearings.
- Drive for LP external gearbox.

No. 7 Strut - Nil.

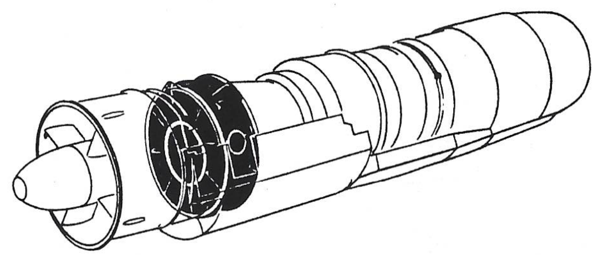
No. 8 Strut - Seventh stage air for pressurizing oil seals and turbine cooling,
-Inter-compressor pressure (P3) tapping for fuel system main metering unit.

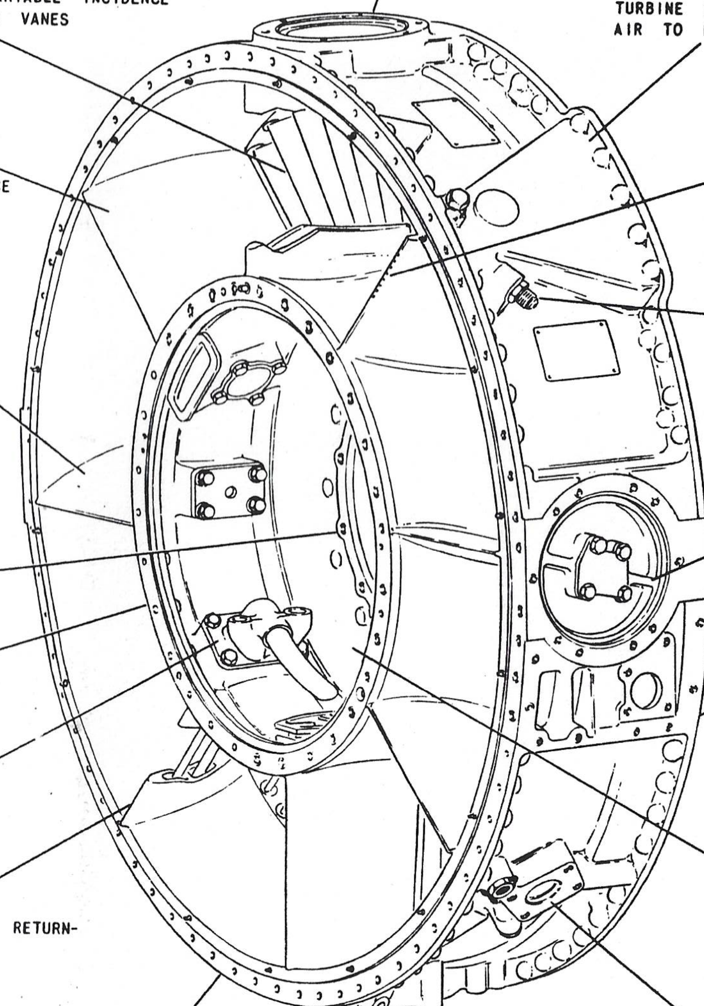
INNER CASING

A machined flange at the front of the cylindrical inner casing provides a mounting for the LP thrust bearing assembly. The HP thrust bearing housing is formed by an inward projecting support flange integrally cast at the rear of the inner casing. A machined flange on the forward face of the bearing housing provides a mounting for the rear of the internal gearbox and oil tank assembly. A cast aluminum cover, embodying three fittings, is attached to the inner end of No. 4 strut. The front fitting is not used, the large centre fitting is the feed to the oil pump, and the rear fitting is the normal flight scavenge oil return. The rear fitting is connected to the internal oil tank by piping; the centre fitting extends downwards to the bottom of the cavity formed by the inner casing.

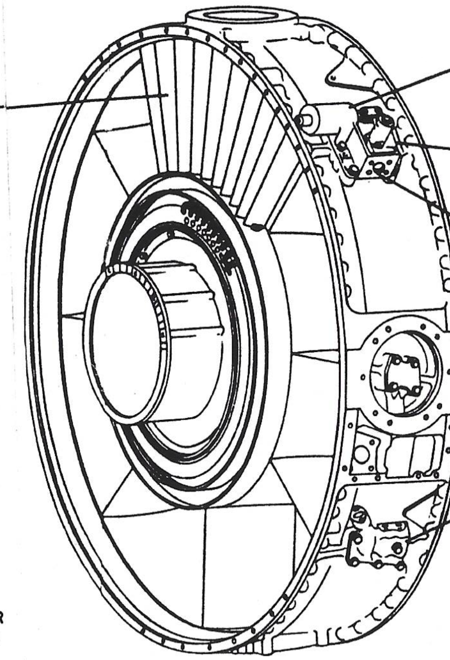
HP COMPRESSOR INLET GUIDE VANES AND ACTUATING MECHANISM

Air flowing from the outlet of the LP compressor passes through the annular duet formed by the inner and outer casings. The outer periphery of the inner casing is slightly concave between the struts to improve the air flow characteristics through the casing. A ring of variable incidence inlet guide vanes at the rear of the duet direct the air into the HP compressor. The outer ends of the hollow stainless steel guide vanes are mounted in steel support bushings located in an outer support ring. This ring is located in a recess in the rear flange of the front frame, outer casing and is retained axially when the HP compressor stator casing is assembled to the front frame. Spindles on the inner ends of the vanes locate in an inner support ring which is bolted to the rear face of the inner casing. The bolts retaining the inner support ring also carry a four groove peripheral air seal which mates with the seal ring on the front face of the HP compressor rotor. A small lever, pinned to the inner end of each vane spindle, is located in a bronze bushing carried in a rotatable unison ring. The steel unison ring, which carries sixty-four lever bushings, is supported by twenty caged roller bearings that are held in position by a bearing retainer. The unison ring, and hence the guide vanes, are rotated by a hydraulic actuator which is externally mounted on the front frame No. 2 strut cover plate. Linear movement of the actuator push rod is transformed, through a link and crank, into rotary movement of an

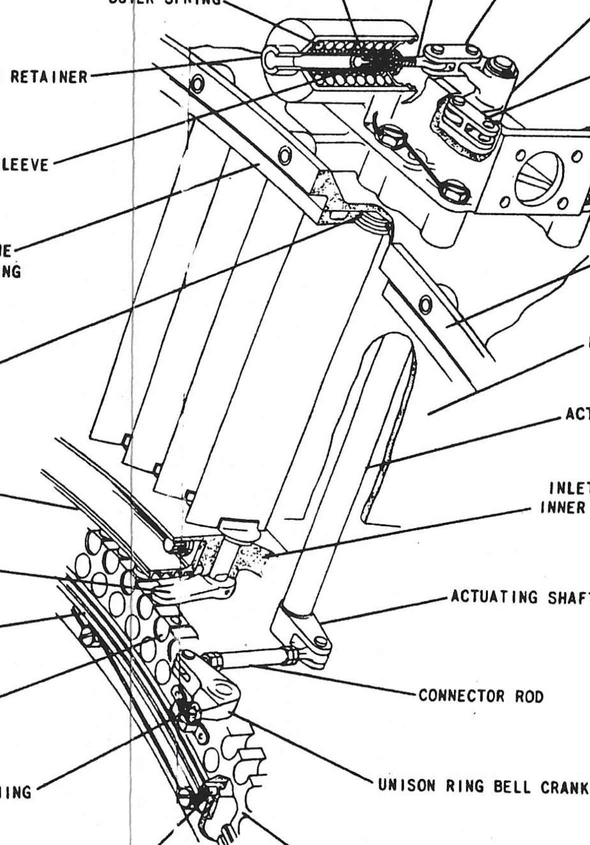




L H FRONT VIEW



R H REAR VIEW



VIEW SHOWING H P COMPRESSOR INLET GUIDE VANE
ACTUATOR MECHANISM

IR 81

FRONT FRAME ASSEMBLY

actuating shaft which passes through the No. 2 strut core. A lever on the inner end of the shaft is linked to a bell crank which, in turn, engages with the unison ring. Internal stops in the hydraulic actuator govern the total rotational movement of the vanes, A spring housing, which is integral with No. 2 strut cover plate, accommodates two concentrically mounted springs. The springs seat on a retainer which bears against a rod end bearing linked to the actuator crank. In the event of failure in the actuator hydraulic circuit, the springs return the guide vanes to their neutral position.

OIL AND AIR SERVICES

Internal passages in the front frame deliver oil to the jets on the fore and aft faces of the HP thrust bearing. Similar passages carry oil from the HP thrust bearing scavenge impellers directly to the internal oil tank. A spring-loaded drain valve which is held closed by pressure oil during engine operation, opens during engine shut-down and allows oil from the scavenge impellers to drain into the front sump. Seventh stage air is piped into No. 8 strut and is tapped off at the front face of the inner casing to supply air pressure to the LP bearing oil seal. The remainder of the air from No. 8 strut bleeds into the interior of the HP compressor rotor to pressurize the HP thrust bearing and LP steady bearing oil seals and to cool the turbine assemblies.

LOW PRESSURE MAINSHAFT ASSEMBLY

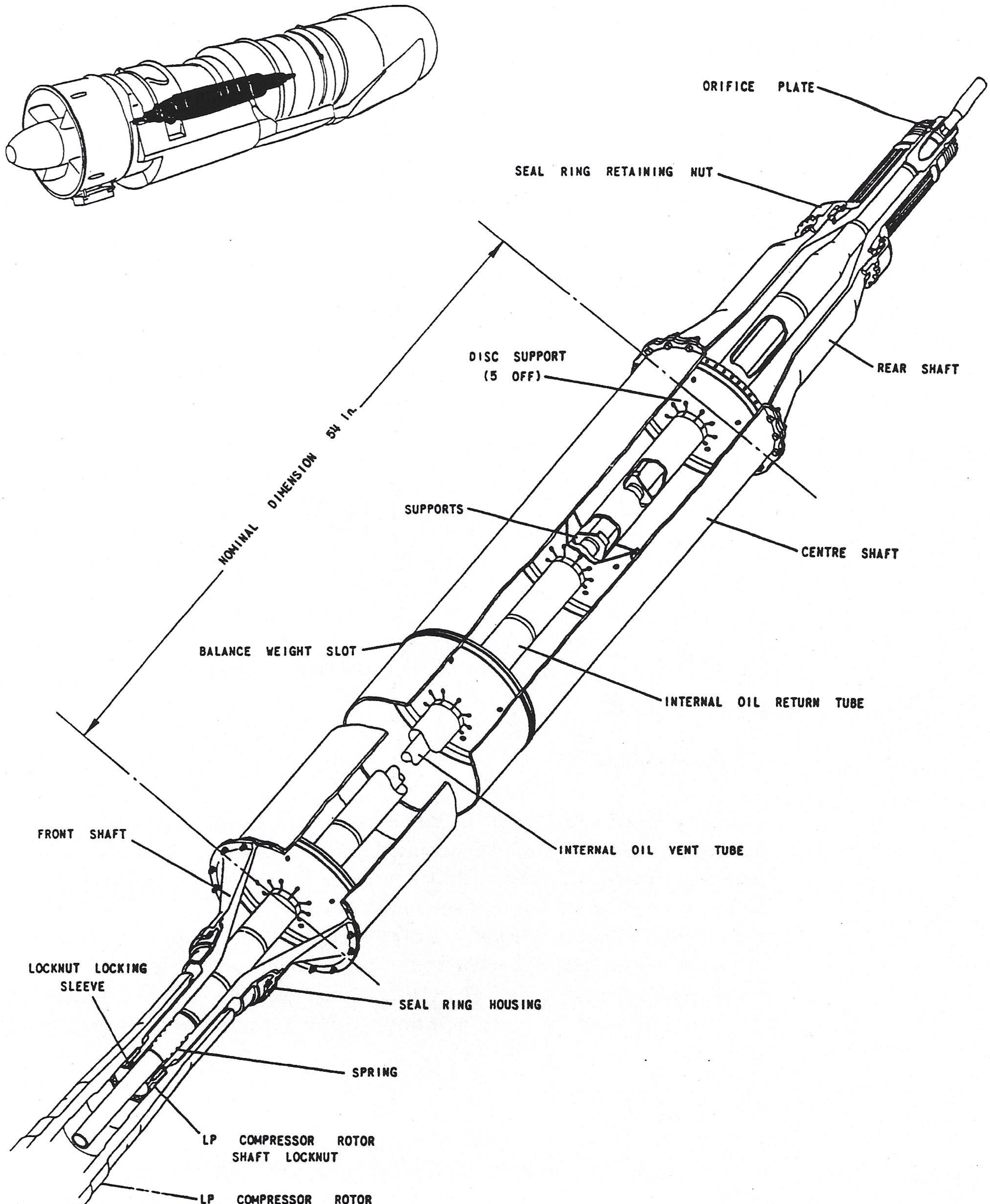
The LP mainshaft is in three sections. The shaft extends forward from the LP turbine rotor to drive the LP compressor rotor. Two concentrically mounted tubes within t h e shaft, namely the internal oil return tube and the internal oil vent tube, form part of the engine lubrication system.

The three sections are of nickel-plated steel, the front to centre section joint and the centre to rear section joint being located by machined spigots on the front and rear sections respectively; stainless steel bolts and nuts secure the joints. The LP compressor rotor shaft is splined to the front section of the main shaft and is locked in position by a locknut. The locknut is internally splined and is retained by a spring-loaded sleeve which slides forward to engage with the locknut splines. The LP turbine rotor shaft is splined to the rear section of the main shaft. Seal rings on the front and rear sections prevent the leakage of oil from the HP compressor rotor 'steady' bearing and the turbine bearing respectively.

The oil return tube is centrally located inside the mainshaft centre section by five stainless steel disc supports which are silver brazed to the outer diameter of the tube. The inner tube is supported within the outer tube by 12, three point location,'Z' section, stainless steel supports which are welded to the inside diameter of the outer tube.

A mixture of air and lubricating oil in the form of froth is returned from the engine rear oil sump to the engine front oil sump via the annular space formed between the inner and outer tubes. The inner tube serves as an engine lubrication system air vent to the rear of the engine. An orifice plate, fitted to the rear end of the inner tube controls the air pressure drop throughout the engine oil scavenge system.

The LP mainshaft assembly and the LP turbine rotor are dynamically balanced as a complete assembly. Correction is made by balance weights at balancing planes of the turbine bearing outer seal ring.



LOW PRESSURE MAINSHAFT ASSEMBLY

INTERNAL GEARBOX AND OIL TANK ASSEMBLY

GENERAL

The internal gearbox 3rd oil tank assembly is housed within the front frame inner casing. The assembly consists basically of a gearbox casing, and two gear trains which supply power to the externally mounted LP and HP gearboxes. When installed in the front frame, the gearbox serves as the inner wall of the front sump of the engine lubrication system, with the casing also forming the inner circular wall of the oil tank. The front and rear walls of the oil tank are provided by the LP and HP thrust bearing housings respectively, when the bearing assemblies are installed in the front frame.

INTERNAL GEARBOX CASING

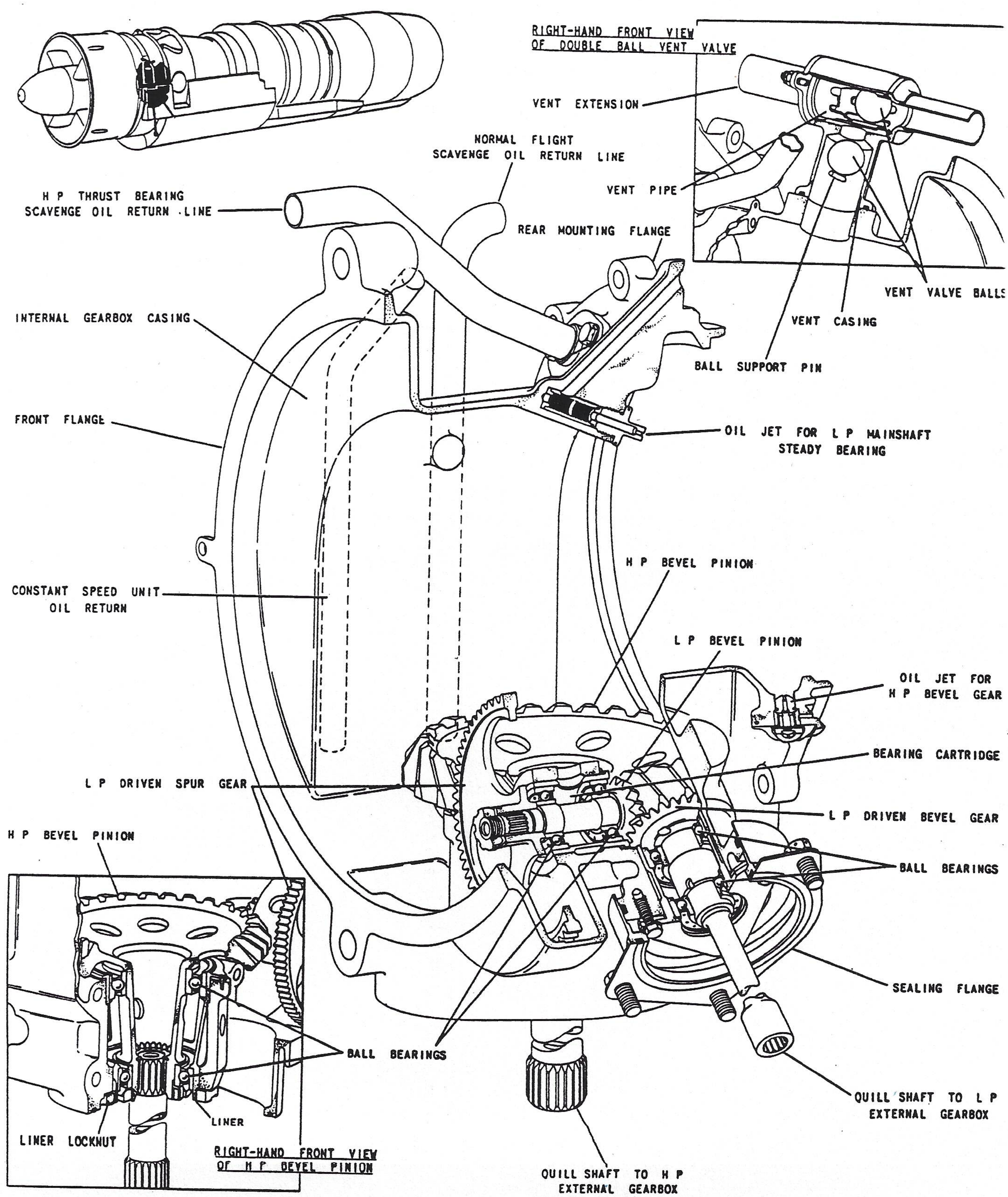
The internal gearbox casing is cast from magnesium, with a. flange on the front and rear faces. The front flange butts against a flange on the rear face of the LP thrust bearing housing, with an 'O' ring interposed in the joint. The rear flange is bolted to a flange on the forward face of the integrally cast HP thrust bearing housing in the front frame casing, The bottom of the internal gearbox casing seats on the inner end of the front frame No. 6 strut with an 'O' ring interposed at the joint. A sealing flange, which fits over the support housing for the LP driven bevel gear, is bolted to the inner end of the front frame No. 6 strut. An 'O' ring is fitted between the sealing flange and the gearbox casing and also between the sealing flange and the front frame casing.

LP GEAR TRAIN

A drive gear mounted on the LP compressor shaft meshes with a spur gear within the gearbox casing, A small bevel pinion gear is splined to the hub of the spur gear and is retained by a locknut and lock washer. The spur gear and bevel pinion gear combination is supported by two, single row ball bearings, the bearing cartridge being housed within an integrally cast boss in the gearbox casing. The drive is turned through ninety degrees by a second bevel gear which is internally splined at its outer end to receive a quill shaft which extends through the front frame No. 6 strut to drive the LP external gearbox. Two single row ball bearings are used to support the driven bevel gear.

HP GEAR TRAIN

A bevel pinion gear meshes with the bevel gear splined to the HP compressor front stub shaft, and is supported by two, single row ball bearings in an integral housing in the bottom of the casing. The upper bearing is pressed onto the bevel



INTERNAL GEARBOX AND OIL TANK ASSEMBLY

pinion gear shaft and mounted in a steel liner. The lower bearing is mounted in the liner, and is retained on the gear shaft by a washer and locknut. A flange on the upper end of the liner locates the liner against the inner face of the housing and serves as a retainer when the liner locknut is tightened. Rotational movement of the liner is prevented by a dowel pin which is fitted through the face of the flange into the housing. A quill shaft, splined to the bottom of the gear shaft, carries the drive to the HP external gearbox and aircraft power take-off assembly which is mounted on the outer end of the front frame No. 5 strut.

LUBRICATION

Two oil jets, located in the rear of the casing, provide lubrication for the LP main shaft steady bearing and the HP bevel pinion gear respectively. On the right- hand side of the casing, two pipes, connected at the lower ends to the No. 4 strut internal cover in the front frame, carry scavenge oil to the oil tank. The pipes carry constant speed unit scavenge oil and normal flight scavenge oil respectively. When the oil supply is being replenished during ground servicing, these pipes serve as the oil tank fill pipe and overflow pipe respectively. An oil pipe and fitting, mounted on a boss at the top of the casing return scavenge oil from the HP thrust bearing to the oil tank. Air transferred to the tank by the scavenge return system is vented to the front sump by a double ball vent valve. The valve also prevents an oil flow from the tank to the front sump in any flight attitude.

HIGH PRESSURE COMPRESSOR STATOR ASSEMBLY

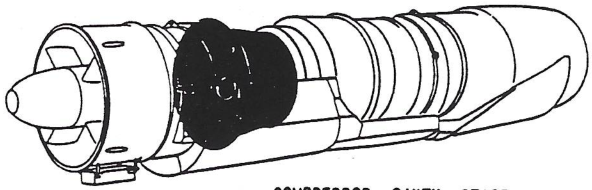
The HP compressor stator assembly forms the structural connection between the front frame and the mid frame, and encases the HP compressor rotor drum. The assembly comprises mainly an outer casing, six stages of stator segments and seven spacer rings.

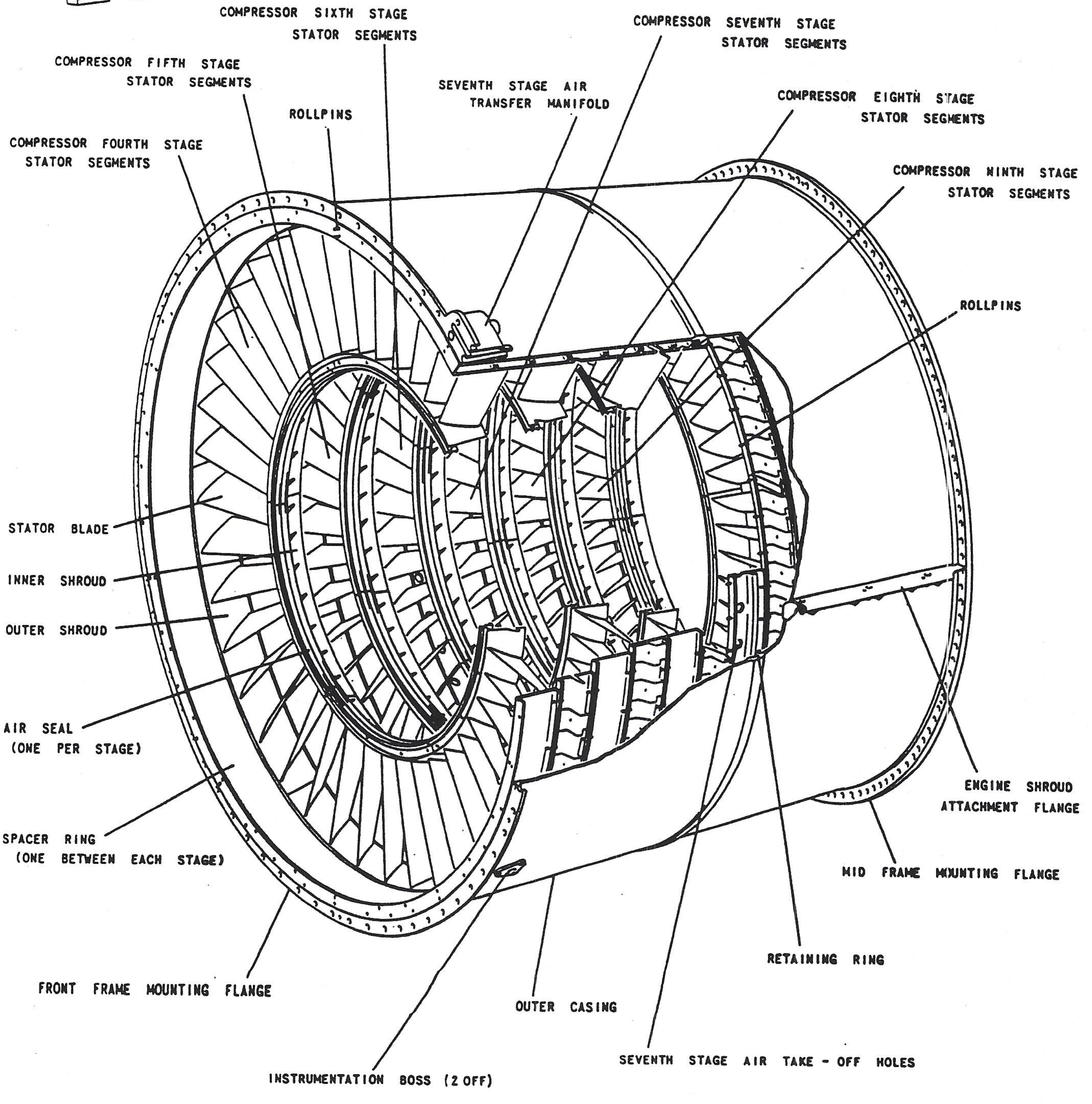
The outer casing consists of an unsplit, conical, sheet steel shroud with a flange welded to each end for bolting the casing to the front and mid frames respectively. A circular retaining ring, integral with the outer casing, has a machined recess on its inner front face, which mates with a hook-shaped projection on the seventh stage spacer ring. The retaining ring serves as a stiffener for the outer casing to prevent ovality occurring in the stator assembly. Two triangular-shaped instrumentation bosses are located near the bottom of the outer casing immediately aft of the forward mounting flange. A sheet metal flange is welded to each side of the casing, along the horizontal centre line, for attachment of the engine shroud.

Each stage of stators is composed of six segments which, when assembled in position, form a continuous ring of stator blades. The number of blades per segment in the fourth to ninth stages inclusive is seven, eight, nine, nine, eleven and eleven respectively. The tenth stage stator segments form part of and are dowelled directly to the mid frame assembly. The stator segments are of stainless steel and consist of inner and outer shrouds brazed to the ends of hollow stator blades. Each aerofoil-shaped stator blade is fabricated from two sheet steel pres sings strengthened by a corrugated stiffener inserted in the blade core. The outer end of each blade is sealed with a steel plate brazed to the outer shroud; the inner end is left open to vent the blade core. An air seal of the two-groove type is riveted to a flange on the inner shroud of each segment to mate with the inter-stage air seals fitted to the HP compressor rotor spacer rings,

The circular spacer rings are of stainless steel, and are located intermittently between each stage of stator segments. Like the segment outer shrouds, the spacer rings are channel-shaped to provide maximum rigidity of the assembly. The flanges of the segment outer shrouds and the spacer rings butt together and are retained by single rows of equi-spaced roll pins. The foremost spacer ring is pinned to the rear of the front frame by two rows of equi-spaced roll pins. A coating of friable material is applied to the inner diameter of each spacer ring to minimize damage that may be caused by the development of a tip rub.

A series of holes in the seventh stage spacer ring, forward of the hook-shaped projection, permits air to be bled off into the annulus formed by the spacer ring and segment assembly, and the outer casing. An air transfer manifold located on the outer casing adjacent to the front frame mounting flange, transfers seventh stage bleed air from this annulus to the passage provided through the front frame No. 8





HIGH PRESSURE COMPRESSOR STATOR ASSEMBLY strut. This flow of bleed air is used for pressurizing oil seals in the main bearing assemblies and for turbine cooling.

NOTE

Although the LP and HP compressors have been treated as separate units, the numbering of the stages has been consecutive from the front of the engine through the two units. This is to be consistent with the numbering used in the engine functional descriptions.

HIGH PRESSURE COMPRESSOR ROTOR ASSEMBLY

The HP compressor rotor assembly is the front rotating component of the engine HP spool, and revolves around the LP main shaft assembly. Together with the stator casing, the HP compressor rotor forms a converging annular passage where further compression of the LP compressor delivery air takes place.

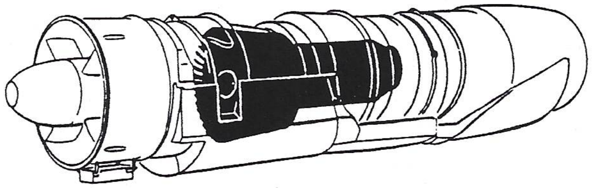
The assembly consists essentially of seven bladed rotor discs and six spacer rings and is supported at the forward end by a stub shaft carried in the HP thrust bearing assembly. The spacer rings and rotor discs are bolted together to form a large diameter which transmits axial thrust loadings to the HP thrust bearing. The discs absorb radial loads imposed by the centrifugal blade forces arising from high rotational speeds. The extension shaft and HP main shaft, extend rearwards from the compressor drum, forming a direct drive from the HP turbine rotor.

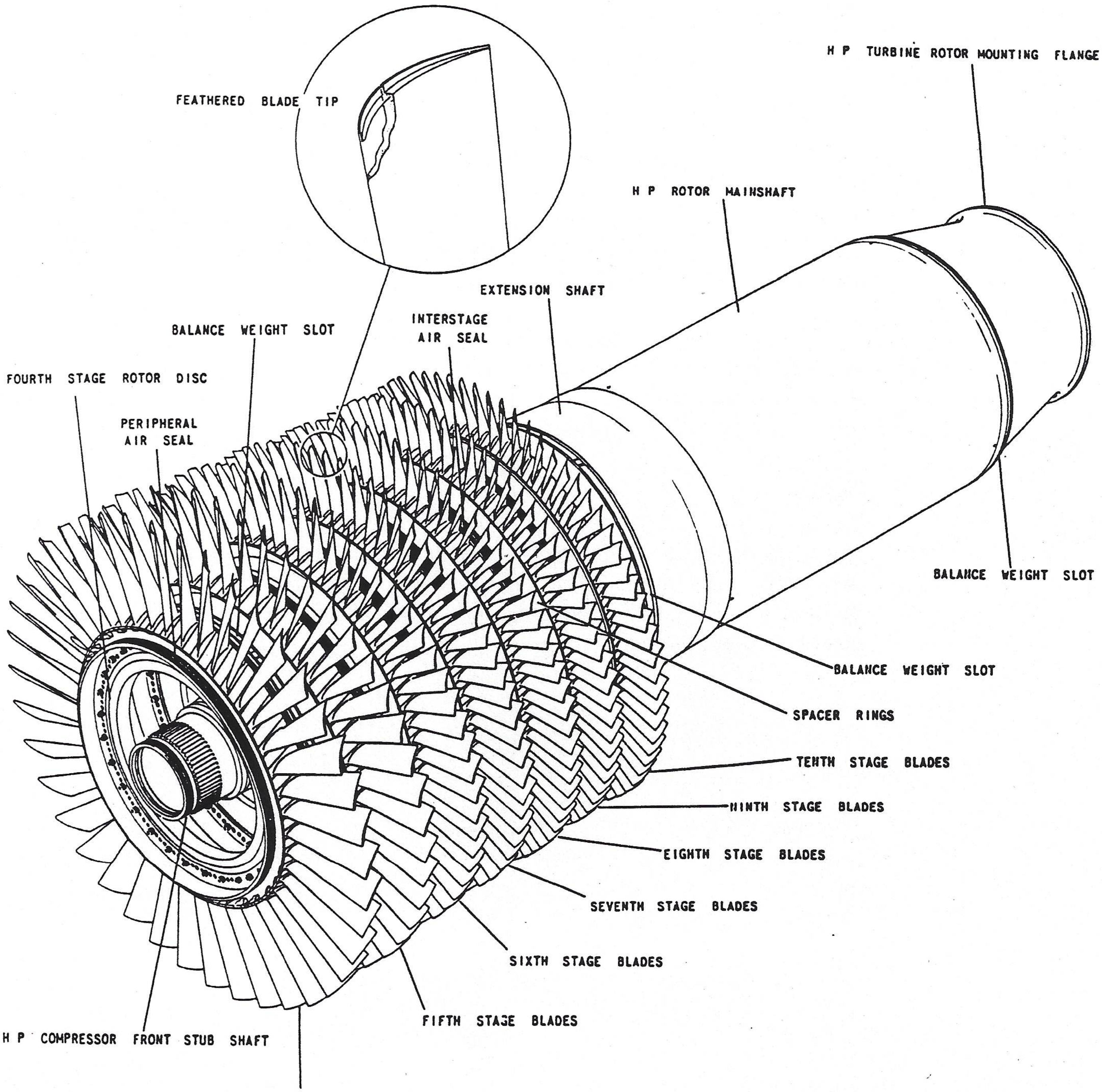
The rotor discs and spacer rings are machined from titanium forgings. Development engines have a steel compressor fourth stage disc, but the use of a titanium disc in this stage is proposed f o r production engines. The fourth stage spacer ring and disc are cantilevered forward from fifth stage disc. The fifth stage disc is bolted to the fifth stage spacer ring, which has a conical extension bolted to the front stub shaft.

The HP compressor r o t o r blades are titanium forgings and have an aerofoil section, with the blade tips feathered to aid in heat dissipation and to minimize damage should a tip rub develop. Blade stops are machined in the rear portion of the blade roots of stages four to nine inclusive, to prevent axial movement of the blades in a forward direction. Blades in t he tenth stage have a stop on the front portion of the root to prevent rearward movement. The fourth and tenth stage blades are secured to the respective discs by two-branch fit tree roots, while the remaining stages employ a cylindrical seat dovetail fixing.

Inter-stage air seals of titanium are riveted to flanges on the spacer rings. The forward extending projections on the seal rings butt against the rotor blade roots in the preceding stage and prevent rearward axial movement of the blades. Forward movement of the tenth stage rotor blades is prevented by a similar projection extending from the rear of the ninth stage seal ring. A peripheral air seal is fitted on the front face of the fourth stage disc to prevent excessive air leakage through the clearance between the HP compressor rotor and the front frame.

The bell-shaped front stub shaft is bolted to the conical extension of the fifth stage spacer ring. A seat and shoulder, machined on the outside diameter of the shaft near the mid-point, provides a location for the HP thrust bearing. The outer diameter of the forward end of the shaft is splined to carry the bevel gear which drives the external gearbox. The bevel gear is retained by a locknut and lock ring, the latter





HIGH PRESSURE COMPRESSOR ROTOR ASSEMBLY

being fitted to the inside of the shaft with a tang protruding through the shaft into the nut. A series of large diameter holes in the conical portion of the front stub shaft permits the entrance of seventh stage compressor air to the interior of the HP compressor rotor.

A steady bearing, consisting of a single roller bearing, is mounted inside the front stub shaft. The inner race of the bearing is located against a shoulder on the front section of the LP main shaft and is retained by the LP compressor shaft and the LP main shaft locknut. Lubrication of t h e steady bearing is accomplished by an oil jet located in the rear part of the internal gearbox housing. The jet sprays oil in a rearward direction along the annulus formed between the LP compressor shaft and the HP compressor front stub shaft. Holes in an oil seal sleeve located at the rear of the steady bearing permit scavenge oil from the steady bearing to be centrifuged through oil ways in the front stub shaft to the HP thrust bearing scavenge impeller. The extension shaft links the compressor drum to the HP mains haft and the HP main shaft is secured to the HP turbine rotor by stainless steel tension bolts and a clamp ring fitted to the rear flange of the main shaft.

Balancing of the HP compressor rotor assembly is done by the addition of weights installed in three circular grooves, one located on the rear portion of the HP main shaft, one at the centre of the extension shaft, and another at the fourth stage spacer ring. The outer balance weights in each group are secured by peening.

NOTE

Although the LP and HP compressors have been treated as separate units, the numbering of the stages has been consecutive from the front of the engine through the two units. This is to be consistent with the numbering used in the engine functional descriptions.

HIGH PRESSURE THRUST BEARING ASSEMBLY

The HP thrust bearing assembly supports the forward end of the HP compressor rotor, and also absorbs the net axial thrust of the HP compressor rotor and the HP turbine rotor. The assembly consists basically of a single row ball thrust bearing, a bearing liner, the internal gearbox HP bevel gear and locknut, and bearing lubrication system components. When assembled in the front frame it is housed within an inward projecting integrally cast support flange at the rear of the front frame.

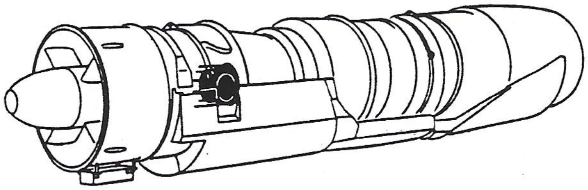
The bearing is retained in the steel liner by a pinned locknut which bears against the rear face of the bearing outer race. The liner is in turn retained within the support flange of the front frame by long steel bolts which also serve to retain the internal gearbox casing in position. The split inner race of the bearing butts against a step machined in the HP compressor rotor front stub shaft, and is held in position by the internal gearbox HP bevel gear. The bevel gear is splined to the front stub shaft and is retained axially by a locknut which is in turn positively locked by the tang of a steel locking ring which engages with holes in the front stub shaft and the locknut.

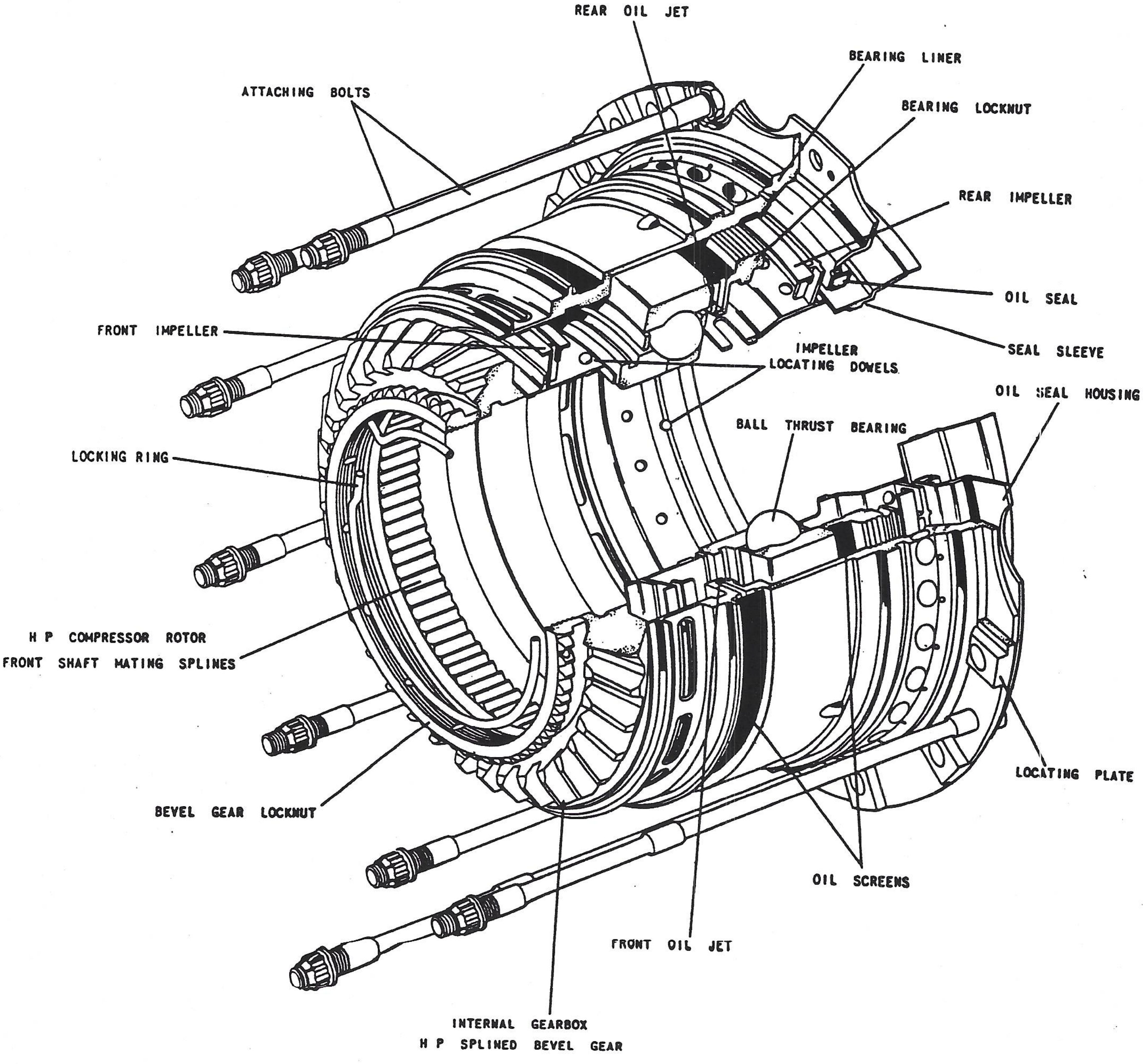
A locating plate, with radially disposed teeth machined on its forward face, is fitted between the bearing liner and the rear face of the front frame. The teeth engage with slots in the front frame, and counteract the effects of thermal differential expansion between the magnesium front frame and the steel liner by keeping the liner centralized.

Lubrication of the bearing is by six oil jets. Three of the jets, located at the front of the bearing, are formed by drillings in the bearing liner while the remaining three located at the rear of the bearing, are formed by drillings in the bearing locknut. Pressure oil is fed through channelling in the front frame to annular cavities adjacent to each set of oil jets, the front annulus being formed between the front frame and the bearing liner, and the rear annulus between the liner and the bearing locknut. Each annulus is provided with a protective oil screen on the, upstream side of the jets.

Two radially vaned impellers, one fitted on each side of the bearing, scavenge the oil from the bearing assembly by centrifugal action. Holes in the bearing liner admit scavenge oil from the impellers to annular cavities which are formed between the liner and the front frame, and which are interconnected to the internal oil tank by channelling in the front frame. The scavenge oil cavities are isolated from the pressure oil cavities by 'O' ring seals.

A single carbon ring oil seal is mounted in an oil seal housing located on the rear face of the bearing liner. A steel seal sleeve which butts against a shoulder on the HP compressor rotor front stub shaft, forms a seat for the oil seal. The rear of the oil seal





HIGH PRESSURE THRUST BEARING ASSEMBLY

is pressurized with compressor seventh stage air to prevent oil seepage past the seal in a rearward direction.

Displacement of the seal sleeve and the bearing rear impeller is prevented by a small locating dowel in the front stub shaft. The bearing front impeller is retained by a similar dowel which locates in a slot on the shaft of the internal gearbox HP bevel gear.

MID FRAME ASSEMBLY

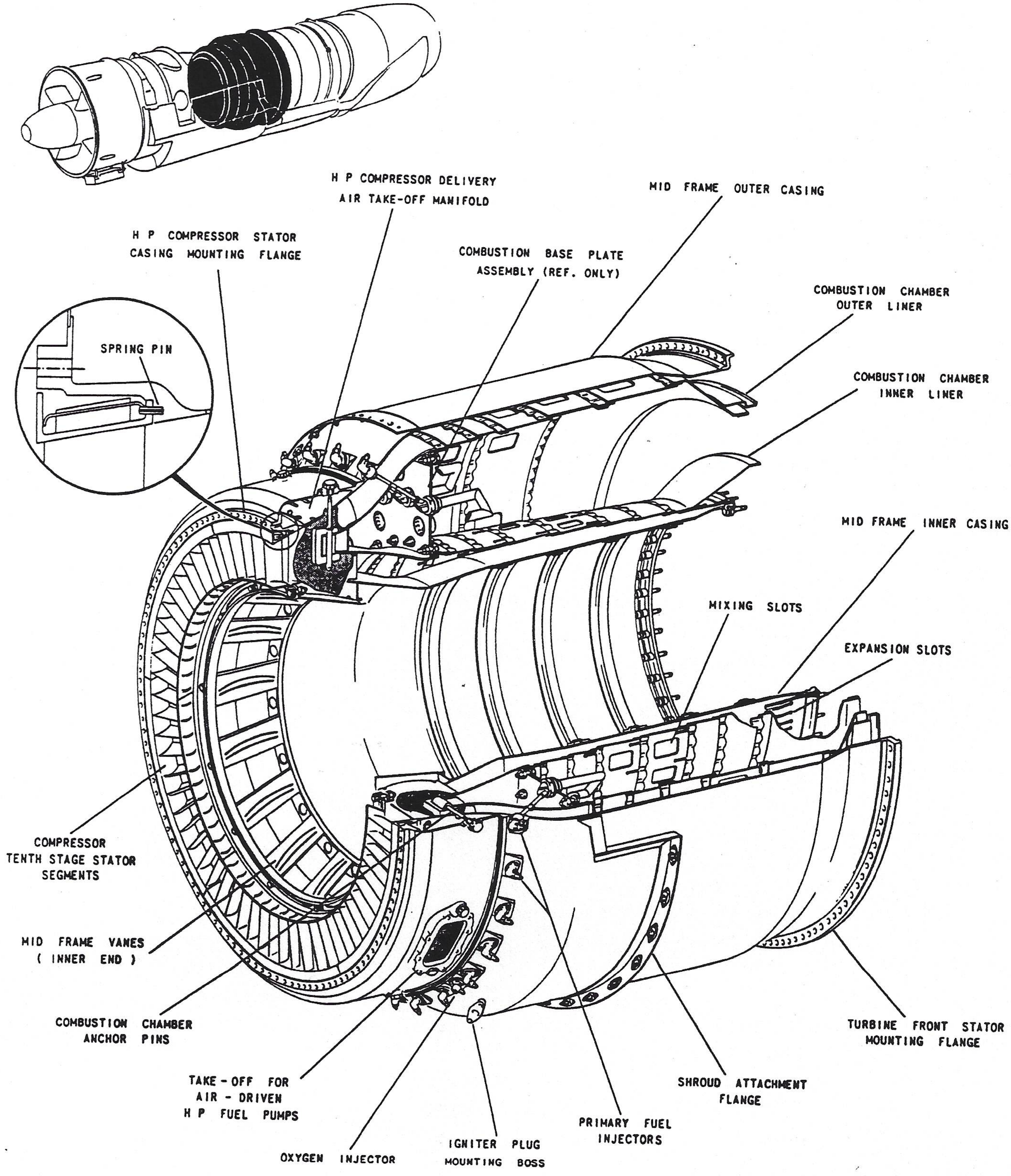
The mid frame assembly houses the annular combustion chamber and forms the structural connection between the compressor and turbine HP sections. The assembly comprises mainly the inner and outer casings, the annular combustion chamber liners, the compressor tenth stage stator segments and the primary fuel injectors. The combustion base plate assembly is shown for reference purposes only and is fully described in a separate advance data sheet. HP compressor delivery air enters the annular opening at the front of the mid frame and is divided into primary and secondary flows; the primary flow passes through the combustion base plate assembly, and the secondary flow passes into the inner and outer annular spaces formed between the combustion chamber liners and the inner and outer casings.

The concentrically mounted inner and outer casings are fabricated from stainless sheet steel; the outer casing is of heavier gauge material to withstand structural loadings and the high combustion chamber gas pressures to which it is subjected. The inner casing separates the combustion chamber from the HP compressor main-shaft. The inner and outer casings are joined at the front by 16 hollow, aerofoil section vanes, the trailing edges of the vanes being recessed to accommodate the combustion base plate assembly frame. Machined bolting flanges on the outer casing provide for attachment of the mid frame to the HP compressor stator casing at the front and to the turbine front stator casing at the rear. A similar flange at the rear of the inner casing is used for attachment of the turbine first stage stator segment inner support. Two bosses, at the bottom of the outer casing, accommodate combustion drain fittings.

An air take-off manifold is located around the periphery of the outer casing the outer shrouds, over the ends of the blades. Steel inner shrouds are brazed to the inner ends of the blades; the inner ends of the blades are left open to vent the blade cores.

The stator segments are pinned to a recess in the front face of the mid frame outer casing by spring pins and retained in position by the rear bolting flange of the HP compressor stator assembly when the engine is assembled. A segment retaining ring is bolted to the inner front face of the mid frame vanes to retain the inner shrouds of the stator segments.

A primary fuel injector is mounted on each of the 32 bosses located around the mid frame outer casing immediately to the rear of the air take-off manifold, The inner ends of the fuel injectors are centred in flared receptacles at the inlets of the combustion tubes of the combustion base plate assembly. The outer end of each injector is carried in a spherical seating which permits self-alignment of the injectors. A fuel metering orifice in each injector is carefully matched to ensure uniform fuel distribution to the combustion tubes.



MID FRAME ASSEMBLY

Two bosses, near the bottom of the mid frame casing in line with the fuel injectors, provide a mounting for the oxygen injectors. When assembled to the mid frame, the inner ends of the oxygen injectors engage with the two hemispherical igniter chambers in the combustion base plate assembly. The outer ends are supported in spherical seatings similar to those used for the primary fuel injectors. An igniter plug is fitted to an angled boss on each side of the mid frame casing at the bottom so that the plugs line up with the igniter chambers. During normal ground starting, only the igniter plugs are used to ignite the fuel/air mixture around the combustion tubes. Relight at altitude is assisted by injecting oxygen into the igniter chambers through the oxygen injectors.

Sheet metal flanges, welded around the lower half of the mid frame outer casing, are fitted with anchor nuts for attachment of the engine shroud assembly.

COMBUSTION BASE PLATE ASSEMBLY

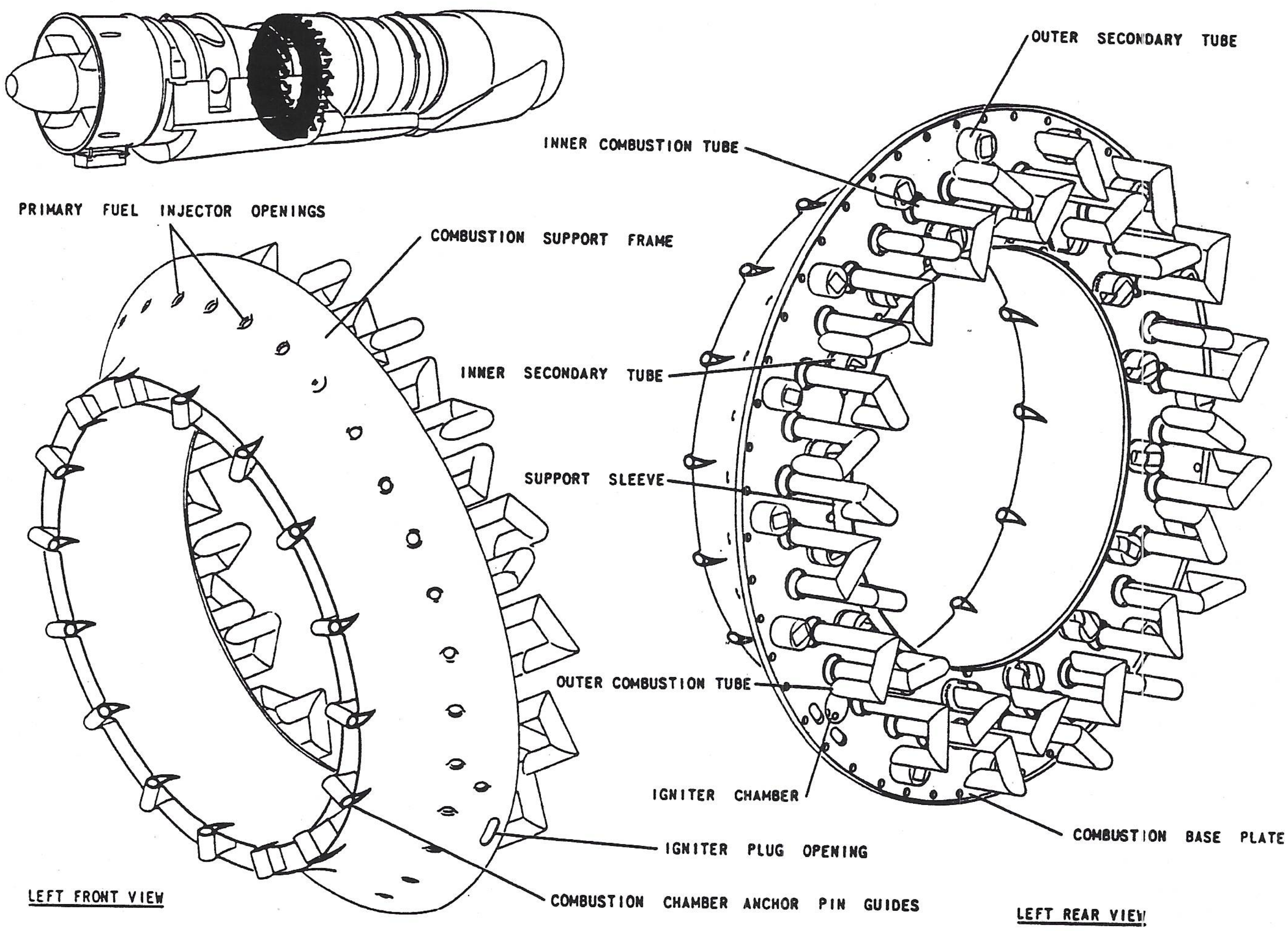
The combustion base plate assembly, which forms the head section of the annular combustion chamber, is located inside the front portion of the mid frame. The assembly consists primarily of a combustion base plate mounted in a support frame, and serves to meter the correct proportion of HP compressor delivery air into the primary zone of the combustion chamber. Combustion tubes and secondary air tubes, extending rearwards from the combustion base plate, create proper conditions for efficient burning of the air and fuel mixture in the combustion chamber.

The combustion support frame comprises circular inner and outer sheet steel plates, contoured to form a snout-shaped divergent annulus. The support frame divides the incoming Hp compressor delivery air into a primary flow and a secondary flow. The primary air flow enters through the snout opening and is diffused in the support frame prior to entering the primary combustion zone. The secondary air flow passes rearwards through inner and outer annular spaces formed between the combustion liners and the mid frame casing, and is admitted into the combustion chamber through openings in the liners to assist combustion in the primary zone and cool the burnt gases prior to their entry into the turbine.

Sixteen streamlined, combustion chamber anchor pin guides are welded equidistantly around the snout opening, between the support frame inner and outer skins. These guides, with the anchor pins, support the forward end of the base plate assembly and keep it concentric with the mid frame casings.

Flanges at the rear of the support frame provide for attachment of the circular combustion base plate to the support frame, and of the complete base plate assembly to the forward ends of the combustion chamber liners. Together with a support sleeve, the base plate is bolted directly to the inner flange at the rear of the support frame, the support sleeve at this location being a sliding fit on the forward end of the combustion chamber inner liner. The base plate is retained to the support frame outer rear flange by the bolts which secure the combustion base plate assembly to the forward end of the combustion chamber outer liner.

An inner and outer circle of stainless steel primary combustion tubes of 16 tubes in each circle, are fitted to the combustion base plate. Each tube is in the form of a "walking stick" which extends rearwards from the base plate, and is angled through two 90' turns so that the outlet of each tube is facing upstream. This configuration produces a flame which passes rearwards over the outer surface of the tubes, resulting in complete vapourization of the fuel as it passes through the heated tubes. Fuel is introduced into the front end of these tubes by means of 32 injectors which pass through dimpled holes in the support frame outer skin and locate in flared receptacles on the tube inlets. The primary air flow through the tubes mixes with and carries the injected fuel to the tube outlets.



COMBUSTION BASE PLATE ASSEMBLY

A double circle of secondary tubes, fitted on the rear face of the base plate, are arranged so that the air passing through these tubes meets with the fuel vapour expelling from the combustion tubes, and form vortexes about which the combustion flame stabilizes. Each of the 14 secondary pipes in the outer circle consists of a cylindrical cup-shaped pressing with a slotted opening in the rear end; the 16 tubes of the inner circle are similar except for the inclusion of a row of small holes around the base of each pipe.

Two hemispherical igniter chambers, each consisting of a slotted dome-shaped pressing, are located on the lower front face of the base plate. Two flared receptacles in each chamber accommodate the inner ends of an igniter plug, and an oxygen and fuel injector. The two igniter plugs are of the low voltage surface gap type, and provide the spark which initiates combustion during the engine starting cycle. The oxygen injectors are provided to improve the re-light characteristics of the engine at altitude.

TURBINE FRONT STATOR ASSEMBLY

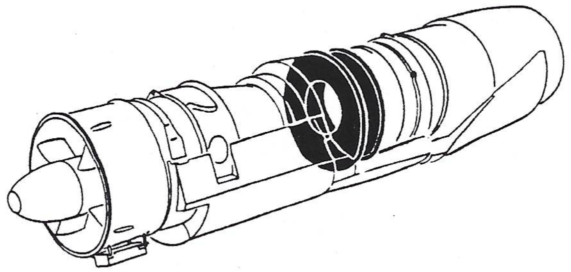
The turbine front stator assembly is the structural connection between the mid frame assembly and the turbine rear stator assembly. It consists mainly of an outer casing, inner and outer supports for the turbine first stage stator segments, and a segmented shroud ring for the turbine first stage rotor. An air seal on the stator segment inner support permits a controlled flow of tenth stage cooling air (HP compressor delivery bleed air) to pass over the front face of the turbine first stage rotor disc. The turbine first stage stator blades increase the velocity of and direct the gas stream onto the turbine first stage rotor blades.

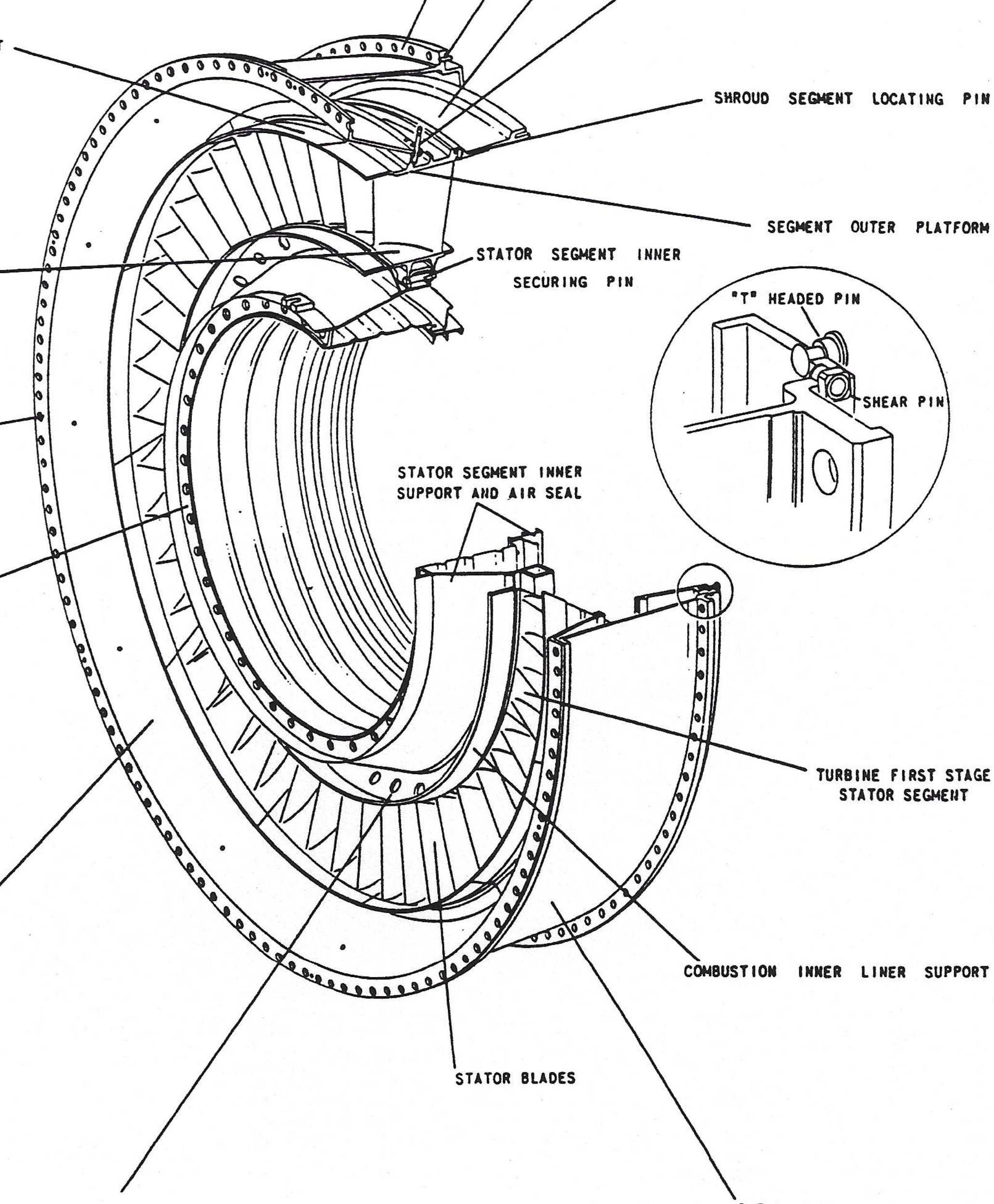
The outer casing is a stainless sheet steel fabrication with machined bolting flanges welded to the front and rear of the casing. The rear flange is stepped to provide support for the front of the turbine second stage stator segments in the rear stator assembly. Twelve holes in the step are fitted with shear pins which engage with slots in the second stage stator segments. In addition, twelve 'T' headed pins are provided on the flange for location of the second stage stator segments. A small spring pin in the rear bolting flange ensures correct positioning of the turbine rear stator during assembly.

The turbine stator segment outer support is a conical-shaped stainless sheet steel fabrication having a front bolting flange and rear section welded to it, the rear section being channelled to form the outer front support for the stator segments. Five holes are drilled through the channelled section at each segment location and these, in conjunction with five holes drilled at a slightly different spacing pitch in the corresponding segment flange, permit a vernier adjustment to be obtained. A securing pin is inserted through the holes showing the best alignment.

The turbine stator segment inner support is bolted to the rear flange of the mid frame inner casing, and serves as a support for the inner ends of the stator segments. A welded projection on the inner support provides radial support for the rear of the combustion chamber inner liner; holes in the projection allow a flow of cooling air over the segment inner platforms. The three-gland air seal ring which mates with the front air seal of the HP turbine rotor assembly, is riveted to the inner cylindrical portion of the support.

Each of the twelve first stage stator segments consists of four hollow aerofoil section blades nicro-brazed between an inner and outer platform. Circumferential ribs on the segment inner and outer platforms ensure an even distribution of the blade stresses. A lip, machined on the foremost rib of the outer platform, mates with and is secured to the channelled section of the stator segment outer support as described in Para 3. The ends of the segment outer platforms overlap to permit expansion and to minimize the escape of hot gases between the joints. A projection on the front face of the segment outer platform provides a support for the rear end





TURBINE FRONT STATOR ASSEMBLY

of the combustion chamber outer liner. A spigot on the rear face of the outer platform supports the front of the turbine first stage shroud segments.

The ribs on the stator segment inner platform are slotted and fit over an axially drilled top-hat section welded to the stator segment inner support. A securing pin with flats on each end, locates in the top-hat section holes and engages with the slots in the inner platform ribs to retain the inner ends of the stator segments circumferentially while permitting free radial movement to allow for thermal expansion.

The twelve turbine first stage shroud segments are arranged circumferentially around the inner diameter of the casing immediately aft of the stator segments. As in the case of the stator segments, the shroud segments overlap each other, to allow for thermal expansion and contraction of the segments without serious effects on the turbine blade tip clearances. The front and rear faces of each shroud segment are channelled and mate with lips on the rear face of the stator segments and the front face of the outer casing rear flange. Circumferential displacement of the shroud segments is prevented by a locating pin passing through each stator shroud segment joint.

NOTE

Although the HP and LP turbines have been treated as separate units, the numbering of the stages has been consecutive from the front of the engine through the two units. This is to be consistent with the numbering used in the engine functional descriptions.

HIGH PRESSURE TURBINE ROTOR ASSEMBLY

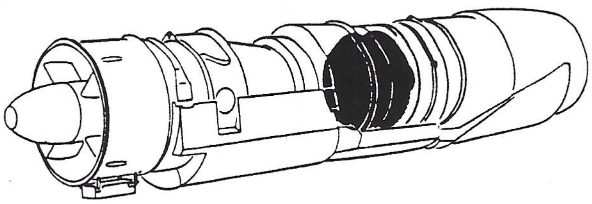
The HP turbine rotor assembly is of a two-stage design which comprises mainly two bladed rotor discs, separated by a spacer, and mounted on a stub shaft which is supported in the HP turbine bearing. The complete assembly is secured to the rear flange of the HP compressor rotor mainshaft by fifteen stainless steel tension bolts and self-locking nuts. The HP turbine rotor assembly absorbs the required proportion of power from the expanding gases passing from the combustion chamber and transmits it as torque power to drive the HP compressor rotor and external accessories.

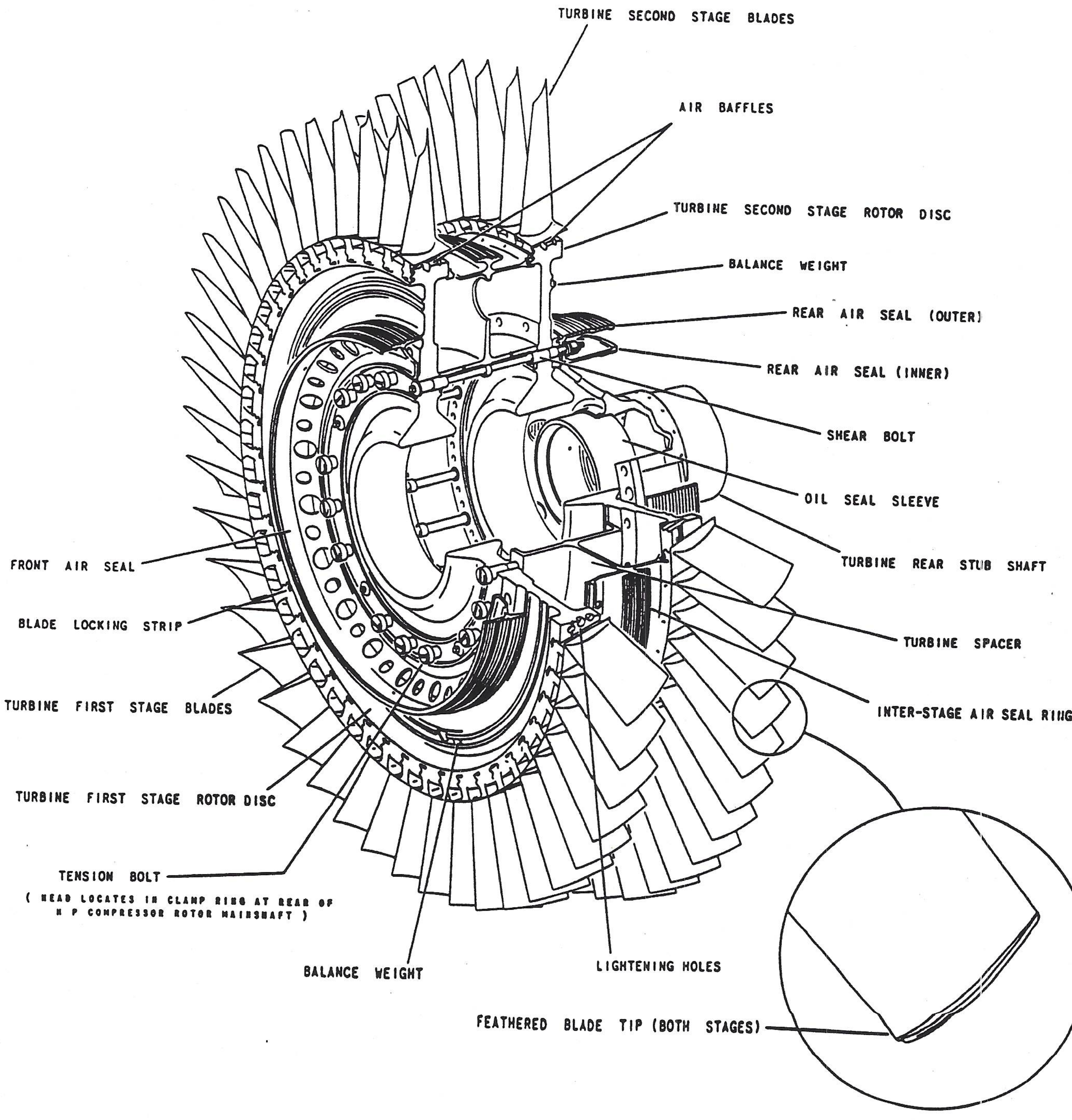
The turbine first and second stage blades are solid cast from heat resistant Inconel material. There are forty-seven blades in the first stage and fifty-three in the second stage. Each blade has a fir tree root for attachment to its respective disc, and an extended neck between the root and the blade platform. The blade tips of both stages are feathered to minimize damage should a tip rub develop. Conventional blade locking strips are used to prevent forward axial displacement of the first stage blades and rearward axial displacement of the second stage blades.

Nicro-brazed stainless steel air baffles are interposed between the extended necks of the blade roots. The baffles are designed to meter a flow of cooling air between the necks and hence reduce the heat transfer from the blades to the discs. Axial movement of the baffles is prevented by tangs which engage with slots in the rims of the turbine discs. The platform on each blade prevents radial displacement of the baffles under centrifugal loads.

Both the first and second stage turbine discs are machined from heat resistant Inconel forgings to withstand the high operating temperature at the disc rims. The discs are of conventional design, and cooling air is passed through holes in each disc web. Lightening holes are drilled in the periphery of the first stage disc between each blade slot.

A spacer which is in the form of cylindrical inner and outer drums inter-connected by an integral web is interposed between the first and second stage turbine discs. The outer drum locates between the rims of the discs and embodies an integral inter-stage air seal ring. The inner drum serves as a spacer shaft between the hubs of the discs. Holes in the web and outer drum provide a passage for cooling air through the inter-disc cavity. A cup-shaped flange at the rear of the outer drum butts against the rim of the second stage turbine disc and forms an annulus around the front face of the blade roots. The flange is drilled to allow cooling air to circulate through the annulus and cool the blade roots. In addition the outer drum portion of the spacer prevents rearward and forward axial displacement of the turbine first and second stage blades respectively.





HIGH PRESSURE TURBINE ROTOR ASSEMBLY

The turbine rear shaft is a robustly designed, nickel plated steel forging. The rear external diameter is nitrided and ground to provide the inner race of the HP turbine bearing. Eight holes drilled in the forward conical section of the shaft pro-vide a passage for cooling air. A finely ground oil seal sleeve is riveted to a spigot on the inner front section of the shaft and mates with the carbon seal ring on the rear section of the LP mainshaft assembly.

In addition to the inter-stage air seal on the turbine spacer, labyrinth-type seals are used at the front and rear of the rotor assembly to separate and apportion the cooling air flows through the turbine assemblies. The front air seal, which butts against the front face of the turbine first stage rotor disc, permits a controlled flow of tenth stage cooling air (HP compressor delivery bleed air) to pass radially out- wards over the front face of the disc. Relatively large holes in the web of the front air seal allow the main flow of tenth stage cooling air to pass into the inter-disc cavity. The front air seal is retained in a channel on the rear flange of the HP compressor rotor mainshaft, rotational displacement of the seal being prevented by two lockpins which engage with slots in the mainshaft flange.

The inner and outer air seals, fitted at the rear of the turbine second stage rotor disc, a r e retained by the HP turbine rotor shear bolts. The inner rear seal separates the seventh and tenth stage cooling air flows; the outer seal provides a controlled flow of tenth stage air to the front face of the turbine third stage rotor disc. With the exception of the front air seal, the components of the HP turbine rotor assembly are bolted together with five stainless steel shear bolts and high temper- ature self-locking nuts. The heads of the shear bolts locate in mating holes in the rear flange of the HP compressor rotor mainshaft. One bolt head, being of a larger diameter, ensures correct location of the complete turbine assembly on the main-shaft.

Balancing of the HP turbine rotor assembly is effected by the addition of weights installed in two circular grooves, one on the front face of the turbine first stage disc and the other on the rear Each of the turbine second stage disc. The outer balance weights in each group are secured by peening.

NOTE

Although the HP and LP turbines have been treated as separate units, the numbering of the stages has been consecutive from the front of the engine through the two units. This is to be consistent with the numbering used in the engine functional descriptions.

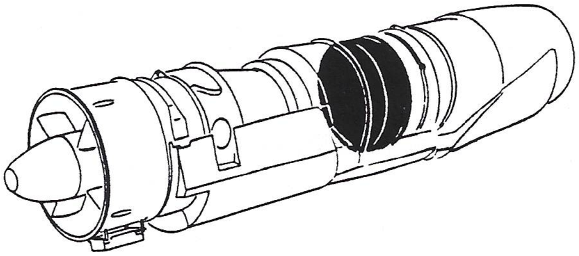
TURBINE REAR STATOR ASSEMBLY

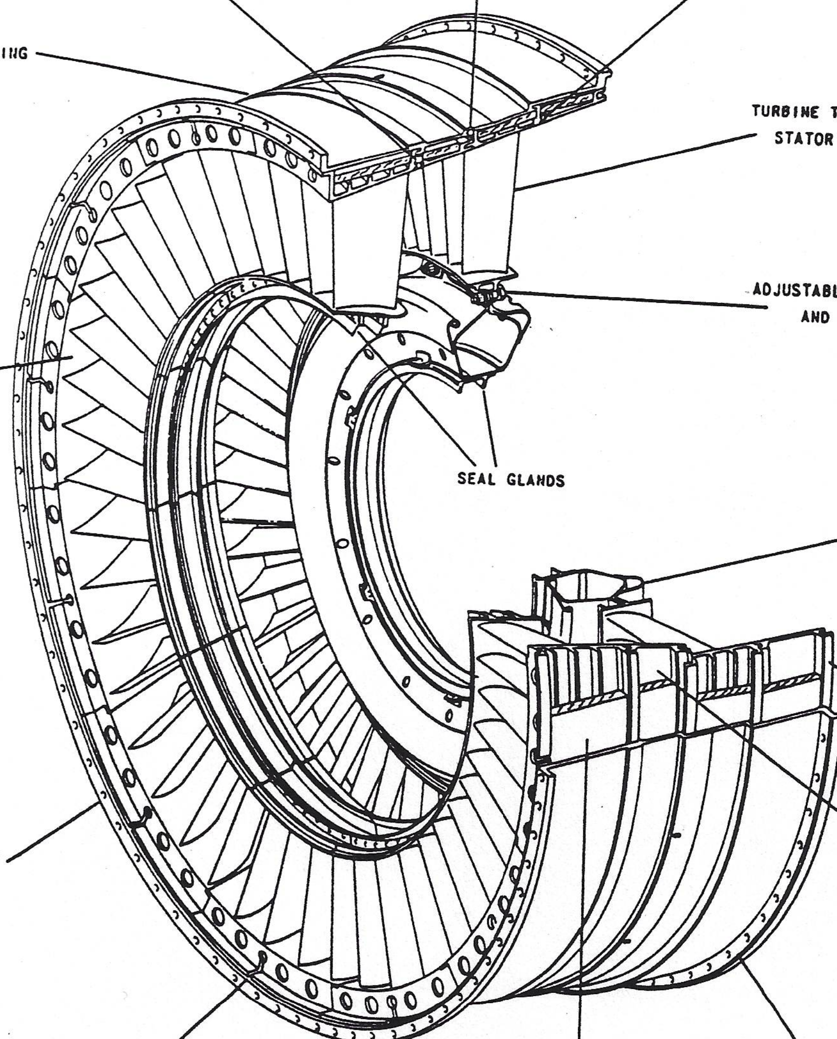
The turbine rear stator assembly is the structural connection between the turbine front stator assembly and the rear frame assembly. It consists mainly of a machined stainless steel outer casing, the turbine second and third stage stator segments, a turbine stator disc and seal assembly, and segmented shroud rings for the turbine second and third stage rotor blades. The stator blades increase the velocity of, and direct the gas stream onto the turbine second and third stage rotor blades.

Each of the twelve turbine second stage stator segments and sixteen turbine third stage stator segments consist of four hollow aerofoil section blades, nicro- brazed to inner and outer platforms. Each stage of stator segments is positioned circumferentially around the inner diameter of the outer casing. The ends of the segment outer platforms overlap to permit expansion and to minimize the escape of hot gases between the joints. Circumferential ribs on the segment inner and outer platforms ensure an even distribution of the blade stresses. The outer platforms of the turbine second stage stator segments are located at the front by locating pins positioned around a step machined on the rear face of the turbine front stator casing; shear pins which engage with the slots in the front lip of the segment outer platforms and holes in the rear face of the turbine front stator casing, prevent circumferential displacement of the segments. A machined groove in the outer casing mates with and retains the rear lip of the segment outer platforms. Two sheet metal glands are riveted to the ribs on the stator segment inner platform and mate with the inter- stage air seal ring which is integral with the HP turbine rotor spacer disc.

The outer platforms of the turbine third stage segments have forward projecting lips machined on the front and rear faces; these lips engage with retaining grooves machined on the inner surface of the outer casing. Circumferential displacement of the turbine third stage stator segments is prevented by shear pins which pass through holes in the outer casing and engage with slots in the segment outer platform front lips.

The turbine second stage shroud segments and third stage shroud segments are arranged circumferentially around the inner diameter of the casing immediately aft of their respective stator segments. The shroud segments overlap each other to allow for thermal expansion and contraction of the segments without serious effects on the turbine rotor blade tip clearances. The front and rear faces of each shroud segment are channelled; the second stage segment channels mate with lips on the front and rear faces of the turbine third and second stage stator segment outer plat- forms respectively; the third stage shroud segments locate on lips machined on the rear face of the turbine third stage stator segment outer platforms and on the front bolting flange of the rear frame assembly. Circumferential displacement of the shroud segments is prevented by a locating pin passing through each stator/shroud segment joint.





TURBINE REAR STATOR ASSEMBLY

The turbine stator disc and seal assembly is bolted to the rearmost rib of each turbine third stage stator segment inner platform. True concentricity is obtained at the seal glands by means of adjustable eccentrically drilled hexagonal bushings. The seal glands are riveted to the stator disc inner diameter and mate with the outer rear air seal of the HP turbine rotor assembly. The stator disc is suitably contoured and ported, and in conjunction with the air seal, apportions the flow of tenth stage cooling air (HP compressor delivery bleed air) over the faces of the turbine second and third stage rotor discs and the third stage stator segment inner platforms.

Insulation blankets are fitted between the segments and the stator casing, to reduce thermal expansion of the casing and to minimize heat transfer to the aircraft structure.

NOTE

Although the HP and LP turbines have been treated as separate units, the numbering of the stages has been consecutive from the front of the engine through the two units. This is to be consistent with the numbering used in the engine functional descriptions.

LOW PRESSURE TURBINE ROTOR ASSEMBLY

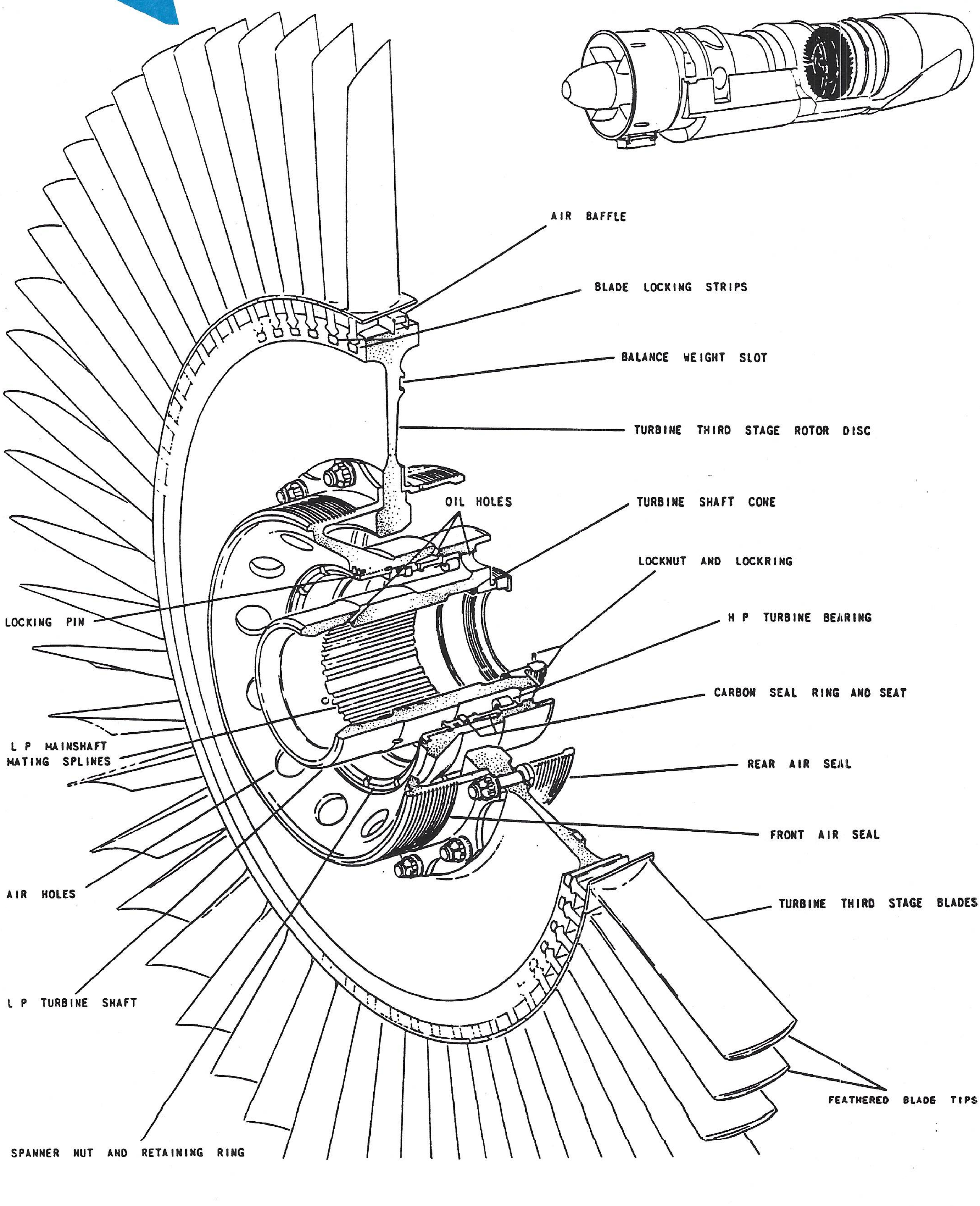
The LP turbine rotor assembly is a single stage design comprising a bladed disc bolted to the LP turbine shaft which is supported by the turbine bearing assembly. The complete assembly, together with the HP turbine bearing, is splined to the LP mainshaft and is centralized at the front and rear by conical seatings. The assembly is retained by a locknut which seats against the rear face of the turbine shaft cone and locked by the tang of a steel lockring which engages with a hole in the LP mainshaft and a slot in the locknut.

The LP turbine rotor assembly absorbs power from the gases passing from the turbine second stage, and transmits it as torque power, via the LP mainshaft, to drive the LP compressor rotor, the LP external gearbox, and the constant speed unit in the inlet frame assembly.

The turbine third stage rotor disc is machined from a stainless steel forging and has fifty-nine solid cast Inconel blades arranged around its outer periphery. The blades are retained in the disc rim by fir tree roots and are retained axially by a tanged locking strip, the tangs being bent outwards against the front and rear face of the disc. The blades have feathered tips to reduce the incidence of damage in the event of blade tip rub. Nicro-brazed stainless steel air baffles are fitted between the extended necks of the blade roots, the baffles being retained axially by tangs which engage in slots in the rim of the disc, and radially by the blade platforms. The function of these baffles is to meter cooling air through the extended necks of the blade roots to reduce the heat transfer from the blades to the disc.

A dovetail slot machined on the rear face of the rotor disc provides for the addition of balance weights during balancing operations. Using the same point of attachment to the LP turbine shaft as the disc, a labyrinth-type rear air seal extends to the rear and mates with a seal extending forward from the turbine bearing assembly. This seal provides a controlled flow of seventh stage cooling air over the rear face of the disc.

The LP turbine shaft is a nickel plated steel forging with the rear external diameter nitrided to form an integral inner race for the LP turbine bearing. On the outer periphery of the shaft, an integral labyrinth-type front air seal mates with the inner rear air seal of the HP turbine rotor assembly. Oil from the bearing assembly passes forward along the LP shaft splines and is directed by centrifugal force through holes drilled diagonally through the LP shaft forward of the internal splines. The oil is then led via drilled holes in the HP turbine rotor shaft to the front face of the HP turbine bearing. This oil is scavenged to the rear sump by centrifugal force through holes in the reversed section of the LP shaft forward of the bearing, and also as an air/oil mixture through passages in the rear conical section of the shaft.



LOW PRESSURE TURBINE ROTOR ASSEMBLY

Housed within the reversed portion of the LP turbine shaft are the outer race and rollers of the HP turbine bearing. This bearing utilizes, when the engine is assembled, the hardened surface of the HP turbine shaft as an inner race. Also housed in the reversed portion of the LP turbine shaft is a carbon seal ring which, together with the HP turbine bearing, and carbon seal ring seat, is held in place by a spanner nut. A locking pin, which is inserted in one of the nut slots, locates in a drilling in the shaft, and is held by a retaining ring housed in a groove machined in the shaft.

NOTE

Although the HP and LP turbines have been treated as separate units, the numbering of the stages has been consecutive from the front of the engine through the two units. This is to be consistent with the numbering used in the engine functional descriptions.

LOW PRESSURE TURBINE BEARING ASSEMBLY

GENERAL

The LP turbine bearing assembly is mounted within the rear frame housing and comprises mainly the housing for the LP turbine bearing, and the engine rear sump, The assembly also embodies features for the distribution and scavenging of oil to and from the LP and HP turbine bearings.

TURBINE BEARING HOUSING

The turbine bearing housing is fabricated from three steel parts welded together to form a mounting for the LP turbine bearing and the location for a, large diameter carbon ring type oil seal. The part which houses the bearing is drilled and channelled at three equidistant points to accommodate the oil tubes which carry lubricating oil to the front face of the bearing. A machined flange on the oil seal housing, provides for attachment of the housing to the forward bolting flange on the inner diameter of the rear frame housing.

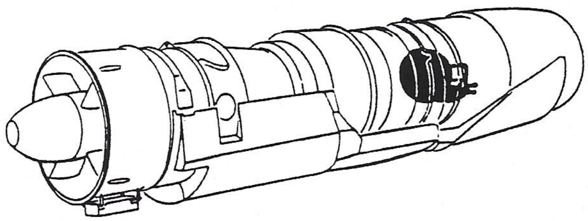
LP TURBINE BEARING

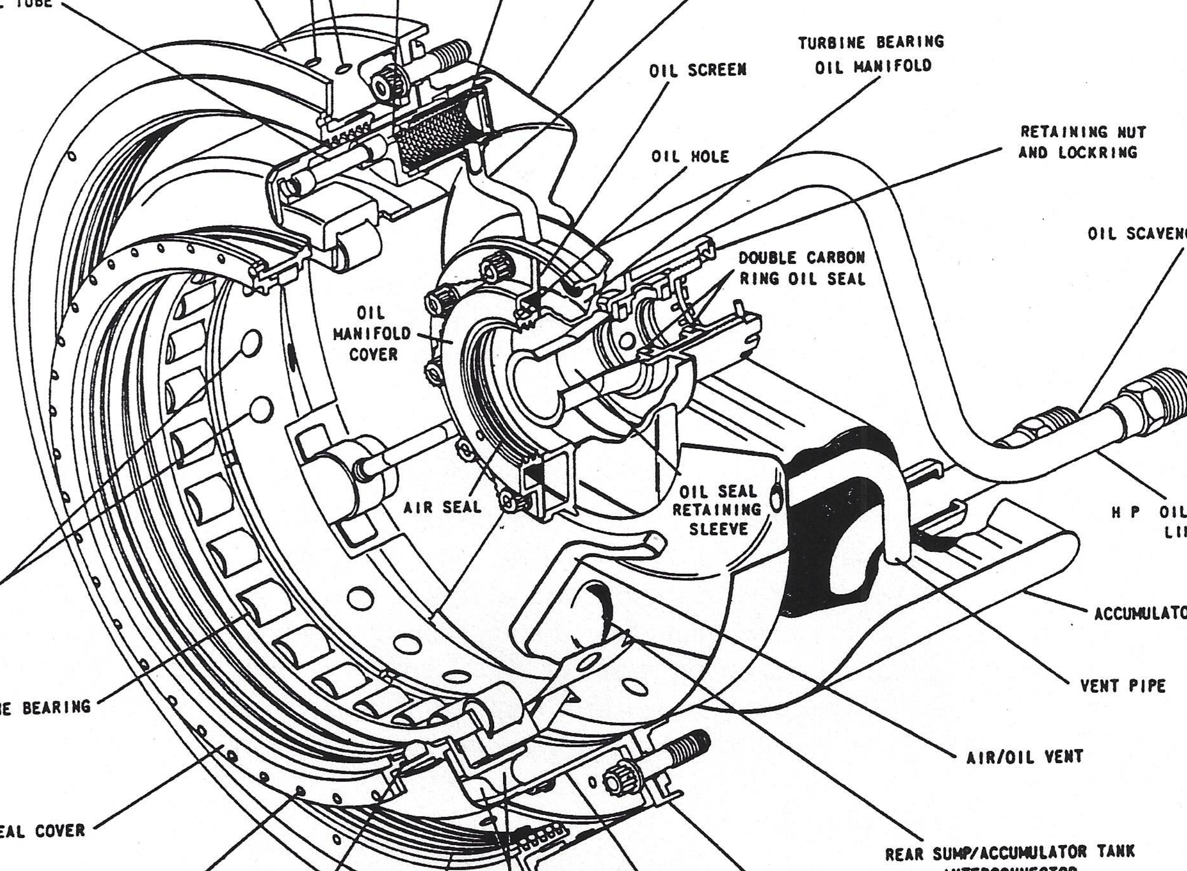
The LP turbine bearing comprises a single row of crowned rollers spaced evenly in the bearing outer race by a silver-plated cage. The bearing outer race locates against a flange on the bearing housing and is retained in position by a flanged extension on the front of the rear sump. Air holes in the extension and the bearing outer race support flange permit a free circulation of cooling air around the bearing.

The LP turbine bearing supports the LP turbine shaft which houses the HP turbine bearing. The HP bearing supports the HP turbine rear stub shaft. The arrangement of mounting the bearings one inside the other in the same transverse plane, reduces the interaction of shaft vibrations and eliminates LP mainshaft deflection.

REAR SUMP AND OIL MANIFOLD

The rear sump is a welded stainless steel assembly which forms the rear cover of the turbine bearing chamber and serves as a collector for the scavenge oil from the bearings and the air/oil mist created by the rotation of the bearing rollers. The hub of the rear sump houses the rear end of the LP mainshaft internal vent tube and accommodates an annular turbine bearing oil manifold. The turbine bearing oil manifold is supplied through a HP oil line which is connected to the inner section oil tubes in the rear frame bullet assembly. From the manifold, oil is supplied to the LP and HP turbine bearings in two separate flows. The oil flow to the LP bearing pas ses radially outward from the manifold through supply lines to three oil screen





LOW PRESSURE TURBINE BEARING ASSEMBLY

housings spaced evenly on the inside of the rear sump outer cylindrical portion. After passing through the screens, the oil flows through oil jets into the oil tubes which lead to the front face of the LP turbine bearing. The flow to the front face of the HP turbine bearing is delivered from the oil manifold through three screen-protected holes in the manifold cover and thence by centrifugal action through drillings and passages in the HP turbine shafting.

An interconnector at the bottom of the rear sump allows scavenge oil from the turbine bearings to drain into an accumulator tank which is welded to the lower rear face of the sump, The oil is scavenged from the accumulator tank through a scavenge line which is connected to the inner section oil tubes in the rear frame bullet assembly. A vent pipe between the top of the accumulator tank and the rear sump ensures proper scavenging from the tank in the event that the oil level in the sump rises above the rear sump/accumulator tank interconnector opening.

Air/oil mist in the bearing cavity is ducted from the bottom of the rear sump, through an air/oil vent, to the annulus formed between the rear sump hub and the internal vent tube. From this annulus the air/oil mist is transferred to the internal oil return tube and thence to the front sump. A machined flange welded to the outer cylindrical section of the rear sump is provided to secure the rear sump and turbine bearing housing to the forward flange of the rear frame housing.

OIL SEALS

The large diameter carbon ring oil seal at the front of the turbine bearing housing seats on the reversed portion of the Lp turbine shaft and, together with the oil seal rings on the LP turbine shaft and the rear shaft of the LP mainshaft assembly, seals the front of the rear sump. The seal ring is retained by an oil seal cover which is riveted to the front part of the bearing housing. A double carbon ring oil seal in the hub of the rear sump seats on the internal vent tube and is pressurized with compressor seventh stage air to complete the sealing of the rear sump. The double seal is retained in the hub by a retaining nut and lockring.

AIR SEALS

Two labyrinth type air seals are provided, one being a small diameter seal integral with the turbine bearing oil manifold cover, the other a large diameter seal which mates with the seal ring bolted on the rear face of the turbine third stage rotor disc. The small seal on the manifold cover seats against the internal oil return tube. The large seal is riveted to the forward end of a cylindrical sheet metal support which uses the same point of attachment as the bearing housing and rear sump. Holes in the seal support apportion the cooling flow of seventh stage air between the rear frame baffle and cover. The seal itself permits a controlled flow of seventh stage air to pass over and cool the rear face of the turbine third stage rotor disc.

REAR FRAME ASSEMBLY

GENERAL

The rear frame assembly is the main rear structural unit of the engine. It provides a suitable structure for attachment of the engine rear mounts and supports the bearings of both turbine rotors. The assembly consists mainly of an outer casing, a rear frame housing which forms the hub of the assembly, five struts, and the rear frame fairing.

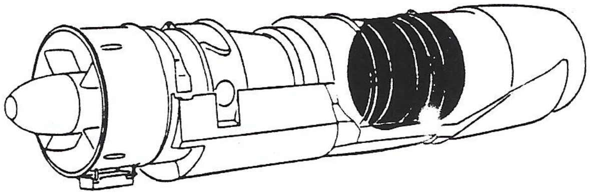
OUTER CASING

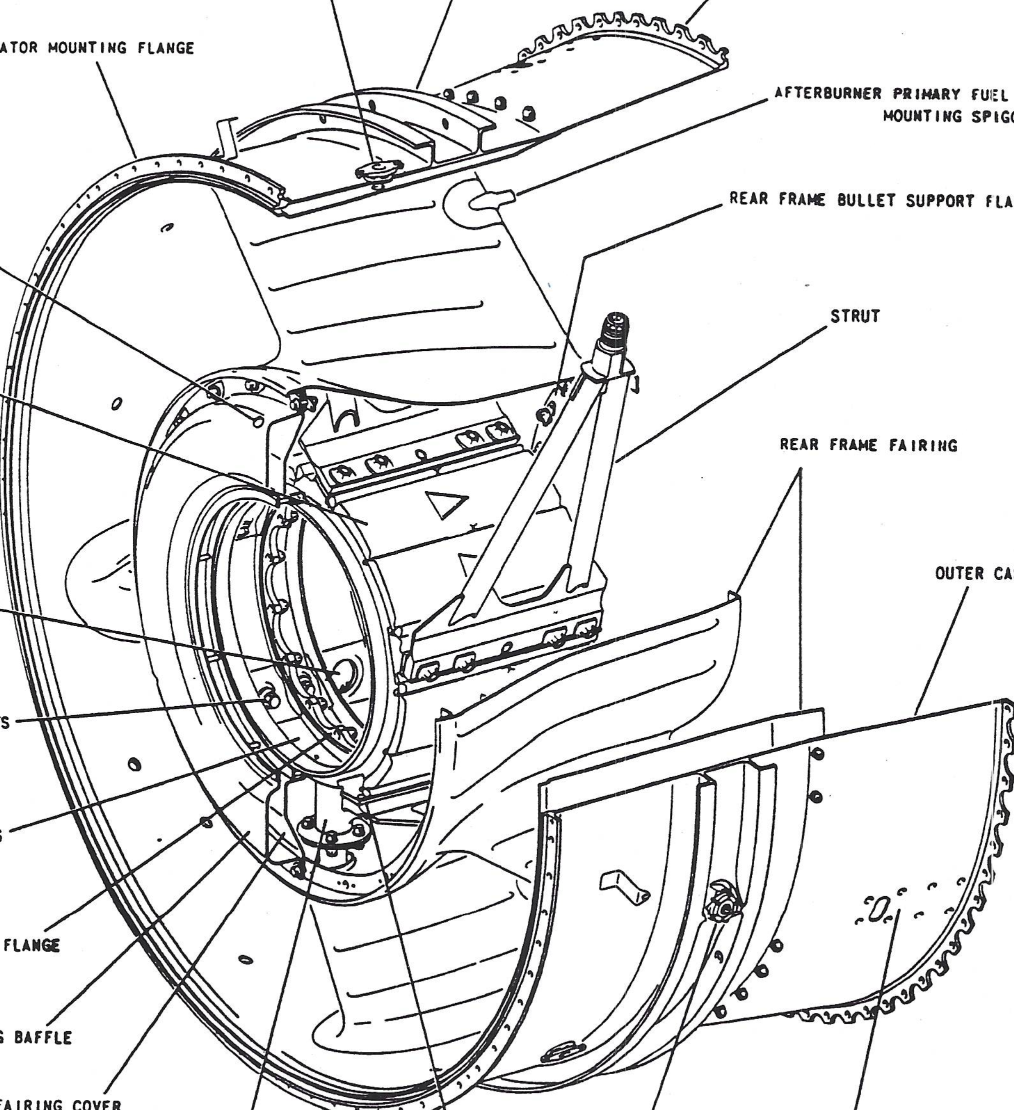
The outer casing comprises a cylindrical front section and a conical rear section which are welded to a channel section main support ring. The support ring provides three points of suspension, one at the top and one on each side, for mounting the rear of the engine. The top mounting is an aircraft fitting which is bolted through holes in the flanges of the support ring, while the side mounts, located above the horizontal centre line of the engine, are used for the attachment of the rear mounting struts. Each side mount comprises a rear mounting pin which is supported in lined drillings in the support ring flanges. Displacement of the mounting pin is prevented by a cotter pin which passee through holes in the head of the mounting pin and a retaining clip. The support ring also carries the outer ends of the rear frame housing support struts.

Machined bolting flanges welded to the front and rear of the outer casing, provide a mounting for the turbine rear stator assembly at the front and the after-burner assembly at the rear. A spigot on the front mounting flange supports the rear of the turbine third stage shroud segments when the turbine rear stator and rear frame assemblies are bolted together. Flanged pads spaced around the periphery of the casing front section provide a mounting for the eight probe, dual thermocouple system used for exhaust gas temperature measurement. Two additional pads on the lower right-hand side of the casing provide alternative mounting positions for the afterburner hot streak relay jet; a third pad at this location accommodates the P7 pressure probe. At the bottom of the casing immediately aft of the main support ring are two bosses, the foremost of which accommodates the oil supply and scavenge lines for the turbine bearing assembly, the rearmost being a mounting for the fuel supply line to the afterburner primary fuel manifold. Provision is made at ten points on the rear section of the casing for attachment of the internally mounted afterburner spray and stabilizer group.

REAR FRAME HOUSING

The rear frame housing encases and supports the turbine bearing assembly and associated sub-assemblies. The housing is a stainless steel machined forging, secured





REAR FRAME ASSEMBLY

centrally and axially by the struts. The turbine bearing assembly is bolted to a flange machined on the inner diameter of the housing. A collector box for seepage oil and waste air is riveted to the lower outside surface of the housing. The collector box is vented to the gas stream through a vent pipe which is attached to the front of the box and passes through an opening in the fairing hub. Four insulation blankets, which serve as a heat shield for the turbine bearing assembly, are positioned and wire locked around the periphery of the housing between the struts; the fifth space is occupied by the collector box.

STRUTS

The five struts are designed to transmit bearing loads to the main support ring, and are arranged to compensate for differential thermal expansion of the casting and rear frame housing. Each strut comprises a solid front leg and a tubular rear leg welded at their outer ends to a shouldered and threaded stub which forms the outer support for the strut, and is secured to the rear frame casing by a castellated nut locked by a cotter pin. The inner ends of the legs are welded to plates which are mounted tangentially on the rear frame housing. Serrations machined on the mating faces of the strut plate, an adjusting strip, and the rear frame housing, permit location of the housing concentrically within the rear frame casing. Elongated holes in the adjusting strip permit it to be moved axially along the bolts to obtain correct bedding of the mating serrations. The adjusting strips compensate for variations between the strut and housing due to tolerance stack-up or service distortion of the parts. An eccentric hexagonal-headed stop pin which is positioned through the housing, adjusting strip and strut plate, is held in position by a cover plate and a retaining ring. The pin absorbs axial loads between each strut and the housing.

REAR FRAME FAIRING

The rear frame fairing provides a smooth passage for the exhaust gases passing through the rear frame by streamlining the struts and smoothly contouring the inner surface of the casing and the outer surface of the rear frame housing. The five aerofoil-shaped vanes of the fairing form streamlined housings for the struts and are integrally formed with the hub of the fairing. The outer ends of the vanes are welded to the cylindrical outer portion of the fairing which is secured to the casing rear section by forty-five mushroom-headed screws, locking nuts, and washers. The hub of the fairing is supported at the front by the fairing cover and the fairing baffle, which in turn are supported at their inner diameters by a spigot machined on the front face of the rear frame housing.

An opening at the bottom of the fairing hub accommodates the vent pipe from the rear frame collector box. Holes in the outer cylindrical portion of the fairing provide openings through which pass the thermocouple probes, the outer ends of the struts, the turbine bearing oil supply and scavenge lines, the afterburner hot streak relay jet, and the P7 probe. A boss is welded on the trailing edge of each vane to support the afterburner primary fuel manifold. Welded around the front flange and riveted to the rear lip of the fairing hub is a series of self-locking anchor nuts. The nuts are used for attachment of the front cover and baffle, and the rear frame bullet assembly respectively. The fairing is strengthened by embossed fluting on the surfaces of the vanes and hub.

REAR FRAME BULLET ASSEMBLY

GENERAL

The rear frame bullet assembly is located at the rear of the inner housing of the rear frame. The main function of the assembly is to provide a smoothly transitioned passage for the engine exhaust gases leaving the rear frame, and to seal the rear end of the rear frame hub cavity into which the internal air vent tube exhausts, In addition, the bullet assembly forms the rear supporting member of the rear frame fairing and houses the inner section of the rear bearing oil tubes. The assembly comprises mainly a fairing support cylinder and ring, a rear frame housing cover a bullet, and the inner and outer sections of the rear bearing oil tubes.

FAIRING SUPPORT CYLINDER AND RING

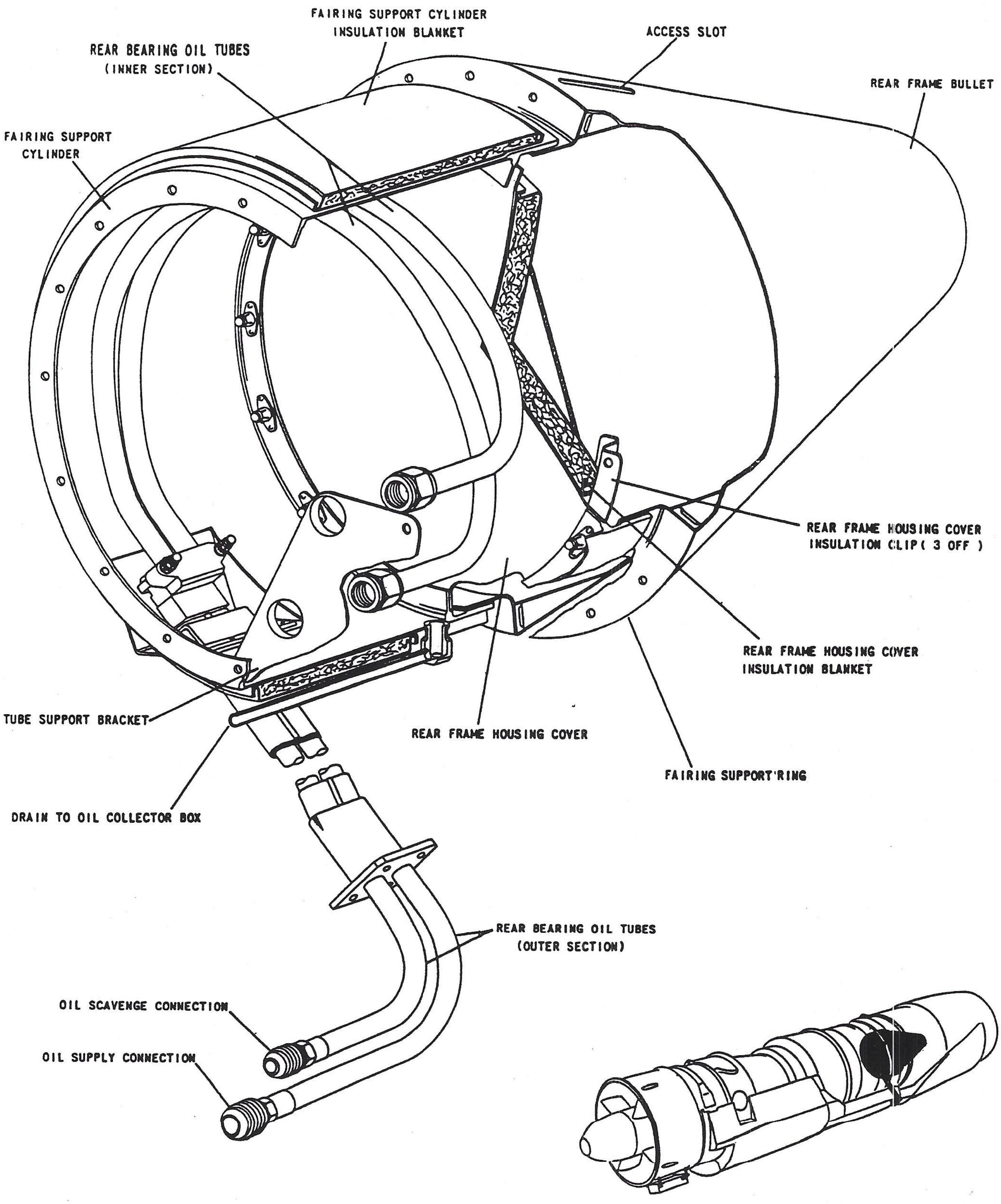
The fairing support cylinder is a stainless sheet steel fabrication with machined flanges welded to the front and rear faces, the front flange being used to attach the fairing support cylinder to the rear bolting flange of the rear frame housing. The fairing support ring consists of an angled circular collar, which locates in the extended portion of the fairing support cylinder rear flange. Together with the rear frame bullet, the support ring is bolted to the inward projecting rear flange of the rear frame fairing, An insulation blanket is wrapped around the periphery of the fairing support cylinder to minimize the transfer of heat to the rear frame hub cavity, A drain, located at the bottom of the fairing support cylinder and immediately forward of the rear flange, removes any residual oil which tends to collect in the rear frame hub cavity. The oil is drained forward into a collector box in the rear frame, from which it is vented into the engine exhaust stream.

REAR FRAME HOUSING COVER

The rear frame housing cover, comprising a concave stainless steel plate, is bolted to the inward projecting rear flange of the fairing support cylinder and is covered on the rear face by an insulation blanket. The rear frame cover and insulation blanket separate the rear frame hub cavity from the relatively high. temperatures inside the rear frame bullet. The insulation blanket consists of a pad of insulation sandwiched between two layers of Inconel foil and is positioned by three equi-spaced insulation clips which are bolted to the rear face of the cover. The blanket is firmly retained against the rear frame housing cover by locking wire which passes between the three insulation clips.

REAR FRAME BULLET

The rear frame bullet is a conical steel pres sing with a mounting flange welded



REAR FRAME BULLET ASSEMBLY

to the front face for bolting the bullet to the rear flange of the rear frame fairing. Access to the mounting bolt heads is gained through slots in the bullet skin immediately behind the front face. An inner skin adjacent to the slots minimizes the entry of hot exhaust gases into the bullet cavity. A small vent hole in the inner skin maintains equal gas pressure loads on each side of the bullet skin.

REAR BEARING OIL TUBES

The rear bearing oil supply and scavenge tubes both consist of an outer section which passes inward from two external connections, through the bottom vane of the rear frame, and an inner section which is housed within the fairing support cylinder. The outer section is secured to a mounting boss at the bottom of the rear frame outer casing and terminates at a junction on the bottom of the support cylinder. The inner section passes from the junction and terminates immediately behind a bracket which supports the oil tube connections of the turbine bearing assembly.

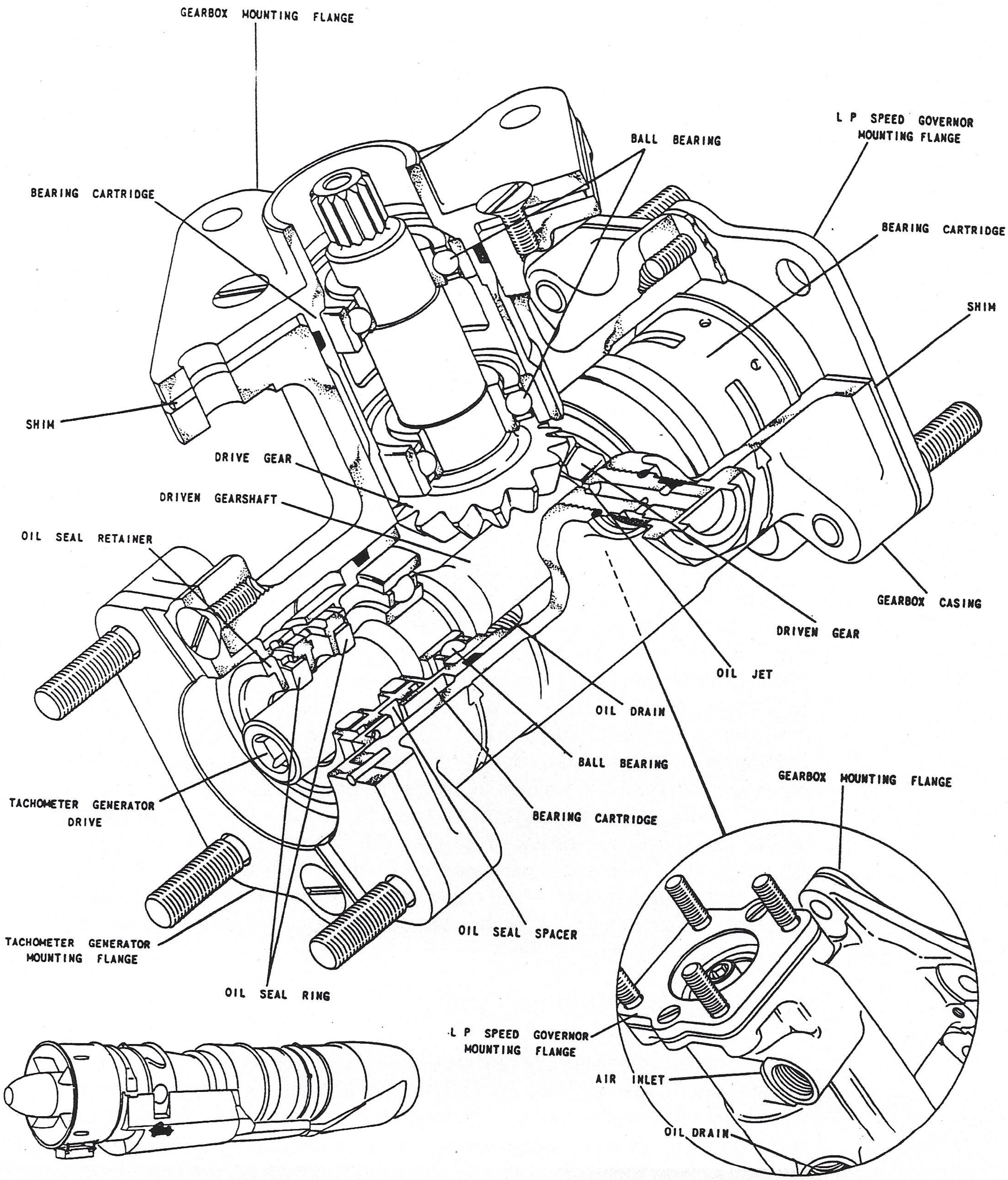
LOW PRESSURE EXTERNAL GEARBOX ASSEMBLY

The LP external gearbox assembly is located on a mounting pad at the outer end of the front frame No. 6 strut, the drive to the gearbox being supplied by shafting from the internal gearbox. The cast magnesium gearbox casing is T shaped in section with a flange at each end of the T head for mounting the LP tachometer generator and the LP speed governor. The tachometer generator and the speed governor measure and limit respectively the rpm of the LP compressor rotor.

The drive is transmitted from a radially positioned shaft to one parallel to the engine axis by means of a pair of case hardened, phosphated, steel, bevel gears. The bevel drive gear on the radial axis is centrally located by two ball bearings in a flanged, steel cartridge, which in turn is retained in the gearbox casing by two machine screws. The screws also locate and retain the steel shim between the flanges of the gearbox casing and the bearing cartridge.

The driven gear is dowelled to a hollow gearshaft and meshes with the drive gear on the radial axis. The shaft and gear combination is mounted in two ball bearings located in bearing cartridges in the gearbox casing. The front and rear ends of the driven gearshaft are machined to accommodate the square-ended driveshafts of the LP tachometer generator and the LP speed governor respectively.

Lubrication of the bevel gears is by a screened oil jet positioned in the outer casing, which supplies a spray of oil to the contact point of the gears. The ball bearings in the gearbox are splash lubricated. External piping delivers pressure oil to the gearbox and carries scavenge oil to the HP external gearbox sump. A pair of oil seal rings, separated by a steel spacer, are fitted at each end of the driven gearshaft to prevent oil seepage from the gearbox. The cavity between the oil seal rings is pressurized with HP compressor air supplied through an external fitting and channelling in the gearbox casing.



LOW PRESSURE EXTERNAL GEARBOX ASSEMBLY

HIGH PRESSURE EXTERNAL GEARBOX

GENERAL

The HP external gearbox assembly is located on the mounting pad at the outer end of No. 5 strut in the front frame casing. When viewed from the rear, the gearbox follows the contour of the front frame, through approximately 40 degrees, up the right-hand side of the engine. The drive for the gearbox is transmitted from the HP compressor front stub shaft to the HP gear train in the internal gearbox assembly and then by a quillshaft to the external gearbox. The assembly consists of a gearbox casing and front cover, together with the gear train required to drive an aircraft power take-off assembly and engine auxiliary components mounted on the gearbox.

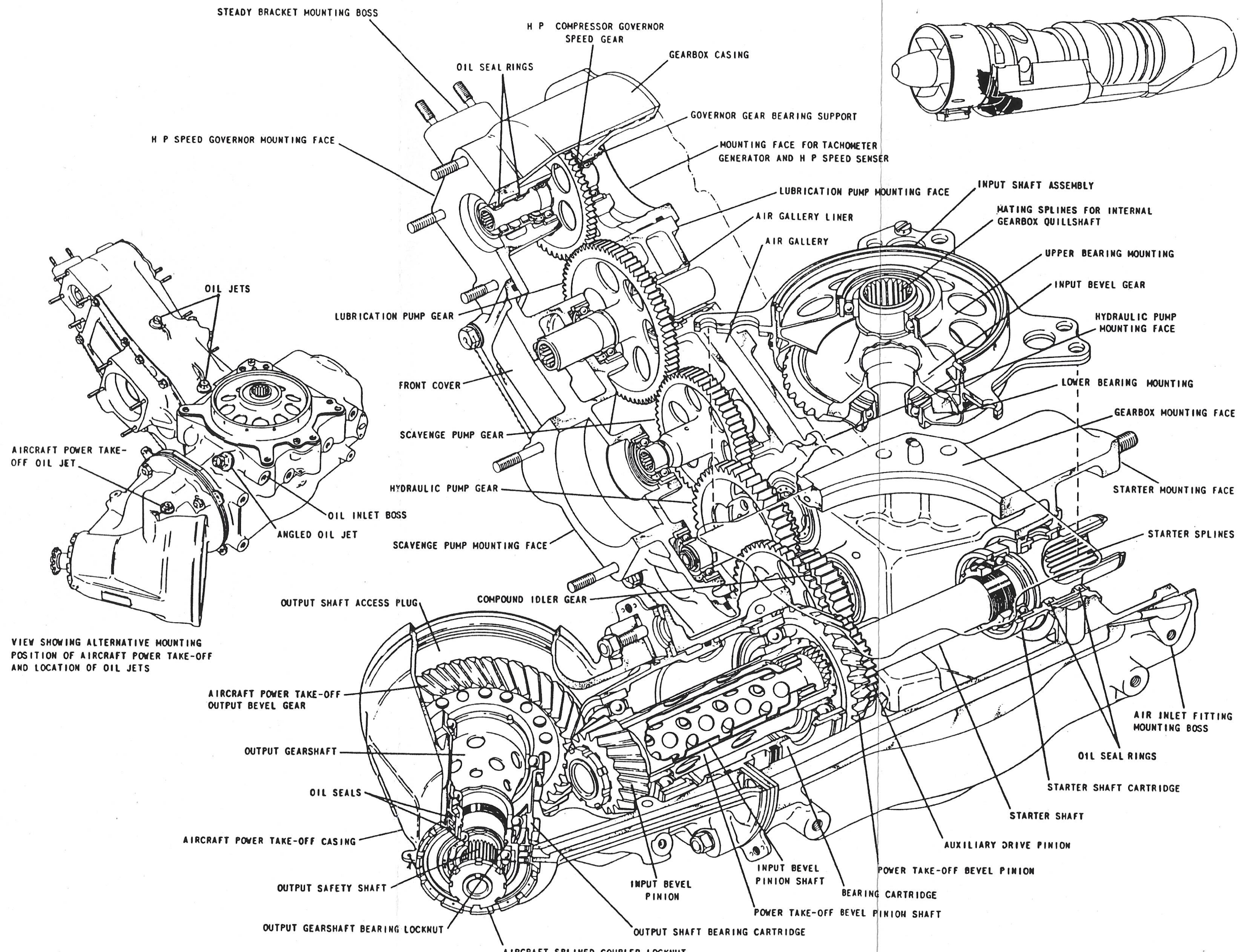
The front face of the gearbox has three pads which accommodate the aircraft power take-off assembly, the engine oil scavenge pump, and the HP speed governor. The rear face has four mounting pads to which are mounted the engine starter, the hydraulic pump, the oil lubrication pump, and the tachometer generator and HP speed sensor.

GEARBOX CASING AND FRONT COVER

The gearbox is a crescent shaped magnesium casting with drillings to supply lubricating oil to the gears and bearings. Forward of the rear face, an integral inner wall houses the bearing cartridges supporting the rear ends of the gearshafts. The cavity formed between the rear' face and the inner wall is sealed and serves as an air gallery for compressor seventh stage air which is used to pressurize the oil seals. The front cover, which is bolted to the front face of the gearbox with an 'O' ring interposed in the joint, is also of cast magnesium. The cover supports the forward end bearings of the hydraulic pump gear, the scavenge pump gear and the lubrication pump gear, and provides a mounting flange for the oil scavenge pump. When the gearbox is installed on the engine it is steadied by a bracket fitted on a mounting boss at the upper right-hand end of the casing, the bracket in turn is secured to the front frame No. 4 strut cover. Four bosses located on the left-hand side of the casing below the gearbox mounting face accommodate the engine oil cooler mounting brackets. The mounting pads for the engine auxiliaries are machined so that their axes are parallel to the engine axis.

INPUT BEVEL GEAR ASSEMBLY

The input bevel gear assembly consists of a bevel gear supported by two single row angular contact bearings installed in bearing mountings. The upper mounting is screwed into the lower mounting, and retained in position by a tanged, steel locking ring. The lower mounting is retained in position on the gearbox mounting face by two fillister head screws.



HIGH PRESSURE EXTERNAL GEARBOX

POWER TAKE-OFF INPUT SHAFT AND BEARING CARTRIDGE

The power take-off input shaft assembly comprises three concentrically mounted shafts with integral gears supported by two ball bearings housed in a flanged steel cartridge. The bearing cartridge mounting flange is fitted between the gearbox casing and the mounting flange of the aircraft power take-off casing with the forward end of the cartridge extending into the aircraft power take-off casing. The three gears comprise an auxiliary drive pinion, an input bevel pinion, and a power take-off bevel pinion. The input bevel gear meshes with the power take-off bevel pinion, the shaft of which extends forward and is supported by a ball bearing at each end. The power take-off bevel pinion shaft is hollow with rowe of lightening holes drilled round the circumference. Internal splines at the rear of the shaft, inside the pinion, mate with splines on the input bevel pinion shaft and the auxiliary drive pinion shaft.

The input bevel pinion shaft is hollow and drilled with lightening holes. A close tolerance diameter at the rear of the input bevel pinion teeth locate the shaft centrally inside the forward end of the power take-off bevel pinion shaft. The input bevel pinion delivers the drive to the aircraft power take-off bevel gear.

The auxiliary drive pinion ehaft is the inner member of the three concentrically mounted shafts. It has a spur gear at the rear and threads with a locknut and washer at the forward end to secure the three shafts together. Internal splines at the rear of the shaft mate with the splines on the forward end of the starter shaft.

AIRCRAFT POWER TAKE-OFF ASSEMBLY

The aircraft power take-off assembly is bolted to the front face of the mounting pad on the front of the HP external gearbox. The assembly consists of a casing, an output shaft assembly, an output safety shaft, a power take-off drive oil seal and an output shaft access plug.

The aircraft power take-off casing is of cast magnesium and is installed on the front face of the HP external gearbox in either one of two positions, approximately 180 degrees apart, dependent upon the engine installation.

The output shaft sub-assembly consists of an output bevel gear bolted to the flanged end of the output gearshaft. The gear meshes with the input bevel pinion. The output gearshaft and bevel gear are supported by two single row ball bearings mounted in a bearing cartridge. The output gearshaft has splines machined on the inner diameter of the forward end which mate with the splined on the rear of the output safety shaft. Three rows of lightening holes are drilled round the body of the shaft.'A blanking plug is installed at the rear of the internal splines and is retained by an internal circlip. Threads on the shaft accommodate a special type of sleeved locknut which has a grease packed ball bearing fitted at the forward end of its inner diameter to support the output safety shaft; a circlip at the front of the bearing retains the bearing and safety shaft in position. The forward outer diameter of the locknut is smooth and provides the seat for a double carbon ring oil seal.

The output safety shaft, which is hollow except for the centre waisted section, fits into the internal splines in the forward end of the output gearshaft. The shaft is located axially by its shoulder, which butts against the front grease packed bearing and is clamped to the bearing by the aircraft splined coupler. The waisted section is to provide a shear spot which, in the event of overload conditions, will shear and thus prevent damage to the gearbox and /or engine.

An oil seal housing is screwed into the forward end of the output gearshaft bearing cartridge. Slots in the forward face of the housing accommodate a wrench for tightening, and a row of holes drilled in the large diameter of the housing provide passage for compressor seventh stage air for pressurizing the oil seals.

Access to the output gearshaft is provided by a plug installed in the casing at the rear of the bevel gear. The plug is of cast magnesium and is a sliding fit in the casing. It is retained by a ring and an 'O' ring forms an oil seal between the plug and the casing. Three equi-spaced integrally cast lugs are provided for withdrawing the plug.

STARTER SHAFT

The starter shaft is a steel forging which is bored out from the front and rear with a small section left solid near the forward end. External splines on the forward end of the shaft mate with the internal splines at the rear of the auxiliary drive pinion. The shaft is supported by a ball bearing mounted at the front end of a bearing cartridge at which point the shaft is retained by a washer and locknut. The bearing is retained in the cartridge by a circlip. A double, carbon ring oil seal is mounted in the rear of the cartridge, the shaft outer diameter providing the seat for the seal rings. Compressor seventh stage air passes through slots in the cartridge to pressurize the cavity between the seal rings. A slinger on the starter shaft between the bearing and the oil seal ring deflects incoming sealing air and prevents oil starvation of the bearing. The slinger also serves to induce oil mist through the bearing. Both the oil mist and the sealing air are exhausted through slots in the starter shaft cartridge into the gearbox sump. Internal splines at the rear of the shaft are for mating with the engine starter driveshaft.

COMPOUND IDLER GEARS

The compound idler gears consist of two integral spur gears mounted on a hollow shaft, the larger gear meshing with the auxiliary drive pinion and the smaller one with the hydraulic pump gear. Each end of the idler shaft is supported by a ball bearing mounted in a cartridge which is an interference fit in the external gearbox casing. At the front of the shaft, a plug and an 'O' ring are fitted in the gearbox casing and retained by an internal circlip. At the rear, the bearing and cartridge are located in position by an air gallery plug, the flange of which butts against a shoulder in the gearbox casing, The air gallery plug is of magnesium and has a flange with four cross grooves to permit air circulation.

HYDRAULIC PUMP GEAR

The hydraulic pump gear consists of two spur gears integral with a shaft. The larger gear meshes with and is driven by the smaller of the compound idler gears, whilst the smaller gear meshes with and drives the scavenge pump gear. The gear-shaft, which is hollow, is mounted on two ball bearings; the inner races butt against shoulders on the gearshaft. Internal splines towards the rear end of the gearshaft, mate with those on the hydraulic pump driveshaft, which fits inside the gearshaft and is retained by a circlip.

The bearing at the rear of the hydraulic pump gearshaft is carried in a steel cartridge which is an interference fit in the gearbox casing. The front bearing is mounted in a steel cartridge fitted to the gearbox front cover. Immediately behind the rear bearing cartridge is an oil seal cartridge and oil seal. The oil seal is of the double ring type and the hydraulic pump driveshaft serves as the seat for the seal rings. Compressor seventh stage air from the air gallery is fed through slots in the cartridge to pressurize the cavity between the seals.

SCAVENGE PUMP GEAR

The scavenge pump gear is a single spur gear with an integral hollow shaft. It is supported at the front by a ball bearing mounted in a cartridge housed in the gearbox front cover, and at the rear by a bearing mounted in a cartridge fitted into the inner wail of the gearbox. Internal splines at the front of the shaft provide the drive for the oil scavenge pump, and the spur gear meshes with and drives the lubrication pump gear.

LUBRICATION PUMP GEAR

The lubrication pump gear is a single spur gear with an integral hollow shaft which is supported by a ball bearing at each end. At the rear, the shaft passes through a steel air gallery liner which is installed between the inner wall and the rear face of the gearbox to prevent oil leakage into the air gallery. Internal splines at the rear end of the shaft provide the drive for the oil lubrication pump, and the spur gear meshes with and drives the HP compressor speed governor gear.

HP COMPRESSOR SPEED GOVERNOR GEAR

The governor spur gear has an integral hollow shaft and is supported by two ball bearings. The rear bearing is mounted in a steel flanged cartridge which is housed in a bearing support installed in the gearbox rear face. The forward section of the shaft is necked and a double carbon ring type oil seal, mounted in a cartridge, seats on this portion of the shaft. Compressor seventh stage air is fed through holes in the cartridge to pressurize the cavity between the seal rings.

Internal splines at the front and rear of the shaft transmit the drive to a HP compressor speed governor, and a tachometer generator and a HP speed sensor respectively.

LUBRICATION

Lubrication of the gearbox is effected by oil jets directed at gear meshes, and the oil mist created by the gear action serves to lubricate the bearings. Two oil jets, positioned at the top of the casing, approximately six inches apart, spray oil onto the spur gear train. A third oil jet of the angled type is located near the top of the gearbox just forward of the gearbox mounting pad, and sprays oil at the meshing point of the input bevel gear and the power take-off bevel pinion. A fourth jet is mounted in the aircraft power take-off for lubrication of the bevel gears. Each oil jet is screened to protect the jet orifices from blockage by foreign matter.

Two oil bobbins are positioned in the oil feed and return passages at the joint between the HP external gearbox and the aircraft power take-off. The bobbin at the top of the joint is in the oil feed passage to the aircraft power take-off, and the one at the bottom is in the oil return passage.

ENGINE FIREWALL ASSEMBLY (Engine Shroud)

GENERAL

The engine firewall assembly, which comprises a front and rear section, isolates the engine nacelle from auxiliary equipment and piping located round the underside of the engine. The assembly was originally named the engine shroud. A flow of air through the auxiliaries compartment formed by the front section, vaporizes and carries away any fuel and oil leakage which may occur during engine running, and hence reduces the risk of fire. Waste air from the auxiliaries compartment and exhaust air from the HP fuel pumps is expelled to atmosphere through ducts in the rear section. The air flows are induced rearward by the action of an airframe-mounted ejector casing located round the engine final nozzle. All openings in the firewall are covered with screens which serve as flame traps in the event of fire.

FRONT SECTION

The front section of the firewall comprises a panelled framework which extends along the lower half of the engine from the inlet frame rear bolting flange to approximately the mid point of the mid frame outer casing. The framework formers and stringers are made from stainless sheet steel and are bolted to supports on the engine casings. Corrugated stainless steel panels are bolted to anchor nuts riveted on the framework, and the panels and framework are detachable to facilitate engine maintenance. Doors on the underside of the firewall provide access to the engine starter, engine controls, and systems installation connections; the starter access door is supplied by the airframe manufacturer.

Screened openings in the front face of the firewall permit a proportion of the nacelle (secondary) air flow to enter the auxiliaries compartment; air entering the compartment is termed tertiary air. In addition, a small screened opening in each side of the firewall permits fire extinguisher fluid to be sprayed into the auxiliaries compartment in the event of fire during ground running. Other openings in the front section of the firewall accommodate the hydraulic oil reserve indicator and the power control linkage connection as well as fuel, oil and electrical connections.

REAR SECTION

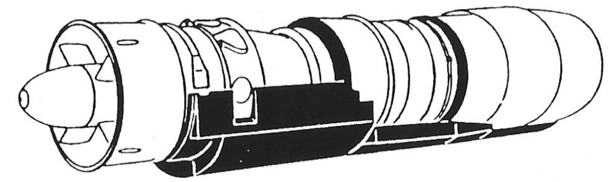
The rear section of the firewall comprises an air duct casing which extends from the rear bulkhead of the front section to the afterburner shroud. The casing is made up of corrugated panels in the form of an inner platform which is supported by brackets bolted to the engine casings, and a channel section outer platform which is bolted to anchor nuts riveted along the edges of the inner platform. Sliding sections in the platform allow fox differential thermal expansion between the firewall and the engine casings, and facilitate removal of the afterburner assembly during ground maintenance.

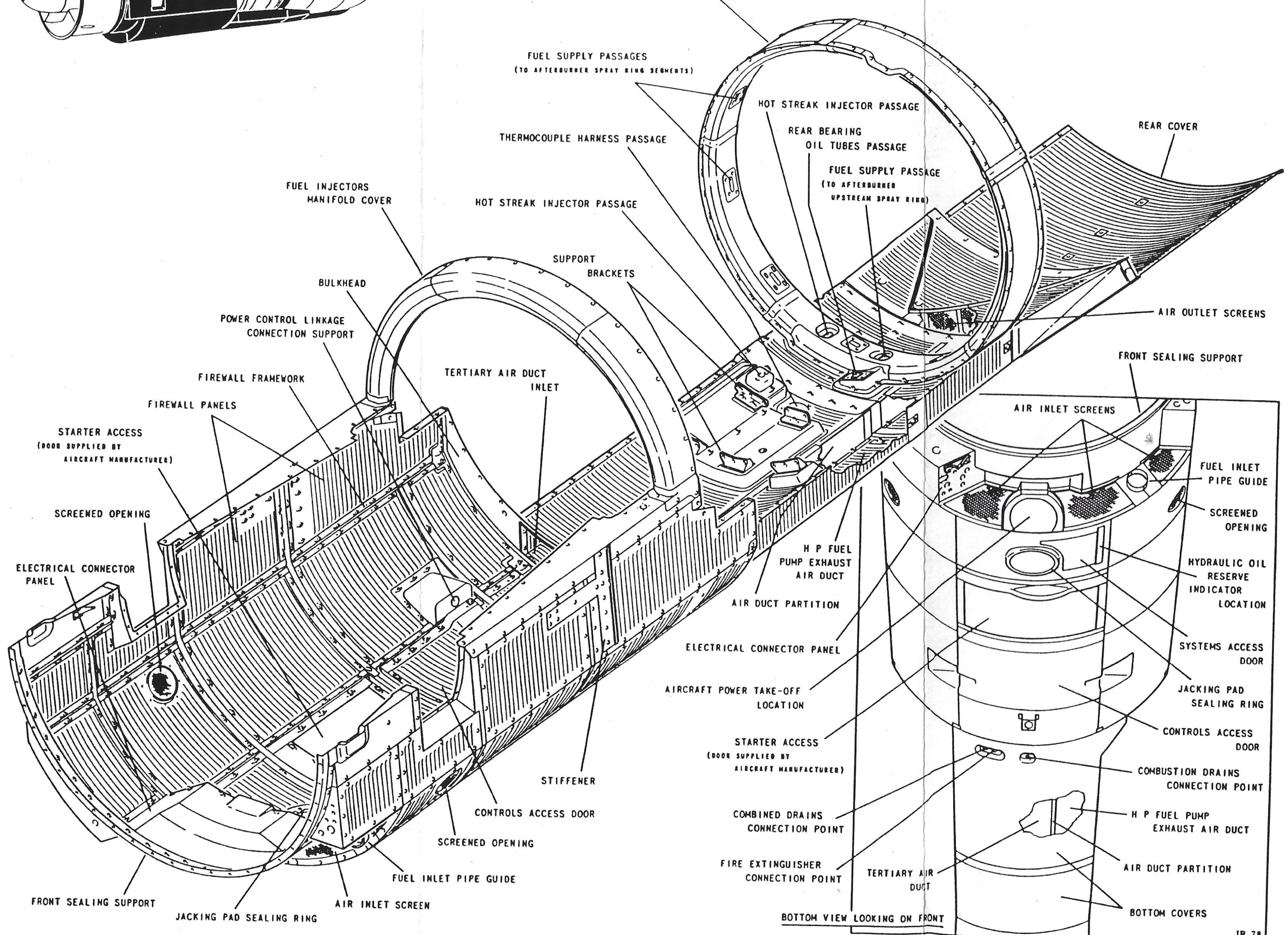
An axial partition between the inner and outer platforms divides the space into two air ducts. The large right-hand duct carries tertiary air rearwards from the auxiliaries compartment and also serves as a channel for fuel, oil and electrical service lines to the rear of the engine. The smaller left-hand duct carries the relatively hot exhaust air from the HP fuel pump air turbines to the rear of the engine. The common outlet from the ducts is screened to prevent rearward flame propogation in the event of fire. A rear cover bolted to the bottom of the afterburner shroud, directs the outlet air from the ducts to the rear of the engine where it joins the secondary air stream being expelled to atmosphere through the airframe ejector casing.

Openings in the inner platform provide passages for the afterburner and hot streak injector fuel supply lines, the rear bearing oil tubes and the thermocouple harness. Small openings in the outer platform accommodate the combined drains and combustion drains connections, and the fire extinguisher connectors.

MANIFOLD COVERS

A manifold cover, which encloses the upper half of the primary fuel injector supply pipes, is vented into the auxiliaries compartment so that any fuel leakage and vapour from this region is exhausted to atmosphere by the tertiary air stream. The cover engages with a machined groove immediately ahead of the injector mounting bosses on the mid frame outer casing and is bolted at the rear to a semi-circle of anchor nuts riveted round the periphery of the outer casing. A similar cover for the afterburner fuel manifold is vented into the tertiary air duct. It is proposed to delete the outer panels of this manifold cover on later engine models.





ENGINE FIREWALL ASSEMBLY (Engine Shroud)

NACELLE AIR RESTRICTOR ASSEMBLY

GENERAL

The nacelle air restrictor assembly is designed to obtain the best matching of the intake, engine, and ejector over the operating envelope of the aircraft. In order to achieve this, the restrictor assembly is composed of two parts. These are a fixed restrictor, a n d a variable restrictor which is made up of four automatically operated flaps.

The flow area provided by the fixed restrictor and the flaps has been chosen to give the highest possible thrust augmentation from the secondary flow at high Mach numbers, and to limit the by-pass flow at low Mach numbers, in order to keep the inlet flow distortion within limits. Because of the pressure drop across the restrictor, it has been possible to stress the portion of the engine tunnel aft of the restrictor assembly for a lower pressure differential across the tunnel wall, and thereby save weight in the aircraft structure. The fixed restrictor assembly is attached to the rear flange of the LP stator casing using the casing attachment bolts.

Detailed information regarding the secondary airflow through the engine tunnel and the ejector action of the final nozzle will be found in the relevant Arrow 2 Engineering Order.

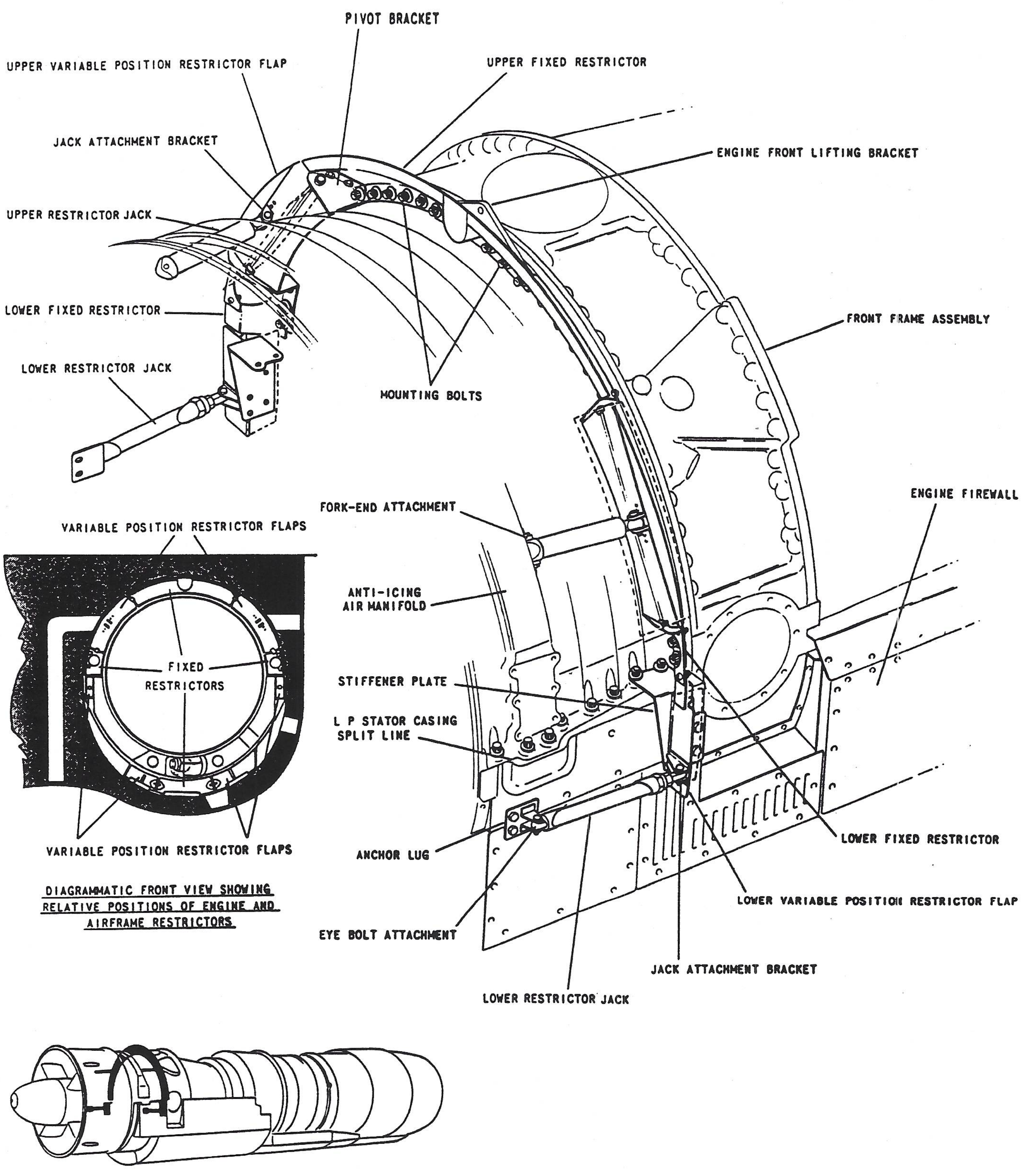
FIXED RESTRICTOR SECTIONS

The o n e large and two small fixed restrictor sections, which are fabricated from stainless steel sheet, extend round the upper half of the LP stator casing interposed by the two upper variable flap sections. Fusion welded, laminated construction provides strength and rigidity to the fixed sections. A 'U' shaped housing formed in the upper fixed restrictor section adjacent to the engine front lifting bracket, provides clearance for the attachment of the engine lifting sling to the bracket.

The two lower fixed restrictor sections are cut away to permit the anti-icing air supply line to pass through them. The outer member of each restrictor section is detachable to facilitate removal of the anti-icing air supply line during engine maintenance.

UPPER VARIABLE POSITION RESTRICTOR FLAPS

Two variable position restrictor f l a p s of aerofoil section are located on the upper half of the LP stator casing and follow the contour of the openings provided by the fixed restrictor sections. Each flap is fabricated from stainless steel sheet and is brazed to a centre tube which acts as a pivot for the flap assembly. Pivot brackets, bolted to the fixed restrictor sections retain the flaps, allowing them to pivot about



NACELLE AIR RESTRICTOR ASSEMBLY

their axes.

The degree of opening of the upper, variable position restrictor flaps is determined by two spring-loaded jacks, the forward ends of which are retained by fork ends bolted to the anti-icing air manifold of the LP stator casing. The jack plungers are pinned to attachment brackets riveted to the flaps.

LOWER VARIABLE POSITION RESTRICTOR FLAPS

The two lower variable position restrictor flaps are hinged to angular stiffener plates, which are bolted to the LP stator casing split line and the engine firewall assembly forward of the rear flange of the casing. Each flap is fabricated in two sections from fusion welded stainless steel sheet. The rear section forms an integral stiffener which also serves as a stop for the flap when in the fully open position. Two brackets brazed to the forward face of the flap, provide a fork for the pin attachment of the lower jack. The forward end of the jack is retained by an anchor lug bolted to the engine firewall.

RESTRICTOR JACKS

The upper and lower jacks, although differing in size, are of the same general construction. The stainless steel jacks each comprise a tubular casing, housing a plunger and a spring.

An internal stop is incorporated in the two upper jacks in the form of a free floating sleeve on the plunger. When the spring is compressed, the sleeve contacts the outer casing end cap, thus preventing further travel of the plunger and determining the maximum open position of the restrictor flap.

OPERATION

During ground running and at aircraft speeds below Mach 0.55 a depression exists in the air intake, and the variable position flaps of the restrictor remain in the closed (vertical) position.

The intake depression causes spring-loaded duct gills, located in the articulating duct forward of the engine, to close to prevent reverse flow into the duct. Under these conditions, the ejector effect of the final nozzle induces a small depression in the compartment between the engine and the engine tunnel (designated as Zone 2), and also at the aft section of the engine accessories compartment (designated as Zone 1).

This depression causes spring-loaded pressure vent doors to open and allow air from atmosphere to enter the engine tunnel. The vent doors are located in the side of the nacelle wall adjacent to the engine front frame, and in the engine access door on the underside of the nacelle. A percentage of the incoming air is drawn into the accessories section due to the depression in the rear section of the compartment.

The remainder of the air flow from the pressure vent doors passes over the front section of the engine, through the relatively small air gap provided by clearance between the restrictor and the contour of the engine tunnel, and is drawn to the rear of the engine to cool and vent the external engine surfaces and aircraft structure.

The cooling and venting air flows eventually combine and pass through the final nozzle ejector. Above Mach 0. 55 a small percentage of additional thrust is provided by the air flows due to heat from the afterburner casing being passed into the engine cooling airstream.

Above aircraft speeds of Mach 0. 55 the pressure in the air intake duct becomes greater than ambient due to the ram effect. Under these conditions the intake duct gills open, allowing the pressure in the bay to rise above ambient and thereby causing the pressure vent doors to close.

The variable position restrictor flaps are designed to open at a specific pressure differential, and thus the time at which they open is dependent on aircraft speed, altitude, a n d the amount of by-pass flow. The point of opening also depends on whether the afterburner is on or off since this has a marked effect on the ejector action of the final nozzle and thus the amount of by-pass flow.

AUXILIARY AND ACCESSORY DRIVES

GENERAL

The auxiliary and accessory drives consist of an HP gear train and an LP gear train, the power to drive both gear trains being drawn from the HP compressor and the LP compressor respectively.

HP GEAR TRAIN

A bevel gear (2) is splined to the HP compressor shaft (1) and drives a bevel pinion (3) which turns the drive through 90 degrees. A quill shaft (4) which is splined to the bevel pinion extends down through No. 5 strut of the inlet frame, and transmits the power from the bevel pinion to an input bevel gear (7) mounted in the HP external gearbox (5). The drive is then turned through 90 degrees by a power take-off bevel pinion (8) mounted on a shaft in the input shaft assembly. This assembly comprises three concentrically mounted shafts with integral gears. Internal splines at the rear of the power take-off bevel pinion shaft, inside the pinion, mate with the splines on the input bevel pinion shaft and the auxiliary drive pinion shaft. The input bevel pinion shaft accommodates an input bevel pinion (9) which drives an output bevel gear (10) in the aircraft power take-off gearbox (6). The auxiliary drive pinion shaft accommodates an auxiliary drive pinion (11) which transmits the drive to a series of spur gears which in turn drive the auxiliary components through internally splined integral shafts.

The initial drive for the gear trains is provided by the engine starter through internal splines in a starter shaft which is in turn splined to the auxiliary drive pinion haft.

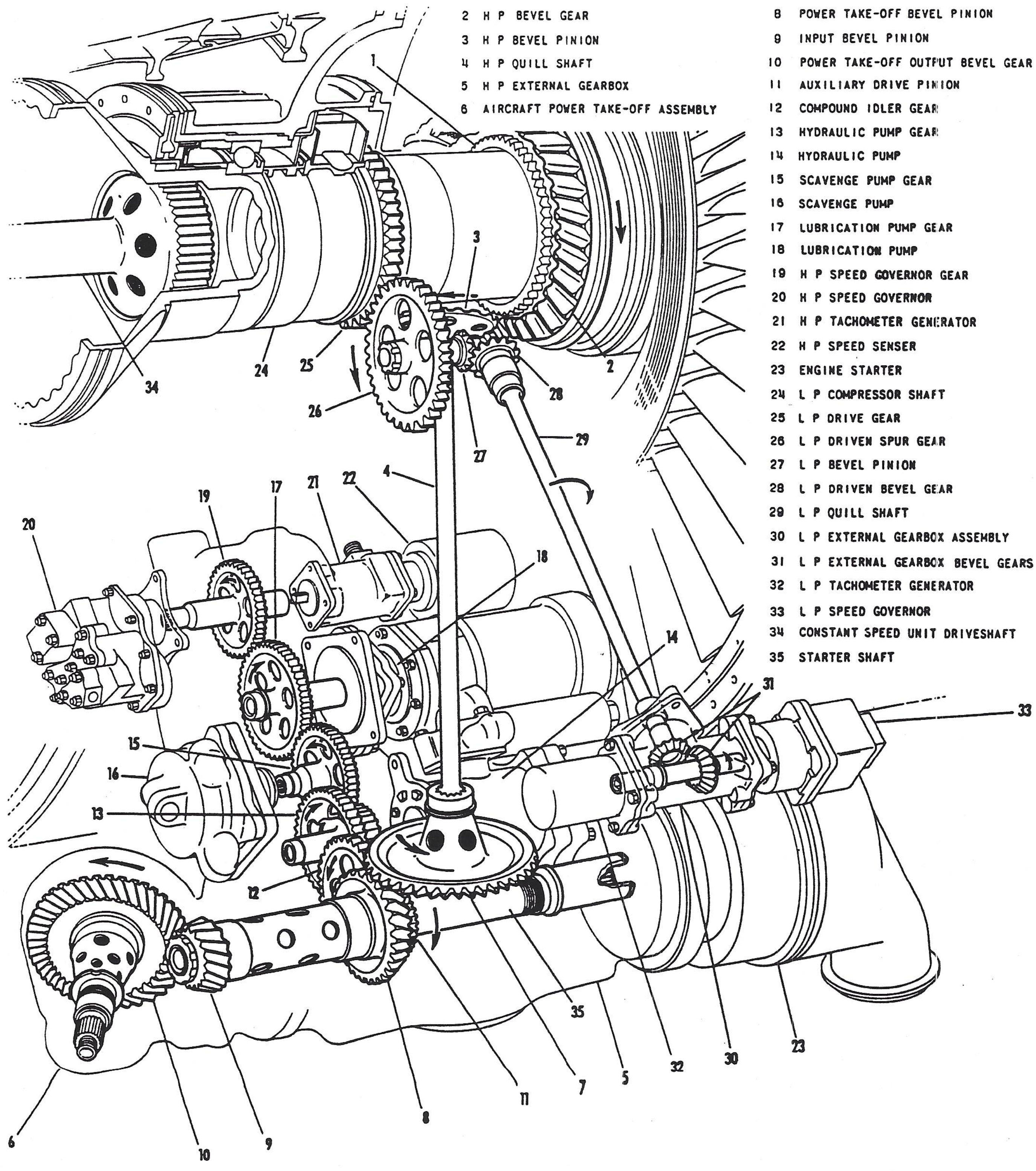
LP GEAR TRAIN

A drive gear (25) is mounted on the LP compressor shaft (24) and drives a spur gear (26) mounted co axially with a bevel pinion (27) which meshes with a driven bevel gear (28), A quill shaft (29) engages with internal splines in the driven bevel gear and transmits the drive through the inlet frame No. 6 strut to a pair of bevel gears (31) in the LP accessories gearbox (30). The driven member of the two bevel gears is mounted on a shaft which is machined to accommodate square-ended drive shafts of auxiliary components.

A drive for an alternator/constant speed unit combination is taken forward of the LP compressor shaft. Internal splines in the shaft mate with the splines on the constant speed unit drive shaft (34).

Lubrication of the gearboxes is effected by oil jets directed at gear meshes, and

1 H P COMPRESSOR SHAFT
2 H P BEVEL GEAR
3 H P BEVEL PINION
4 H P QUILL SHAFT
5 H P EXTERNAL GEARBOX
6 AIRCRAFT POWER TAKE-OFF ASSEMBLY
7 INPUT BEVEL GEAR
8 POWER TAKE-OFF BEVEL PINION
9 INPUT BEVEL PINION
10 POWER TAKE-OFF OUTPUT BEVEL GEAR
11 AUXILIARY DRIVE PINION
12 COMPOUND IDLER GEAR
13 HYDRAULIC PUMP GEAR
14 HYDRAULIC PUMP
15 SCAVENGE PUMP GEAR
16 SCAVENGE PUMP
17 LUBRICATION PUMP GEAR
18 LUBRICATION PUMP
19 H P SPEED GOVERNOR GEAR
20 H P SPEED GOVERNOR
21 H P TACHOMETER GENERATOR
22 H P SPEED SENSER
23 ENGINE STARTER
24 L P COMPRESSOR SHAFT
25 L P DRIVE GEAR
26 L P DRIVEN SPUR GEAR
27 L P BEVEL PINION
28 L P DRIVEN BEVEL GEAR
29 L P QUILL SHAFT
30 L P EXTERNAL GEARBOX ASSEMBLY
31 L P EXTERNAL GEARBOX BEVEL GEARS
32 L P TACHOMETER GENERATOR
33 L P SPEED GOVERNOR
34 CONSTANT SPEED UNIT DRIVESHAFT
35 STARTER SHAFT



AUXILIARY AND ACCESSORY DRIVES

the oil mist created by the gear action serves to lubricate the bearings.

Refer to the Advance Data Sheets for the HP and LP external gearboxes for complete construction details of the gears and shafts in the HP and the LP gear trains and details of rotational direction and relative speeds.

LUBRICATING OIL SYSTEM

GENERAL

The engine lubricating oil system is self-contained and operates basically on the dry sump principle. The system consists mainly of an internal tank, two oil pressure supply pumps and a scavenge pump, an oil temperature regulator, and the necessary components for oil distribution.

The quantity of oil supplied to the various components considerably exceeds that normally required for lubrication; this is to ensure that such items as bearings and gears are effectively cooled. The oil flow is controlled by jet orifice size and line resistance to the various outlets.

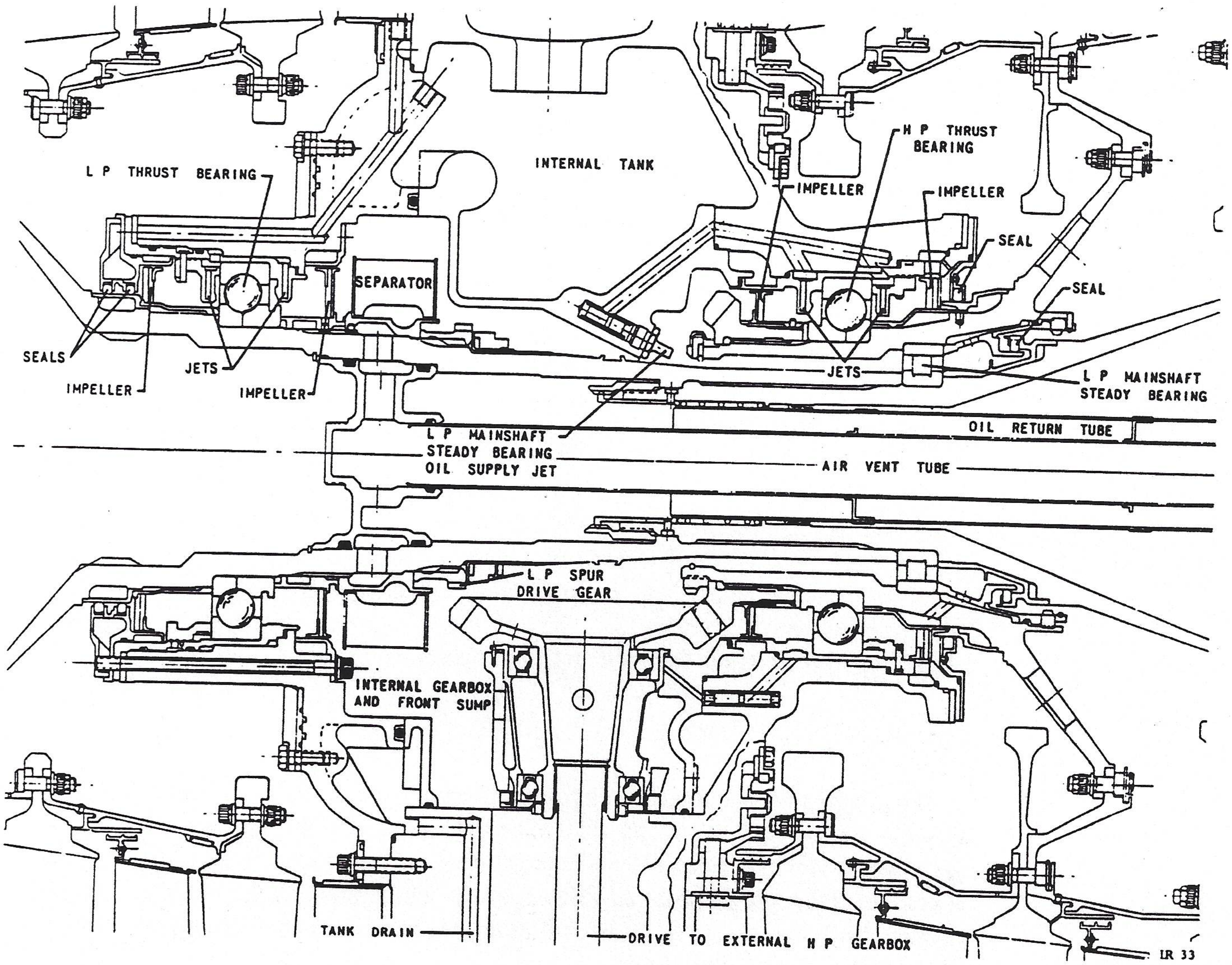
A feature of the lubricating system is the use of steel-backed carbon ring seals with air at high pressure applied to the seals to prevent oil leakage; the pressurizing effect is a major factor in the efficient scavenging of the oil system. Inverted flight is not a normal military requirement and no special provision is made for anti-g conditions. However, the engine will function inverted without detriment for periods up to one minute should the oil supply to the bearings and gears be interrupted.

OIL TANK

An annular shaped oil tank is provided, using the inner hub of the front frame as the tank outer wall. The internal gearbox casting forms the inner circular wall of the tank, the front and rear walls being provided by the LP and HP bearing housings respectively. The oil tank is vented to the front sump through a double ball vent valve, in order to exhaust air transferred by the scavenge return system to the tank, The double ball vent valve also prevents oil flow from the tank to the front sump in any flight attitude. Refilling is carried out by attaching a pres- sure oil supply to a quick disconnect fitting located near the oil filter on the under- side of the engine. An adjacent quick disconnect fitting connects to an overflow pipe from the tank and indicates when the correct oil level has been reached. The tank is drained by means of a cock at the bottom of the front frame No.5 strut. The capacity of the tank is five Imperial gallons (six US gallons), four-fifths of which is occupied by oil.

PUMPS

The oil pumps are of the positive displacement type employing a special form to the front sump in any flight attitude. Refilling is carried out by attaching a pressure oil supply to a quick disconnect fitting located near the oil filter on the underside of the engine. An adjacent quick disconnect fitting connects to an overflow pipe from the tank and indicates when the correct oil level has been reached. The tank is



LUBRICATING OIL SYSTEM

drained by means of a cock at the bottom of the front frame No.5 strut. The capacity of the tank is five Imperial gallons (six US gallons), four-fifths of which is occupied by oil.

PUMPS

The oil pumps are of the positive displacement type employing a special form of internal-external gear system known as the Gerotor mechanism. The pumping action of this mechanism is described in detail in Part 4 of EO 15-2SHA-2 and EO 15-25HB-2. The three pumps employed in the engine lubricating system are mounted on the HP external gearbox. The larger of the two single element pressure pumps supplies the main engine requirements whilst the smaller unit provides a pressure oil supply solely for the aircraft alternator drive constant speed unit. The scavenge pump unit, composed of two elements in a single casing, returns oil to the tank from the engine main circulating system. An oil flow indicator is provided in the pilot's cockpit. The indicator is actuated by a switch which senses the pressure differential across the main pressure pump,

FILTER AND BY-PASS VALVE

The filter has a re-usable 33 micron element of the stacked disc type, formed from calendered wire cloth. A by-pass valve incorporated in the filter assembly opens at 30 psi pressure difference and prevents undue restriction of the oil flow should the element become clogged by foreign matter. The filter body is retained to its housing by a single self-locking bolt, and access for servicing is provided by a panel on the underside of the engine shroud. A check valve located on the filter adaptor prevents oil drainage from the tank into the circulating system through the pressure pump element when the engine is inoperative.

OIL TEMPERATURE REGULATOR

The engine oil is cooled by circulation through a conventional heat exchanger through which fuel is passed as the cooling medium. A pressure relief valve operating at 150 psi protects the oil temperature regulator from excessive pressure. A combined thermal and by-pass valve opens at temperatures below 15"C (59"F) or pressure differences above 40 psi, allowing oil to by-pass the cooling element to achieve minimum warm up time.

ROTARY VALVE

A rotary valve, interconnected with the engine throttle linkage is interposed in the pressure oil supply immediately downstream of the oil temperature regulator. The purpose of this valve is to divert the flow of pressure oil from the engine main circulation to the tank during engine rundown" when the engine throttle is closed.

This prevents the possibility of oil accumulating in the engine bearings, and leaking into the turbine or compressor casing after the engine has stopped. The valve has a single inlet and two outlets, and to prevent interruption of the flow, the valve is ported so that from 0 degrees to 10 degrees throttle angle the outlet to the tank is open, and from 5 degrees to 110 degrees throttle angle, the outlet to the engine circulation is open. An overlap when both outlets are open together is therefore obtained between 5 and 10 degrees throttle angle. This porting ensures that the full pressure supply is delivered to the engine before the idling position of 13 degrees throttle angle is reached.

INTERNAL GEARBOX LUBRICATION

Pressure oil is supplied through an oil jet to the meshing point of the spiral bevel gears which transmit the drive from the HP rotor shaft to the internal gearbox; pressure oil is also fed to the driven gear support bearings. The gear train from the LP rotor, being lightly loaded, is lubricated by oil mist. The lower portion of the internal gearbox casting forms the front sump. Oil from the separator and internal gearbox components collects in the front sump, and gravitate s to the external gearbox sump, through No.5 strut of the front frame.

EXTERNAL LP AND HP GEARBOX LUBRICATION

Pressure oil is supplied by external connections to both the LP and HP gear-boxes for jet lubrication of the gear trains. The oil seals are of the double floating ring type, the space between the seals being supplied with high pressure air tapped from the HP compressor. Drainage from the LP to the HP gearbox is by an external gravity line. The HP gearbox sump is scavenged by the main scavenge pump element.

OIL SEALS

The main oil seals used in the Iroquois are each composed of a steel-backed carbon ring located in a housing. The housing locates the ring axially and permits it to float with minimum clearance on the surface of the adjacent rotating component. As the pressure oil supply to the bearings and gears is by jets, no appreciable internal pressure head need be contained by the seals, thus a supply of high pressure air tapped from the HP compressor and applied to the seal, is sufficient to prevent oil leakage. It should be noted here, that a limited flow of air escapes through the seal to mix with the oil, as detailed later.

ENGINE MAIN BEARING LUBRICATION

The HP and LP thrust ball bearings, the LP mainshaft steady roller bearing, and the HP and LP turbine roller bearings, comprise the main engine bearings. Each of these bearings is supplied with oil through the main pressure line. In the case of the LP thrust bearing, oil is fed from a tapping in the front frame through screens to six jets, three equally spaced on each side of the bearing to ensure, in addition to lubrication, adequate cooling and heat distribution. A radially vaned scavenge impeller is mounted on either side of the bearing and these discharge the oil through passageways leading directly into the tank. The air on the front of the LP bearing housing is at third stage LP compressor pressure. At this point a double carbon ring oil seal is fitted, and to maintain an efficient sealing effect, the space between the two seals is pressurized by seventh-stage HP compressor air.

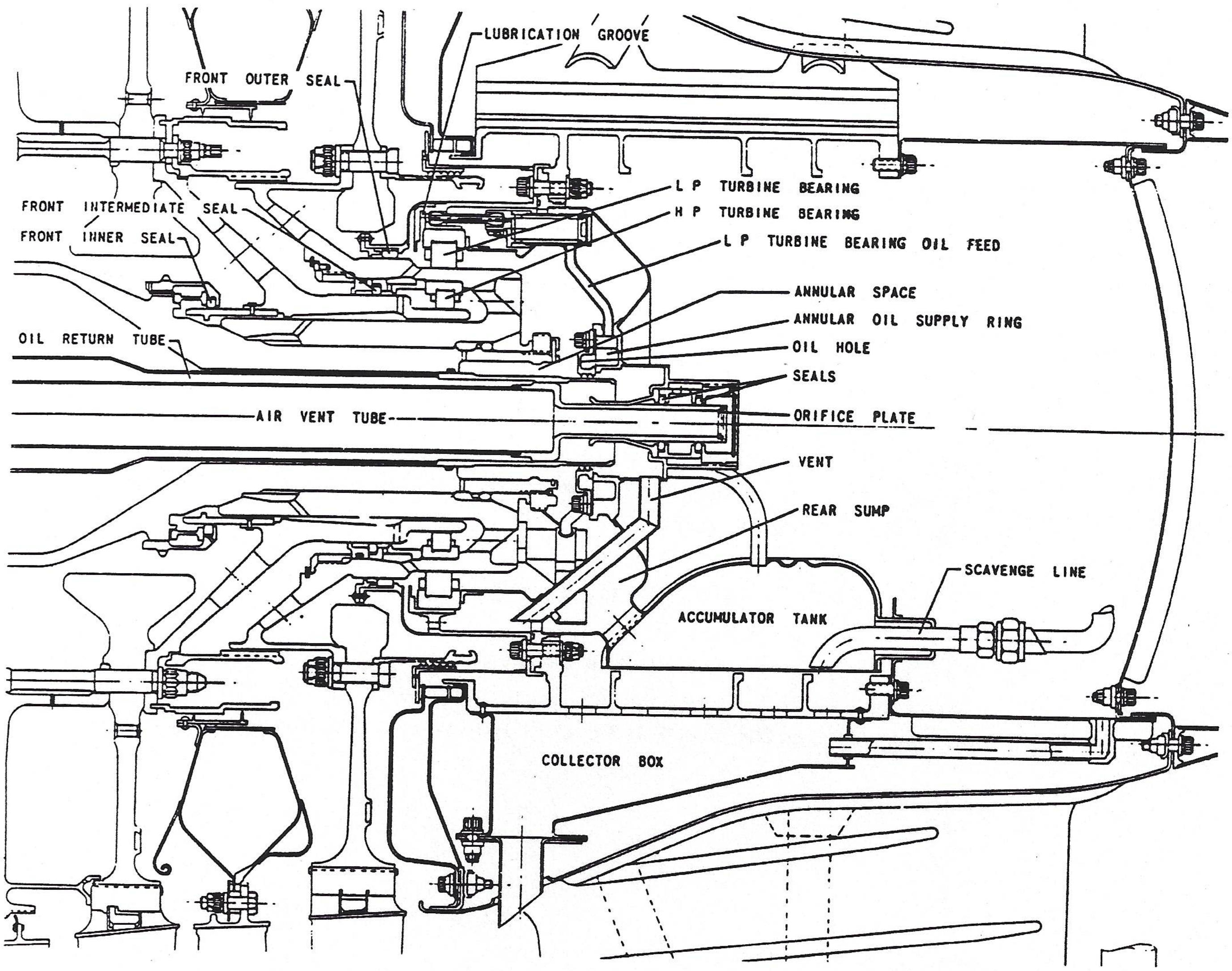
The feed arrangements, jets, and impellers used on the HP thrust bearings are similar to those described for the LP bearing. Scavenge oil in the passages from the impeller to the tank can, however, drain to the front sump by means of a drain valve operated by pressure oil. As the main supply pressure falls during engine rundown, the valve opens to drain away oil accumulating in the HP thrust and steady bearings, which might otherwise leak through the seals into the compressor casing. A single carbon ring oil seal is fitted at the rear of the HP bearing, the air at the exterior of the bearing housing being at seventh stage HP compressor pressure.

The oil supply for the LP mainshaft steady roller bearing ie conveyed by drillings in the internal gearbox casting to a single screened jet discharging into the annular space between the LP compressor shaft and the HP compressor front shaft. After flowing through the bearing, the oil passes through drillings in the HP compressor front shaft to the HP bearing impeller and is scavenged to the tank. A single carbon ring oil seal is fitted at the rear of the bearing, the ambient air being at seventh-stage HP compressor pressure.

The LP and HP turbine roller bearings are each supplied with pressure oil fed into an annular ring on the inner face of the rear sump, see Figure 3-3-2. Three equally spaced holes in the forward face discharge oil into the annular space between the oil return tube and the LP shaft. This oil, by centrifugal force, makes its way through drillings and spline clearances to the forward face of the HP bearing. Oil for the LP bearing is piped from the annular ring to the concentric lubrication groove immediately forward of the bearing, In both cases the oil flows rearward through the bearings and drains into the rear sump. The front inner, front intermediate and front outer oil seals on the HP and LP turbine assemblies are all pressurized by seventh stage compressor air, and single carbon ring oil seals are fitted at these locations.

OIL CIRCULATION

The circulation of pressure oil from the internal tank to the various engine components is indicated in Figure 3-3-3. A large portion of the oil collected in the rear sump is in the form of an oil air mist due to air leakage through the seals and the



LUBRICATING OIL SYSTEM

ANTI-ICING SYSTEM

GENERAL

During engine operation in weather conditions conducive to icing, the formation of ice at the engine air intake is prevented by a hot air, surface heating, anti-icing system. The system is fully automatic in operation and is de signed to operate at air pressures up to approximately 45 psi.

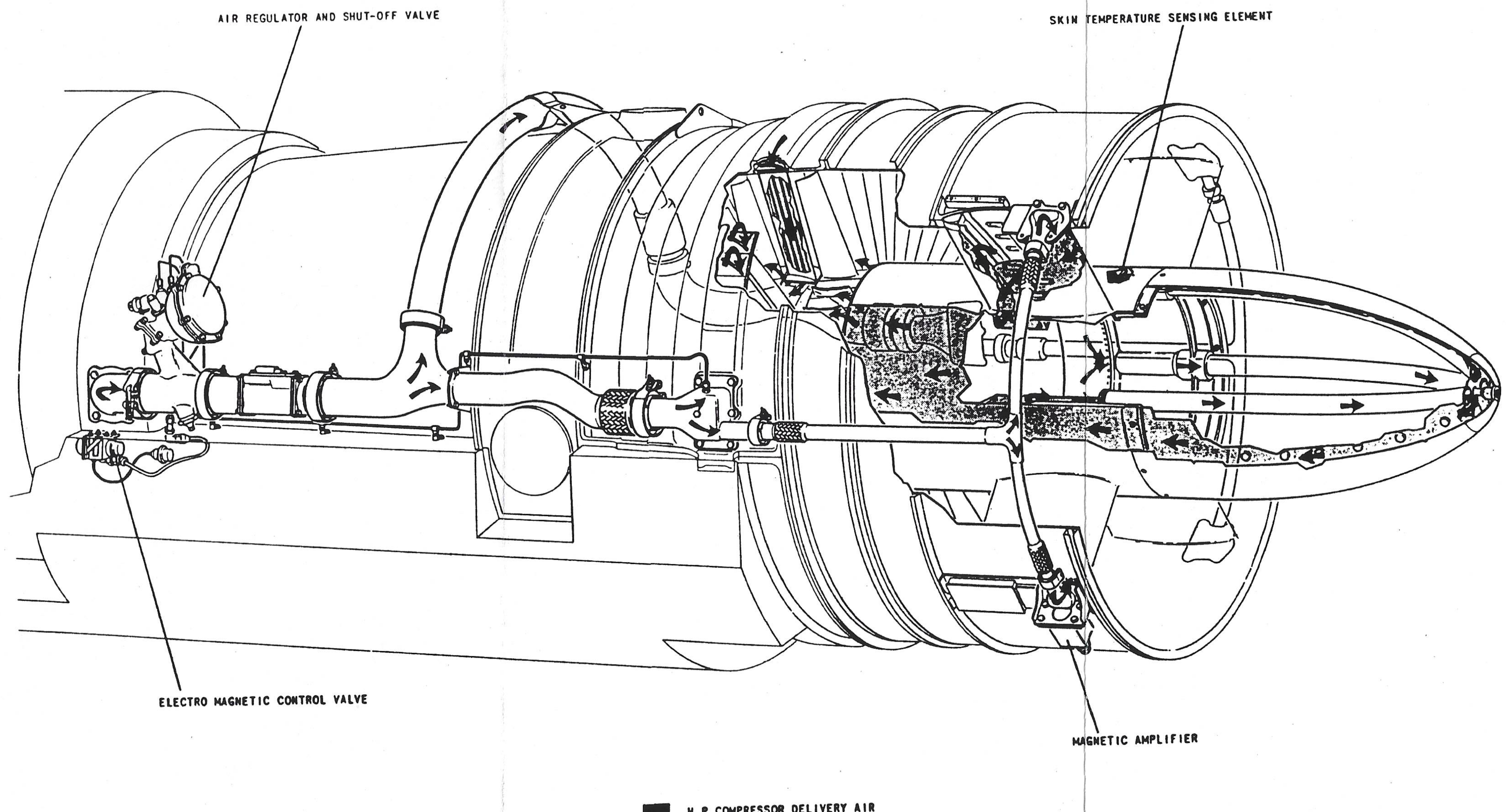
A supply of air, bled from the delivery side of the HP compressor, is supplied to the LP compressor hollow first stage stator blades, and to the inlet frame assembly where the air heats the outer skins of the nose bullet and frame struts. Since the temperature and pressure of the tapped air increase with engine speed, only a small proportion of the available supply of air is required during high speed operation. Provision is made to compensate for these variations in temperatures and pressures.

EXTERNAL PIPING AND DUCTING

The supply of air is piped externally from the upper right-hand side of an air take-off manifold immediately downstream of the HP compressor to an air manifold formed around the LP compressor stator casing, thence to air ducts at the outer ends of the four inlet frame struts.

COMPRESSOR STATOR BLADE HEATING

The compressor first stage stator blades are heated by a flow of air from the LP compressor stator casing air manifold. As each blade is hollow and open-ended the air flows through the blades and is expelled inwards to the engine air stream.



ANTI ICING SYSTEM

churning action of the bearings, This mixture flows through the rear sump vent into the rotating oil return tube, as the rear sump air pres sure is always slightly higher than that at the separator in the front sump. This flow is assisted by the forward air flow from a double floating ring seal pressurized by seventh stage compressor air, located at the rear of the oil return tube. At extreme altitude when the air flow is reduced, the oil may tend to separate from the air in the oil return tube. To accommodate this condition the diameter of the oil return tube outer member increases in two increments, from rear to front. These local conical sections impel the oil forward due to centrifugal effect.

On emerging from the oil return tube the air and oil flows through radial holes in the LP rotor shaft into the separator, which centrifuges all oil droplets of 10 microns and greater into the front sump, The air flows inward through the separator vanes into the air vent tube, then rearwards into the space behind the rear sump in the exhaust bullet. Air returned by the scavenge pumps to the tank is vented to the front sump, and passes through the separator to the exhaust bullet in the same manner. An orifice plate located at the rear of the air vent tube restricts the flow, and therefore controls the overall air pressures throughout the system to the required proportions. The air discharges through a collector box on the underside of the exhaust bullet into the main exhaust gas stream. Any oil accumulating in the exhaust bullet drains into the collector box and is expelled with the outgoing air.

Oil collecting in the rear sump, drains into a small accumulator tank to which the auxiliary scavenge pump is connected. The purpose of this tank and pump is to ensure continuous scavenging of the rear sump during engine rundown, when the air pressure may be inadequate for efficient scavenging of the sump through the oil return tube.

ALTERNATOR CONSTANT SPEED UNIT DRIVE OIL SYSTEM

The alternator, constant speed unit, and drive is provided by the airframe contractor, however, the oil supply required to operate this equipment is drawn from the internal tank by a pressure pump mounted on the HP external gearbox. The pump suction line extends only to the half-full level in the tank so that an adequate oil reserve for engine lubrication is always maintained, should lose from the constant speed unit drive system occur. A separator incorporated in the return system discharges both oil and air into the internal tank.

FIRE DETECTOR AND EXTINGUISHER SYSTEMS

GENERAL

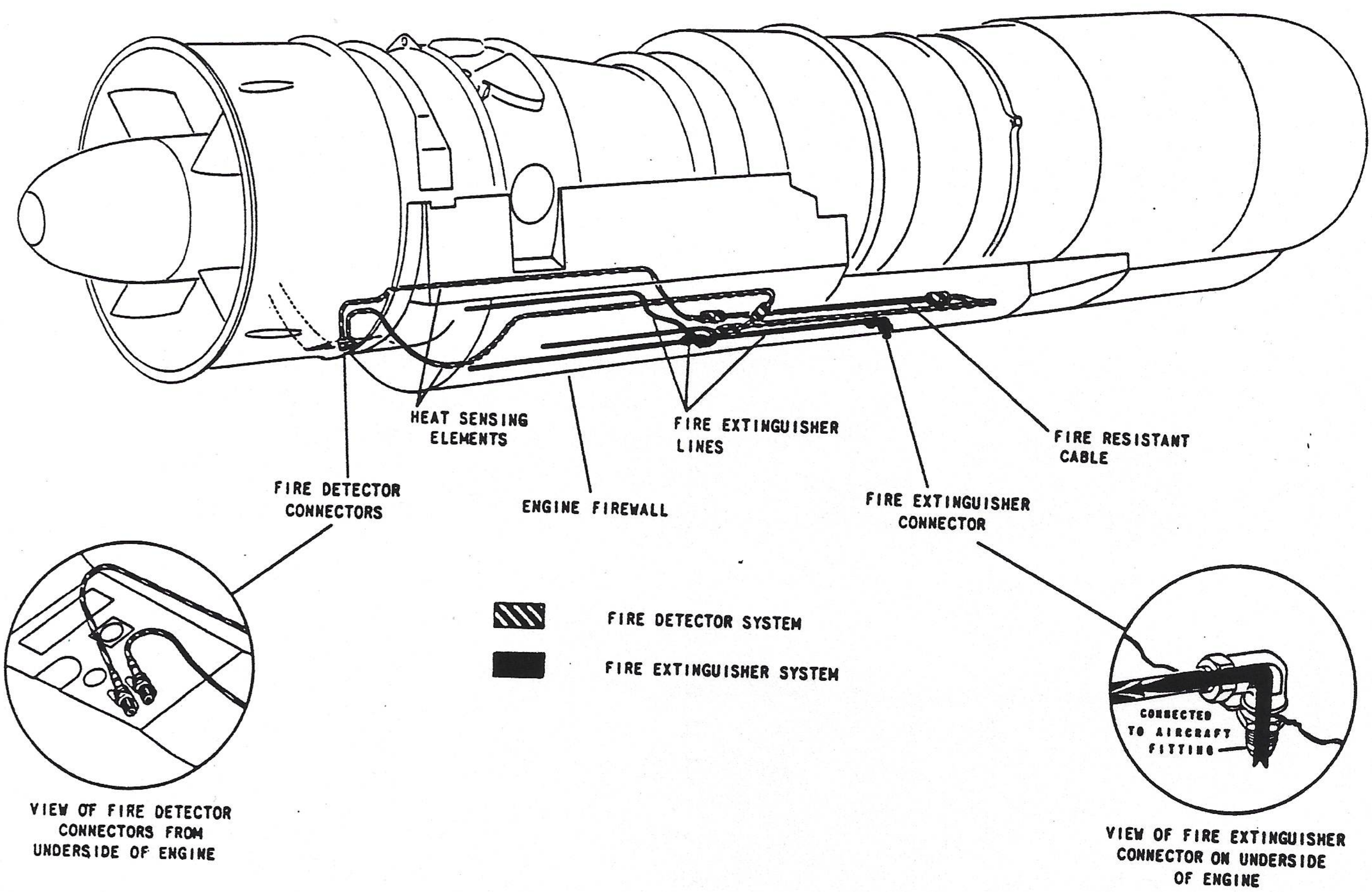
The fire detector system for the Iroquois is of the continuous-wire, heat and fire detection type consisting of heat sensing elements, a control unit and two coloured cockpit warning lights. The fire extinguisher system comprises a network of lines which carry extinguisher fluid to the forward region of the engine accessories compartment. A threaded connector on the engine firewall assembly connects the lines to a supply line from the aircraft mounted fire extinguisher bottles.

FIRE DETECTOR SYSTEM

Three heat sensing elements. together with a fire resistant cable, form a continuous loop inside the engine firewall assembly, passing near the top of the engine firewall assembly on the right-hand side of the engine, down towards the bottom centre at the mid-frame, and then rearwards along the bottom of the firewall to the rear frame. The element assembly returns along the left-hand side of the engine in a route opposite to the right-hand route, with the exception that at the front of the firewall assembly it is routed under the engine to the right-hand side. Each end of the element assembly is connected to a socket receptacle on the engine firewall electrical connector panel located near No. 4 strut of the front frame; the receptacles are connected to mating plugs in the aircraft fire detector system. Two elements are also positioned around the engine nacelle. These, together with the fire detector control unit, are included in the aircraft part of the. system; refer to the applicable Arrow 2 Engineering Order for details.

The three heat sensing elements are identical and consist of a semi-flexible Inconel tube enclosing a ceramic thermistor core and one internal wire, Each element is fitted with a plug at one end and a receptacle at the other. A short length of fire resistant cable, with a socket at each end, connects the elements at the rear section of the engine firewall. As the temperature coefficient of resistivity of the thermistor material is negative, the resistance between the wire and the Inconel tube varies inversely with the temperature of the element. The system monitors the resistance variations of the sensing element to provide an amber light over Heat signal at 205'C (400'F) and a red light fire signal at 288'C (550'F). No signal is given for normal temperature changes up to the average maximum ambient temperature of 17T'C (350'F).

The system also incorporates an averaging temperature sensing control which ensures that the total length of the detector element must be subjected to the preceding temperatures before an alarm is given, Since a fire would probably not affect the complete element at one time, the temperature necessary to cause an alarm is



FIRE DETECTOR AND EXTINGUISHING SYSTEMS

inversely proportional to the length of the element in the fire. An excessive rate of heat rise, above the normal ambient temperature, illuminates the red light instead of the amber light to indicate an abnormal temperature increase due to a fire hot spot. Upon elimination of the hazard, the high resistance of the thermistor re- establishes itself, and the system is ready to detect any further hazards. The existence of a break in the sensing element can be established by a continuity check. However, the system continues to function as a detector in spite of a break.

FIRE EXTINGUISHER SYSTEM

The engine portion of the fire extinguisher system, when operating, is supplied with extinguisher fluid through a connection located on the underside of the engine firewall assembly, adjacent to the combustion drains fitting. Inside the engine fire-wall a short length of pipe extends forward from the connector to a cross fitting from which three open-ended lines carry the fire extinguisher fluid to the region between the outer ends of the front frame No. 5 and 6 struts, and to the regions fore and aft of the HP external gearbox. For details of the fire extinguisher bottles and controls, refer to the applicable Arrow 2 Engineering Order.

In the event of fire during an engine ground run, provision is made for a manual fire extinguishing procedure. Two fire traps, each consisting of a screened opening, are located one on either side of the engine firewall centre section, near the bottom of the engine. The screened openings line up with openings. in the aircraft nacelle structure which permit the insertion of hand or mobile fire extinguisher nozzles.

AFTERBURNER ASSEMBLY

GENERAL

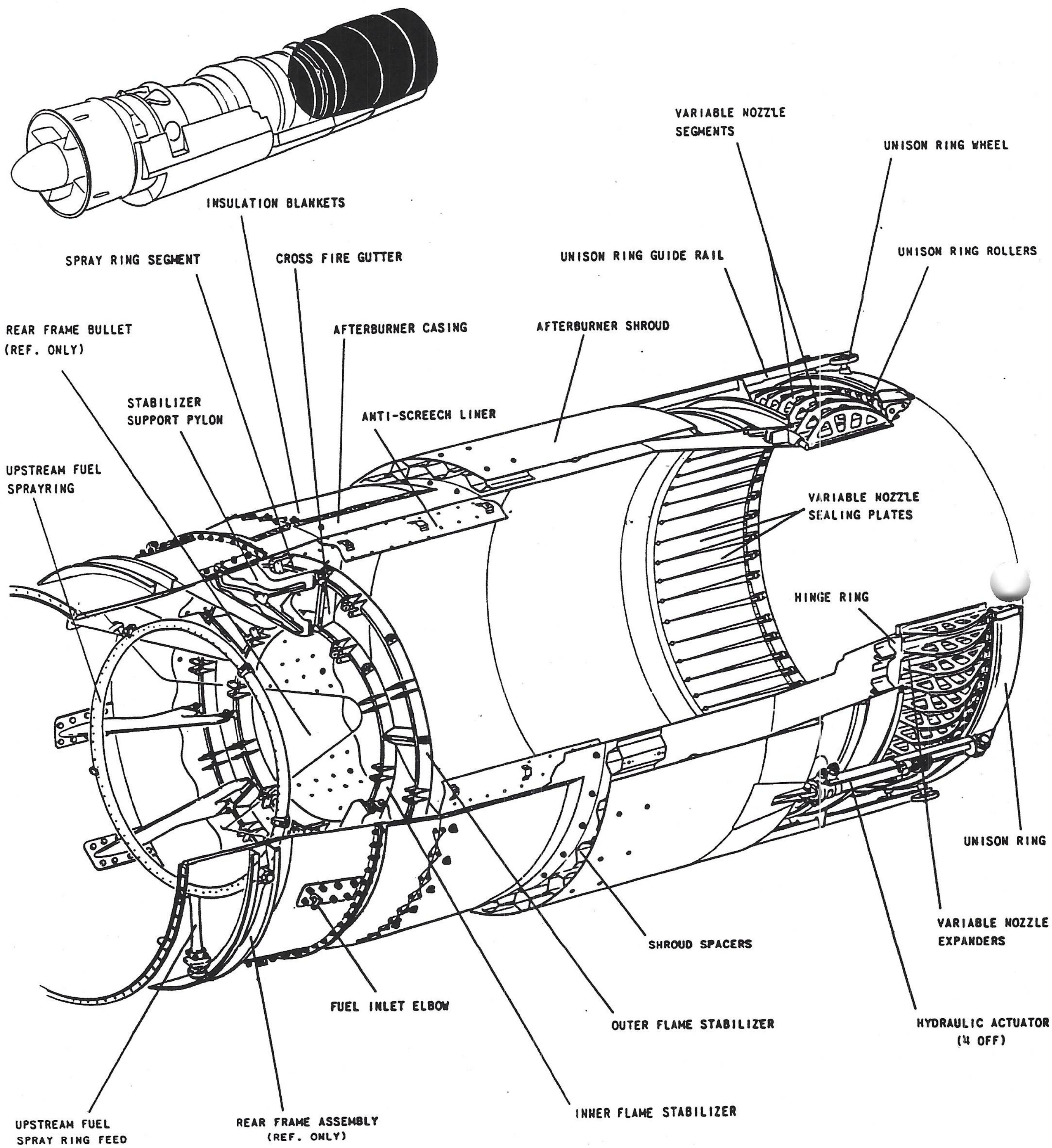
After burning is a method of thrust augmentation used primarily to improve the performance of an aircraft under take-off, climb or combat conditions. Since only a proportion of the total air entering the combustion chamber is used in the engine combustion cycle, a considerable amount of oxygen is available in the exhaust gas stream to assist further combustion. Fuel is injected and burned in the exhaust gas stream at a point between the turbine and the final nozzle thus increasing the temperature and exit velocity of the exhaust gases which results in an increase in thrust. The mixture must be easy to ignite under all flight conditions and altitudes, and a stable flame which will burn steadily over a wide range of mixture strengths and gas flows is necessary to ensure smooth and efficient operation of the after-burner.

The Iroquois afterburner assembly is integral with the engine and is designed to fulfil the general requirements detailed in the preceding paragraph. In addition to the final nozzle, spray, and stabilizer group, the afterburner consists of a casing an anti-screech liner, and a shroud. A hot streak ignition system is used to start combustion of the afterburner fuel flow.

Due to the increased volume of exhaust gases when the afterburner is in operation, an increase in final nozzle area is required to avoid excessive exhaust gas temperature and high turbine back pressure. To meet this and other requirements, the engine is equipped with a variable area final nozzle, operated by four automatically controlled hydraulic actuators. The fuel supply to the afterburner is also automatically controlled to provide full thrust modulation over the entire range of afterburner operation. Details of the final nozzle control system and afterburner fuel control system will be issued at a later date.

AFTERBURNER CASING

The afterburner casing is a hollow cylinder of stainless steel sheet which extends rearward from the engine rear frame assembly. The casing is fabricated from five circular sections which are overlapped and welded together. The divergent conical front section of the casing has a machined bolting flange welded to the forward edge for attachment of the complete afterburner assembly to the engine rear frame. The convergent conical rear section of the casing has a circular hinge ring welded to its rear edge. A contoured groove machined on the rear face of the hinge ring accommodates the forward ends of the variable nozzle segments. At approximately the centre of the afterburner casing, a circle of shroud spacers is welded to the outside of the casing for attaching the forward end of an afterburner shroud. The stainless steel spacers have a hexagonal section, and are designed to accommodate



AFTERBURNER ASSEMBLY

the differential thermal expansion between the afterburner casing and the shroud, and to transmit the axial loads of the final nozzle hydraulic actuators attached to the rear of the shroud. The front portion of the afterburner casing is covered by insulation blankets which minimize heat radiation to the adjacent airframe structure.

ANTI-SCREECH LINER

Forward of the mounting spacers, two circles of holes around the casing accommodate the attaching bolts of an anti-screech liner. The anti-screech liner comprises a perforated stainless steel sheet with axial corrugations, and is located round the inner wall of the afterburner casing. The liner prevents high amplitude resonant vibrations in the afterburner casing by absorbing and dissipating the high frequency gas pressure fluctuations which originate in the region of the flame stabilizer during afterburner operation.

AFTERBURNER SHROUD

The afterburner shroud encases the rear half of the afterburner casing, and is fabricated from circular spot welded sections of stainless steel sheet. The front of the shroud is bolted to hexagonal shroud spacers fitted to the afterburner casing, whilst at the rear, the shroud is supported by a circle of guides which engage with 'M' value during afterburner operation. From the shroud, the air is then directed over the variable nozzle segments to cool the final nozzle outer surfaces and reduce heat radiation to the final nozzle actuators.

FINAL NOZZLE

The final nozzle, fitted to the rear of the afterburner casing, is of the segmented, variable area type. The final nozzle area is varied by four hydraulic actuators, the forward ends of which are retained by fork-ends at the rear of the afterburner shroud. The actuators are equi-spaced round the final nozzle at 45 degrees from the vertical, and are designed for operation in the relatively high ambient temperatures at the final nozzle. The rear ends of the actuators are eye- bolted to a unison ring. Four double-sided roller guide rails, welded to the rear of the afterburner shroud and equally spaced between the actuators, accommodate four pairs of rollers that are mounted on and carry the unison ring. The rollers ensure that the unison ring is centrally located during fore and aft movements. The unison ring is a rectangular sectioned ring, fabricated from stainless steel sheet. Four brackets, spaced at 45 degrees from the vertical on the outer diameter of the unison ring, mate with eye bolts on the rear of the actuators. Inward projecting brackets, welded to the inner face of the unison ring, carry sixty stainless steel unison ring rollers which bear against hardened cam faces on the outer edges of the final nozzle segments.

The forward ends of the sixty cast stainless steel final nozzle segments are located round the rear of the afterburner casing in the contoured groove of the hinge ring. A braided Inconel tape is spot welded in the hinge ring groove and locates the segment ends securely while cushioning the movement of the segments and forming a gas tight seal. Sealing plates and flexible metal expanders are interposed between the nozzle segments to form a closely knit, gas tight, fully expandable nozzle. Insulation is packed in each expander and is retained in position by covers which are pinned to the rear ends of the sealing plates.

The final nozzle area is varied by the axial movement of the unison ring which causes the unison ring rollers to move along the segment cam faces and pivot the segments about the hinge ring. During actuation, the unison ring is held normal to the final nozzle axis by four flexible cables which interconnect the hydraulic actuators. A worm gear arrangement in each actuator drives the flexible cables and ensures synchronous movement of the actuators and hence correct axial positioning of the unison ring.

SPRAY AND STABILIZER GROUP

The spray and stabilizer group consists of ten stabilizer support pylons, an inner and an outer stabilizer and segmented spray ring and an upstream fuel spray ring. The upstream fuel spray ring is an elliptical sectioned circular stainless steel tube designed to deliver a large proportion of the fuel supply to the stabilizers. Drilled orifices in the leading edge of the spray ring are angled alternately inward and outward so that the fuel spray is broken into a wide band of small droplets which avoids overloading of the stabilizers with raw fuel and hence improves the rich limit characteristics of the afterburner and reduces the possibility of flame out. Brackets on the forward face of the spray ring are bolted to a spigot on the trailing edge of each rear frame vane. The spray ring has a single feed which is slightly offset from the vertical at the bottom of the rear frame outer casing.

The stabilizer support pylons, are equally spaced round the inner diameter of the engine rear frame. The outer ends of the pylons are bolted to the engine rear frame outer casing immediately forward of the rear flange. The 'Y' shaped pylons are of stainless steel sheet with an aerofoil section and extend inward and rearward into the inlet of the afterburner assembly. A fuel inlet elbow on the outer end of each pylon transfers fuel to a 'Y' shaped pipe located inside the pylon. The aft ends of the pipes are welded to inner and outer spray ring segments. The segments are made from short lengths of stainless steel tubing which, when assembled in position, form two segmented fuel spray rings. Equi-spaced fuel orifices are drilled in the down stream face of the spray ring segments.

Two flame stabilizers are fitted immediately down stream of the segmented spray rings, the outer stabilizer being supported by all ten pylons, the inner stabilizer by five of the pylons. Both stabilizers are of stainless steel to withstand oxidation and distortion, and have a 'V' cross-section, the apex of which points upstream. A circular disced groove in the apex of each stabilizer collects the fuel from the spray ring segments and evenly distributes it over the stabilizer regardless of any slight distortion or displacement a of the spray rings relative to the stabilizer. Five radially disposed, stainless steel cross fire gutters with a cross section similar to that of the flame stabilizers, are equally spaced between the inner and outer stabilizers to assist in an even distribution of flame during afterburner operation.

AFTERBURNER IGNITION SYSTEM

The hot streak method is used to light up the afterburner. A hot streak igniter valve operates automatically on commencement of the light up sequence, and introduces intermittent pulses of metered fuel into the primary combustion zone of the Engine combustion chamber. The injected fuel ignites and produces a core of extremely hot gases which extends through the HP and LP turbine sections and ignites the afterburner fuel at the flame stabilizers. The core of hot gases is augmented by additional fuel injected through a relay jet located on the engine rear frame outer casing..

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19. 7-0558-50. Engine Manifold Access Panel.
20. 7-0562-9. Wing Centre Box.
21. 7-0564-31. Outer Wing Skin Panels - Main Box Detail Stressing.
22. 7-0554-12. Prelim. Investigation for Centre Fuselage Torsion.
23. 7-0559-7. Rear Fuselage Skinning.
24. 7-0500-1. Basic Data for Stressing.
25. 7-0500-16. Derivation of Loads for Wing Design Cases.
26. 7-0510-10. Fin Analysis.
27. 7-0510-3. General Aircraft Analysis for Symmetrical Loading Cases.
28. 7-0510-9. Summary of Centre Fuselage Analysis.
30. 7-0574-1. Aileron Loads.
31. 7-0582-1. Elevator.
32. 7-0583-16. Matrix Ribs.
33. 7-0590-1. Landing Gear Ground Reactions. (Early Basic Design.)
34. 7-0583-8. Spar, Rib and Skin Stresses.
35. 7-0583-12. Fin - Detail Stressing of Hinge Fittings.
36. 7-0590-2003. Landing Gear Design Cases.
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