CONTENTS.

ROLLS-ROYCE/TURBOMECA.

ADOUR MK.811 AND MK.815.

INTRODUCTION.

The MK's 811 and 815 Adour are identical engines and can be fitted to the Jaguar Aircraft in any configuration. The MK.811 is a new engine and the MK.815 is an uprated MK.804.

The Adour is a twin spool turbo-fan engine,incorporating a by-pass duct.It has a two stage low pressure (LP) compressor and a five stage high pressure (HP) compressor.

The compressors are driven by separate single stage turbines,via co-axial shafts.

Each shaft rotates in an anti-clockwise direction (viewed from the rear).The LP shaft is supported by two roller bearings,the LP compressor front bearing and the LP turbine bearing and is located by an inter-shaft bearing.

The HP shaft is supported at the rear by the HP turbine roller bearing and at the forward end by the HP location bearing.

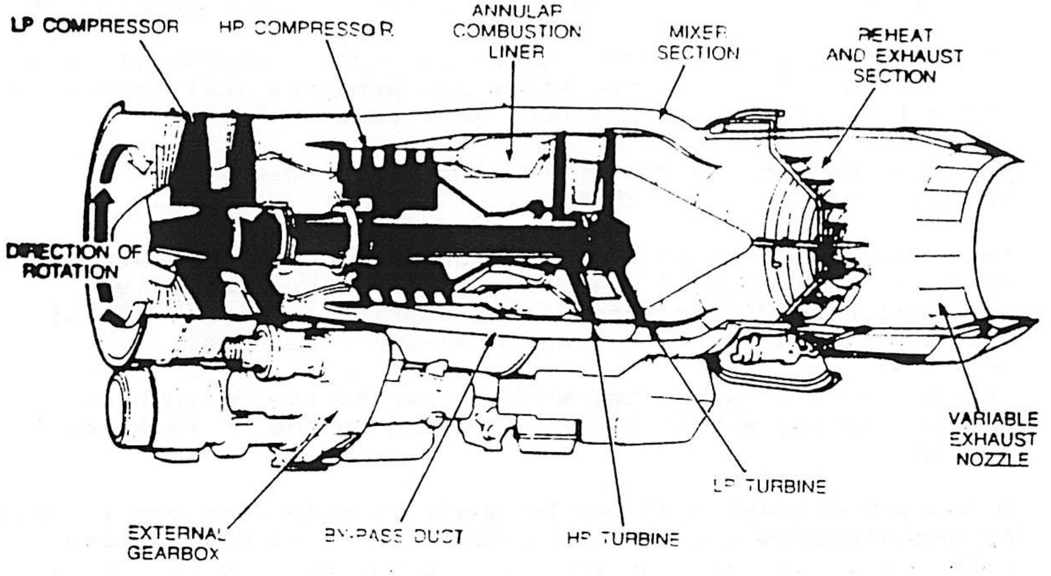
A forward extension of the HP shaft is supported and located by two bearings and carries a bevel drive to the external high speed gear-box.The area around the bevel drive is known as the internal gear-box.

The external high speed gear-box drives ancillary units necessary for the operation of the engine and aircraft.

To ensure stability during starting at low pressure ratios a bleed valve is fitted to pass air from the HP compressor outlet into the by-pass duct.After start up the bleed valve will be closed and will remain closed until the engine is shut-down.

An annular combustion chamber is used incorporating eighteen main fuel spray nozzles.

Thrust can be augmented by an after-burner system to a maximum of 52% of the max available normal thrust.



ENGINE BASIC LAYOUT.

LEADING PARTICULARS.

GENERAL.	
Engine Types.	Adour Mk's.811/815.
Direction of Rotation.	Anti-clockwise,(both shafts)viewed from the rear.
THRUST.	
Test bed thrust at Max.rating.	Non after-burning 25.0 Kn(5620 lbs). After-burning,37.37 Kn (8400 lbs).
No air bleed or power off-take, no intake losses.	
COMPRESSORS.	
Low Pressure (LP) compressor.	
Type.	Two stage,axial flow.
Pressure ratio.	2.45 : 1
Air flow.	42.6 Kg/sec.(94 lbs/sec).
Rev.min.	14144,(105.5%).LP speed is designated NL.
High pressure (HP) compressor.	
Type.	Five stage,axial flow.
Pressure ratio.	4.40 : 1.
Air flow.	23.8 Kg/sec.(52.5 lbs/sec).
Rev.min.	16132 (104%).HP speed is designated NH.
COMBUSTION CHAMBER.	
Type.	Annular.
Igniter plugs.	Two high energy plugs,approx.40 degrees each side of bottom dead centre.
Fuel spray nozzles.	Eighteen fuel spray nozzles.
TURBINES.	
High pressure (HP) turbine.	
Type.	Axial flow.
Stages.	One.
Cooling.	Air film cooled blades.Air cooled disc.
Low pressure (LP) turbine.	
Type.	Axial flow.
Stages.	One.
Cooling.	Air film cooled blades.Air cooled disc.

BY-PASS DUCT.	Annular chamber around the engine,from the delivery end of the LP compressor to the outlet of the exhaust mixer.
SYSTEMS.	
Engine fuel system.	
Low pressure fuel pump.	Centrifugal impeller type.
High pressure fuel pump.	Multi-plunger,servo controlled,variable stroke with hydro-mechanical governor.
Fuel control unit.(FCU).	Altitude sensing unit with throttle valve and HP shut off valve,temperature and LP speed solenoid and incorporating a dashpot acceleration switch.
LUBRICATION SYSTEM.	Self-contained continuous lubrication.
Pump.	One pressure three return sections.
Capacity,(Tank and system).	11.9 litres.(21 pts.).
Minimum quantity of oil in tank and system.	9.0 litres.(16 pts.).
Usable quantity of oil.	2.8 litres.(5 pts.).
Oil consumption at stated conditions.	0.57 litres/hour.(1 pint/hour.).Maximum.
Oil low pressure differential warning switch.	Switch mounted on the port side of the LP compressor case.Minimum differential 71Kpa.(10.3 lbf/in2.).
GAS TEMPERATURE MEASUREMENT.	Six double element thermo-couples spaced circumferentially in the exhaust unit hot gas stream,aft of the LP turbine trailing edge.A T2 sonic thermo-couple can be found on the port or stbd.(depending on the Mk. of the engine)side of the Module 03.

COOLING AND SEALING AIR.

LP compressor delivery (P2) air pressurises the air seals at the LP compressor bearings and thrust bearing,and cools the outside of the LP shaft.HP compressor delivery air (P3) cools the turbine blades and the front face of the HP turbine disc.Air from an intermediate stage of the HP compressor (HP3) cools the rear face of the HP turbine disc and the front and rear face of the LP turbine disc.Air from the by-pass duct cools the exhaust cone.

ANTI-ICING SYSTEM.

A continuous supply of warm air from the LP turbine shaft is fed through a tube inside the LP shaft to the nose fairing to prevent the formation of ice in the intake.

STARTING SYSTEM.

The engine is rotated by an air operated starter,driving through the high speed gear-box.Ignition is supplied by two high energy units supplying two surface discharge igniters in the combustion chamber.Fuel is metered to fuel spray nozzles,starting fuel being controlled by a sub-idle fuel control unit (SIFCU) via the engine FCU to the nozzles.

INDICATION SYSTEMS.

Oil low pressure warning. Differential pressure switch.

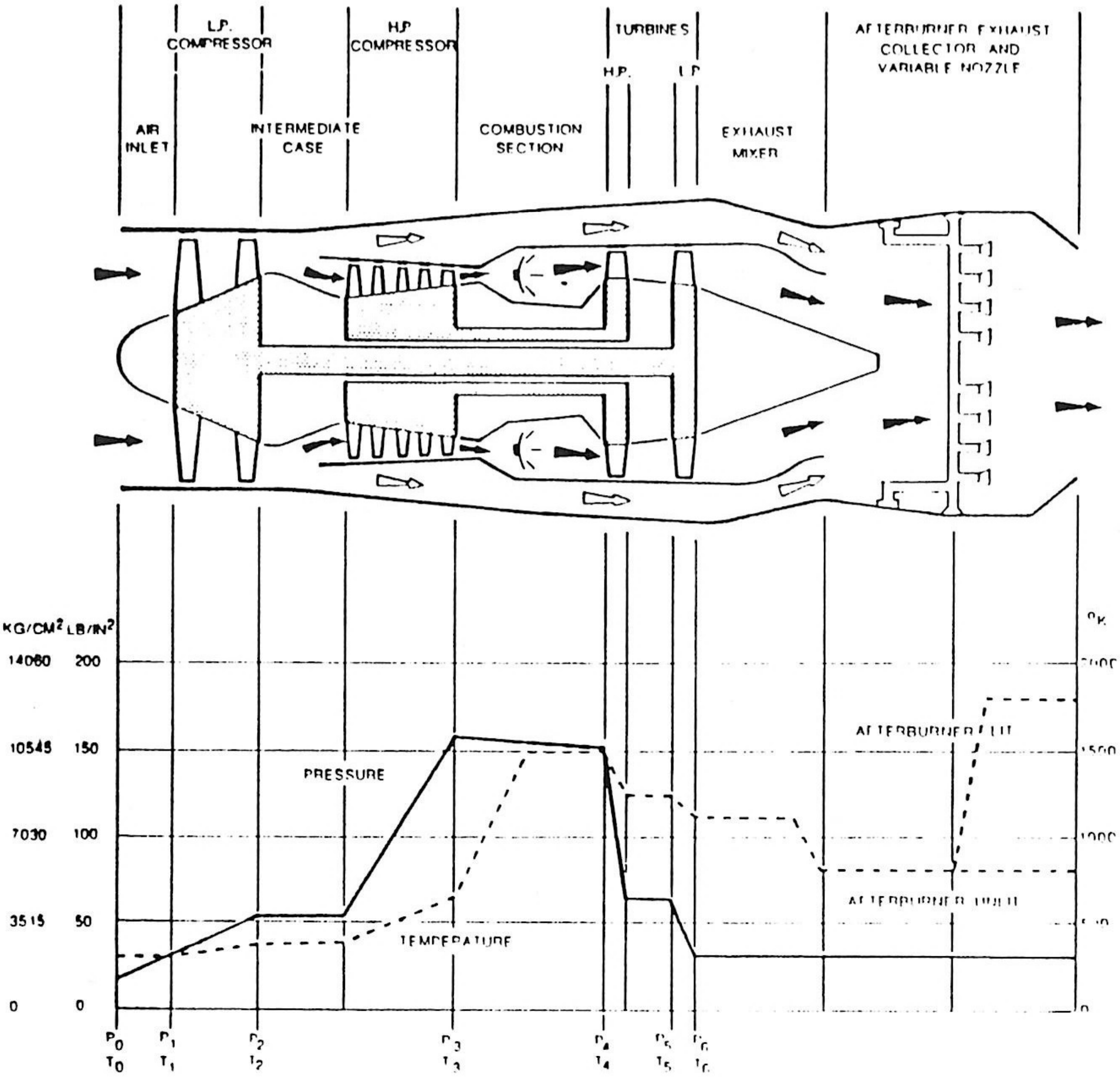
Fuel low pressure warning. Pressure switch fitted to the filter housing block.

After-burner nozzle position.	Indication transmitter fitted to the diffuser case on the exhaust collector.
Over heat warning.	Temperature sensing device fitted to the LP cooling air outlet.
HP shaft speed.	Tachometer generator fitted to the port side of the high speed gear-box.
LP shaft rotation.	Two probes fitted in the internal gear-box.
Turbine gas temperature.(TGT).	Six double element thermo-couples mounted aft of the LP turbine.

AFTER-BURNER SYSTEM.

Exhaust collector.	The exhaust collector consists of the exhaust collector case to which is secured the diffuser case.Mounted on the diffuser case is the after-burner fuel spray nozzle assembly,the nozzle rams and the fuel non-return valves.Mounted on the rear of the exhaust collector case is the nozzle actuating fairing,the segment actuating ring and eight master and eight sealing flaps.
After-burner fuel control unit.	The after-burner fuel control unit controls the fuel to the main manifolds,supplies fuel to two catalytic igniters and determines the area of the variable nozzle under after-burning conditions.Fuel flow is delivered by a vapour core type HP fuel pump,with a servo operated inlet throttle valve supplying a scheduled flow to the after-burner and flow to operate the rams.

Vapour gutter metering unit.	A pressure sensitive unit with a throttle valve,metering valve and check valves.The VGMU maintains vapour gutter flow through-out the after-burning cycle.
Part throttle after-burning selector valve.	A pilot selected,solenoid controlled valve which enables after-burning to be selected with the engine in the dry range.
<u>CONTROLS.</u>	Single lever cockpit control mechanically connected through a cambox to the shut-off valve,FCU and the ABFCU.



P_0 T_0 AMBIENT
P_1 T_1 INTAKE
P_2 T_2 L.P. COMPRESSOR DELIVERY
P_3 T_3 H.P. COMPRESSOR DELIVERY
P_4 T_4 H.P. TURBINE ENTRY
P_5 T_5 H.P. TURBINE OUTLET
P_6 T_6 L.P. TURBINE OUTLET

GAS FLOW DIAGRAM.

ROLLS-ROYCE/TURBOMECA.

ADOUR MK's 811 815.

BASIC OPERATION.

The engine produces thrust by the rearward acceleration of air drawn into the inlet.

The acceleration is caused by a combustion process.A higher degree of thrust can be obtained by the use of the after-burner system,which is another combustion process in the exhaust section.

Air entering the engine is first compressed by the LP compressor and approximately half of this air enters the HP compressor where it is further compressed.This air is then mixed with fuel and burned,the resultant gases are mixed with the by-pass air and are exhausted to atmosphere via the propelling nozzle.

The degree of thrust produced by the engine is a function of the air mass flow and the temperature to which the air is heated by the combustion process.

In the Jaguar installation control of both engine and after-burning fuel flows is by a single cockpit lever.This lever also operates the high pressure shut off valve.(For starting and stopping the engine).

ENGINE CONTROL.(NON AFTER-BURNING RANGE).

Basically movement of the throttle in the non after-burning or dry range selects a fuel flow.A capsule mechanism in the fuel system corrects this selected flow for changes in ambient pressure (P0) and intake pressure (P1).

TURBINE TEMPERATURE LIMITATION.

As measurement of turbine entry temperature (TET) is difficult with conventional thermo-couples,gas temperature is measured at the turbine outlet (T6).
The T6 obtained during engine pass-off test,at an acceptable max thrust or TET,varies between engines.This is the reason why the max output of the engine is referred to as Max.Dry and not Max RPM.The pass-off T6 is reduced to a common value for all MK's 811 and 815 engine by fitting a BALLAST RESISTOR across the thermo-couple output.The common output read on the cockpit gauge or test box will therefore be 640 degrees C.The ballast resistor is located in the Thermo-couple Junction Box at the rear of the engine,immediately behind the oil tank.(Light green in Colour).

The corrected value is known as Turbine Gas Temperature (TGT) and is supplied to the cockpit gauge and an aircraft mounted control amplifier which acts as a top temperature controlling device to limit the TGT to 640 degrees C maximum.

The control amplifier has limited control over the fuel flow,independent of the throttle,by an electrical signal to the Fuel Flow Control Unit solenoid.

At Max Dry with the ambient temperature above 15 degrees C.the fuel flow selected would result in a higher TGT than specified in limits.The amplifier,via the FCU solenoid,will then reduce the selected flow to the maximum value of TGT.

NL SHAFT SPEED CONTROL.

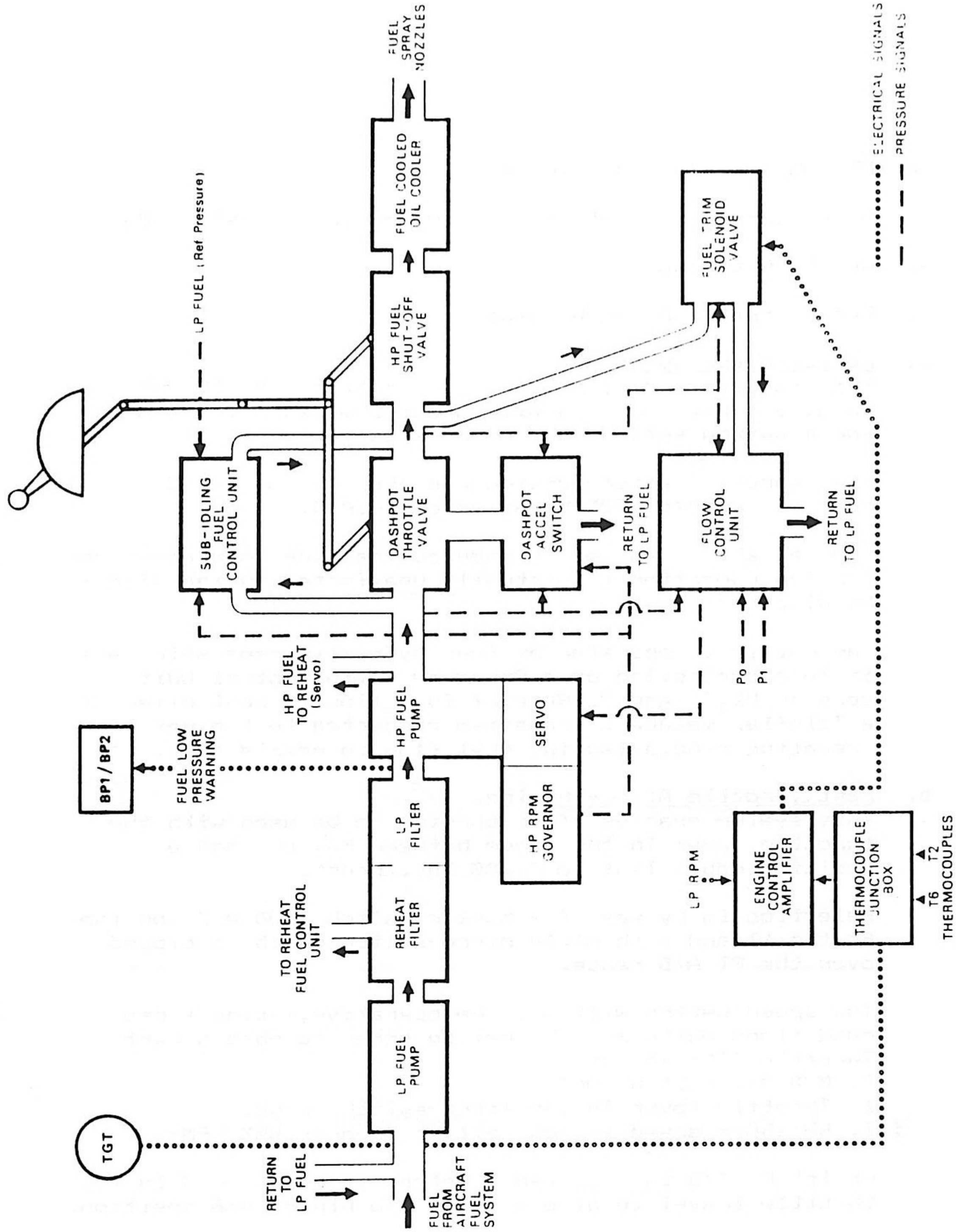
An electrical signal of LP compressor speed (NL) is taken via speed probes and a phonic wheel located in the internal gear-box and fed to the control amplifier.With lower temperatures,ie approaching 0 degrees C.,NL would tend to exceed its maximum limit (104.5% RPM) before the limiting temperature 640 degrees C. had been achieved.In this case the control amplifier would once again send a signal to the FCU solenoid to reduce fuel and so reduce speed.

TGT AND NL LIMITATION.

Only one limiting control can function at any one time,either NL or TGT.
The control amplifier will always reduce current to the solenoid to reduce fuel.The reason for this is that should the amplifier or solenoid fail the current would reduce to zero and the system would go to full permissible bleed,the TGT and RPM would drop below maximum.The system is then said to have failed safe.

T2 COMPENSATION OF THE T6 SIGNAL.

Engine performance and turbine blade life are a function of the turbine entry temperature (TET).The amplifier controlling parameter is T6 but the difference between T6 and TET varies with air entry temperature.Therefore to optimise performance whilst maintaining a constant limiting TET,compensation of the T6 signal is required.The output signal of the T6 therm-couples is first trimmed so that all engines give the same TGT output for a given performance figure,thus all amplifiers can be set to the same T6 control point and are therefore interchangeable between engines.This signal is then fed through a series resistor to the TGT gauges and amplifier.The T2 thermo-couple output signal is fed via a bridge network across the series resistor thus backing off part of the T6 signal.Circuit resistances are so arranged so that for 20 degrees C.increase of T2 the T6 signal is reduced by 11 degrees C.,ie the raw T6 will have to rise by 11 degrees C. to give the same datum to the amplifier.



ENGINE FUEL AND CONTROL SYSTEM.

ENGINE CONTROL. (After-burning)

After-burning is selected in two quite separate modes:

a. Normal After-burning.

b. Part Throttle After-burning.

a. Normal After-burning.
This is selected by moving the throttle into the after-burning range.Light up will occur immediately the A/B speed switch setting has been exceeded.

The degree of after-burning can then be modulated between Max A/B (52% boost) and Min.A/B.

The variable area nozzle ensures that the compressor and turbine operation is virtually unaffected during after-burning.

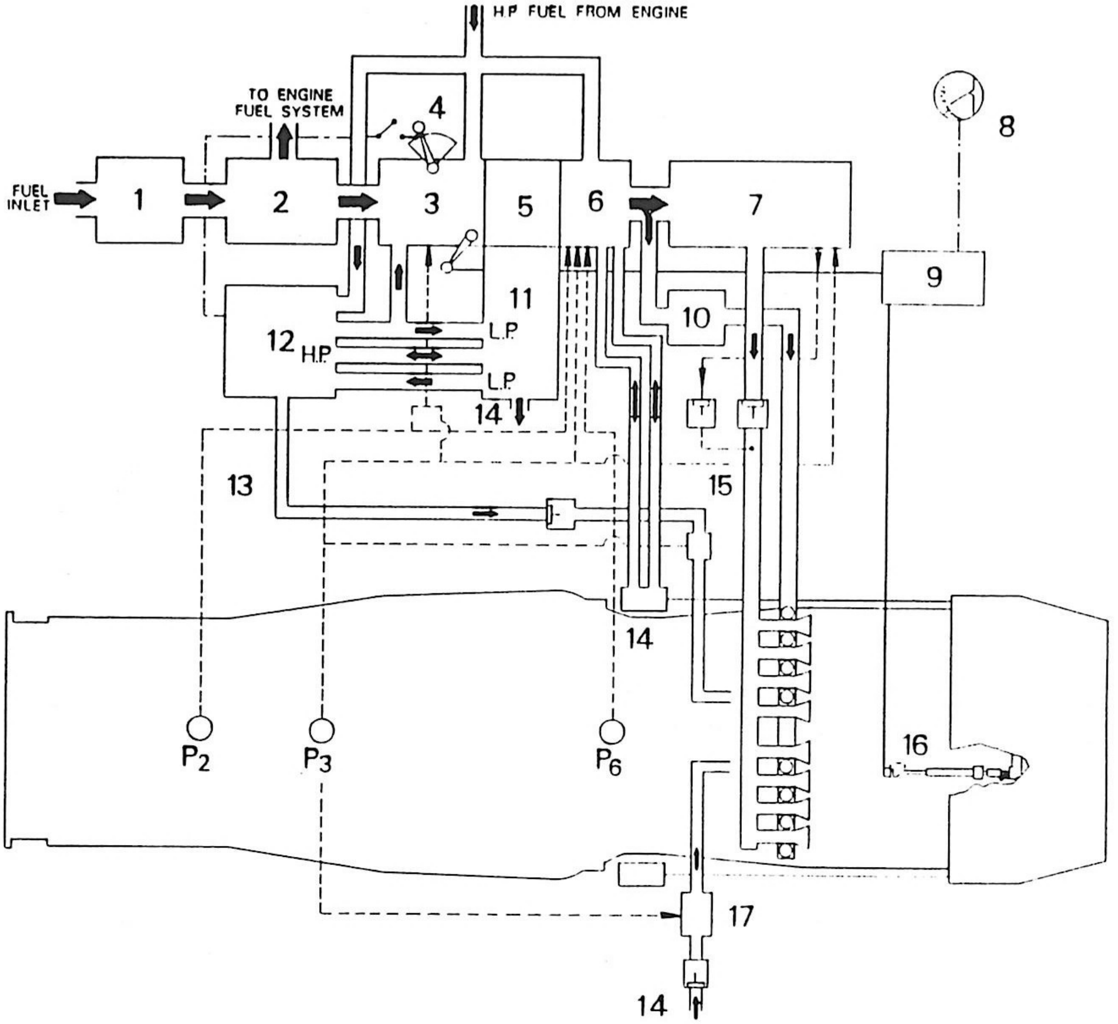
The nozzle is operated by four hydraulic rams which are in turn controlled by a Pressure Ratio Control Unit, sensing P2,P3 and P6.Rate of fuel flow is controlled by a Teleflex feedback mechanism connected to the nozzle operating ring,balancing fuel flow to nozzle area.

b. Part Throttle After-burning.
This system enables after-burning to be used with the throttle lever in the range between Max Dry and a position equivalent to 2,000 lbs.thrust.

Selection is by way of a Master Switch (MOD A/B).on the Port sill and a throttle micro-switch which is closed over the PT A/B range.

The speed switch will also be operative,making three conditions which must be met in order to obtain Part Throttle After-burning.
i. MOD A/B switch 'ON'.
ii. Throttle lever in the micro-switch range.
iii. NH above speed switch setting.(Approx.80% RPM).

Whilst PT A/B is selected a detent is positioned in the throttle travel to give a 'feel' to Min.PT A/B position.



1 L.P. FUEL PUMP
2 VELOCITY CLEANED FILTER
*3 INLET FLOW CONTROL UNIT
4 PILOTS THROTTLE LEVER AND PART THROTTLE AFTERBURNING MASTER SWITCH
*5 VAPOUR CORE PUMP
*6 PRESSURE RATIO CONTROL UNIT
7 AFTERBURNER DISTRIBUTION VALVE
8 NOZZLE POSITION INDICATOR
9 NOZZLE POSITION POTENTIOMETER
10. MAIN FUEL FILL N.R.V.
*11 CIRCUIT CONTROL VALVES
12. PART THROTTLE AFTERBURNING SELECTOR VALVE

13 No2 CATALYST FEED
14 No1 CATALYST FEED
15 RESTRICTOR BLOCK No2 CATALYST FEED
16 NOZZLE POSITION SIGNAL
17 CATALYST FEED FILTERS ASSEMBLY No1 CATALYST

* AFTERBURNER F.C.U.
——— MECHANICAL SIGNAL
- - - - AIR SIGNAL
— - — ELECTRICAL SIGNAL
NON RETURN VALVE

AFTER-BURNER FUEL SYSTEM.

ADOUR MK.811 AND MK.815.

PROPULSION UNIT.

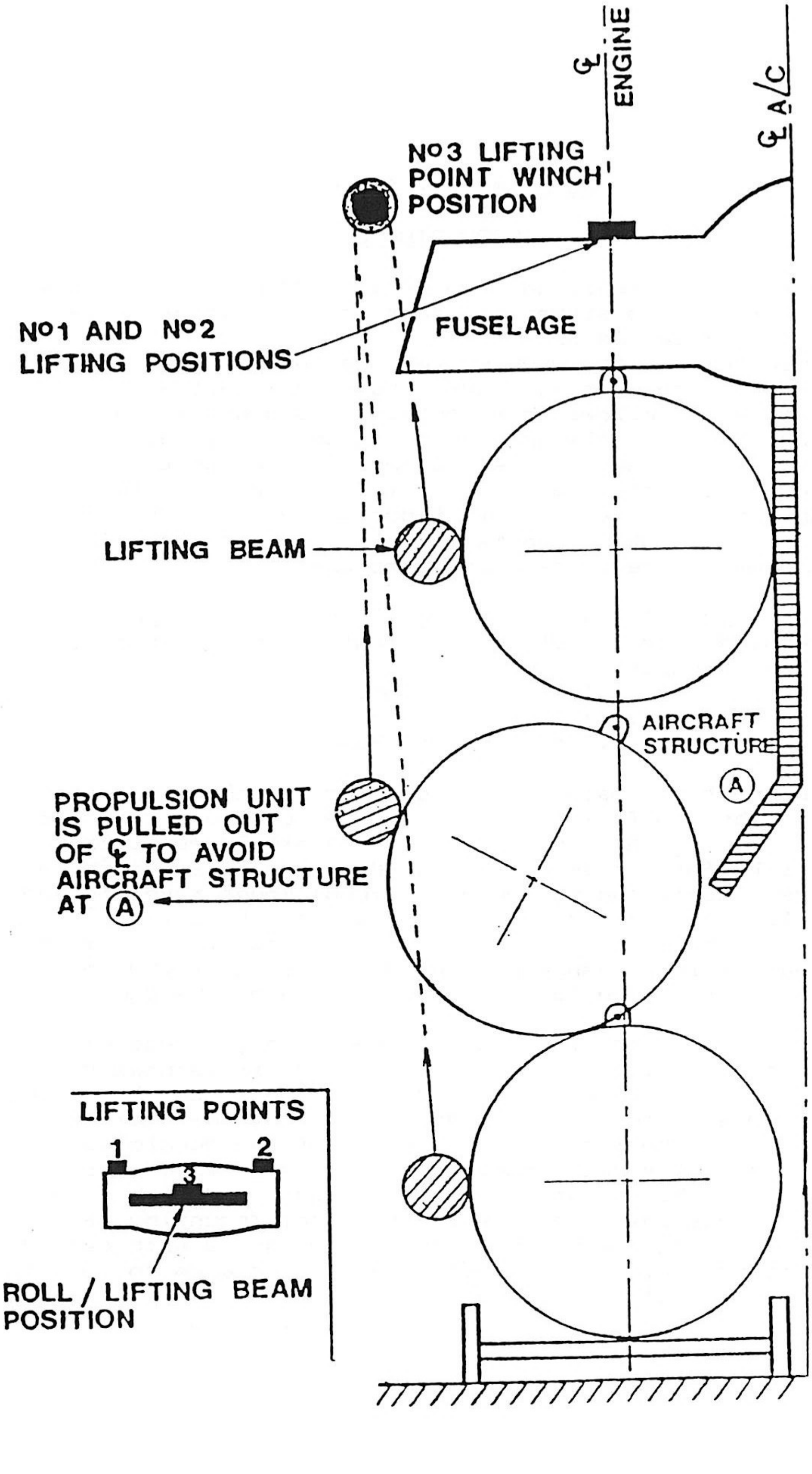
As stated previously the two Mk's of Adour are the same,and can be fitted to either the port or stbd.installation position of the Jaguar.
However the engines when fitted are not 'handed',ie.there is not a difference between port and stbd.mounting.
Therefore it follows that certain components whilst perfectly accessible on a port engine will be hidden on a stbd.one and therefore necessitate removal of the engine to change that particular component.A typical instance of this is the Air Bleed Valve,whilst perfectly accessible on a port engine it cannot be reached on a stbd.engine,therefore the engine will have to be removed to change it.

During a propulsion unit change,three major components will be removed from the old power plant and refitted to the new one.These components are:-

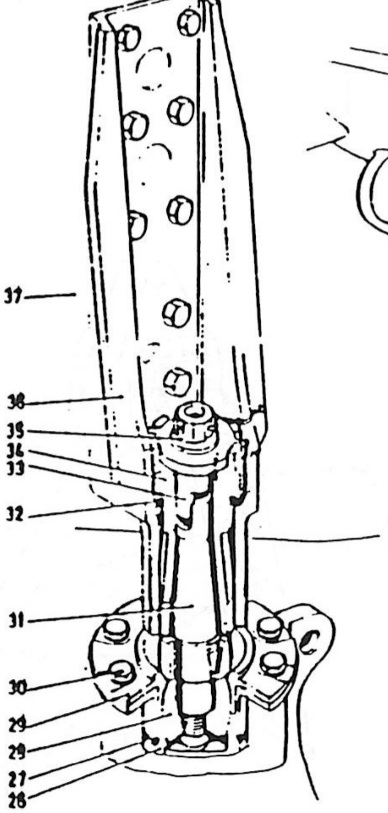
1.....The Air Starter.
2.....The AC Generator.
3.....The Hydraulic Pump.

There are three main engine mounting attachment points per engine,the two forward mounts can be found,one each side, on the top of the Module 03 and a third single mount on the top of the Diffuser case just forward of the engine fire seal. The rear mount and the outboard front mount take the shape of 'pip pins'and the forward inboard mounting is in the form of a spigot and spherical trunnion.The two forward mountings are easily interchangeable and during fitment the spigot and spherical trunnion take the thrust load of the engine.

During raising and lowering of the engine,because of the shape of the lower part of the fuselage,it is necessary to swing the engine outwards to clear the airframe.To do this three hoists are required,the main raise/lower hoists are attached,at the front to the centre of the Module 03 and at the rear to the rear mounting attachment point,for this purpose a cable is attached to the mount and is housed in the fuselage until required.A third roll/mounting bar is attached along the centre line of the engine,with careful positioning this roll/mounting bar can be used to roll the engine clear of the fuselage whilst lowering front and rear. The reverse applies when installing the engine.
(See diagram overleaf).

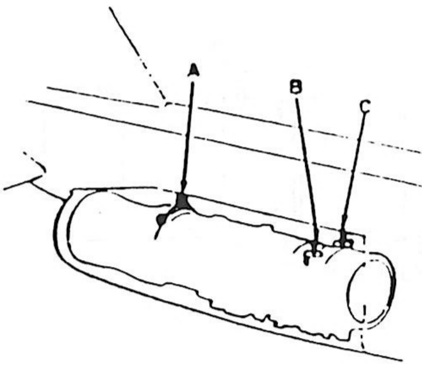


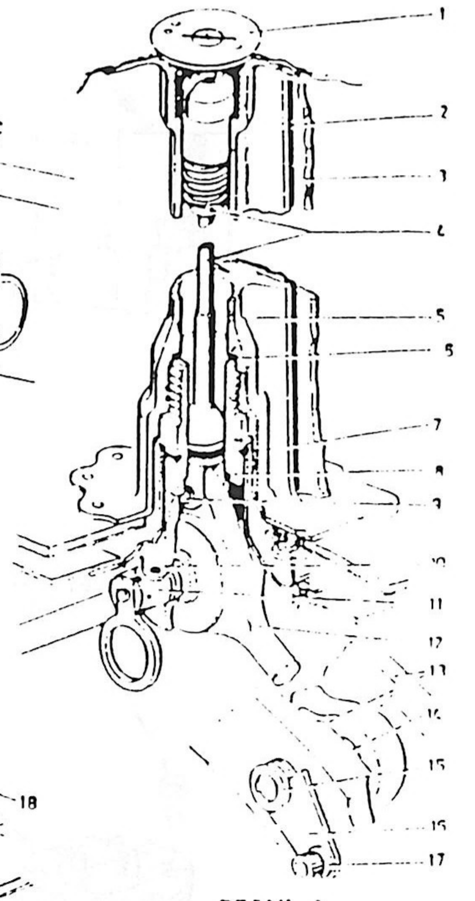
RAISING AND LOWERING THE ENGINE.



DETAIL C

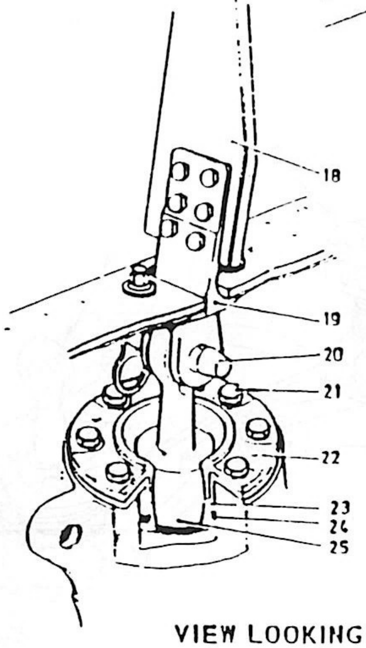
VIEW LOOKING AFT





DETAIL A

VIEW LOOKING AFT



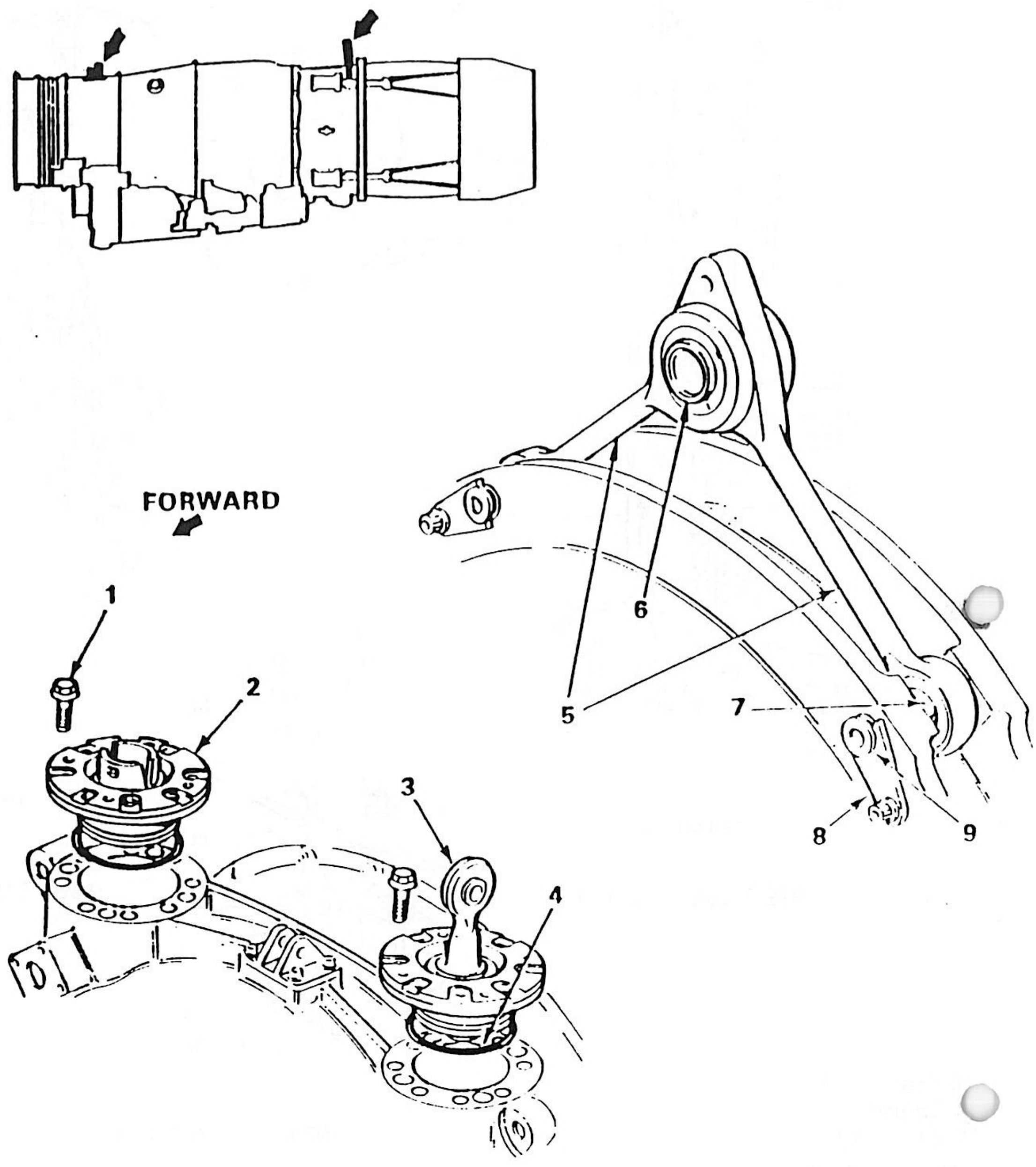
VIEW LOOKING AFT

Detail 'A'.
1.Cover Plate.
2.Packing.
3.Frame 35.
4.Cable Assy.
5.Tube.
6.Shim.
7.O-ring Seal
8.Fork-ended Lug.
9.Pin.
10.Stop.
11.Double lock Pip Pin.
12.Tangential Link.
13.Diffuser Case.
14.Spherical Bearing.
15.Headless Pin.
16.Locking Plate.
17.Locking Plate Bolt.

Detail 'B'.
18.Frame 32.
19.Bracket.
20.Double lock Pip Pin.
21.Mounting Bolt.
22.Cover.
23.Inner Housing.
24.O-ring Seal.
25.Spherical Link.

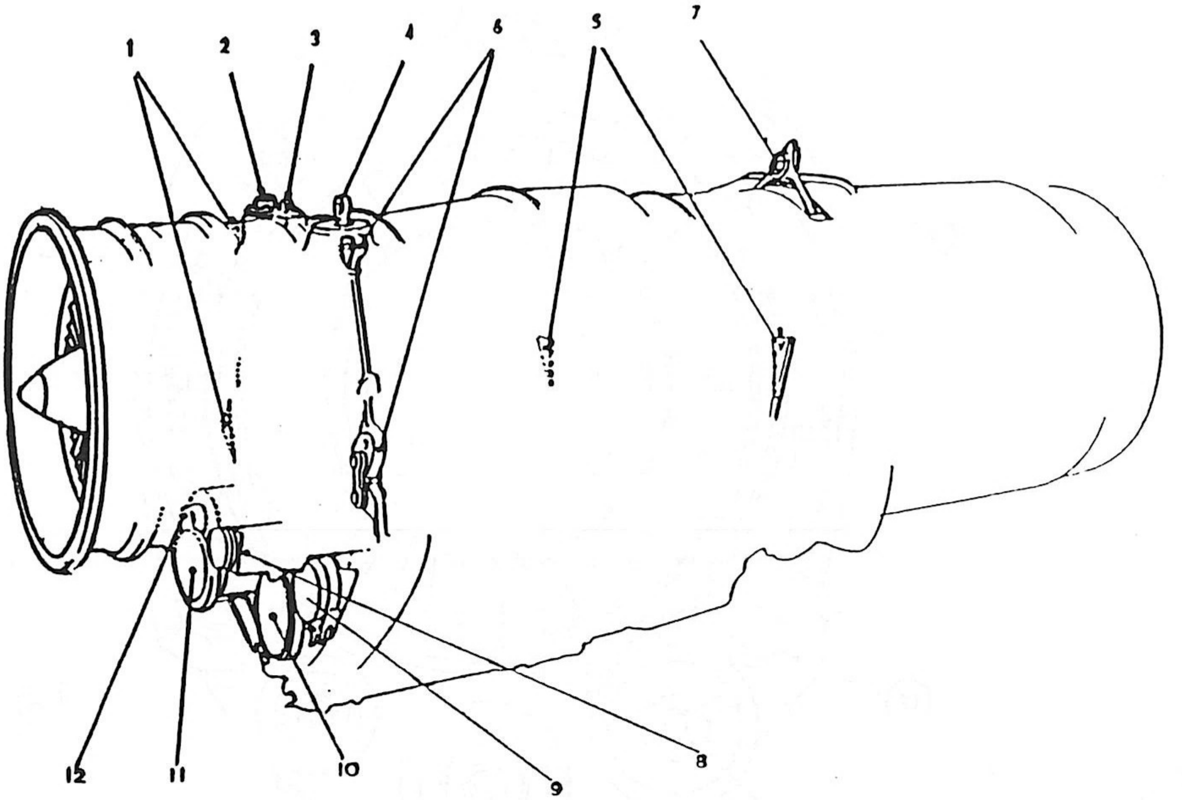
Detail 'C'.
26.Inner Housing.
27.O-ring Seal.
28.Spherical Trunnion.
29.Cover.
30.Mounting Bolt.
31.Spigot.
32.Packing.
33.Locking Sleeve.
34.Tapered Housing.
35.Attachment Bolt.
36.Trunnion Housing.
37.Frame 32.

PROPULSION UNIT MOUNTINGS.



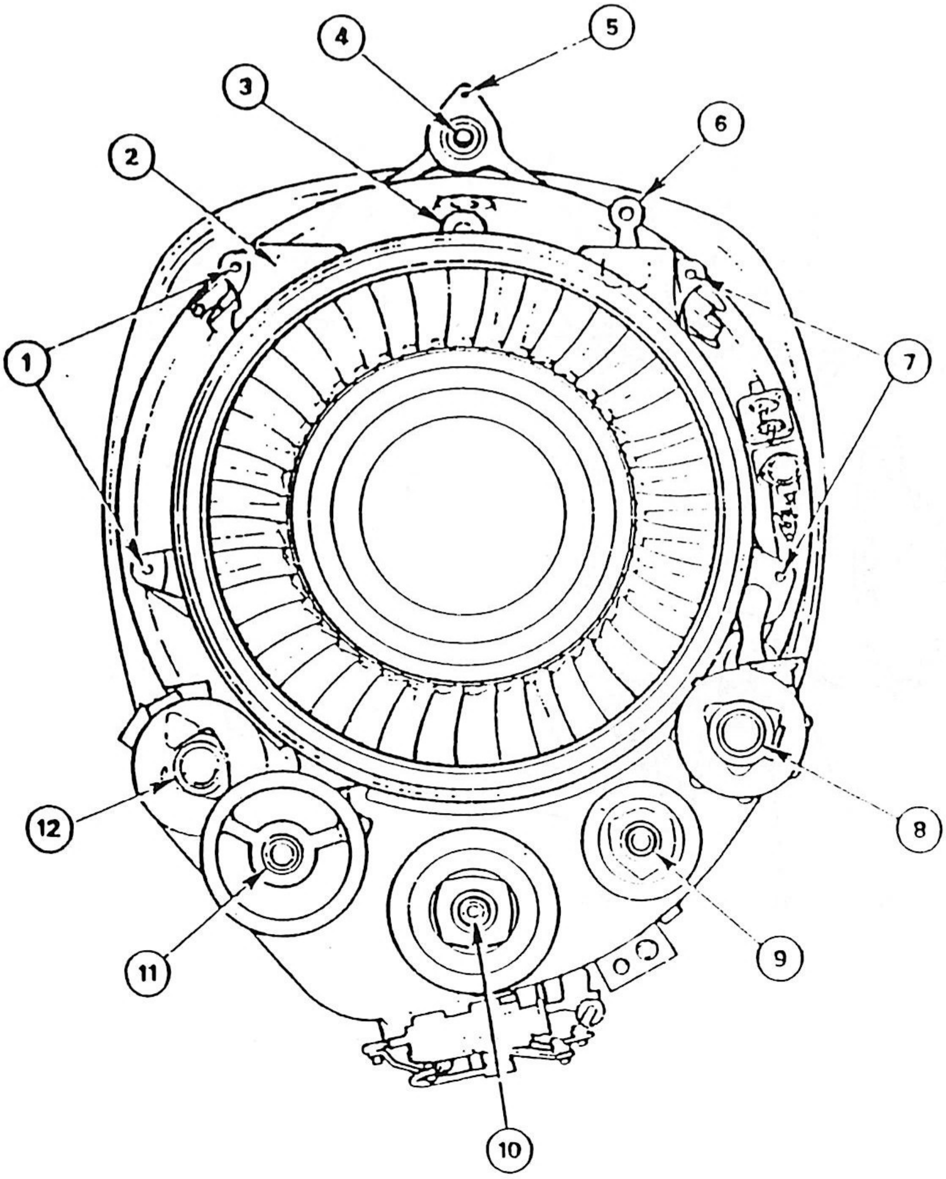
1. Housing Attachment Bolt.
2. Spherical Trunnion.
3. Spherical Link.
4. Sealing Ring.
5. Tangential Link.
6. Airframe Attachment Point.
7. Spherical Bush.
8. Locking Plate.
9. Headless Pin.

ENGINE MOUNTS.



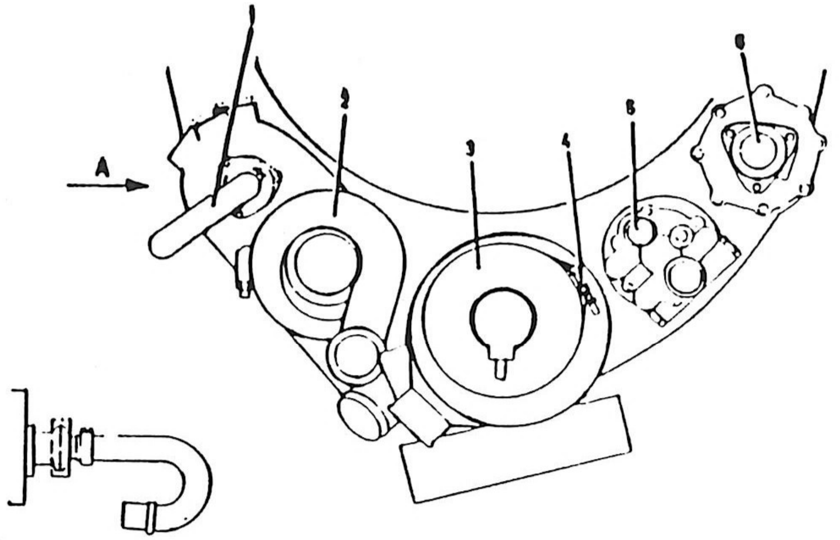
1. Trolley Fixing Point. (Front).
2. Spherical Trunnion.
3. Engine Front Slinging Point.
4. Spherical Link.
5. Trolley Fixing Points. (Rear).
6. Installation Slinging Point.
7. Rear Mounting Spherical Link and Slinging Point.
8. LP Fuel Inlet connection.
9. Hydraulic Pump Mounting.
10. AC Generator Mounting.
11. Starter Motor Mounting.
12. High Speed Gear-box, Breather Connection.

<u>PROPULSION UNIT MAIN CONNECTIONS AND ATTACHMENT POINTS.</u>



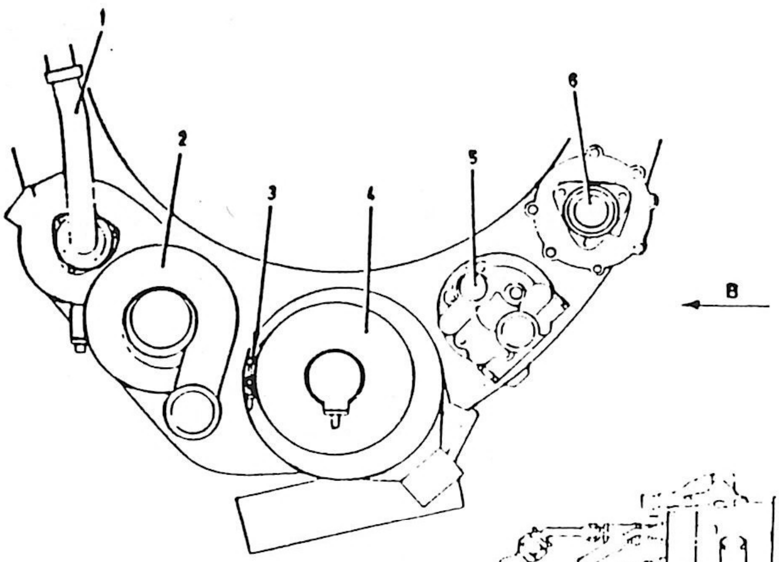
1. Installation Slinging Point.Stbd.
2. Front Mounting.
3. Installation Hoisting Point.Front.
4. Rear Mounting.
5. Hoist Point.
6. Front Outboard Mount.
7. Installation Slinging Point.Port.
8. LP Fuel Inlet.
9. Hydraulic Pump Mounting Point.
10. AC Generator Mounting Point.
11. Starter Mounting Point.
12. External Gear-box Breather.

ENGINE AND AIRFRAME CONNECTIONS.(FRONT VIEW).

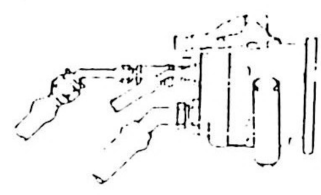


DETAIL A

PORT INSTALLATION



STARBOARD INSTALLATION



DETAIL B

<u>Port installation.</u>
1. Gear-box Breather.
2. Starter.
3. AC Generator.
4. V Clamp.
5. Hydraulic Pump.
6. LP Fuel Pump.

<u>Starboard Installation.</u>
1. Gear-box Breather.
2. Starter.
3. V Clamp.
4. AC Generator.
5. Hydraulic Pump.
6. LP Fuel Pump.

<u>FRONT VIEW OF GEAR-BOX PORT/STARBOARD.</u>

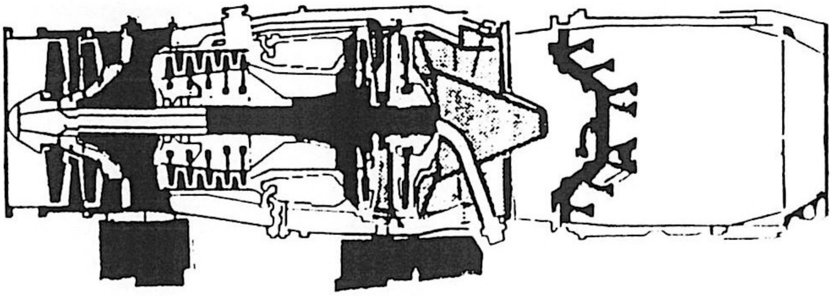
PROPULSION UNIT.

JAGUAR INSTALLATION.

The design of the Propulsion Unit enables it to be readily stripped into twelve modules, some of which have a finite life, and a number of non-modular parts which are replaced on condition.
Rotating assemblies are joined by CURVIC couplings, this device allows pre-balanced rotating assemblies to be fitted with the same ease as static assemblies.

The modules are: (12)

M01	LP COMPRESSOR ASSEMBLY.
M02	LP COMPRESSOR OUTLET GUIDE VANES.
M03	INTERMEDIATE CASE. N°PLATE, GEARBOX, FORWARD MOUNTS, VIEWING PORT HPT.
M04	HP COMPRESSOR ASSEMBLY.
M05	HP NOZZLE GUIDE VANE ASSEMBLY.
M06	HP TURBINE, BLADES, DISC AND SHAFT.
M07	LP TURBINE NOZZLE GUIDE VANES AND TURBINE BEARING ASSEMBLY.
M08	LP TURBINE, BLADES, DISC AND SHAFT.
M09	EXHAUST MIXER.
M10	EXTERNAL HIGH SPEED GEARBOX.
M11	OIL TANK, FILTERS AND OIL COOLER.
M12	AFTER-BURNING MANIFOLD ASSEMBLY.



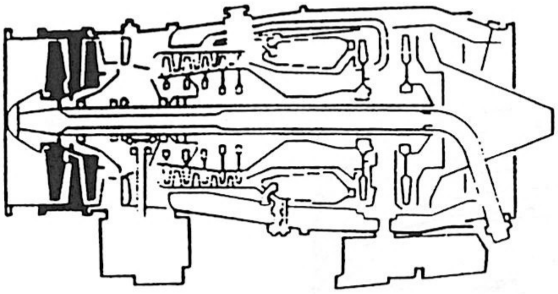
AIR INTAKE FAIRING.

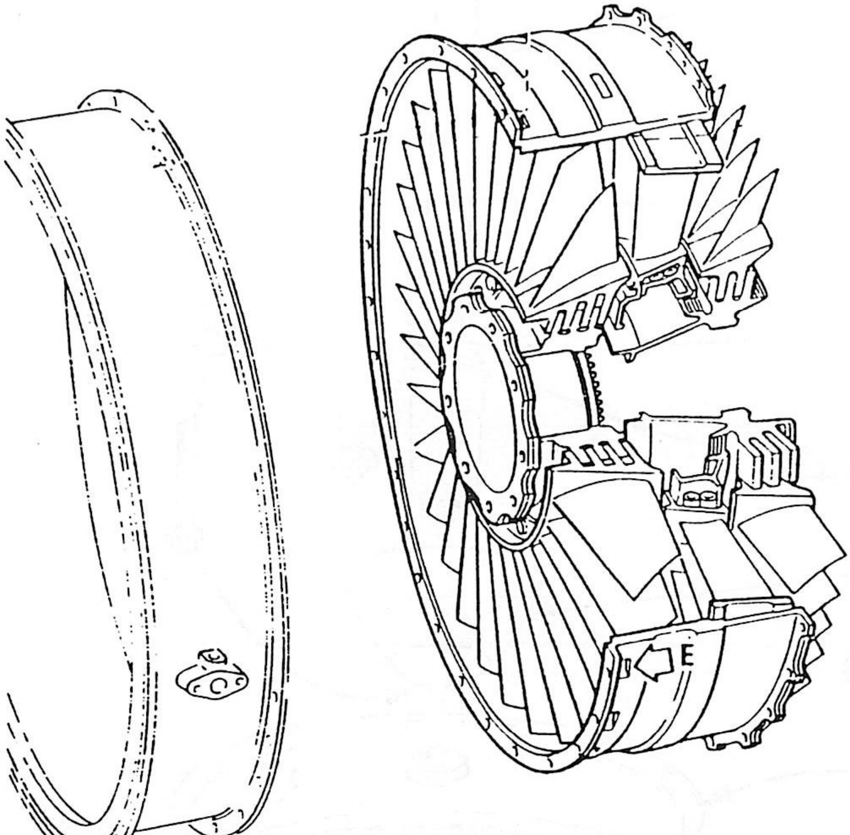
The air intake fairing is bolted to the front flange of the LP compressor case and forms a transition section between compressor case and the aircraft intake.
The forward flange of the fairing houses a 'T' sectioned sealing which mates with the aircraft intake.
Inspection ports are provided to enable inspection of the LP compressor,using a viewing instrument,when installation circumstances do not permit direct viewing.A special tool is provided to rotate the compressor,through the intake casing,so that all blades may be inspected through one port.

MODULE 01.
LP COMPRESSOR,STAGE ONE AND TWO BLADES,STAGE ONE STATOR.

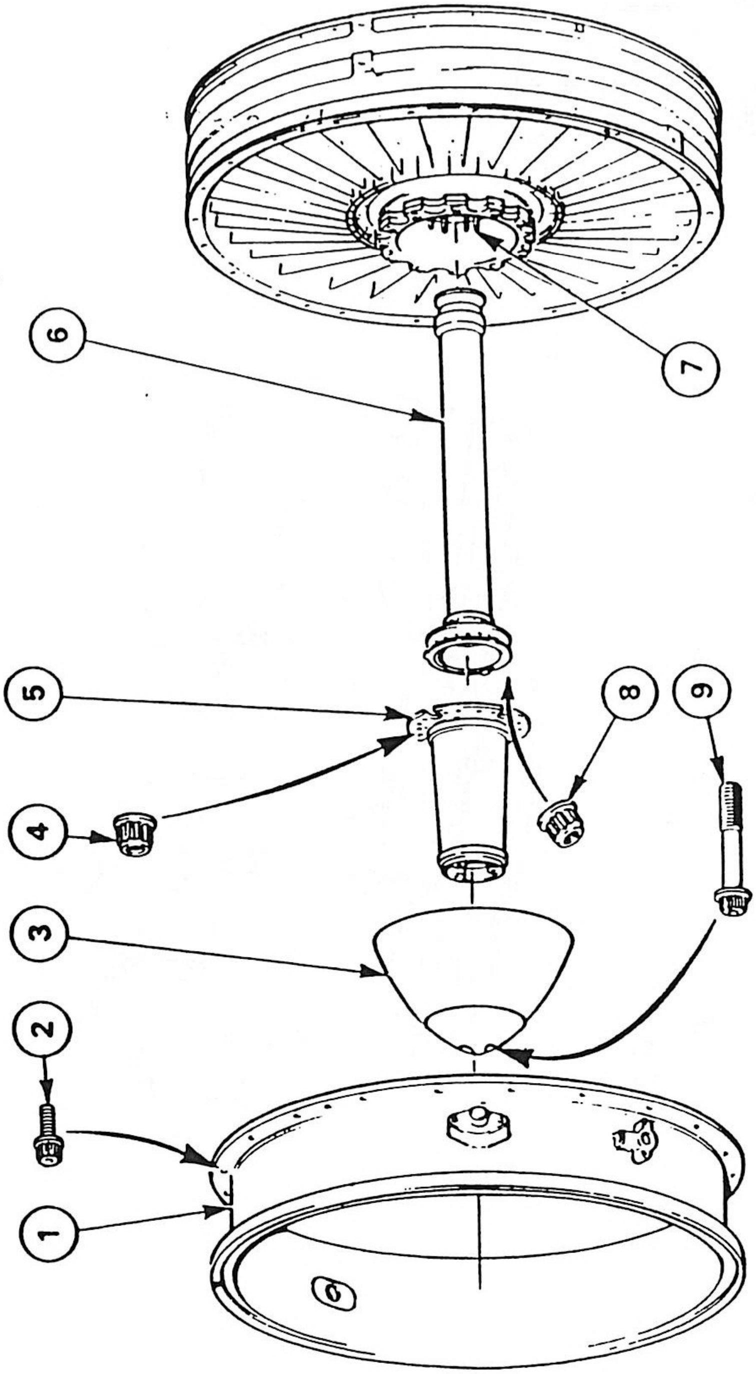
The LP compressor case houses the stage one stator vanes which are located and retained in a recess around the inner diameter of the case.
The LP stage one stator assembly is a fabricated ring of vanes,with inner and outer platforms.The outer platforms locate the vane assembly in the compressor case and the inner platforms locate the vane assembly on circular seal members,which are loaded onto rubber damping rings to damp out vibration.

The LP compressor rotor consists of two discs bolted together each disc having peripheral flanges to which the rotor blades are attached.The blades are secured to the disc by retaining pins held in position by lockplates.A 'CURVIC' coupling secured to the front disc transmits the drive from the LP turbine to the compressor.
The air inlet spinner is secured by bolts to the front anti-icing tube which is located and secured inside the LP shaft.





MODULE 01.

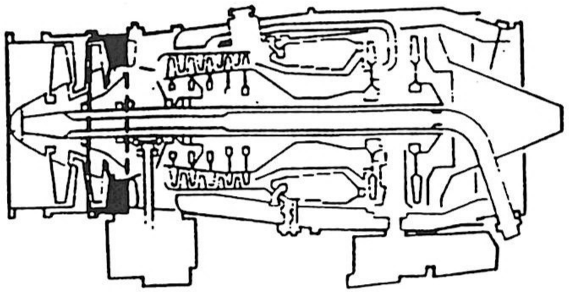


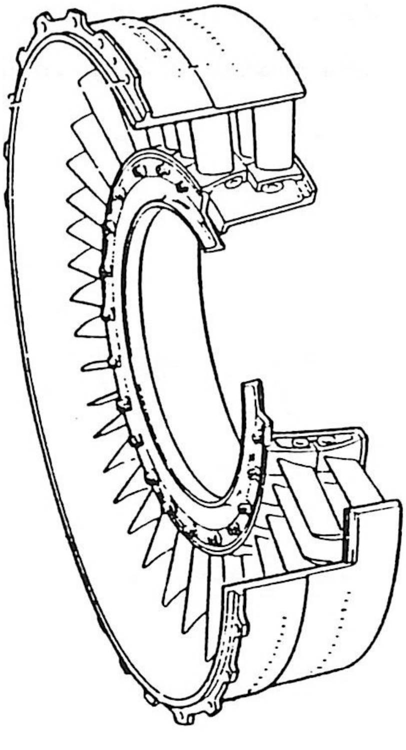
1. Air Intake Fairing.
2. Intake Fairing Bolt.
3. Spinner Cone.
4. Anti-icing Tube Nut.
5. Front Anti-icing Tube.
6. Rear Anti-icing Tube.
7. Compressor Rotor Retaining Bolt.
8. Compressor Rotor Retaining Nut.
9. Spinner Cone Bolt.

SPINNER AND ANTI-ICING TUBES.

MODULE Ø2.
LP COMPRESSOR STAGE TWO STATORS AND STATIC SEALS.

The stage two stator and seal assembly consists of two fabricated rings of stator vanes together with a static seal.
The static seal is bolted to the front face of the front vane inner platform and forms an air seal with the rotating air seal on the rear of the LP compressor rotor.
The stator vane inner platforms are loaded onto rubber damping rings which damp out vibration.
The complete assembly is fitted into the recess in the front inner diameter of the intermediate case.





MODULE 02.

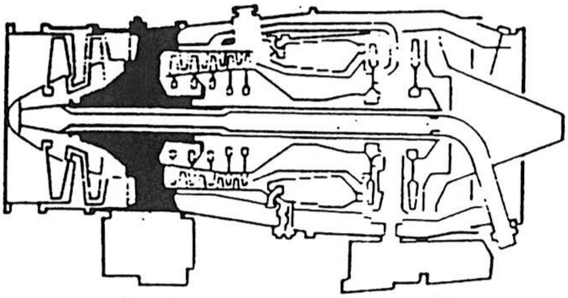
MODULE 03.

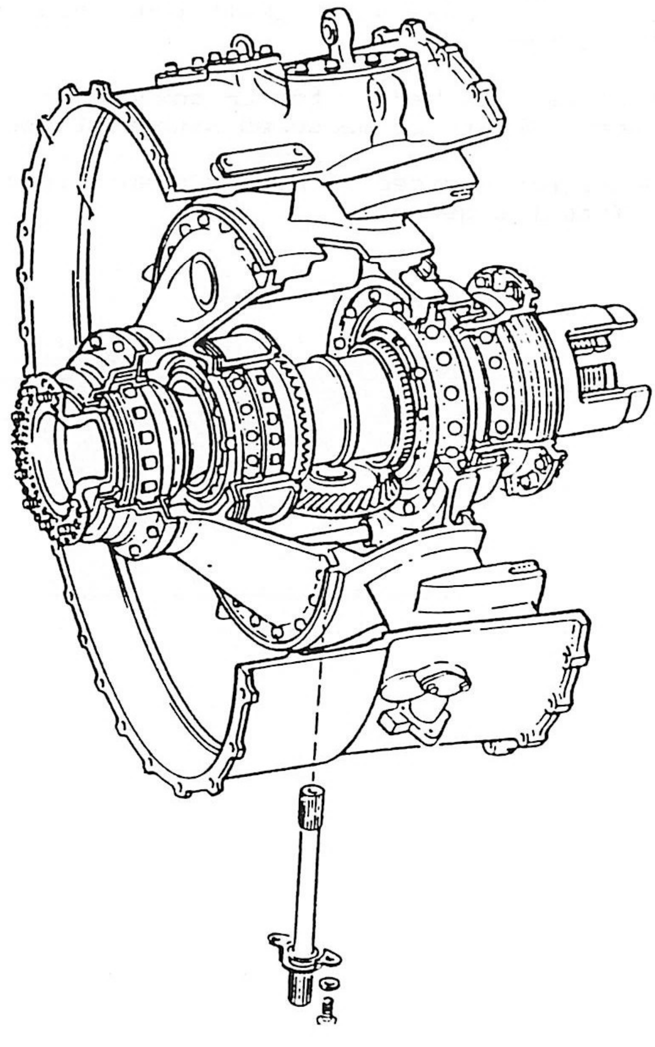
INTERMEDIATE CASE.

The compressor intermediate case incorporates six struts which support the internal gearbox and a circumferential airfoil fairing which divides the LP compressor airflow,one airflow passing into the HP compressor and the other into the by-pass duct.Engine front mounts,external gearbox mounts and LP speed probe housings are incorporated in the casing.

Inspection ports are provided to enable inspection of the HP compressor.The compressor may be rotated,to facilitate inspection on an installed engine,via the starter motor.

The manufacturer's data plate is also incorporated on the casing.





MODULE 03.

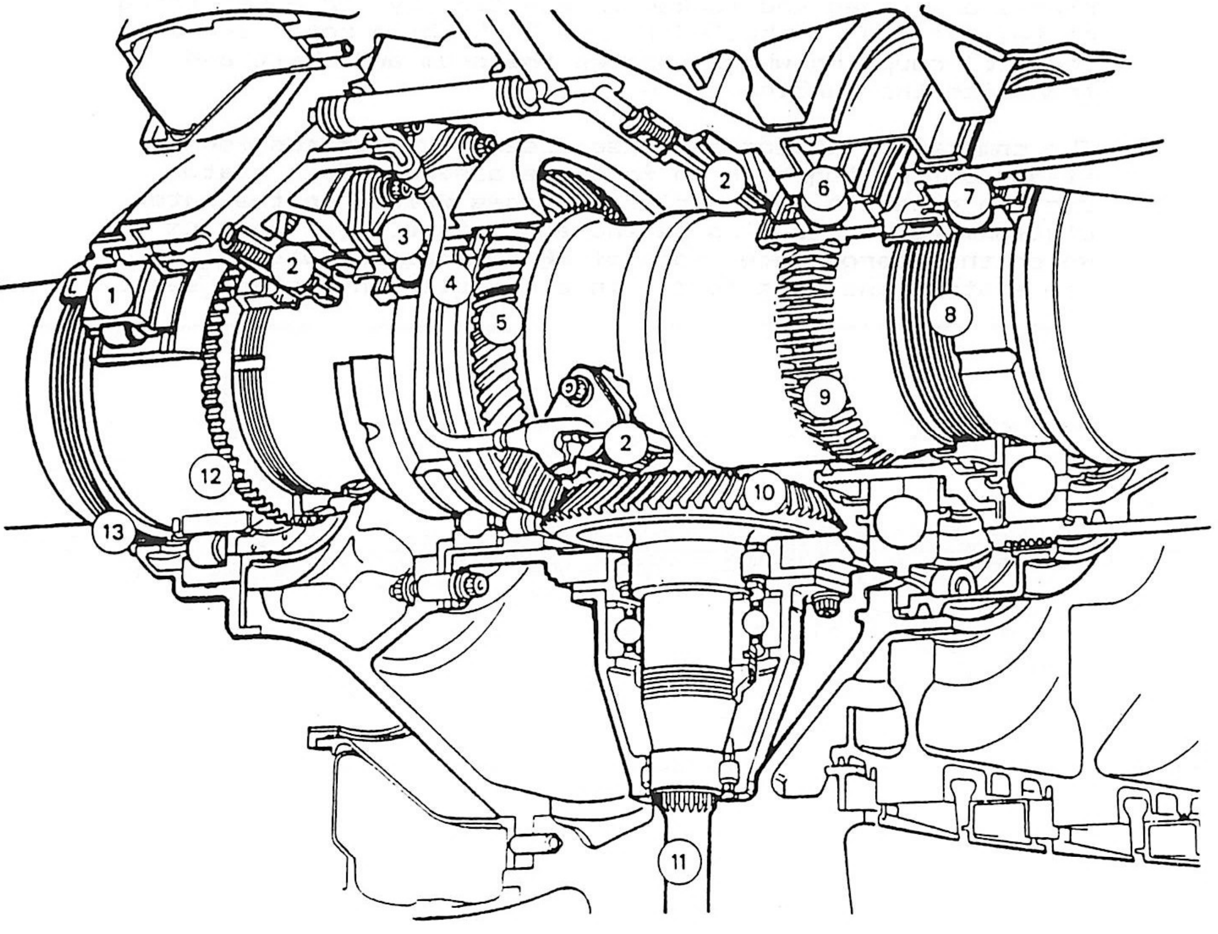
MODULE 03.
INTERNAL GEARBOX.

The internal gearbox comprises a driving bevel gear on an extension of the HP compressor shaft and a driven bevel gear assembly secured in the intermediate case.Both gears are supported in ball and roller bearings.A splined quill shaft transfers the drive from the driven bevel gear assembly to the high speed external gearbox.

Also located in the gearbox are the LP compressor shaft front bearing,the HP compressor shaft front bearing and an inter-shaft bearing.

A phonic wheel is attached to the LP compressor shaft to enable LP speed (NL) to be measured with test equipment.

Labyrinth seals,pressurised by P2 air,ensure that no oil loss occurs from the gearbox.



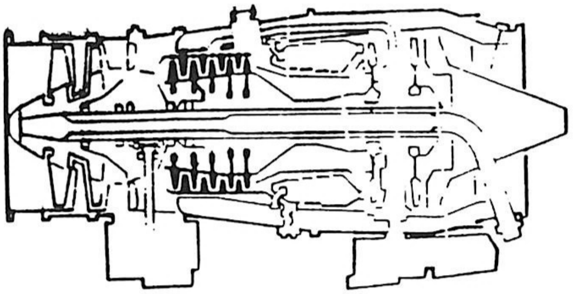
1.LP Compressor Bearing.
2.Oil Metering Jets.
3.Internal Gear-box Ball Bearing.
4.Internal Gear-box Roller Bearing.
5.Driving Gear.
6.HP Compressor Bearing.
7.Inter-shaft Bearing.
8.LP Compressor/Turbine Shaft.
9.Internal Gear-box Drive Shaft.
10.Driven Gear.
11.External Gear-box Drive Shaft.
12.Phonic Wheel.
13.Labyrinth Oil Seal.

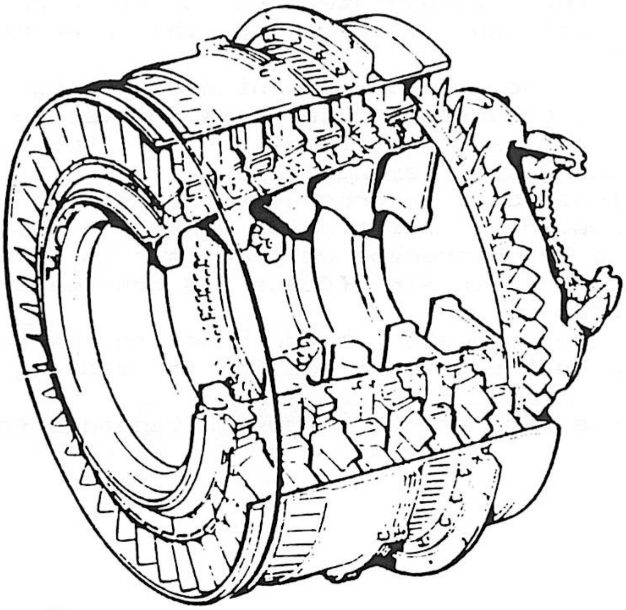
INTERNAL GEAR-BOX.

MODULE 04.
HP COMPRESSOR ASSEMBLY,DRUM,BLADES AND STATORS.

The HP compressor comprises of five machined discs welded together to form a drum into which the five stages of rotor blades are keyed and locked in position by blade retaining plates.The drum is bolted to the HP turbine rotor shaft by a 'curvic' coupling which locates the drum and shaft and transmits the turbine drive.

The compressor stator and case assembly comprises four stages,bolted together to form one assembly.Each stator section consists of a series of vanes welded on the outer platform to form a ring,behind each stage is an annulus into which the appropriate stage of HP compressor rotor blade. The stator vane tips locate in a circular interstage seal.

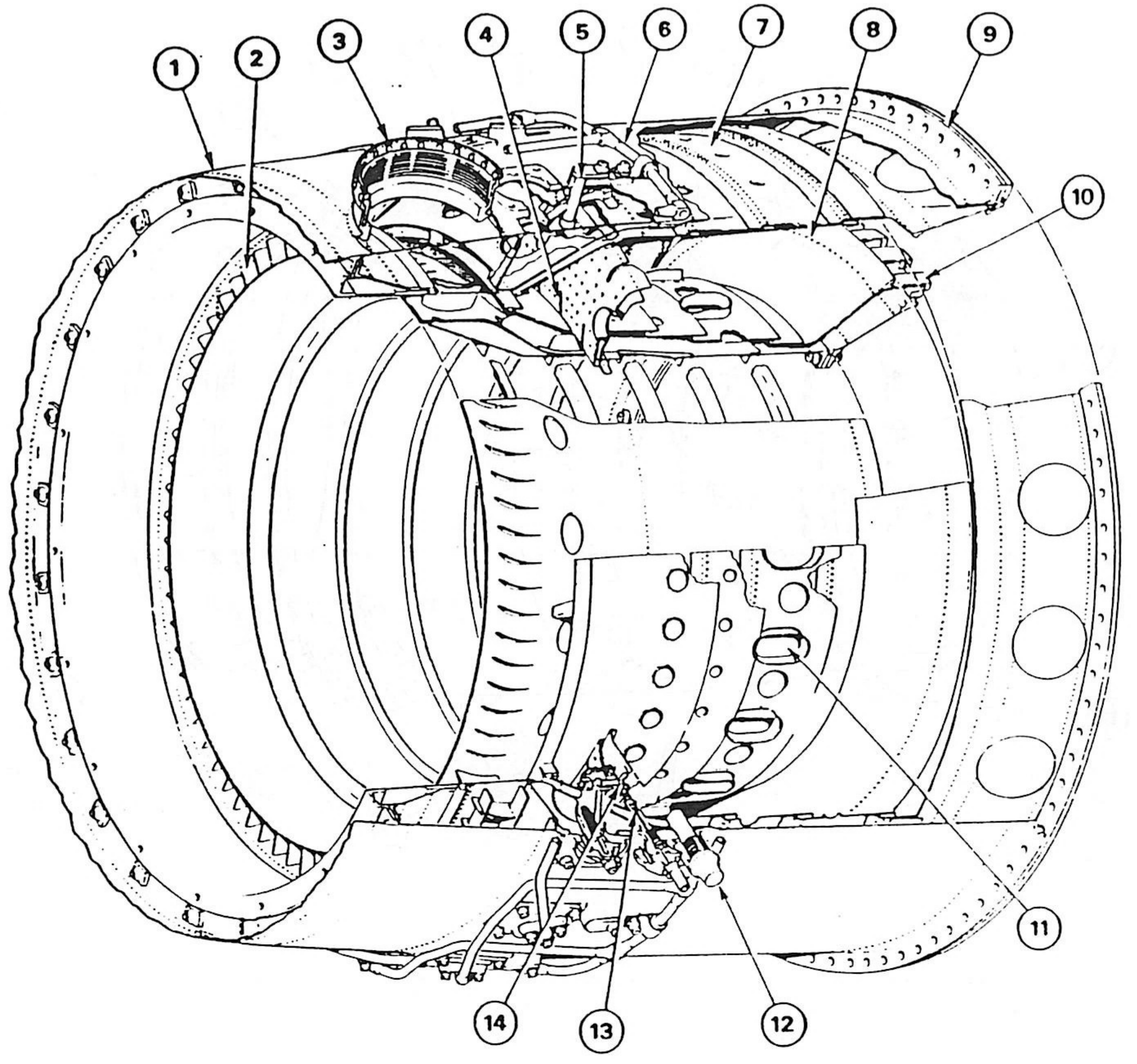




MODULE 04.

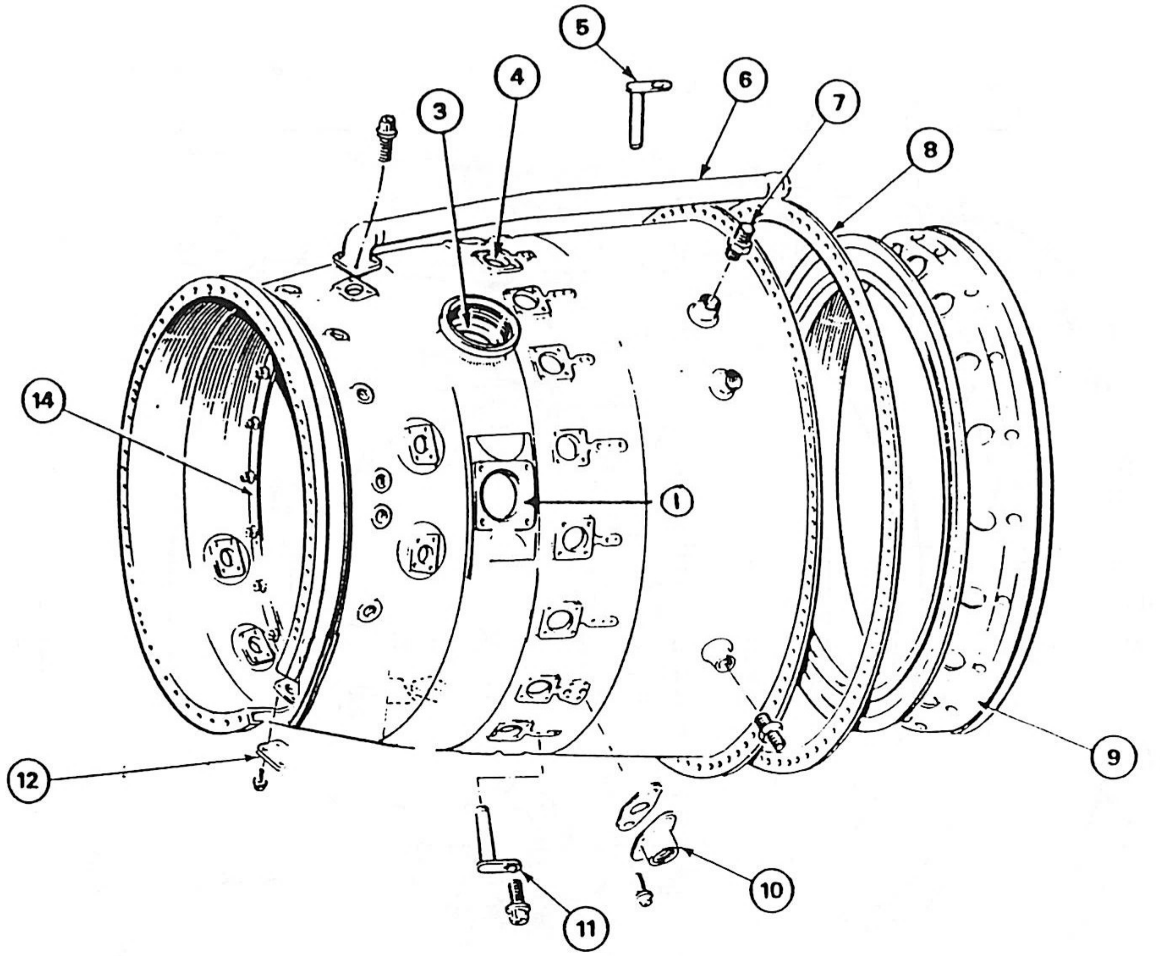
COMBUSTION SECTION.
NON-MODULAR.

The combustion section comprises a circular combustion outer case into which is mounted a combustion liner.A deflector plate provides the location for the fuel spray nozzles.
The combustion liner is surrounded by an inner and outer case which contains and directs compressor delivery air into the combustion area.
The inner and outer cases are also structural members,the outer case joins the intermediate case to the LP nozzle guide vane outer case and forms part of the inner walls of the by-pass duct.
Eighteen fuel spray nozzles and two high energy igniters are fitted through the combustion outer case.Mounted on the combustion outer case are fuel inlet manifold tubes which convey fuel to the fuel spray nozzles.
The combustion inner case incorporates the HP compressor outlet guide vanes.These outlet guide vanes are hollow and serve to transfer HP compressor delivery air to an annular area from which the cabin air offtake and compressor bleed valve are supplied.
Also mounted on the combustion outer case are the tubes carrying HP3 air to the turbine section for cooling purposes.
To the rear of the case are the three P3 tappings for engine services.



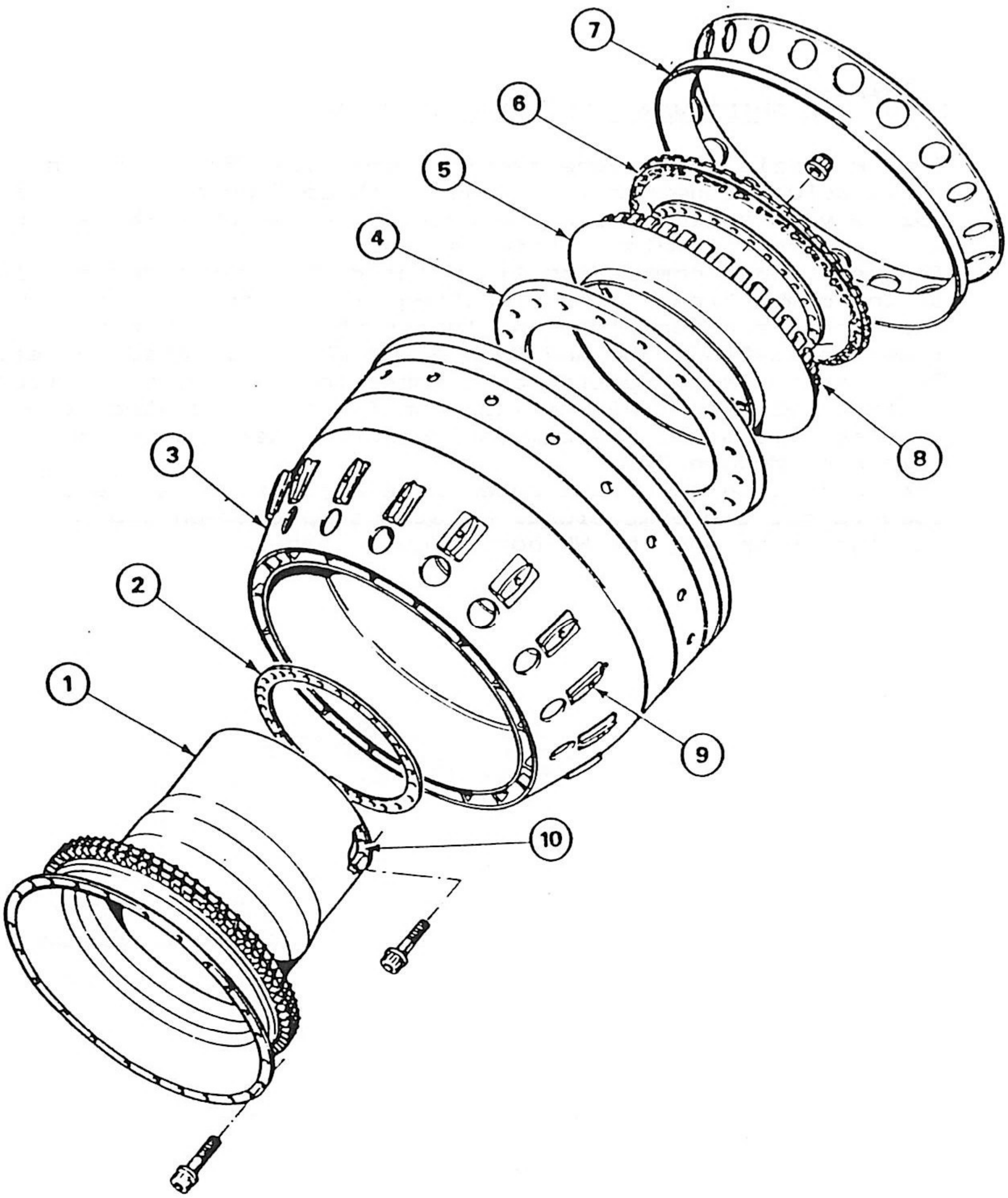
1. Combustion Outer Case.
2. HP Comp.Outlet Guide Vanes.
3. HP Air Offtake.
4. Deflector Plate.
5. Combustion Liner Locating Pin.
6. Fuel Inlet Manifold Tubes.
7. Outer Combustion Liner.
8. Rear Inner Combustion Liner.
9. Comb.Case,Turbine Case Flange.
10. HP NGV Locating Fingers.
11. Inner Combustion Liner.
12. Igniter Plug.
14. Fuel Spray Nozzle.

COMBUSTION SECTION.



1. Mounting for Air Bleed Valve.
3. HP Air Offtake Position.
4. Fuel Spray Nozzle Bosses.
5. Flanged Pin.
6. HP3 Cooling Air Tube.
7. Spherical Seating P3 Union.
8. Combustion Case Spacer.
9. Outer Diffuser Case.
10. HE Igniter Adaptor.
11. Flanged Pin.
12. Blanking Plate.
14. Mounting Flange for Front Inner Combustion Case.

COMBUSTION OUTER CASE.

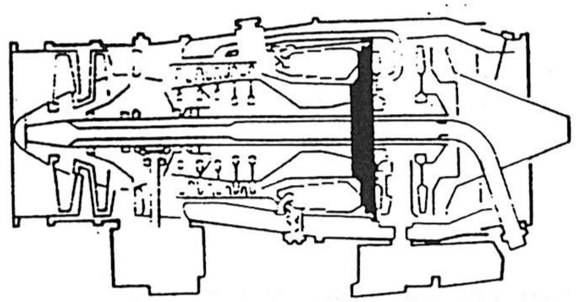


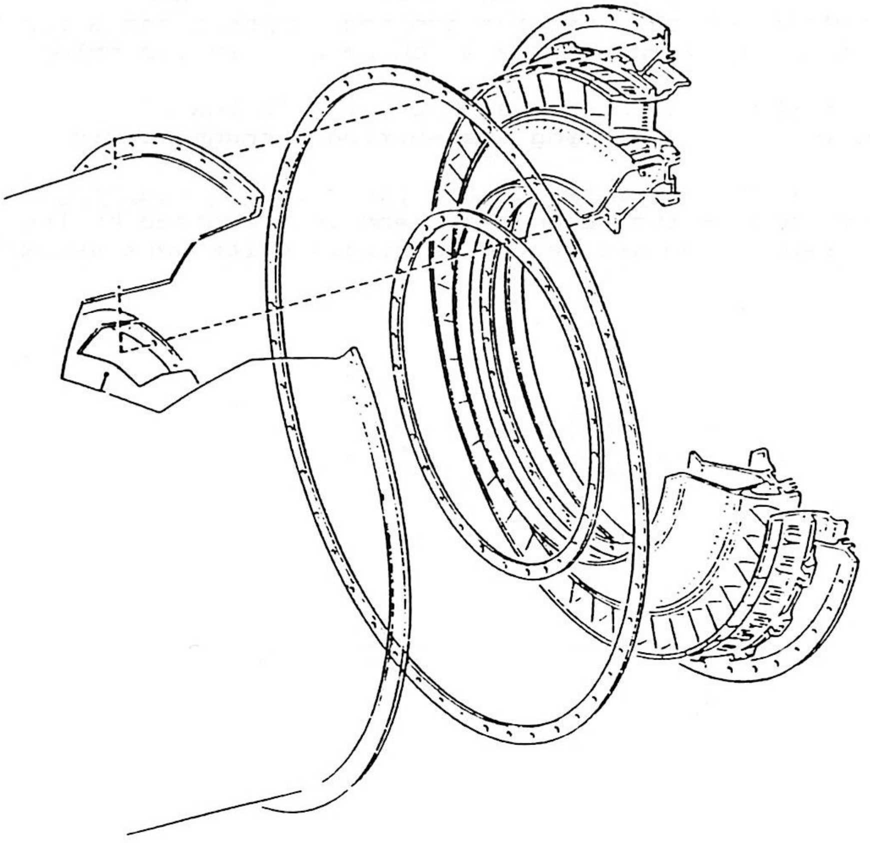
1. Front Inner Combustion Case.
2. Adjusting Spacer.
3. Front Combustion Liner.
4. Deflector Plate.
5. Rear Innr Combustion Liner.
6. Rear Inner Combustion Case.
7. Rear Outer Combustion Liner.
8. HP NGV Location Fingers.
9. Flanged Pin Locating Pads.
10. Flange Mounting HP Nozzle Guide Vanes.

COMBUSTION LINER ASSEMBLY.

MODULE 05.
HP NOZZLE GUIDE VANES,LOCATING RINGS AND SEALS.

The HP nozzle guide vane assembly comprises 57 air cooled vanes welded together in groups of three forming a circular nozzle vane assembly secured together by an HP turbine front air seal and an outer retaining ring.
The rear inner combustion liner forms the rear inner section of the combustion chamber,locating fingers incorporated on the liner rear face hold and locate the lugs on the rear inner combustion case and locate the HP nozzle guide vanes.
The rear outer combustion case forms the rear outer section of the combustion chamber.The rear flange is located between the rear flange of the combustion outer case and the front flange of Module 05.
The combustion inner and outer case adjusting spacers are used to set the dimensional relationship between the HP turbine rotor and the HP nozzle guide vanes.





MODULE 05.

MODULE 06.

HP TURBINE ROTOR.

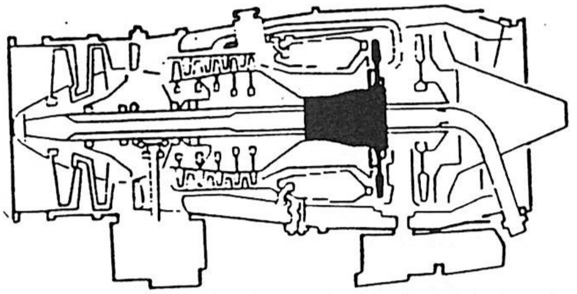
The HP turbine rotor assembly comprises a disc,78 turbine blades,rotor shaft and stub shaft.

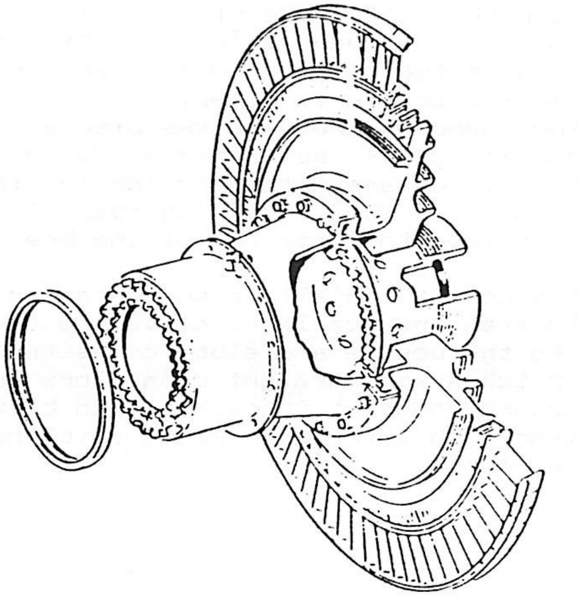
The turbine blades are keyed to the disc by 'FIR TREE' roots and retained in position by locking plates which fit in circumferential grooves in the rear face of the turbine disc.The blades are air cooled and incorporate peripheral and platform sealing lands.

The turbine disc incorporates three labyrinth air seals which retain air supplied for cooling purposes and a curvic coupling on the forward face which mates with the rotor shaft.

The rotor shaft connects the HP turbine to the HP compressor,the drive being transmitted through curvic couplings.

The stub shaft is secured to the inner curvic coupling on the rear face of the rotor shaft and is supported by the HP turbine bearing housed in the LP nozzle guide vane assembly.

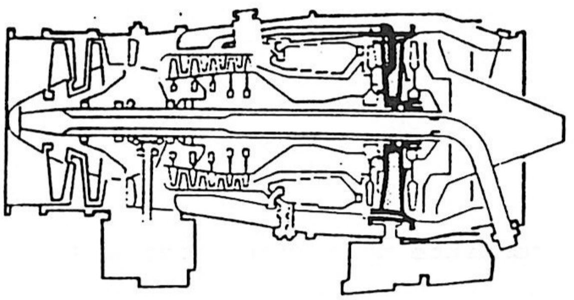


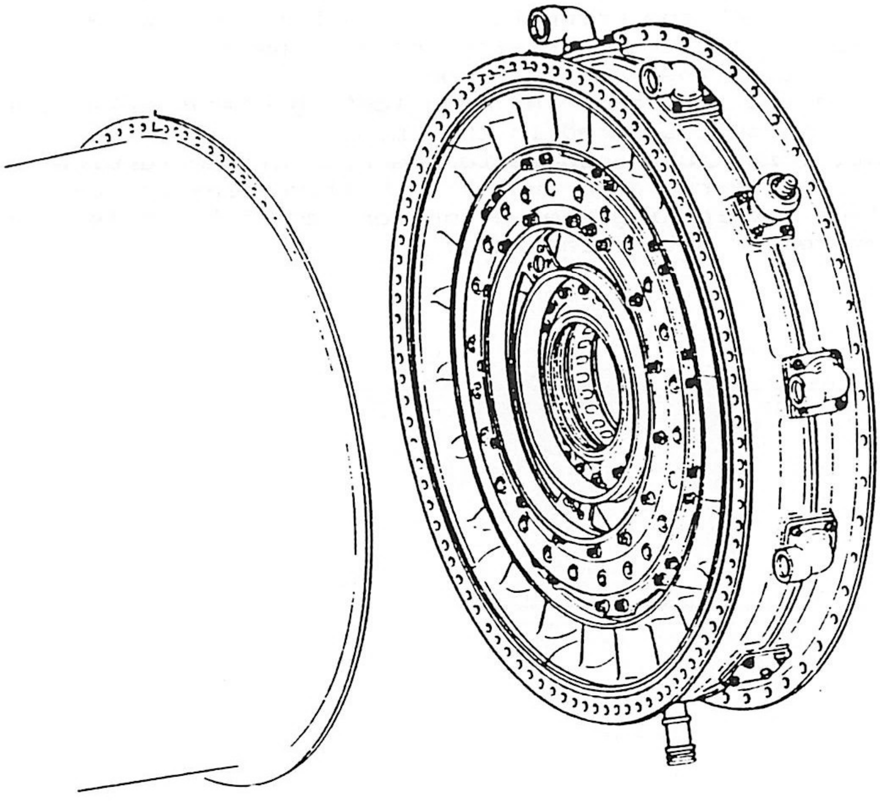


MODULE 07.
LP NOZZLE GUIDE VANES,CASING,BEARING AND SUPPORT.

The nozzle case and turbine bearing housing is formed by an outer case into which are fitted the LP nozzle guide vane segments.Attached to the rear of the segments is a bearing support panel which houses the HP and LP turbine roller bearings.Passing through the outer case and LP nozzle guide are tubes which convey cooling air,vent air,feed oil and scavenge oil.
The hollow aerofoil shaped guide vanes are welded together in twelve sets of two,forming segments on which are radial bosses integral with the outer vane platform.The vanes have platforms which form a continuous flange at the leading and trailing edges to which the bearing housing support panel and the LP turbine disc seal are fitted.
The turbine bearing support panel and the disc air seal are secured to the rear flange of the nozzle guide vanes.The HP turbine bearing and spacer are fitted inside the forward end of the bearing support and the LP bearing retaining ring and spacer are located inside the rear end of the bearing support panel.
The nozzle case has bosses radially disposed around the periphery which locates the nozzle guide vane outer platforms.Fitted to the bosses are elbow connectors,which locate cooling air tubes and straight connectors which locate oil feed,return and vent tubes.Situated between the front and rear flanges is a trunnion mount which houses the oil tank support pillar.

BYPASS AIR FOR COOLING





MODULE 07.

MODULE Ø8.

LP TURBINE ROTOR.

The LP turbine rotor assembly consists of a shaft,disc and 94 turbine blades.

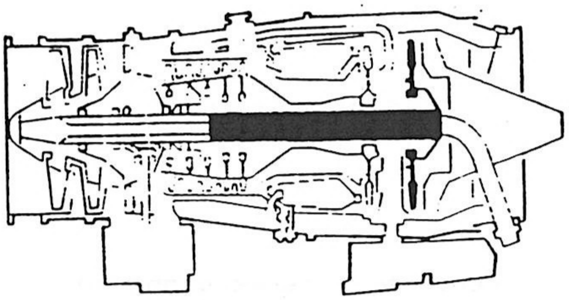
The blades are keyed to the disc by 'FIR TREE' roots and are retained by locking plates which fit into circumferential grooves in the rear face of the disc.

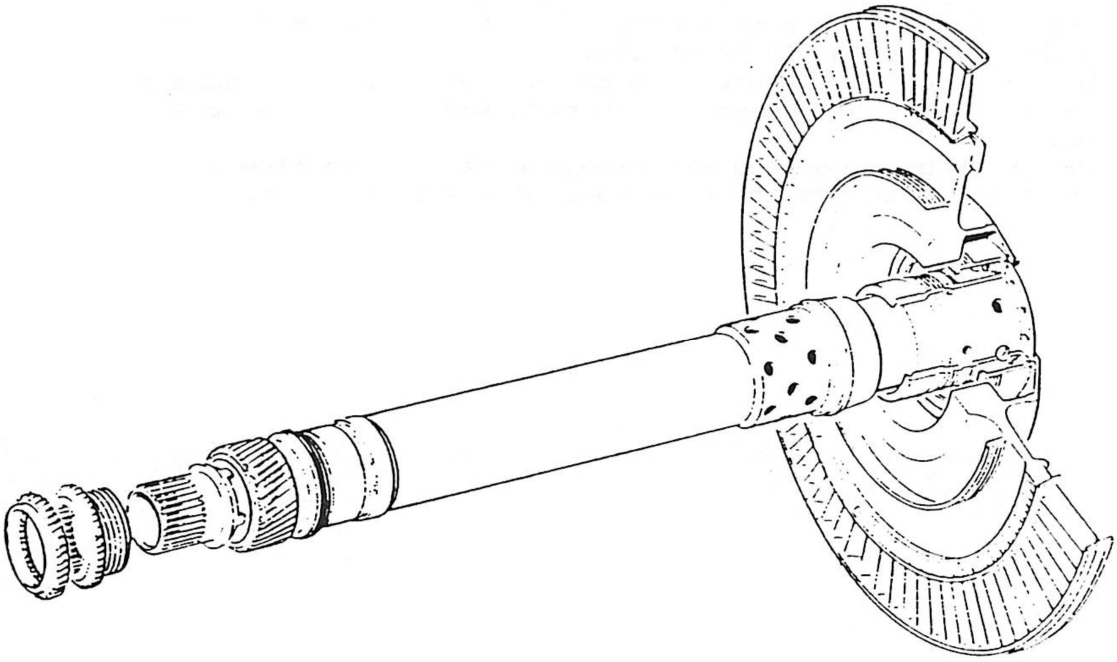
The disc incorporates a labyrinth air seal on the forward face and a curvic coupling on the rear face through which the LP turbine shaft is secured to the disc.

A coupling nut screwed into the forward end of the turbine shaft provides the retention feature between the LP compressor and turbine shafts and also permits axial adjustment of the turbine rotor.

The coupling nut is locked by a locking sleeve splined into a coupling seat secured in the inter-shaft.

An anti-icing tube secured to the rear of the turbine shaft and passing forward through the shaft,retains the LP coupling nut locking sleeve and locates in the bore of the LP compressor anti-icing tube.



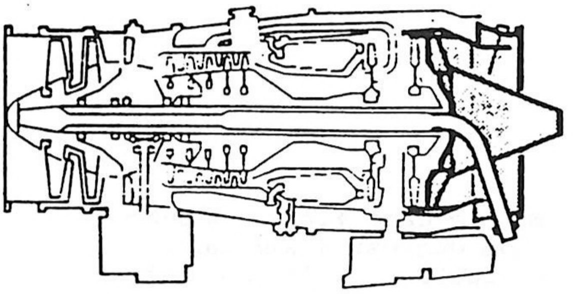


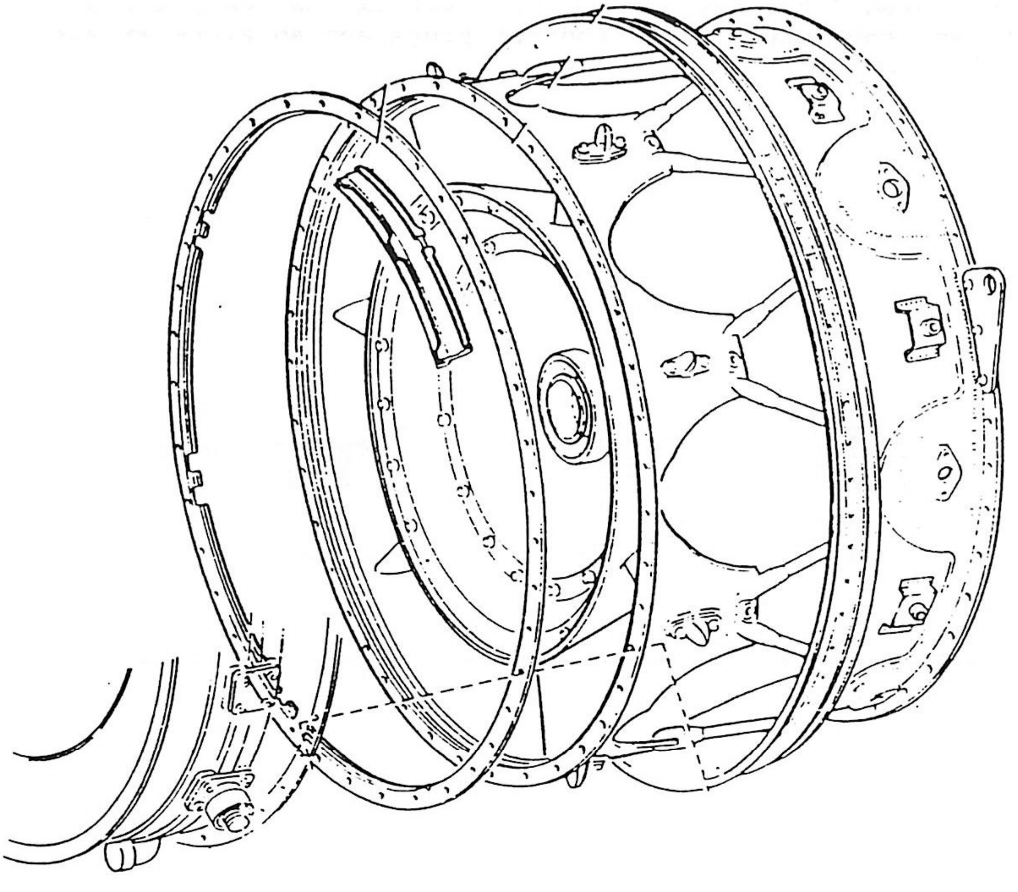
<u>MODULE 08.</u>

MODULE 09.

EXHAUST MIXER AND CONE.

The exhaust mixer consists of two concentric cases connected by seven radially mounted 'A' frame struts welded to sole plates around the inner diameter of the outer case.
The exhaust mixer case front flange is secured to the LP nozzle guide vane rear flange and the mixer case rear flange is connected to the exhaust collector diffuser section.
The exhaust cone is secured to the exhaust mixer by hollow spokes passing through aerofoil struts to the front sole plates of the 'A' frame struts.
The air scoops protrude into the by-pass air and induce a cooling air flow through the spokes and into the exhaust cone.
The LP turbine cooling air flange controls the flow of cooling air across the rear face of the LP turbine.



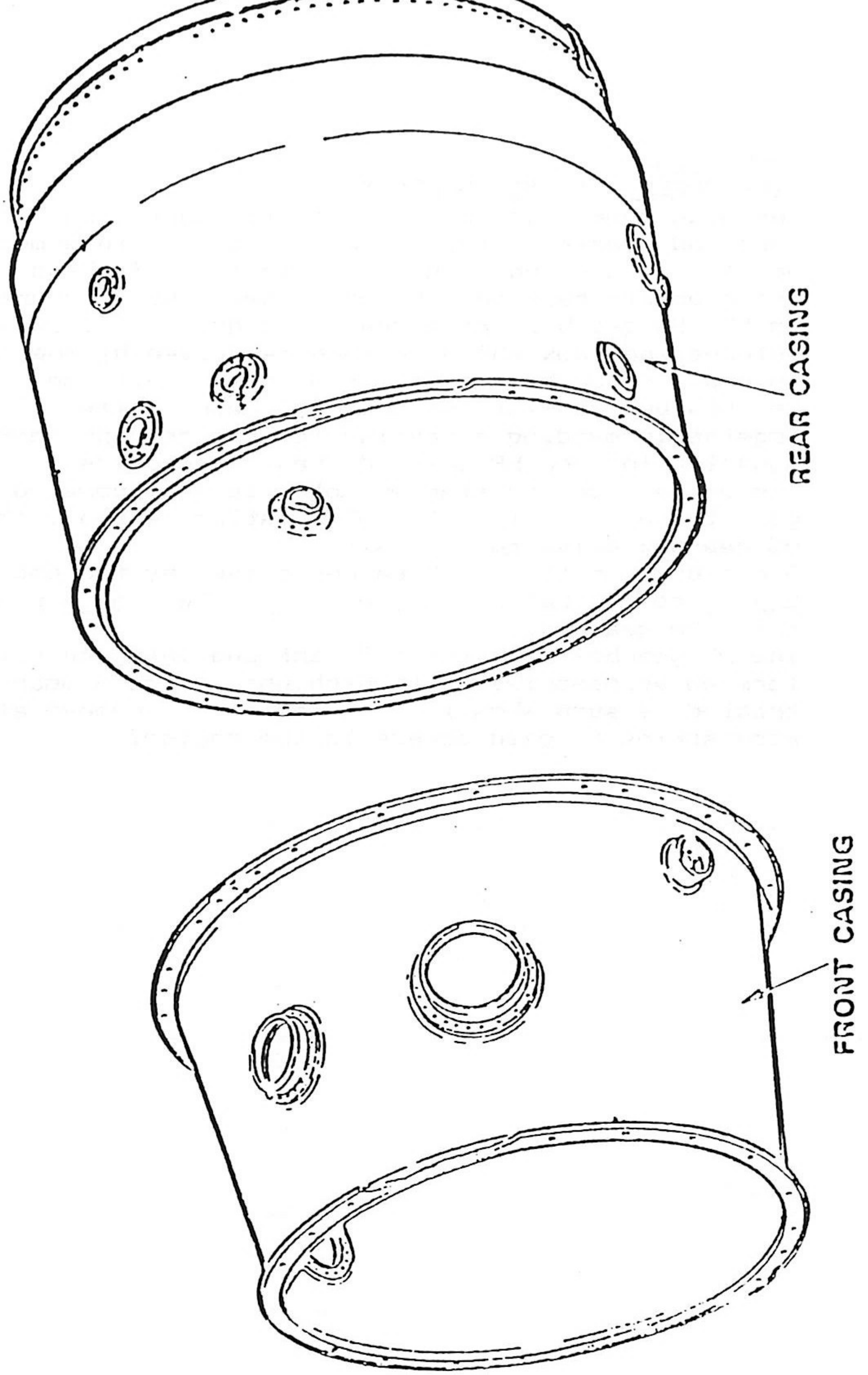


MODULE 09.

BY-PASS CASING.

NON-MODULAR.

The divided flow from the intermediate case flows through the annular by-pass duct area to the exhaust mixer unit.
The by-pass casing consists of two sections bolted together through the mating flanges;the front section being bolted to the intermediate case rear flange.The rear by-pass section is supported on a piston ring type seal attached to the exhaust mixer front face which prevents leakage of air from the by-pass duct and allows freedom of expansion.
Sole plates,fitted with spherical seats,allow the passage of oil feed and return tubes,igniter plugs and an aircraft air supply duct.



BY-PASS CASING - NON-MODULAR.

MODULE 10.

HIGH SPEED EXTERNAL GEARBOX.

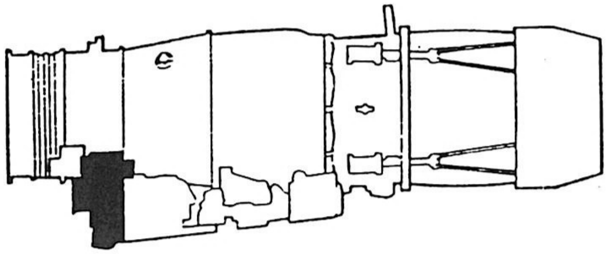
The high speed external gearbox is mounted and retained by lugs and dowels to the lower half of the intermediate case. One lug is secured with a link to the left hand side of the intermediate case,and the other two lugs to mounts adjacent to the HS gearbox drive shaft.The gearbox is driven from the internal gearbox which in turn is driven by the HP rotating assembly through the HS gearbox drive quill shaft.

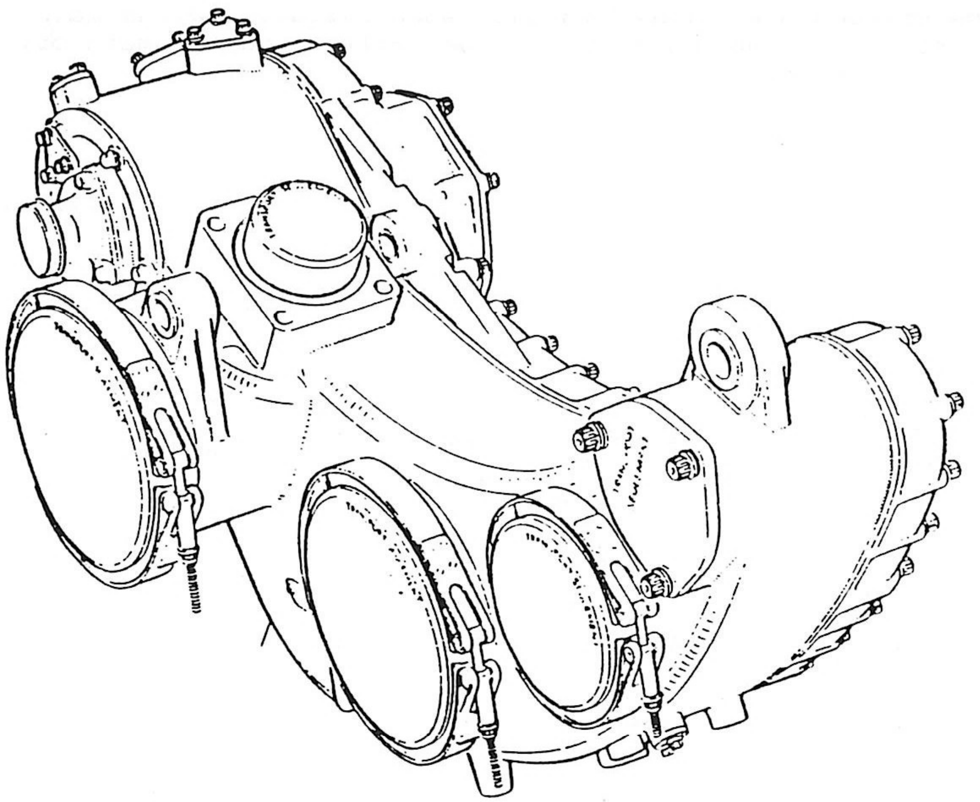
The gearbox consists of two half cases bolted together,providing a housing for the driving gear train and mounting for the HP shaft driven accessories.

The drive from the starter motor is incorporated into the gear train and drives the HP rotating assembly through the HS gearbox drive quill shaft.

A gearbox centrifugal breather driven by the gear train separates and returns any oil from the vent air system back into the gearbox.

The HS gearbox with the oil tank and interconnecting tubes form an accessories pack which,whilst not a module,is treated as such when it is necessary to remove all accessories to gain access to the engine.



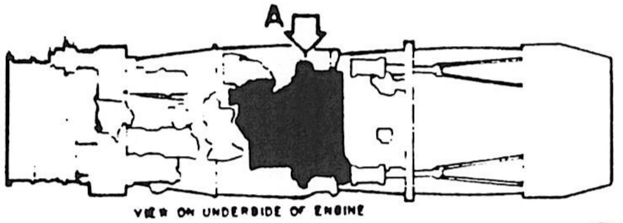


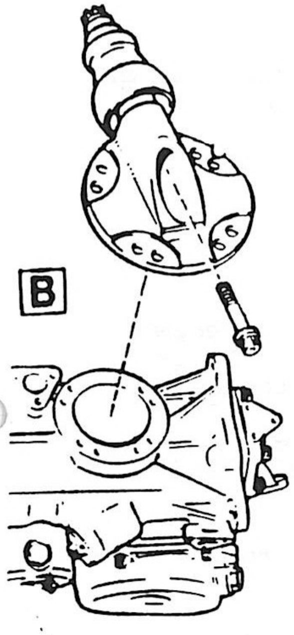
MODULE 10.

MODULE 11.

OIL TANK,COOLER AND FILTERS.

The oil tank,cooler and filter assembly is attached to the engine at the rear underside of the by-pass duct.
The complete assembly is attached at the front by a hollow support pillar,passing through the by-pass duct,mounted on the LP NGV case and at the rear by two links to the exhaust mixer rear flange.
The cooler and filter assembly is bolted to and forms the front wall of the oil tank.
Three filters are located in the assembly,they are,the main LP fuel filter,the after-burner fuel filter and the main oil pressure filter.


A
VIEW ON UNDERSIDE OF ENGINE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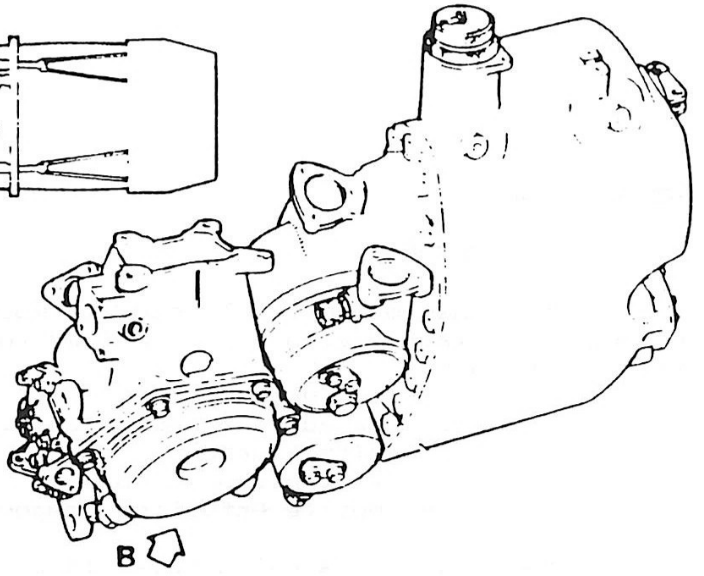
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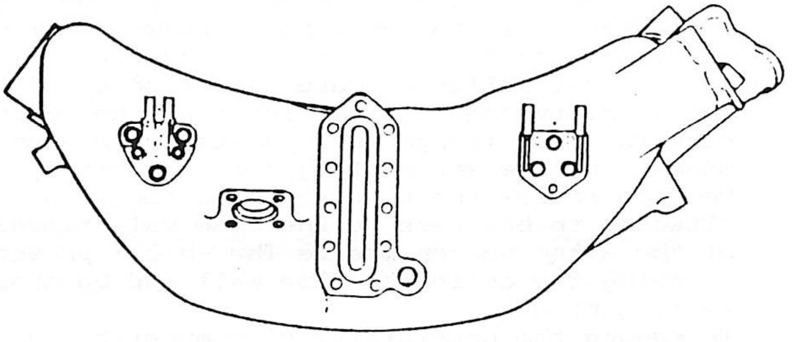


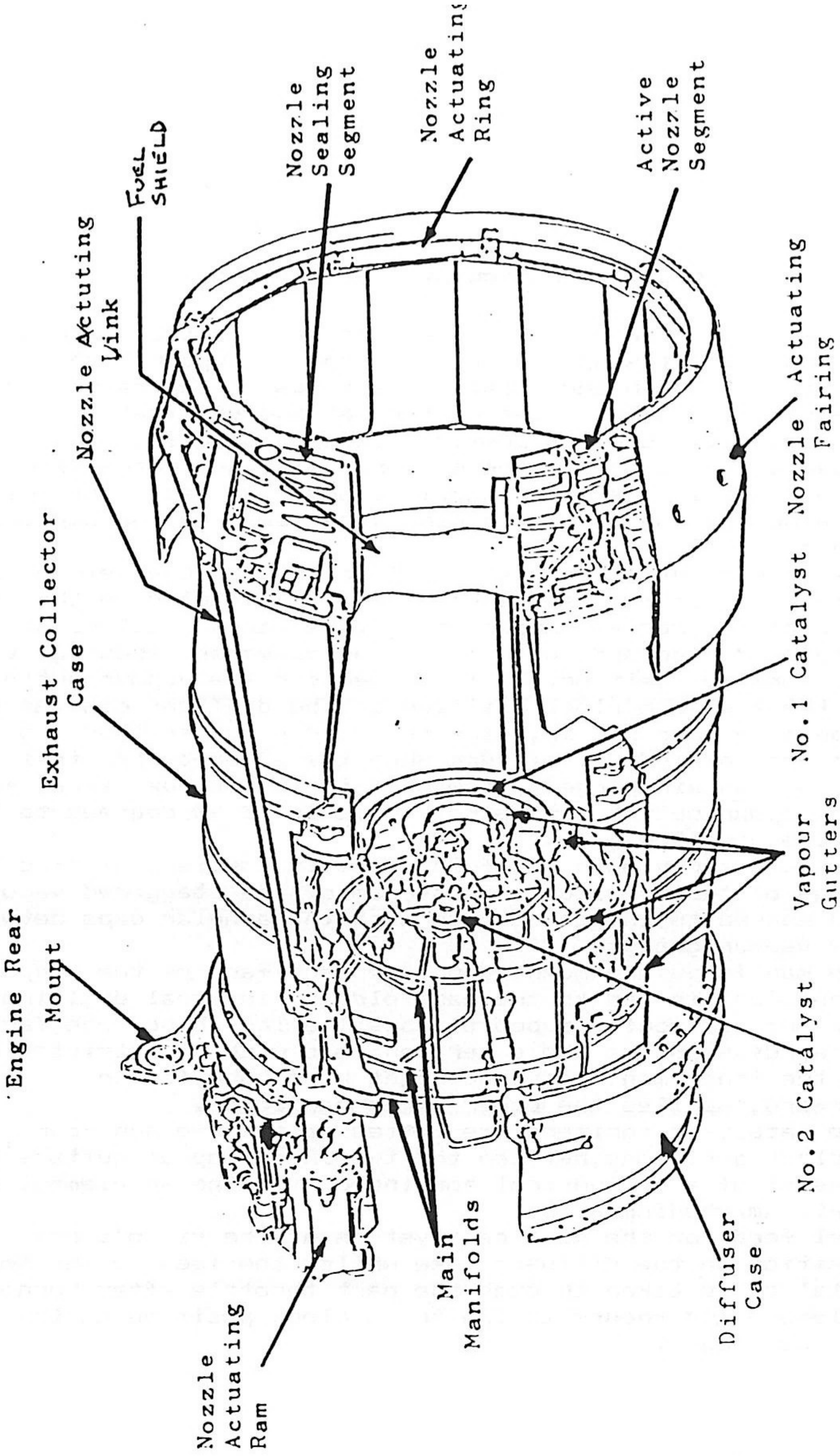
NON-MODULAR.

EXHAUST COLLECTOR.

The after-burner exhaust collector is mounted on the rear of the exhaust mixer casing and comprises the following five main components:

i Diffuser Case.
ii Exhaust Collector Case.
iii After-burner Vapour Gutter and Manifold.
iv Variable Area Nozzle.
v Nozzle Actuating Components.

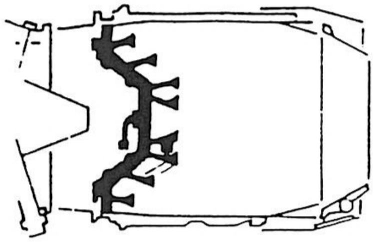
The diffuser case is a cylindrical forging with a divergent inner contour and front and rear flanges.The front flange is secured to the exhaust mixer and the rear flange to the exhaust collector case.
Also secured to the diffuser case is the engine rear mount,the after-burner vapour gutter and manifold module, the four nozzle actuating rams and the fireseal.
The exhaust collector case is a fabricated cylinder,divergent at the front and convergent at the rear.The rear flange incorporates lugs upon which are mounted active and sealing nozzle segments.
Mounted inside the exhaust collector is a fuel shield attached to brackets on the case wall immediately downstream of the after-burner module.The shield prevents excess fuel reaching the collector case wall and burning the braided sealing rings.
To reduce the possibility of combustion in the braided sealing ring area,cooling air is supplied to the rear inner cone via cooling channels.
A drain valve, located on the bottom centre line of the collector case,drains overboard any residual fuel in the collector case eg,after an engine failure to light up during the starting sequence.(Wet Start).
A thermal insulation blanket is mounted around the exhaust collector and consists of two dimpled stainless steel sheets interposed by a heat insulating material.

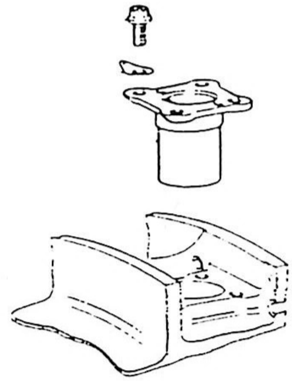


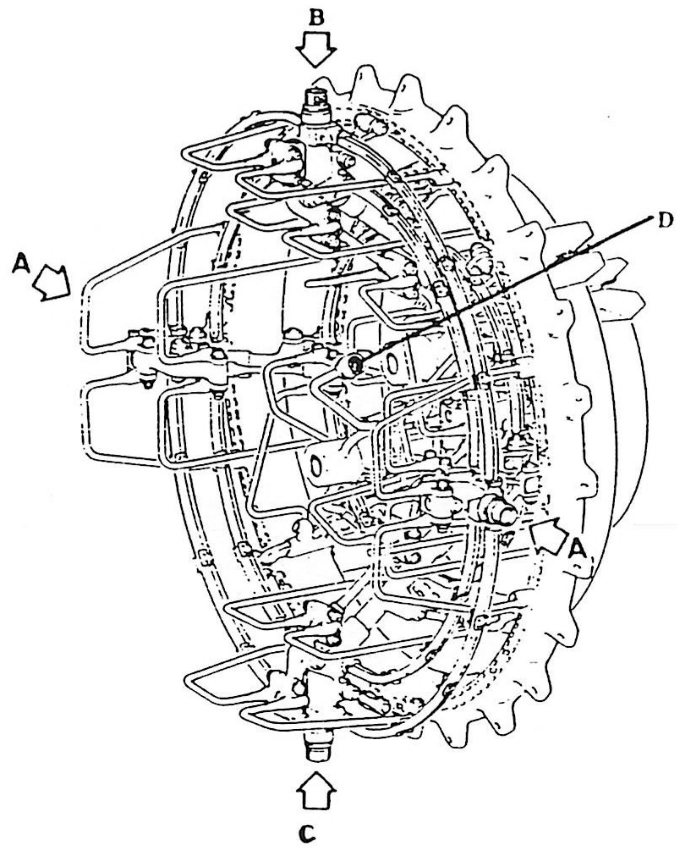
EXHAUST COLLECTOR C/W MO.12.

MODULE 12.
AFTER-BURNER VAPOUR GUTTER AND MAIN MANIFOLD.

The after-burner vapour gutter and main manifold are mounted on four radial support tubes.The radial support tubes protrude through and locate in sleeves which are bolted to the diffuser case at the horizontal and vertical positions.The sleeves provide location,both internally and externally,and permit thermal expansion and retraction to take place in the spray nozzle assembly.A gas tight seal is obtained by use of piston ring type seals on the support tubes.
The vapour gutter consists of four annular channels of blunt nosed 'V' section.Each section is link mounted to the rear face of the radial support tubes.The vapour gutters are staggered rearwards with the large diameter vapour gutter in the forward position.The fuel feed for the vapour gutters is at the twelve o'clock position on the diffuser case.An air tube,supplying P3 air,joins the vapour gutter feed tube to provide an air/fuel mixture when the after-burner is in use,and an air purge system when it is not.Fuel spray from the vapour gutter feed spray tubes is at 90 degrees to the engine air flow.
The fuel spray main manifold assembly consists of circular rings of tubing situated upstream of the staggered vapours and spaced to inject fuel through the annular gaps between the vapour gutters.
The manifolds are mounted on the rear face of the support tubes.Fuel is fed to the manifolds by internal drillings in the two horizontal support tubes.The left hand tube,facing forwards,supplies the outer manifold with a restricted flow to the inner manifolds.The right hand tube,facing forward,supplies the other three manifolds.
Two catalytic igniters are fitted at the two and four o'clock positions,between the two inner vapour gutters and consist of a cylindrical housing containing an element of platinum/rhodium alloy.
Fuel feed for the No.1 catalyst is at the six o'clock position on the diffuser case whilst the feed to the No.2 catalyst is taken through the part throttle after-burner solenoid and thence to the ten o'clock position on the diffuser case.





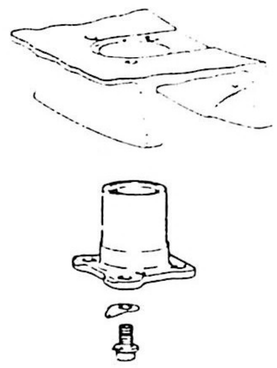


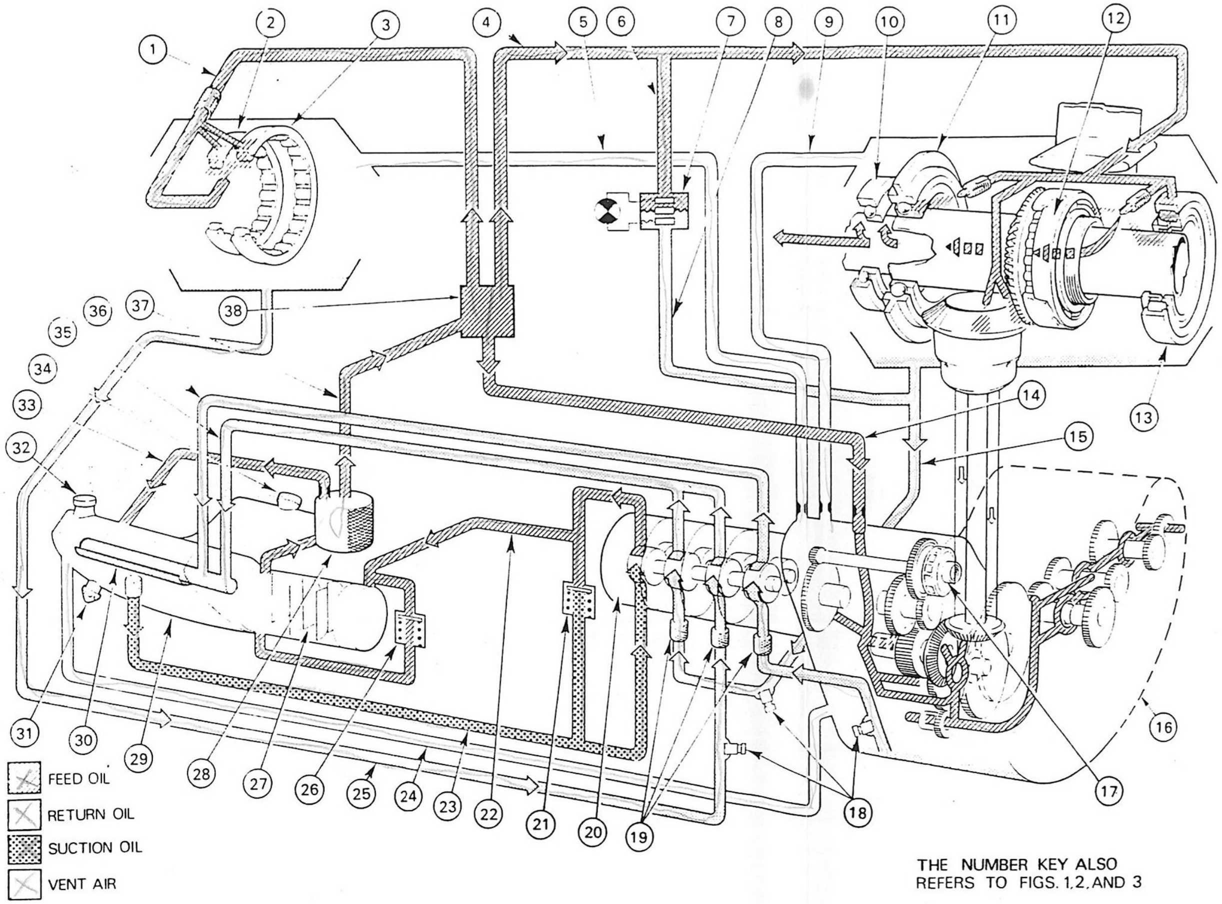
A. Main Manifold Feed.

B. Vapour Gutter Feed.

C. No.1 Catalyst Feed.

D. No.2 Catalyst Feed.





1. OIL FEED, TRANSFER HOUSING TO TURBINE BEARINGS
2. L.P. TURBINE BEARING
3. H.P. TURBINE BEARING
4. OIL FEED, TRANSFER HOUSING TO INTERNAL GEARBOX
5. VENT, TURBINE BEARINGS TO H.S. GEARBOX
6. FEED OIL TO OIL PRESSURE SWITCH
7. LOW OIL PRESSURE WARNING SWITCH
8. RETURN OIL TO OIL PRESSURE SWITCH
9. VENT, INTERNAL GEARBOX TO H.S. GEARBOX
10. INTERSHAFT BEARING
11. H.P. COMPRESSOR LOCATION (THRUST) BEARING
12. INTERNAL GEARBOX BEARINGS
13. L.P. COMPRESSOR BEARING
14. OIL FEED, TRANSFER HOUSING TO H.S. GEARBOX
15. OIL RETURN, INTERNAL GEARBOX TO OIL PUMPS
16. H.S. GEARBOX
17. CENTRIFUGAL BREATHER OUTLET
18. MAGNETIC CHIP DETECTORS
19. RETURN OIL STRAINERS
20. OIL PUMPS
21. PRESSURE RELIEF VALVE
22. OIL FEED, OIL PUMPS TO F.C.O.C.
23. OIL FEED, TANK TO OIL PUMPS
24. VENT, TANK TO H.S. GEARBOX
25. OIL RETURN, TURBINE BEARINGS TO OIL PUMPS (FOUR SECTIONS)
26. BY-PASS VALVE
27. FUEL COOLED OIL COOLER (F.C.O.C.)
28. PRESSURE OIL FILTER
29. OIL TANK
30. DE-AERATOR TRAY
31. OIL TANK PRESSURE FILLER
32. OIL TANK GRAVITY FILLER (RIGHT-HAND INSTALLATION)
33. METERED OIL SPILL
34. OIL TANK GRAVITY FILLER (LEFT-HAND INSTALLATION)
35. OIL RETURN, INTERNAL GEARBOX/TURBINE BEARINGS —OIL PUMPS TO TANK
36. **OIL RETURN, H.S. GEARBOX—OIL PUMPS TO TANK**
37. OIL FEED, PRESSURE FILTER TO TRANSFER HOUSING (TWO SECTIONS)
38. OIL FEED TRANSFER HOUSING

Oil system diagram

INVERTED FLIGHT (BALL VALVE)

OIL CONSUMS.
1 pt hour

ADOUR MK'S 811/815.
OIL SYSTEM.

REQUIREMENTS.

The system must provide lubrication for bearings.gears and splines under all engine operating conditions.

Additionally,the oil provides cooling for the bearings and assists in obtaining a uniform temperature distribution around them.

Oil is also used to reduce engine vibration by 'SQUEEZE FILM' damping of the HP and LP turbine bearings and the LP compressor front bearing.

Three sub-systems are employed to satisfy these requirements and they are:-

(a). PRESSURE SUPPLY. x1 PRESS RELIEF VALVE (OPEN 210psi)
This provides the means of delivering the oil from the tank to the areas requiring lubrication together with the necessary cooling,filtration and pressure regulation.

(b). SCAVENGE RETURN. x3 BY PASS VALVE (50 psi)
This system returns the oil to the tank after the lubrication process. Incorporated in the system are three scavenge pumps,strainers and magnetic chip detectors.

(c). VENTING. LOW OILPRESS DIFFERENTUAL (10psi)
To prevent excessive air pressure,certain areas of the engine are vented to atmosphere.

We can now deal with the operation of the complete system by analysis of these sub-systems.

(a). PRESSURE SUPPLY.
The oil is carried in an engine mounted tank.This has both pressure and gravity filling points.A gear type pump delivers oil to a 'Purolater'coiled wire filter via a fuel cooled oil cooler.The cooler is just prior to delivery to the fuel burners and therefore the fuel is high pressure delivery fuel.

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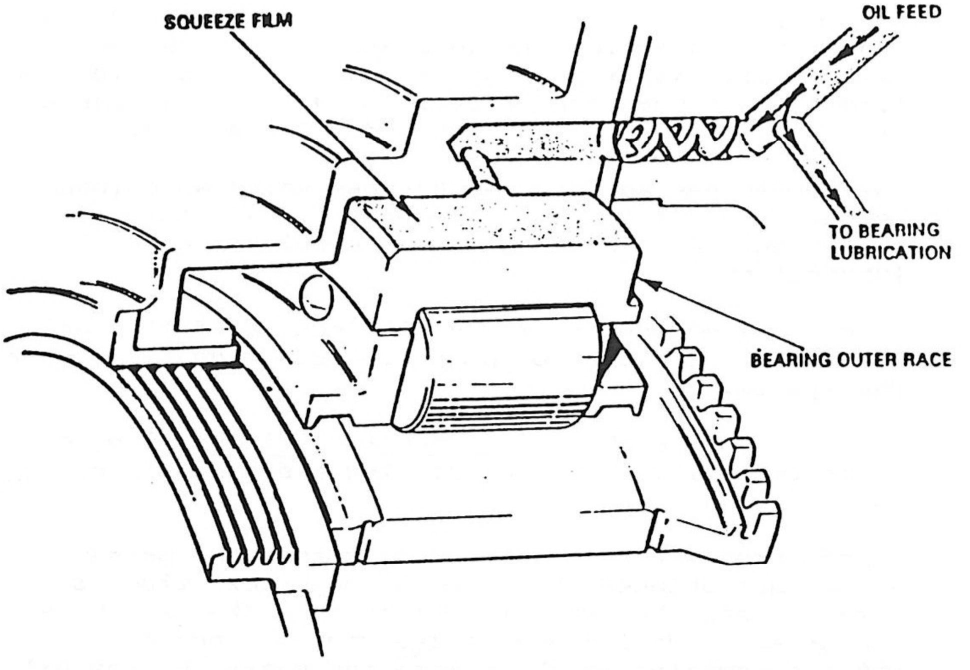


LP COMPRESSOR BEARING SHOWING SQUEEZE FILM DAMPING.

To protect the system from excessive pressure during starts at low ambient temperature,a high pressure relief valve is fitted in the head of the pump,on the line between pump and filter.Should the valve operate oil is returned to the inlet side of the pump.

The cooler has an integral by-pass valve which,under 'cold oil' conditions,will open thus by-passing the cooler and ensuring an adequate supply of oil for lubrication.

There is a metered spill of oil from the filter back to the tank to provide for possible future development of the system.

From the filter the oil passes to a distribution point where the oil is divided into the areas requiring lubrication.

A pressure switch in the system senses the pressure difference between the internal gear-box return oil pressure and the feed oil pressure,ie.The switch senses the pressure difference across the gear-box oil metering nozzles,which is more indicative of the oil flow than oil pressure alone.

The switch will cause a low pressure warning light on the cockpit CWP to illuminate if the pressure falls to a pre-set value.(10 psi diff.).

We can now examine the three areas requiring lubrication.
These are:-
The internal gear-box.
The external gear-box.
The turbine bearings.

<u>The Internal Gear-box.</u>
Drillings in the gear-box casing supply oil to three metering nozzles,and also to provide 'squeeze film' oil for the LP compressor front bearing.
The foremost of these three nozzles directs three jets of oil.These lubricate:-
The LP compressor front bearing.
The HP compressor front bearing.This oil is directed between the two shafts and is centrifuged into an oil catcher.Here the flow is divided and fed through drillings to lubricate the rear of the HP compressor front bearing both sides of the intershaft bearing and the helical splines on the intermediate shaft.The bevel gear ball and roller bearings are lubricated via an oil catcher.

The centre metering nozzle sprays oil onto the driven bevel gear and into the end of the external gear-box drive shaft. The oil in the drive shaft is then centrifuged through radial drillings to lubricate the bearings.

The rear nozzle directs a jet of oil under the cage lip on the front side of the HP compressor front bearing.

Turbine Bearings.
Two drillings in the bearing housing provide 'squeeze film' oil around the outer tracks of each bearing.

A nozzle directs two jets of oil, one forward for the HP turbine bearing, one rearwards for the LP turbine bearing. The oil supplied to the HP turbine bearing is also used to form a hydraulic seal between the HP and LP shafts to prevent oil leaking into the LP cooling air.

External Gear-box.
The oil supply to this section is via a series of drillings and chambers from which tappings are taken for the lubrication of gear trains and their bearings, and the gear-box driving bevel gears.
Gears that have no positive feed are splash lubricated. An oil trough in the gear-box ensures lubrication of the gears that carry the initial starting loads.

(b). SCAVENGE RETURN.

The three gear type scavenge pumps draw oil from the three lubricated areas. Each return line contains a scavenge strainer.
Oil returning from the internal gear-box and the turbine bearings passes over a magnetic chip detector fitted in each line.
All oil returned to the tank falls on to a de-aerator tray fitted in the top of the tank. Air mixed with the oil is then released to pass through the oil tank vent.

(c). VENTING.

The turbine bearings, the internal gear-box and the oil tank are all vented into the external gear-box.
The oil tank has, in fact, two vents to cope with both normal and inverted flight.
A ball valve situated between the two vents ensures that when one vent is open the other is closed, thus preventing loss of oil from the tank.
Venting overboard from the external gear-box is by way of a centrifugal breather.

This consists of a rotor containing a number of radial drillings ported to the interior of the rotor shaft which is vented to atmosphere.
The venting flow must travel radially inwards and since oil vapour is heavier than air,the two are separated and the oil retained within the gear-box.
Should a higher than normal oil consumption become apparent and there is no external signs of oil loss,first check the centrifugal breather line for blockage.

DATA.

Capacity.-Tank and System.	11.9 litres.(21 pts).
Minimum Quantity of oil, Tank and System.	9.0 litres.(16 pts).
Usable Capacity.	2.8 litres.(5 pts).
Tank Capacity.	6.53 litres.(11.5 pts).
Pressure Pump Delivery.	1446 litres.(318 gals). per hour,
Pressure Relief Valve.	14.76 kg/cm2.(210 psi).
Oil Cooler By-pass Valve.	3.52 kg/cm2.(50 psi).
Oil Low Pressure Warning Switch.	0.70 kg/cm2.(10 psi). Pressure Differential.

ADOUR 811/815.

OIL SYSTEM.

SERVICING.

The following system checks are necessary when servicing the oil system:-

- Oil sampling.
- Oil level replenisment checks and oil drainage.
- Magnetic chip detectors.
- Oil pressure filter and scavenge strainer checks.
- Unit removal and replacement procedures.

WARNING.

THE SYNTHETIC OILS USED IN THE ENGINE CONTAIN ADDITIVES WHICH,IF ALLOWED TO CONTACT THE SKIN FOR PROLONGED PERIODS,CAN BE TOXIC THROUGH SKIN ABSORPTION.

THE OILS SPECIFIED FOR USE IN THE OIL SYSTEM ARE SYNTHETIC PRODUCTS AND ARE INJURIOUS TO PAINTWORK AND CERTAIN TYPES OF RUBBER AND MUST NOT BE ALLOWED TO CONTAMINATE THOSE PARTS OF THE ENGINE NOT NORMALLY IN CONTACT WITH OIL.ANY OIL SPILT DURING SERVICING MUST BE CLEANED UP IMMEDIATELY.

COMPLETE BREAKDOWN OF THE ENGINE SYNTHETIC OIL CAN BE CAUSED THROUGH CONTAMINATION BY THE AMOUNT OF ALKALINE CLEANERS THAT CAN CLING TO THE WALLS OF A NOMINALLY EMPTY CONTAINER. EXTREME CARE THEREFORE MUST BE EXCERCISED TO PREVENT ALKALINE CLEANERS FROM COMING INTO CONTACT WITH THE OIL,DIRECTLY OR INDIRECTLY,EG,INDISCRIMINATE USE OF CANS OR CONTAINERS.

OIL SAMPLING.

The purpose of oil sampling is to assist in fault diagnosis. The procedure basically consists of drawing off approx.250 m.litre from the oil tank as soon as possible after an engine ground run.The equipment used must be scrupulously clean and dry before use.

Immediatelt before use rinse containers with lead free petrol,dry off with an air blast and then rinse twice with clean engine oil before filling with the sample.

The containers must be labelled giving the following information:

- Sample register number.
- Description,official ref.number and spec of the oil.
- Point from which sample was taken.
- Date sample taken.

Engine number.
Engine running hours.
The amount of oil used to replenish the tank since the last sample was taken.
Reason for check.

OIL LEVEL AND RELENISHMENT.

The oil level is checked via the oil level sight glass,the glass is calibrated on each side,pints on the left and litres on the right,ensure that when you are reading the amount used you are using the correct measure.To ensure consistency of results the level check should follow an engine shut-down at approx.the same time period,but not less than five minutes after shut-down.The system can be replenished by using either pressure or gravity.The gravity method will require the engine door to be hinged open.

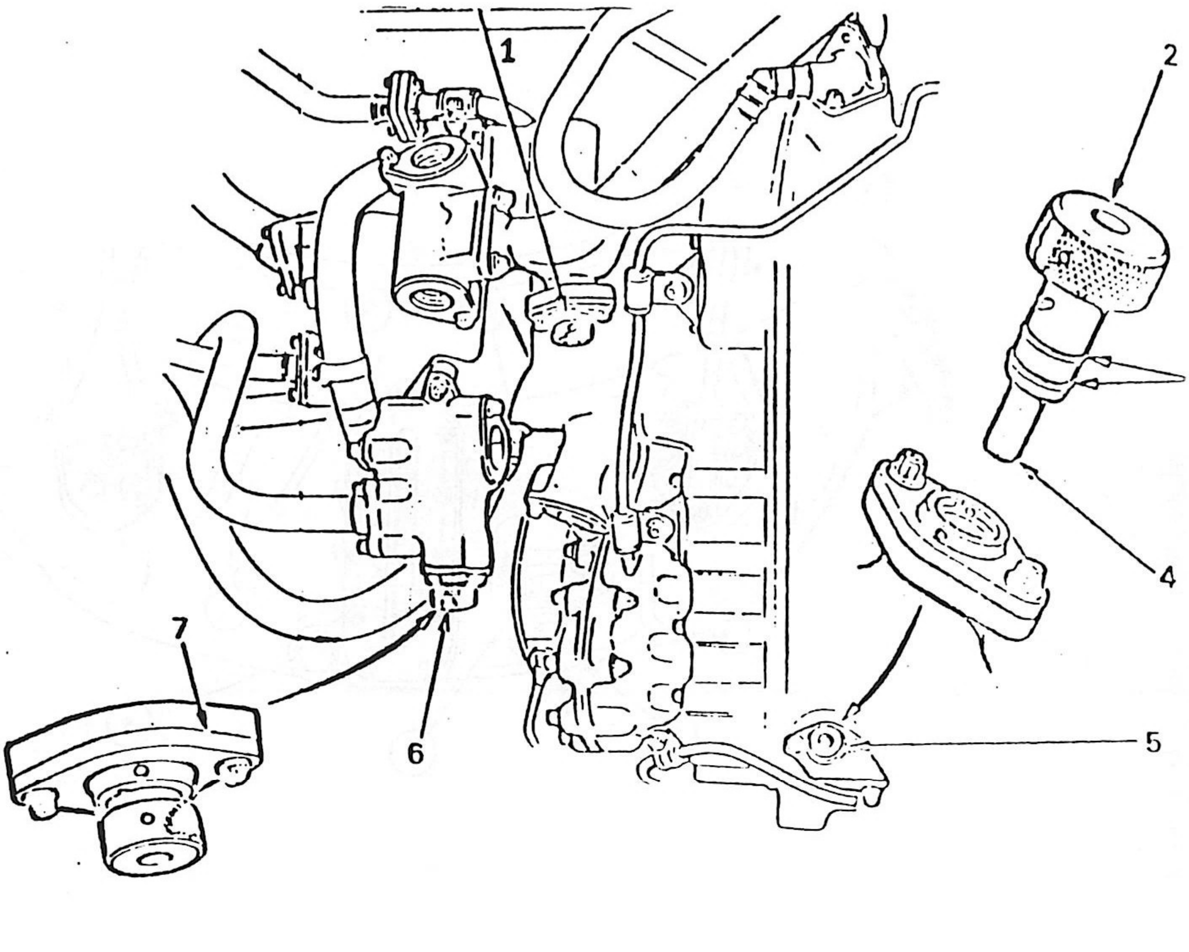
OIL SYSTEM DRAINING.

When draining the system a clean container of at least 21 pints capacity is required.Remove the plug to the right side of the sight glass and drain the tank.When refitting the plug a new washer should be fitted and the plug torque loaded to the correct value. To drain the external HS gear-box a special tool consisting of a magnetic chip detector with the centre removed can be used,remove the existing chip detector and insert the hollow one,when draining is complete refit the original chip detector.

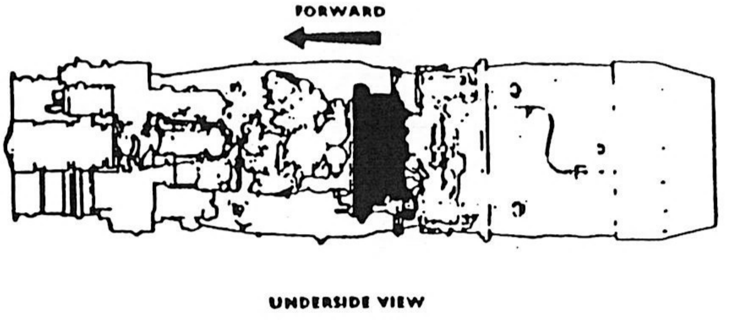
MAGNETIC CHIP DETECTORS.

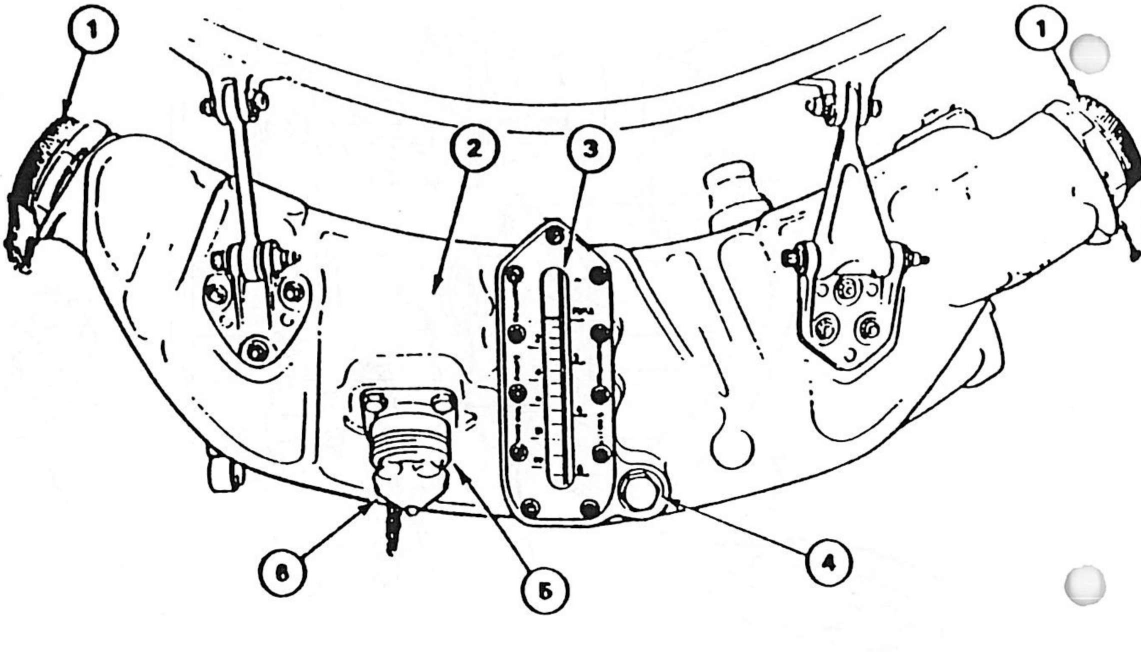
At pre-set intervals the three detctors are removed and sent to EFDC for analysis.The particles adhering to the magnetic plug can be examined and an accurate assessment of these gives an early warning of engine or system failure.
The detectors are colour coded to indicate from which part of the system they were removed,the coding is as follows.
Black......Turbine Bearings
Red........Internal gear-box.
Green......External HS gear-box.
Ensure that when fitting a clean set of detectors that the coding is adhered to and also that the magnetic chip detectors are fitted with seviceable seals.(Two per detector).
If an engine is being rejected as a result of chip detectors or engine oil filter inspection the metal contaminant must be returned,suitably wrapped and labelled,with the engine

MAGNETIC CHIP DETECTORS.



1.Magnetic chip detector,internal gearbox.(Red).
2.Magnetic chip detector.
3.Seal rings.(Two off).
4.Magnet.
5.Magnetic chip detector.HS G/box.(Green).
6.Magnetic chip detector.Turbine bearings.(Black).
Magnetic chip detector.Fully engaged.

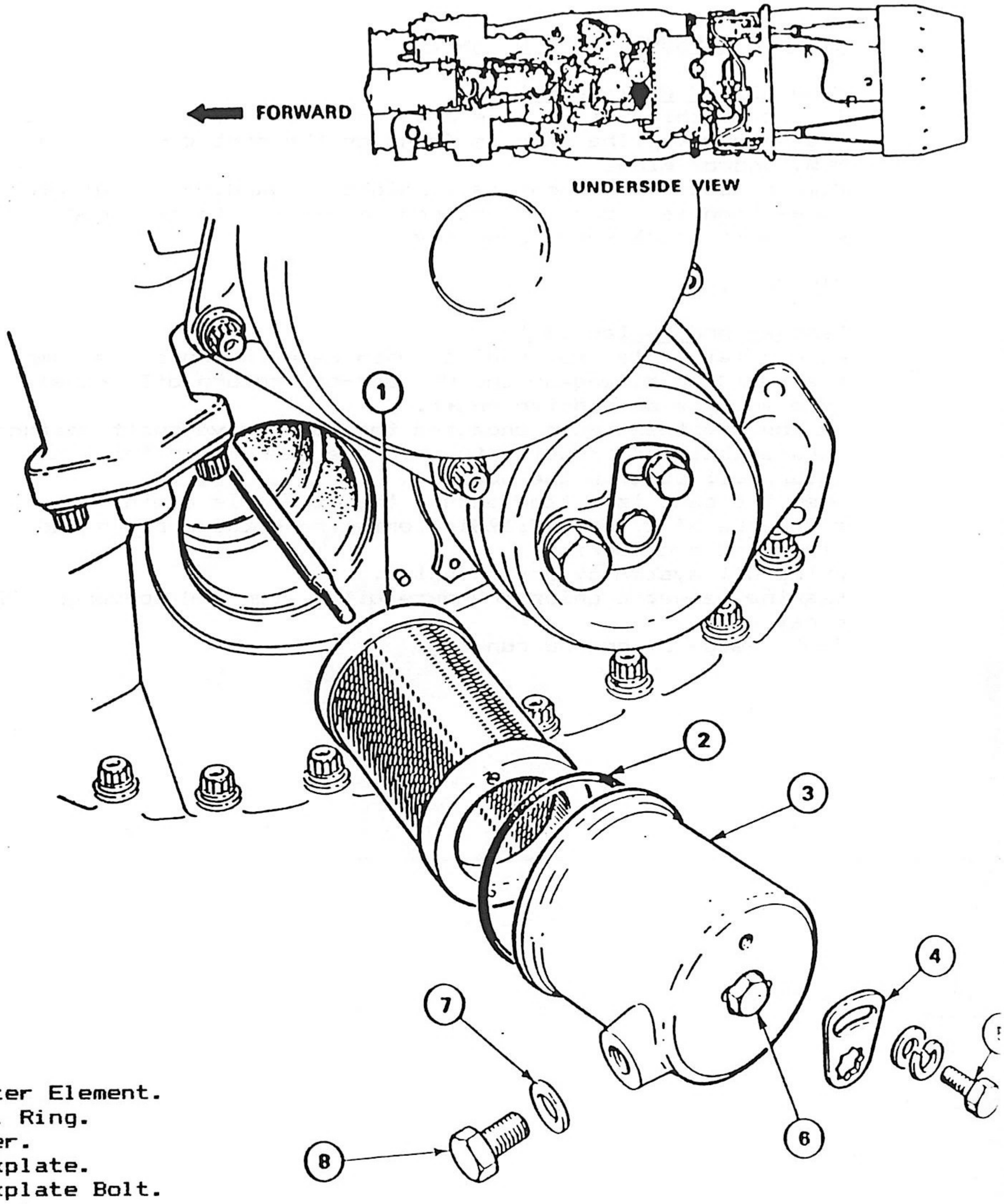




1.Gravity Filler Cap.
2.Oil Tank.
3.Sight Glass.

4.Drain Plug.
5.Pressure Filler Connection.
6.Pressure Filler Blankig Cap.

<u>OIL TANK.SERVICING POINTS.</u>



1. Filter Element.
2. Seal Ring.
3. Cover.
4. Lockplate.
5. Lockplate Bolt.
6. Capnut.
7. Flat Washer.
8. Drain Plug.

PRESSURE FILTER - REMOVAL.

LOW OIL PRESSURE WARNING SWITCH

Removal and Replacement.

Access to this unit on a starboard engine will necessitate engine removal.The unit is found on the port side on the M001 approx midway.

Removal and replacement is straight forward,ensure electrcal connection is clean and not contaminated with oil,ground run engine to check serviceability.

OIL PUMP.

Removal and replacement.

No special tools are required.When removing,move the pump rear-ward to disengage the HS gear-box return oil transfer tube and the pump drive shaft.

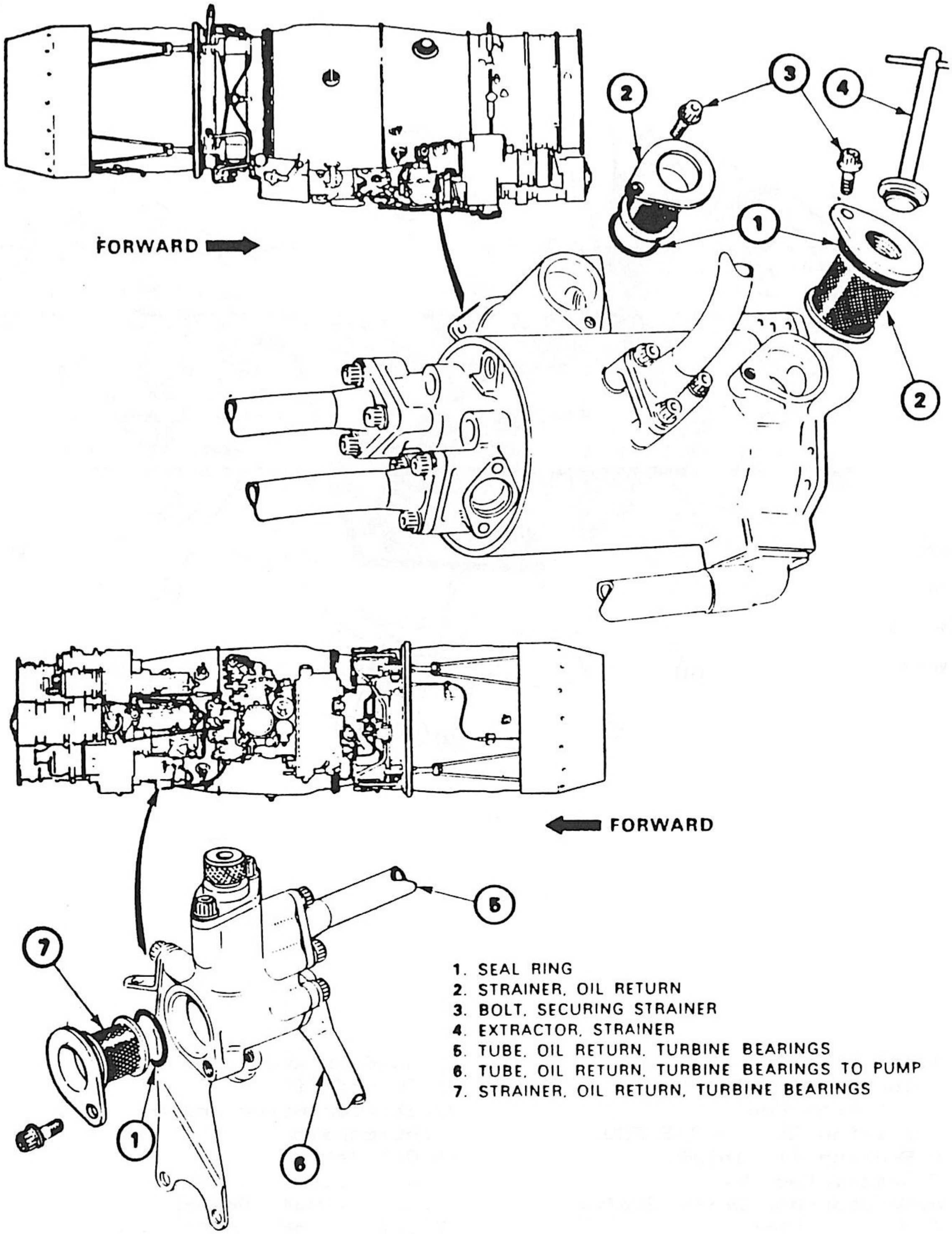
During refitment when engaging the pump drive shaft splines ensure that the transfer tube in the gear-box enters the return oil port in the pump.

When the pump is fitted ensure that there is a minimum clearance of 2.50mm.(0.100in).existing between pipes and pipes and accessories.

Prime oil system by dry cranking.

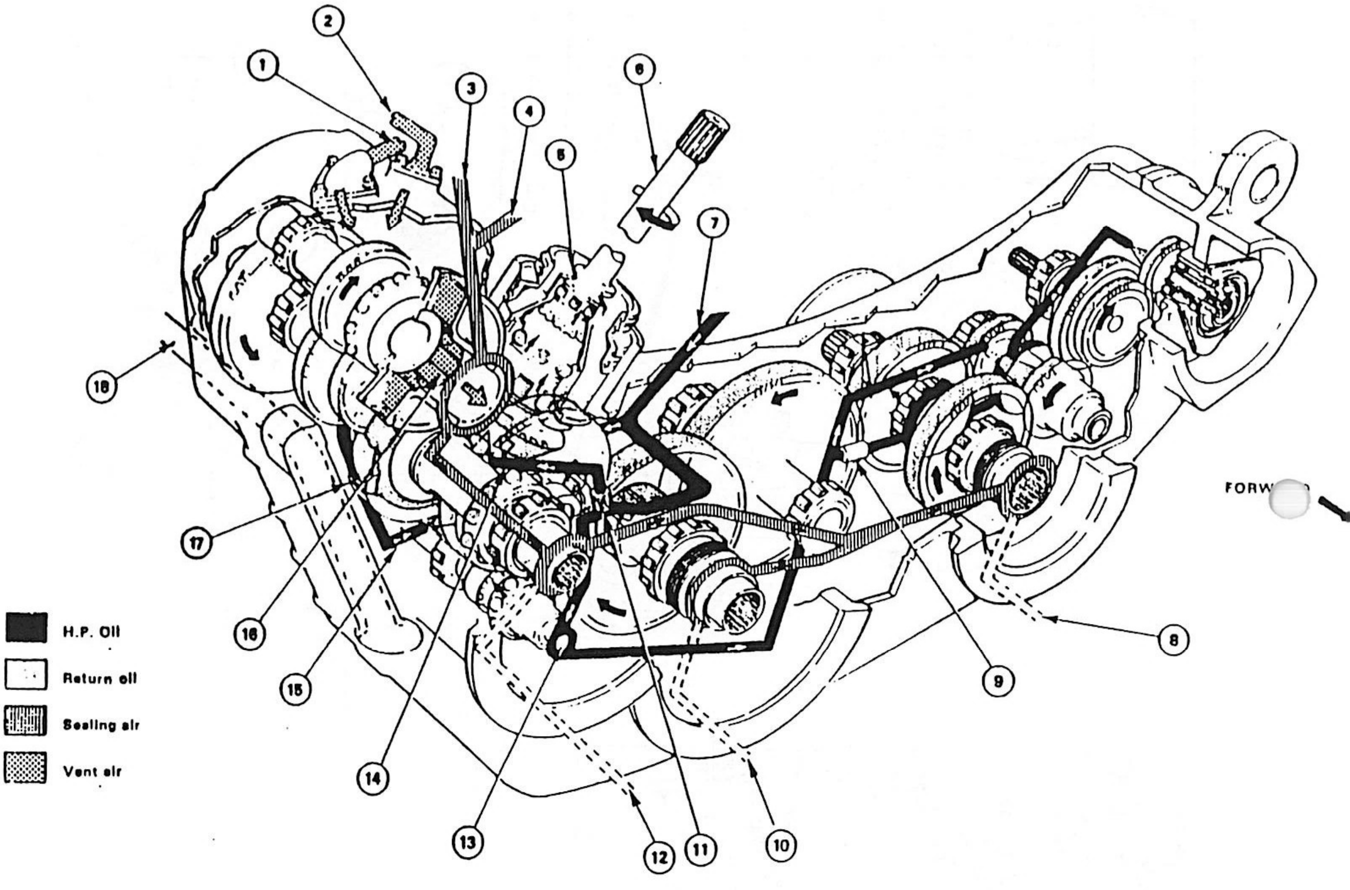
Examine magnetic chips,pressure oil filter and scavenge oil strainers.

Test system by ground running.



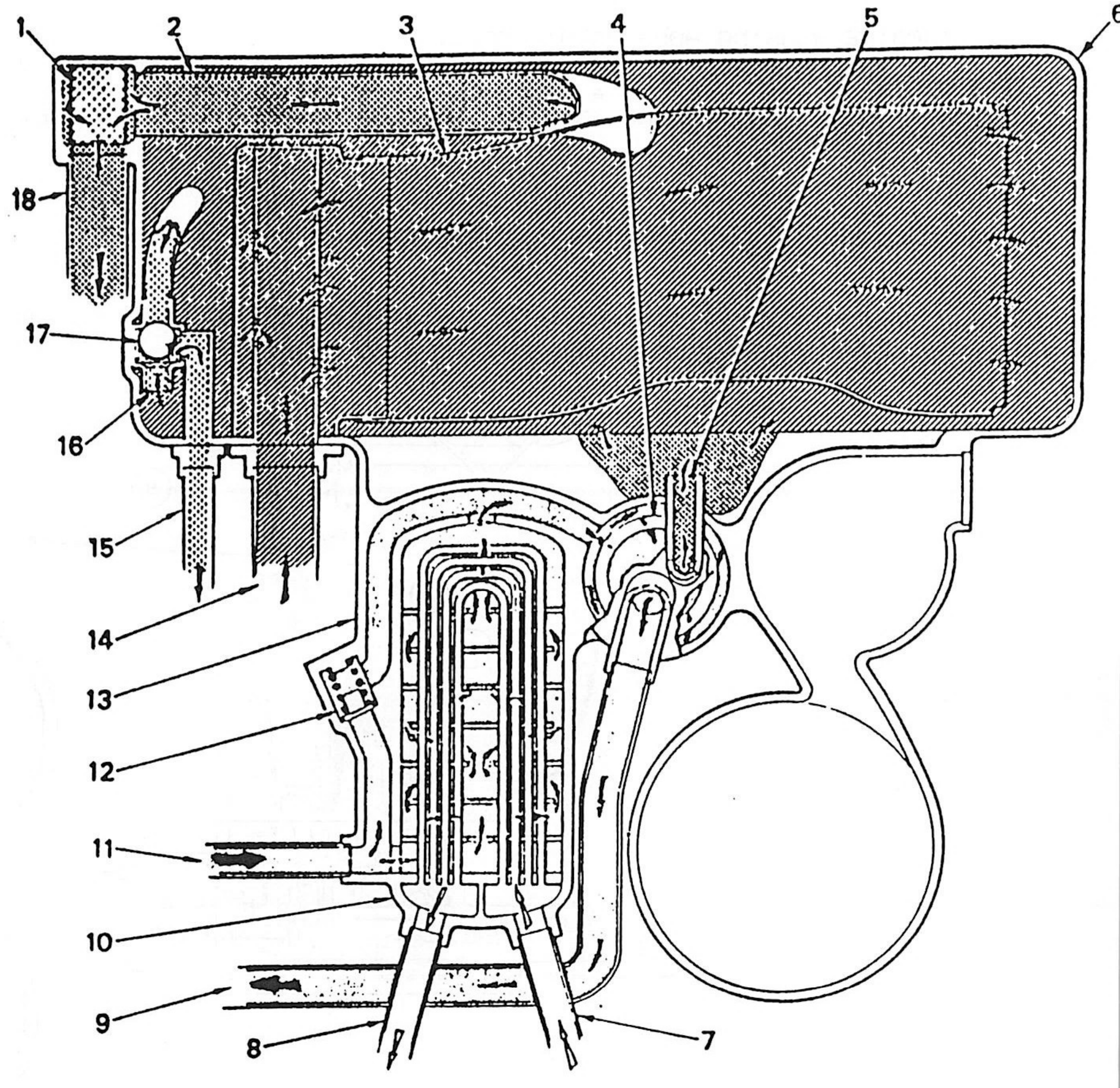
1. SEAL RING
2. STRAINER, OIL RETURN
3. BOLT, SECURING STRAINER
4. EXTRACTOR, STRAINER
5. TUBE, OIL RETURN, TURBINE BEARINGS
6. TUBE, OIL RETURN, TURBINE BEARINGS TO PUMP
7. STRAINER, OIL RETURN, TURBINE BEARINGS

<u>RETURN OIL STRAINERS - REMOVAL.</u>



1. Internal Gear-box and Turbine Bearing Vent.
2. Oil Tank Vent.
3. Sealing Air to A/B FCU.
4. Sealing Air Inlet.
5. Restricted Vent.
6. HS Gear-box Drive Shaft.
7. HP Oil Inlet.
8. Hydraulic Pump Drain.
9. Attenuator.
10. AC Generator Drain.
11. Thread Filter.
12. Starter Motor Drain.
13. Attenuator.
14. Oil Jet.
15. Oil Jet.
16. Centrifugal Breather.
17. Oil Trough for Starting.
18. Return Oil to Tank via Pump.

HIGH SPEED GEAR-BOX - LUBRICATION.

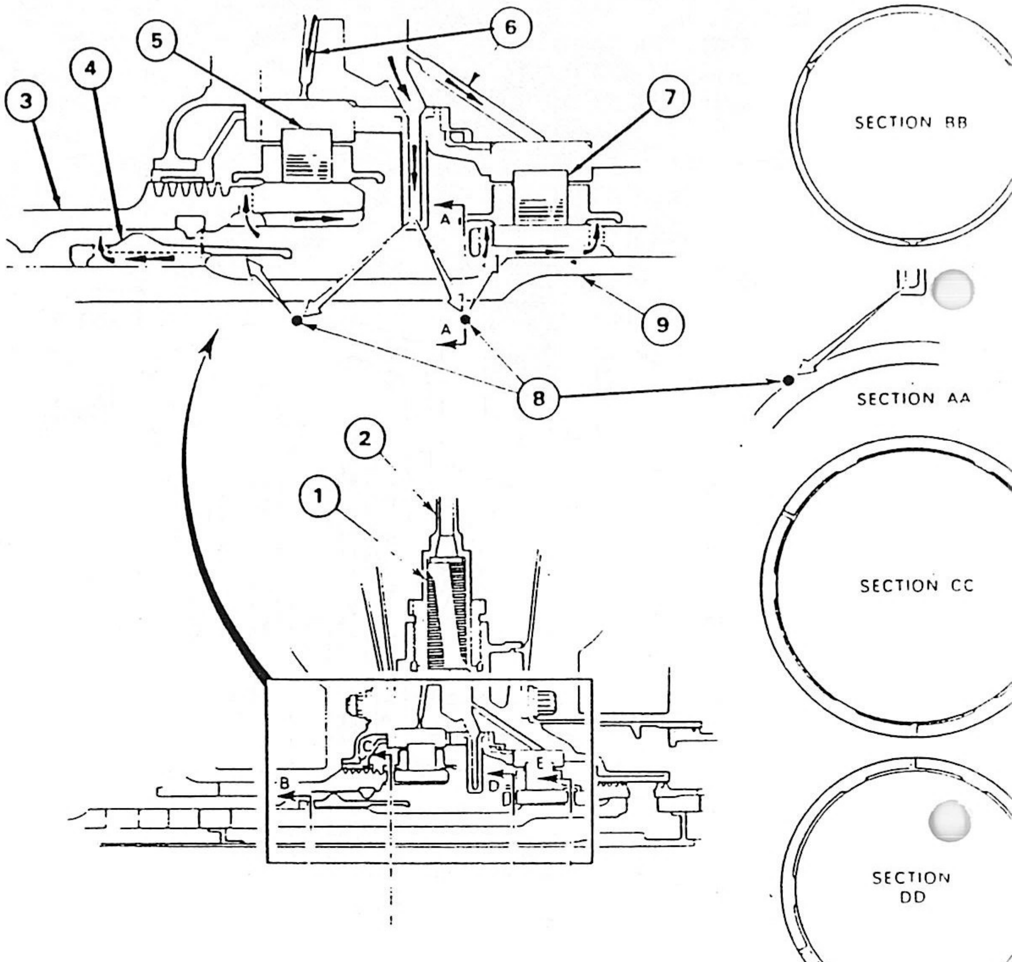


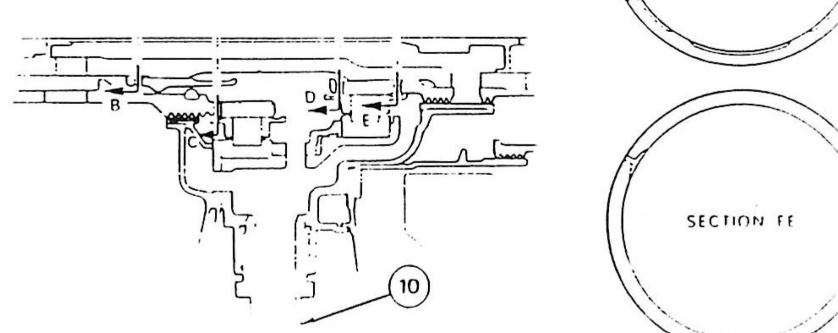
1. Oil Outlet Strainer.
2. Internal Oil Supply Tube.
3. De-aerator Tray.
4. Oil Pressure Filter.
5. Oil Spill.
6. Oil Tank.
7. Fuel Inlet.
8. Fuel Outlet.
9. Oil Out to Bearings.
10. Fuel Cooled Oil Cooler.
11. Oil In from Oil Pump.
12. Bypass Valve.
13. Oil Tank Front Cover.
14. Return Oil from Oil Pumps.
15. Vent Air to HS Gear-box.
16. Normal Flight Vent.
17. Vent Air Ball Valve.
18. Oil Tank Outlet to Oil Pump.

<u>OIL TANK AND OIL COOLER.</u>

TURBINE BEARING HOUSING OIL SEAL.

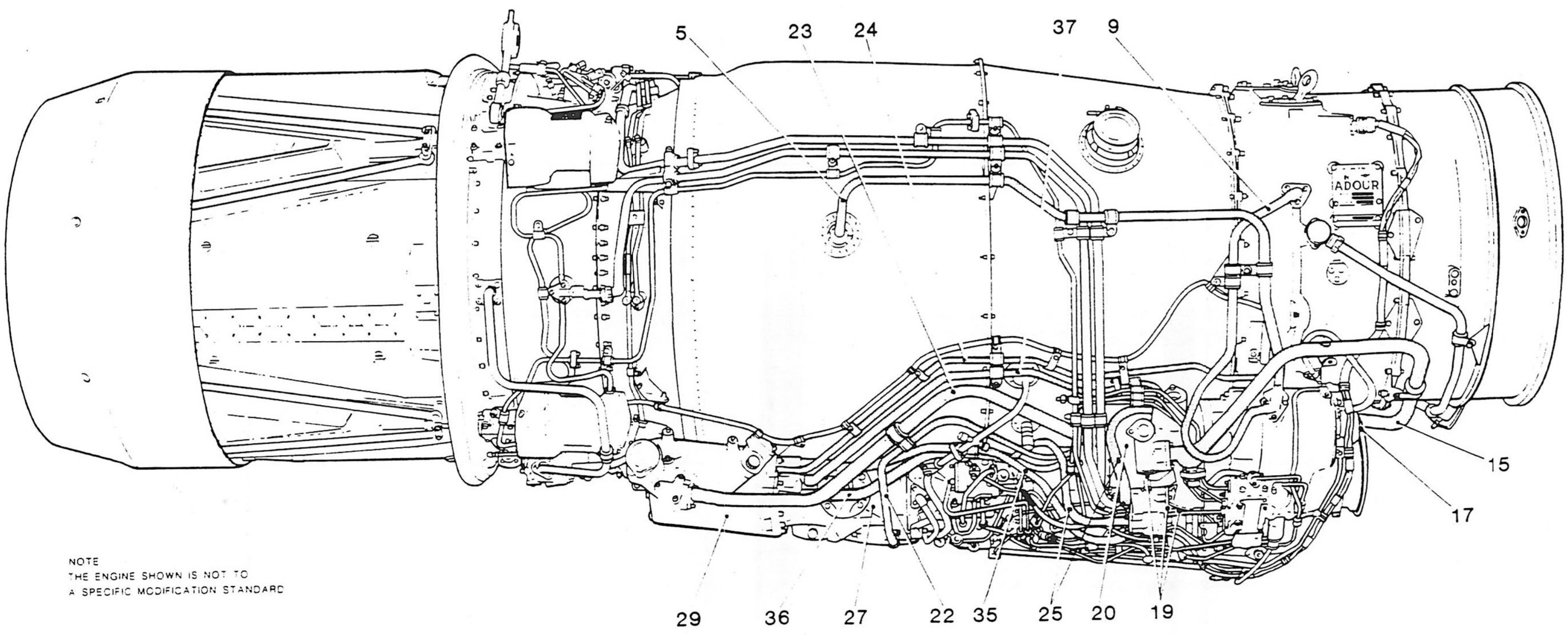
Oil leakage from the turbine bearing housing into the cooling air is prevented at the front by a hydraulis seal (4) formed with the oil between the LP (9) and HP (3) turbine shafts,and at the rear by a labyrinth seal.



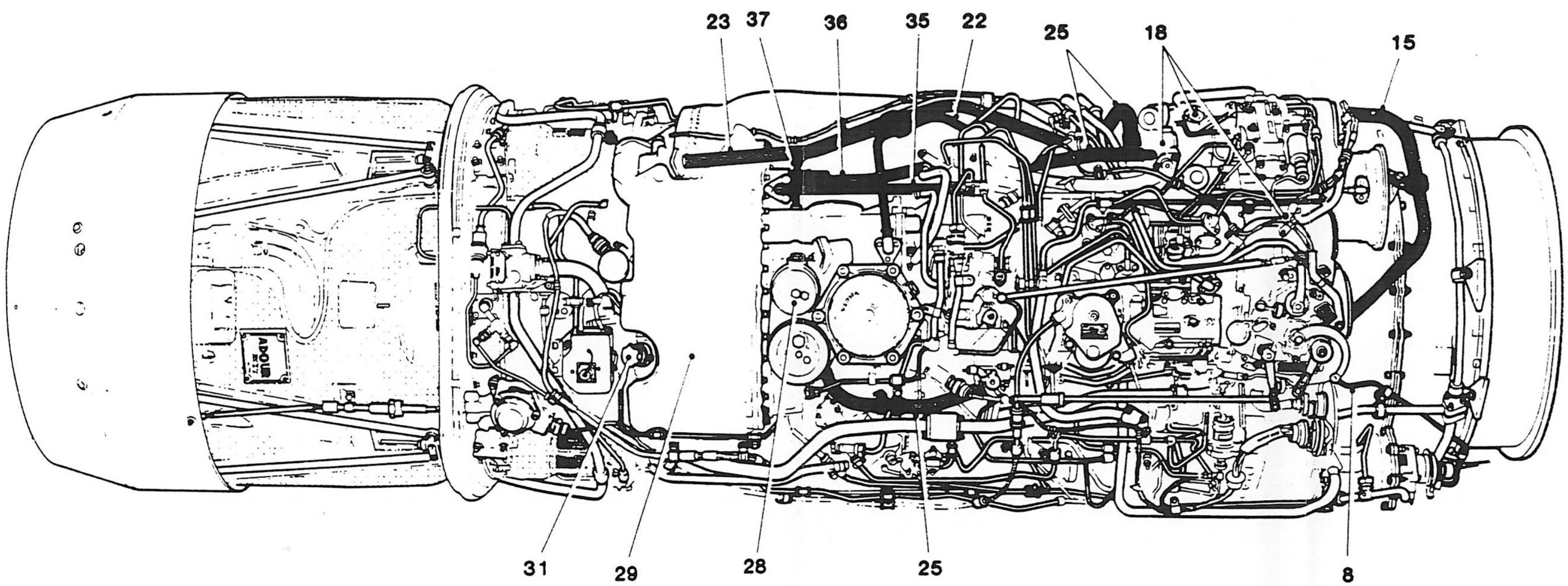


1. Thread Filter.
2. OilFeed Tube.
3. HP Turbine Shaft.
4. Hydraulic Seal.
5. HP Turbine Bearing.
6. Oil Squeeze Film Feeds.
7. LP Turbine Bearing.
8. Oil Jets Contact.
9. LP Turbine Shaft.
10. Oil Return Tube.

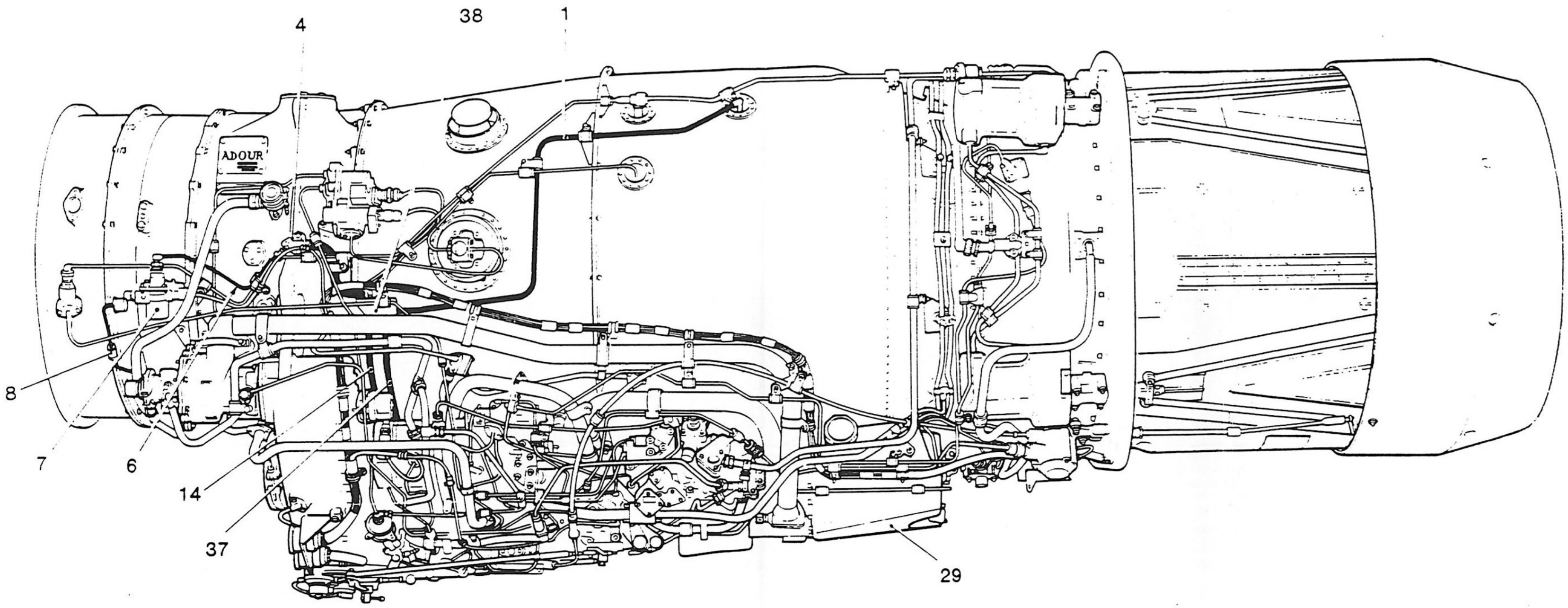
TURBINE BEARING LUBRICATION.



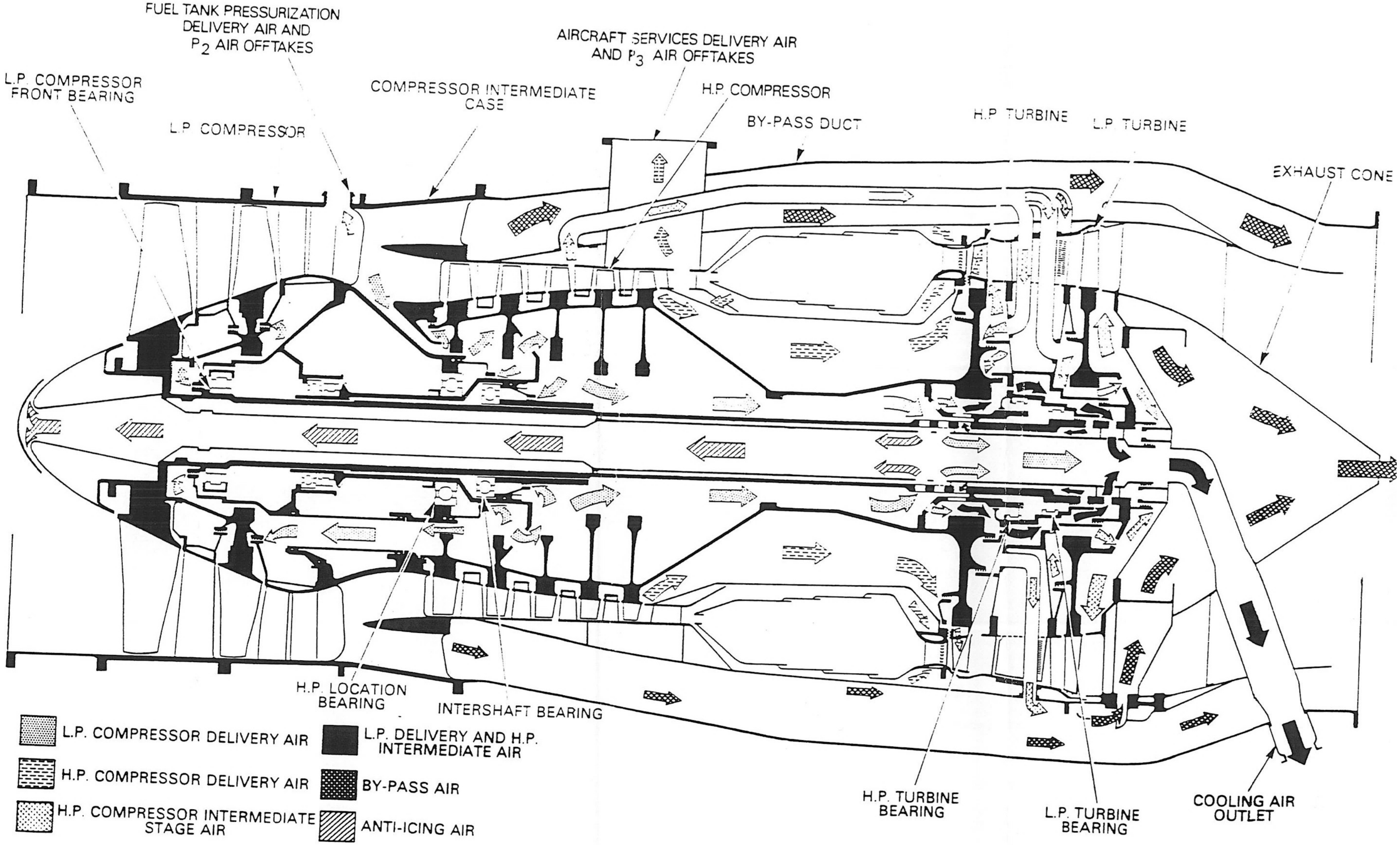
Location of oil tubes and assemblies, right-hand view



Location of oil tubes and accessories,
Underside view



Location of oil tubes oil accessories,
Left-hand view



Cooling, sealing and anti-icing air diagram

ROLLS-ROYCE/TURBOMECA.

ADOUR MK.s 811/815.

AIR SYSTEM.

Air is tapped from the engine to meet the requirements of various airframe and engine operations.

These tappings are listed below:

P0.......Ambient pressure,sensed at the engine Fuel Control Unit.
P1.......Intake pressure,taken forward of the 1st.stage LP Compressor.
P2.......Taken after the LP Compressor.

HP3......Taken from the 3rd.stage of the HP Compressor.

P3.......Taken after the HP Compressor. COOLING TURBINE

P6.......Taken after the LP Turbine.

These tappings satisfy the following requirements.

a........Engine internal cooling,sealing and de-icing.

b........General propulsion unit services.

c........General aircraft services.

d........HP compressor bleed valve operation.

a. Engine Internal Cooling,Sealing and De-icing.
P3 air is used to cool the combustion section,the HP turbine nozzle guide vanes,the HP turbine blades and the front face of the HP turbine disc.
HP compressor stage three air (HP3) is used to cool the LP nozzle guide vanes,the rear face of the HP turbine disc and the front and rear face of the LP turbine disc.

P2 air is used to pressurise the internal gear-box and turbine oil seals.An overboard outlet for internal air is provided via holes in the LP turbine shaft and a cooling air tube fitted inside the shaft leading to the exhaust cone.Exhaust cooling air is vented to atmosphere via the cooling air outlet in the engine door. OIL ~~FUELS~~ SEALS

An engine internal overheat detector is fitted in the outlet,should exhaust cooling air temperature exceed 400 degrees C.,an OH1 or OH2 light (Red). will illuminate on the CWP. TURBINE AREA

The air inlet spinner is continually supplied with air from the cooling air tube,inside the LP turbine shaft,this air flows from the spinner back into the intake thus de-icing the intake.
The P1 probe is supplied continuously with air from a tapping at P3.Cooling and anti-icing flows are shown on the internal air flow diagram.

b. General Propulsion Services.

P1 Probe.
Air intake pressure is used in conjunction with P0 (ambient pressure) to compensate the fuel flow for changes in altitude and forward speed.
The tapping is a probe projecting into the air flow in the air intake,P1 being sensed by a forward facing orifice and fed directly to the fuel control unit.

P2.
P2 is a control parameter supplied to the after-burner fuel control unit and is sensed at the forward facing slots of two probes rear of the LP compressor.
P2 is also taken to the external gear-box to supply the gear-box internal air blown seals and the after-burner pump air blown seals.
The two P2 probes are connected by a balance pipe to compensate for any changes in pressure on each side of the engine.

P3 Offtakes. SELECTED IN COCKPIT
There are three P3 offtakes located on the port side of the engine,these are not probes,they connect to three unions on the combustion outer case,and carry out the following functions.

THe upper offtake supplies anti-icing air forward to the P1 probe and also rearwards to the vapour gutter fuel feed line.This supply assists with combustion and when the after-burner is not in use supplies air to the vapour gutter and catalyst lines thereby purging them of any surplus fuel.

The middle offtake supplies air for the operation of the Air Bleed Valve.

The lower offtake supplies air to the after-burner fuel control unit as a control parameter.The air is supplied via a momentum separator which returns part of the air back to P2.

P6.
This is also an after-burner control parameter and is located in the same plane as the thermo-couple harness on the lower port side of the engine and projects into the gas flow aft of the LP turbine.

P6 cont.
To prevent a carbon build-up in the tube,thus disturbing the after-burner control ratio and possibly causing surge,a flow of P3 air is introduced into the line.This flow is supplied through a 0.6mm restricted orifice to minimise the effect the air might have on the after-burner fuel control unit pressure signal. Only engines with Mod.A01037 embodied have this extra tube.The tube can be located just below the momentum separator running aft to the P6 probe.

c. <u>General Aircraft Services.</u>
An offtake of P3 air is taken from the rear of the HP compressor and is used to supply air for cabin conditioning and pressurisation.During ground testing of the engine ,when power checks are necessary ,this service must not be used because of the large amount of air bled from the engine supply thus reducing the efficiency of the engine.

A P2 offtake,at the P2 connection,is used to provide fuel tank pressurisation.

Both the fuel tank pressure connection and the cabin conditioning connections are duplicated on the engine.Ensure on fitment that the '<u>not in use'</u> connection is blanked off in the correct manner.

d. <u>Air Bleed Valve Operation.</u> P3 AIR 61 +-4

i. Purpose.
The air bleed valve is fitted in the compressor outlet to ensure stability during starting at low pressure ratios. The valve bleeds air from the HP compressor outlet into the by-pass duct.
After initial closure of the valve it will remain closed until the engine is shut-down.

ii. Description.
A circular poppet type valve controls airflow through a port in the HP compressor casing.Attached to the stem of the valve is a piston operating in a cylinder.a spring around the valve stem biases the valve to the open position.

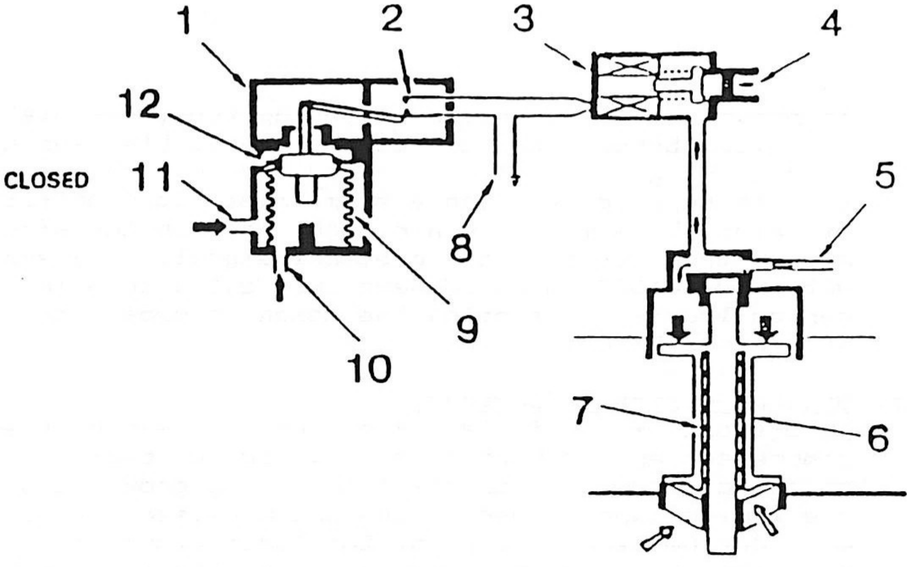
iii. Components.
Three components make up the Air Bleed Valve system.

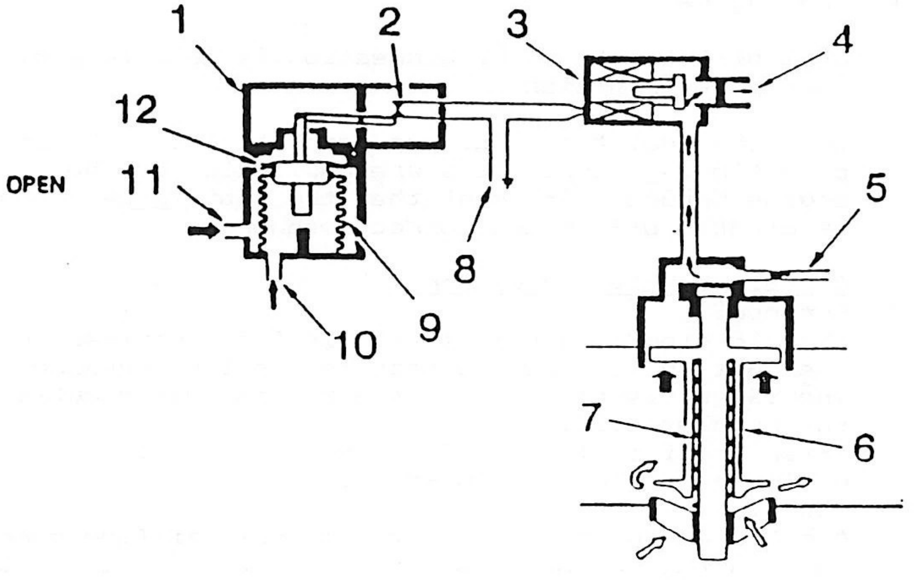
a. The Air Bleed Valve.

b. The Solenoid valve.

c. The Differential Pressure Switch. 61 +-4 CLOSES

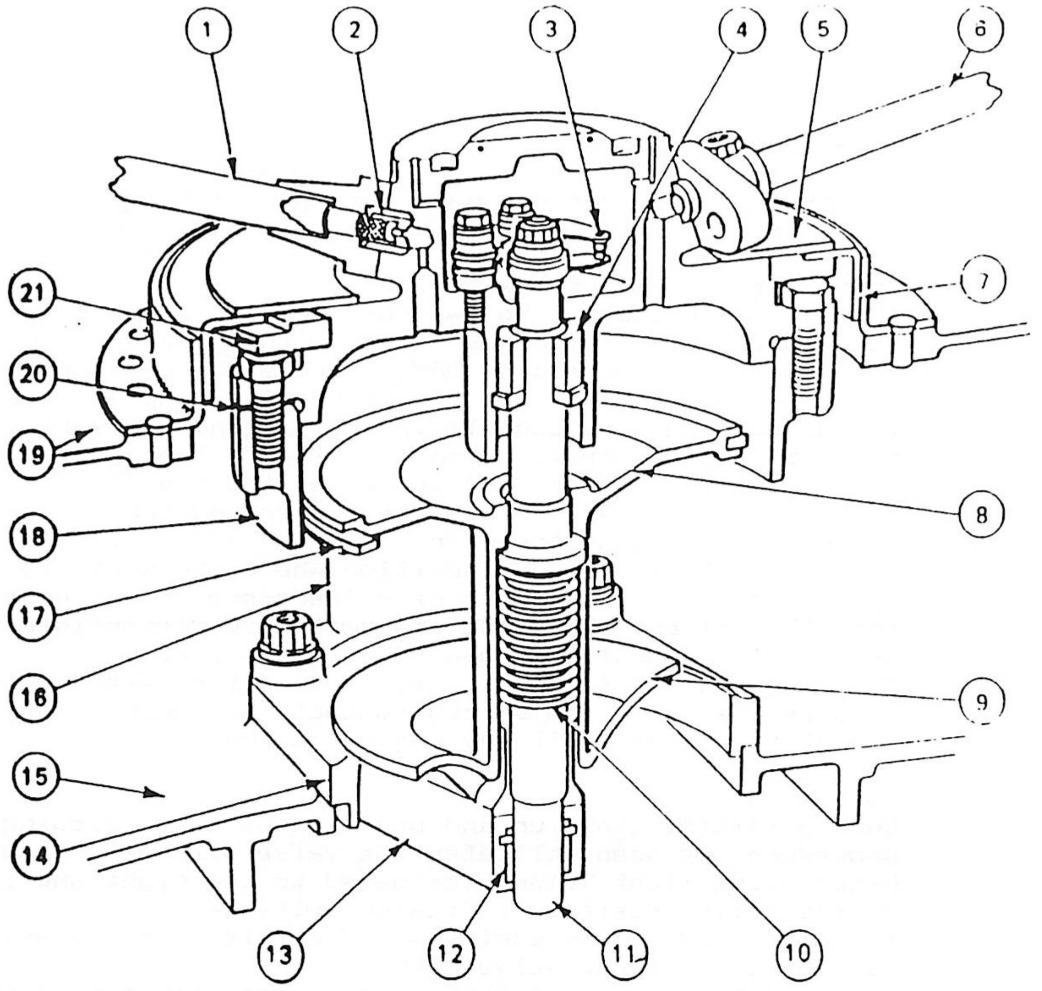
a. Solenoid Valve.
An electrically operated valve,which is energised to the open position.





1. Differential Pressure Switch.
2. Differential Pressure Switch Contacts.
3. Solenoid Control Valve.
4. Overboard Vent.
5. P3 Operating Air.
6. Air Bleed Valve Assy.
7. Coil Spring.
8. Electrical Power Supply.
9. Capsule.
10. HP Fuel Pump Governor Pressure.
11. LP Fuel Inlet Pressure.
12. Spring Disc.

BLEED VALVE OPERATION - SCHEMATIC.



1. P3 Air Inlet Pipe.
2. Filter and Restrictor.
3. Position Indicator Switch.
4. Upper Carbon bush.
5. Air Seal Retaining Ring.
6. Air Outlet Pipe.
7. Spherical Air Seal.
8. Servo Control Piston.
9. Bleed Valve.
10. Coil Spring.
11. Spindle.
12. Lower Carbon Bush.
13. Body Ribs.
14. Mounting Flange and Valve Seat.
15. Combustion Outer Case.
16. Aerofoil Section.
17. Carbon Piston Ring.
18. Cylinder.
19. Front By-pass Duct.
20. Gasket.
21. Air Seal Stepped Support Plate.

HP COMPRESSOR AIR BLEED VALVE.

Solenoid Valve./cont.

In this position air can pass through the Air Bleed Valve and on through the Solenoid Valve to atmosphere.

b. Differential Pressure Switch.
The switch is subject to two fuel pressures,one of which is a constant or reference pressure the other pressure increases with increasing RPM.The constant pressure is taken from the inlet side of the backing pump and passed to the outside of a capsule in the switch.A variable,or increasing pressure,is taken from the HP fuel pump governor and passed to the inside of the capsule.
Attached to the capsule stem is a micro-switch.As engine speed increases,and therefore governor pressure,the capsule will expand to a position where the contacts on the micro-switch will be broken.Therefore it can be seen that the differential pressure switch is responsible for the initial signal to close the bleed valve.
A spring disc is fitted to the stem of the switch which ensures that once the switch contacts are broken they cannot be remade until the engine is shut-down.

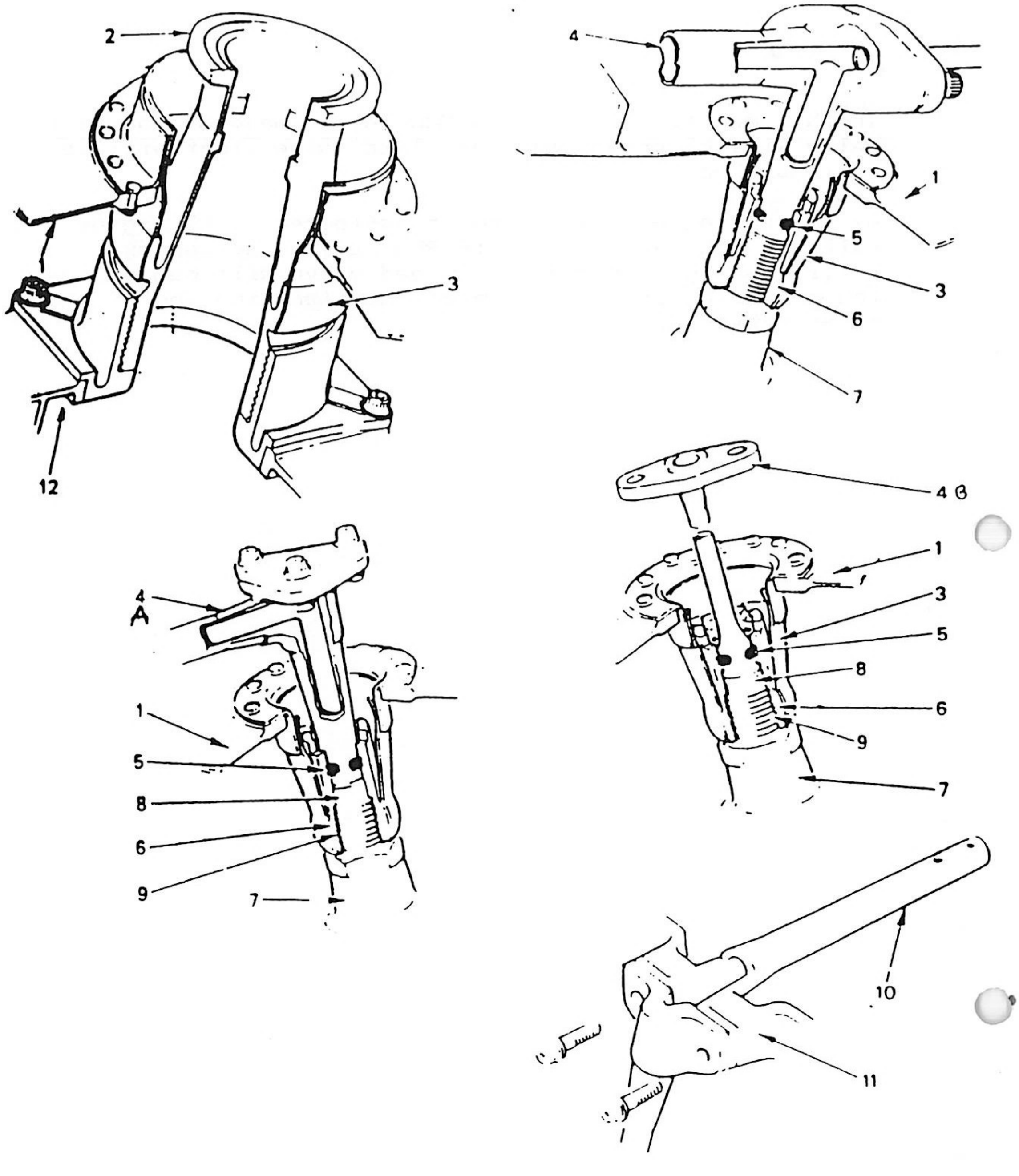
iv. Operation.
During initial start up and until bleed valve closing procedure has been initiated the valve will remain open.A bleed valve light (amber),situated to the right and left of the nozzle position indicators,will be illuminated.With the engine at idle this is known as:
Idle Speed....Bleed valve 'OPEN'.
Under no circumstances must engine performance runs be carried out with the bleed valve in the open position.
In the open position the solenoid valve is energised open and P3 air is venting to atmosphere,thus allowing no P3 pressure to the top of the bleed valve piston.

Bleed Valve Closure.

Increase engine RPM to 61% + or - 4%.
Pressure increases inside the capsule and the capsule expands,the micro switch points open and the spring disc deflects to ensure they are held in the open position.
The solenoid valve is de-energised and the P3 bleed to atmosphere is cut off.
P3 pressure acts on the top of the bleed valve piston and closes the valve against by-pass air pressure and spring pressure.
Return the throttle to the idle position and note that the RPM has risen from the original idle point by approx.4% RPM,there will also be a small drop in TGT.In this position idle is known as:
Idle position......Bleed valve closed.

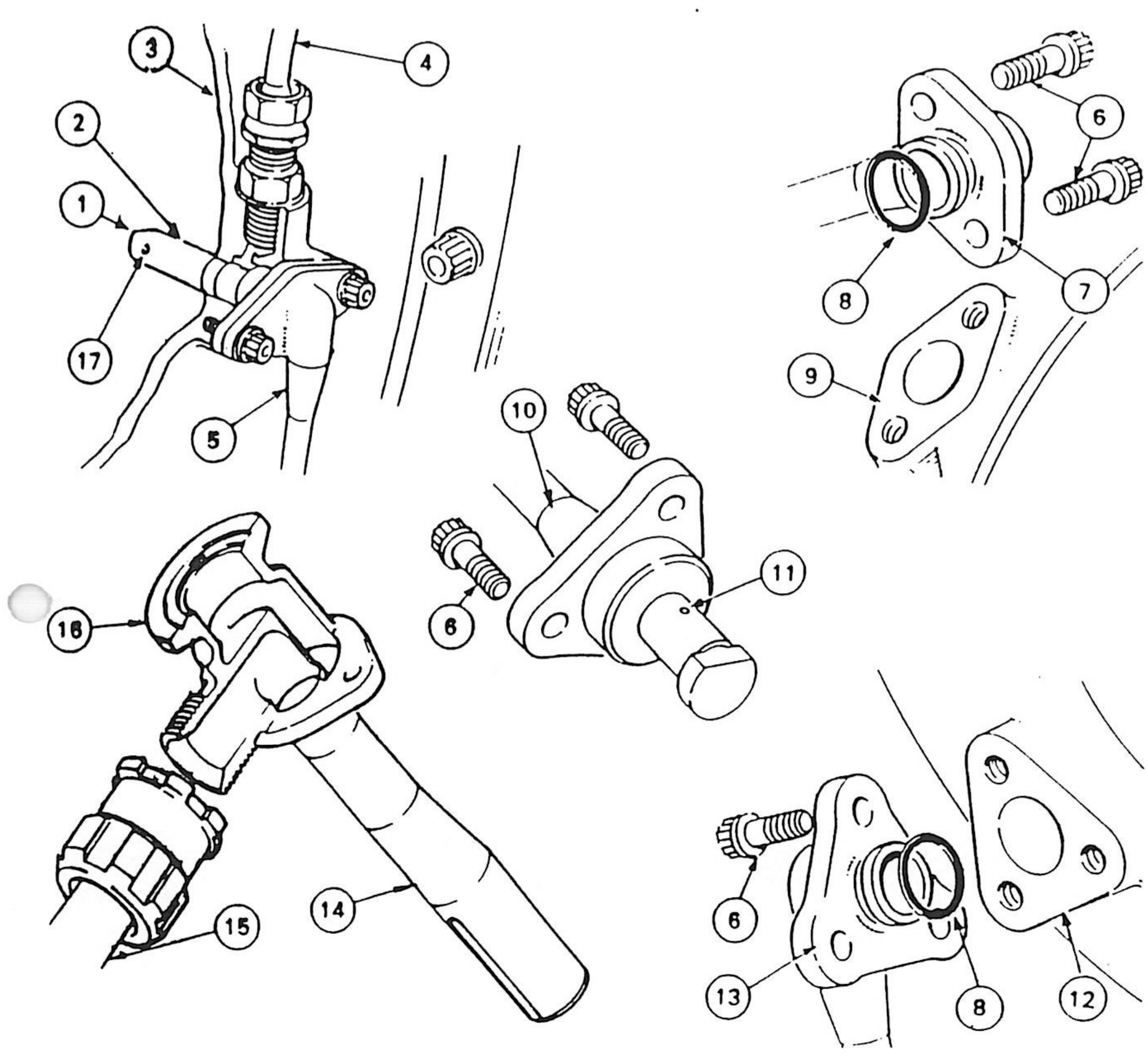
In this position a micro-switch in the head of the bleed valve will be opened and the bleed valve light will be extinguished.

As the spring disc will remain deflected until engine RPM falls to 45% +- 2% ,and idle RPM remains at approx. 60%,it can be seen that the bleed valve will remain in the closed position through all acceleration and deceleration conditions.



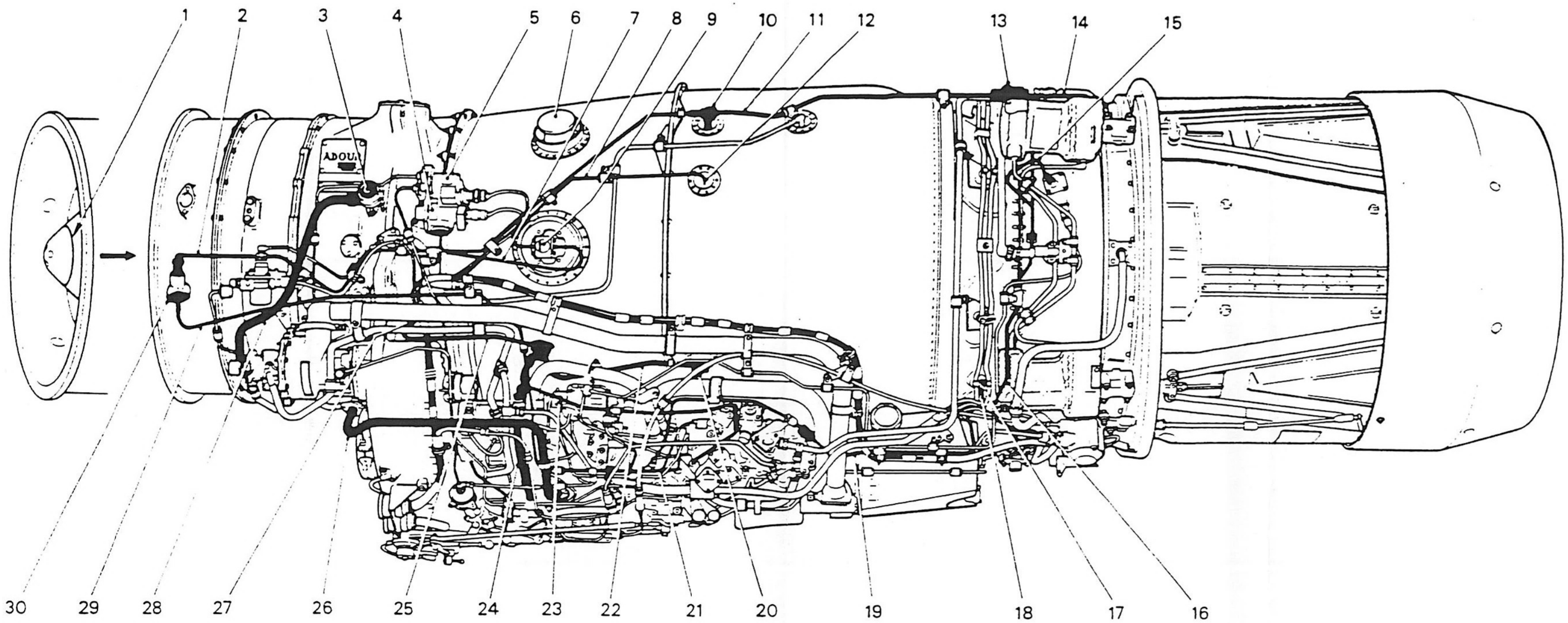
1. By-pass Duct.
2. Cabin Air Offtake.
3. Sealing Sleeve.
4. P1 De-ice and V.Gutter Purge.
4A. P3 to A/B.FCU.
4B. P3 to Air Bleed Valve.
5. Thrust Wire.
6. Union Nut.
7. Combustion Outer Case.
8. Ferrule.
9. Thread Insert.
10. P6 Pressure Probe.
11. Exhaust Mixer Casing.
12. Combustion Outer case.

<u>P3 AND P6 PRESSURE TAPPINGS</u>



1. Anti-icing Air Outlet.
2. P1 Probe.
3. Air Inlet Fairing.
4. Anti-icing Air Pipe.
5. P1 Air Pressure to EFCU.
6. Securing Bolts.
7. P2 Air Pipe Ferrule.
8. Seal Ring.
9. Boss on HS Gear-box.
10. Pipe,P3 Return to Intermediate Case.
11. Air Outlet Hole.
12. Boss On Intermediate Case.
13. P2 Air Pipe Ferrule.
14. Probe P2 Air on Intermediate Case.
15. Pipe,P2 Air to A/B FCU>
16. Fuel Tank Pressurisation Air.
17. P1 Pressure Sensing Orifice.

<u>P1 AND P2 PRESSURE TAPPINGS AND P3 AIR SPILL.</u>



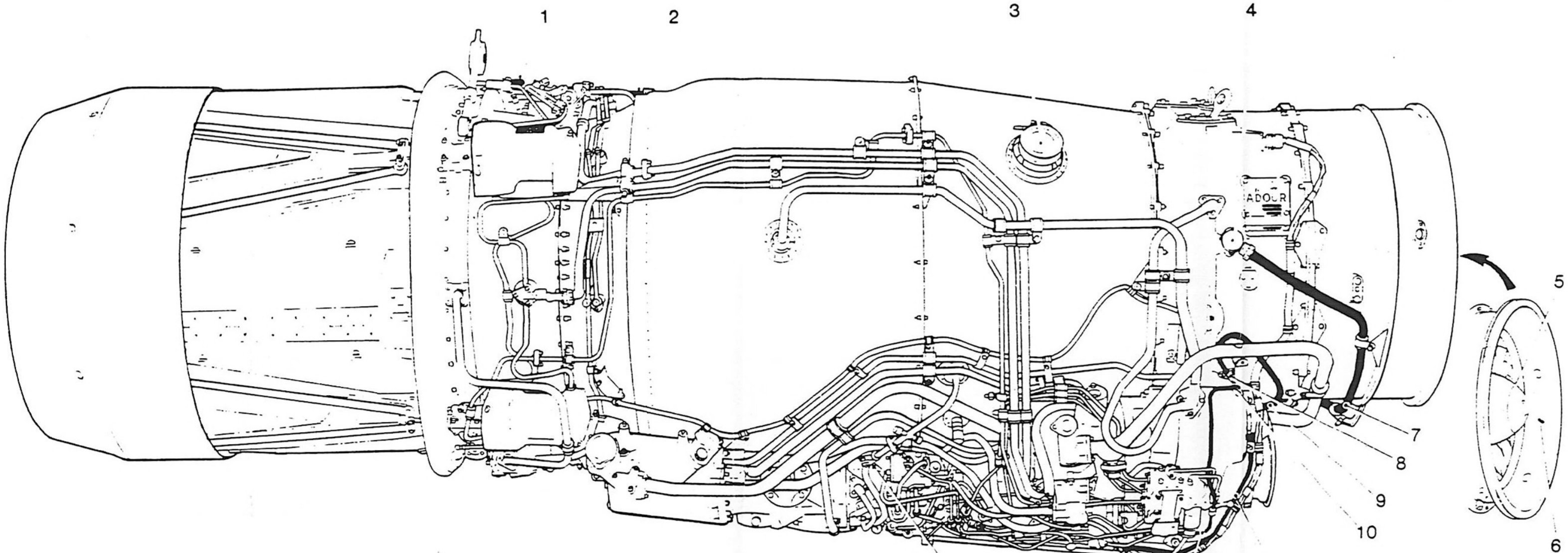
NOTE–
ENGINE SHOWN IS NOT TO A SPECIFIC MODIFICATION STANDARD

ABBREVIATIONS

E F C U	ENGINE FUEL CONTROL UNIT
A/B F C U	AFTERBURNER FUEL CONTROL UNIT
A/B D V	AFTERBURNER DISTRIBUTION VALVE

1 SPINNER ASSEMBLY ANTI-ICING AIR OUTLET
2 TUBE P_3 – P_1 PROBE ANTI-ICING
3 TAPPING CONNECTION – P_3 TO A/B F C U AND P_2 OFFTAKE – FUEL TANK PRESSURIZATION (LEFT-HAND INSTALLATION)
4 AIR BLEED SOLENOID CONTROL VALVE
5 AIR BLEED DIFFERENTIAL PRESSURE SWITCH
6 P_3 OFFTAKE – CABIN SERVICES (LEFT-HAND INSTALLATION)
7 TUBE P_3 – BLEED VALVE TO SOLENOID CONTROL VALVE
8 TUBE – P_3 TO BLEED VALVE
9 COMPRESSOR AIRFLOW CONTROL BLEED VALVE
10 TAPPING CONNECTION P_3 – P_1 PROBE ANTI-ICING AND AFTERBURNER PURGE
11 TUBE P_3 – CATALYST FEED
12 TAPPING CONNECTION – P_3 TO BLEED VALVE
13 VAPOUR GUTTER AIR SUPPLY NON-RETURN VALVE
14 TUBE P_3 – VAPOUR GUTTER SUPPLY NON-RETURN VALVE TO FUEL/AIR MIXING BLOCK
15 TUBE – P_3 TO No 2 CATALYST
16 TUBE – P_3 TO No 1 CATALYST
17 TAPPING CONNECTION – P_6 TO A/B F C U
18 TUBE – P_6 TO A/B F C U FIRST SECTION
19 TUBE – P_6 TO A/B F C U FOURTH SECTION
20 TAPPING CONNECTION – P_3 TO A/B F C U
21 TUBE – P_1 TO E F C U THIRD SECTION
22 TUBE – P_3 TO A/B F C U FIRST SECTION
23 TUBE – P_3 TO A/B D V
24 TUBE – P_3 TO A/B F C U SECOND SECTION
25 TUBE – P_3 TO A/B F C U THIRD SECTION
26 TUBE – P_2 TO A/B F C U SECOND SECTION
27 CONNECTION – P_3 TO A/B F C U SPILL RETURN TO INTERMEDIATE CASE
28 TUBE – P_2 TO A/B F C U FIRST SECTION
29 TUBE – P_1 TO E F C U FIRST SECTION
30 TAPPING CONNECTION – P_1 TO E F C U

Location of air tubes and assemblies. Left-hand view

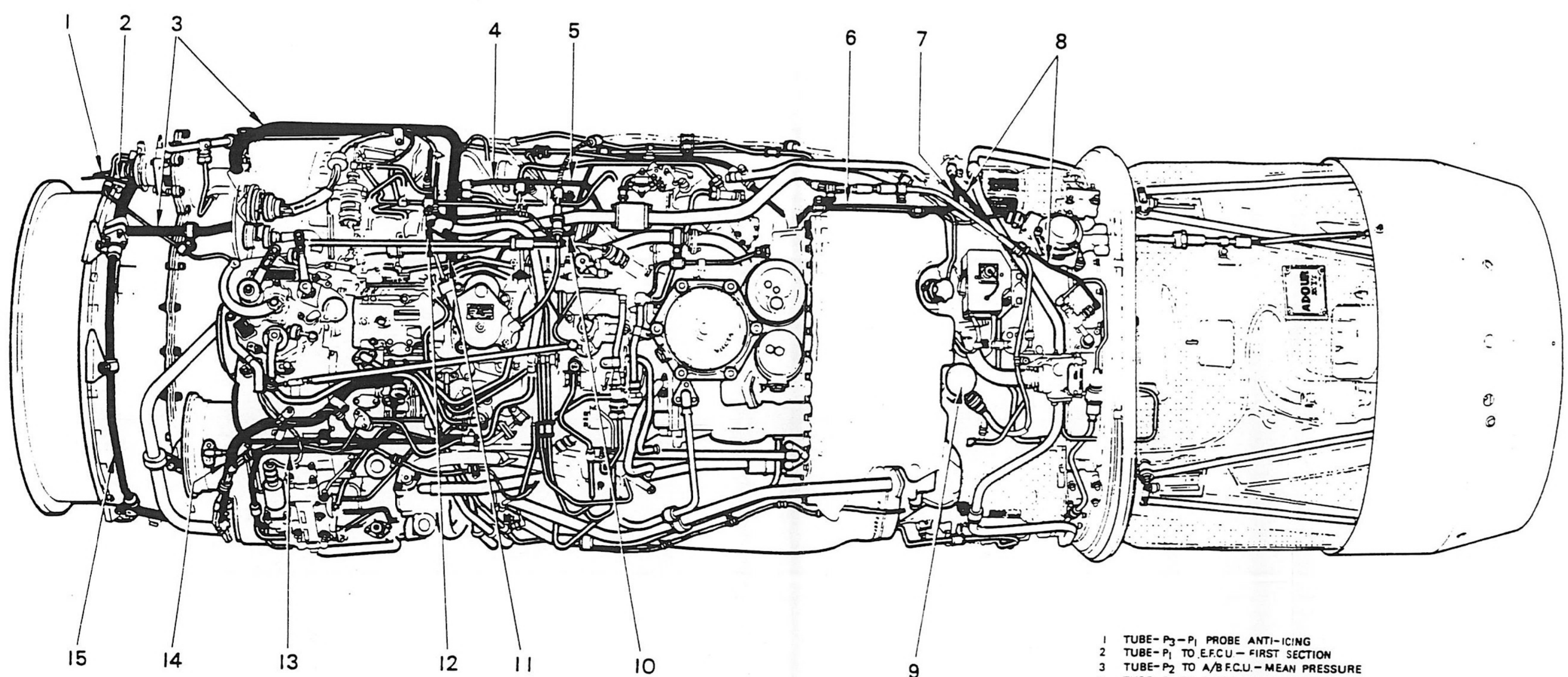


1 TUBE-P_3 VAPOUR GUTTER SUPPLY NON RETURN VALVE TO FUEL/AIR MIXING BLOCK
2 VAPOUR GUTTER AIR SUPPLY NON RETURN VALVE
3 P_3 OFFTAKE-CABIN SERVICES (RIGHT-HAND INSTALLATION)
4 TAPPING CONNECTION-P_2 TO A/B.F.C.U. AND P_2 OFFTAKE-FUEL TANK PRESSURISATION (RIGHT-HAND INSTALLATION)
5 SPINNER ASSEMBLY ANTI-ICING AIR OUTLET
6 PROBE-P_1 TO E.F.C.U.
7 TUBE-P_2 TO A/B.F.C.U.
8 TAPPING CONNECTION-P_2 TO GEARBOX AND A/B.F.C.U. AIR BLOWN SEALS
9 TUBE-P_2 TO GEARBOX AND A/B.F.C.U. SEALS
10 TAPPING CONNECTION-P_2 TO A/B.F.C.U. AIR BLOWN SEAL
11 TUBE-BREATHER BALANCE
12 TUBE-P_2 TO A/B.F.C.U. AIR BLOWN SEALS
13 TUBE-P_0 ENGINE BAY TO E.F.C.U.

NOTE
ENGINE SHOWN IS NOT TO A SPECIFIC MODIFICATION STANDARD

ABBREVIATIONS
E.F.C.U.-ENGINE FUEL CONTROL UNIT
A/B.F.C.U.-AFTERBURNER FUEL CONTROL UNIT

Location of air tubes and assemblies. Right-hand view

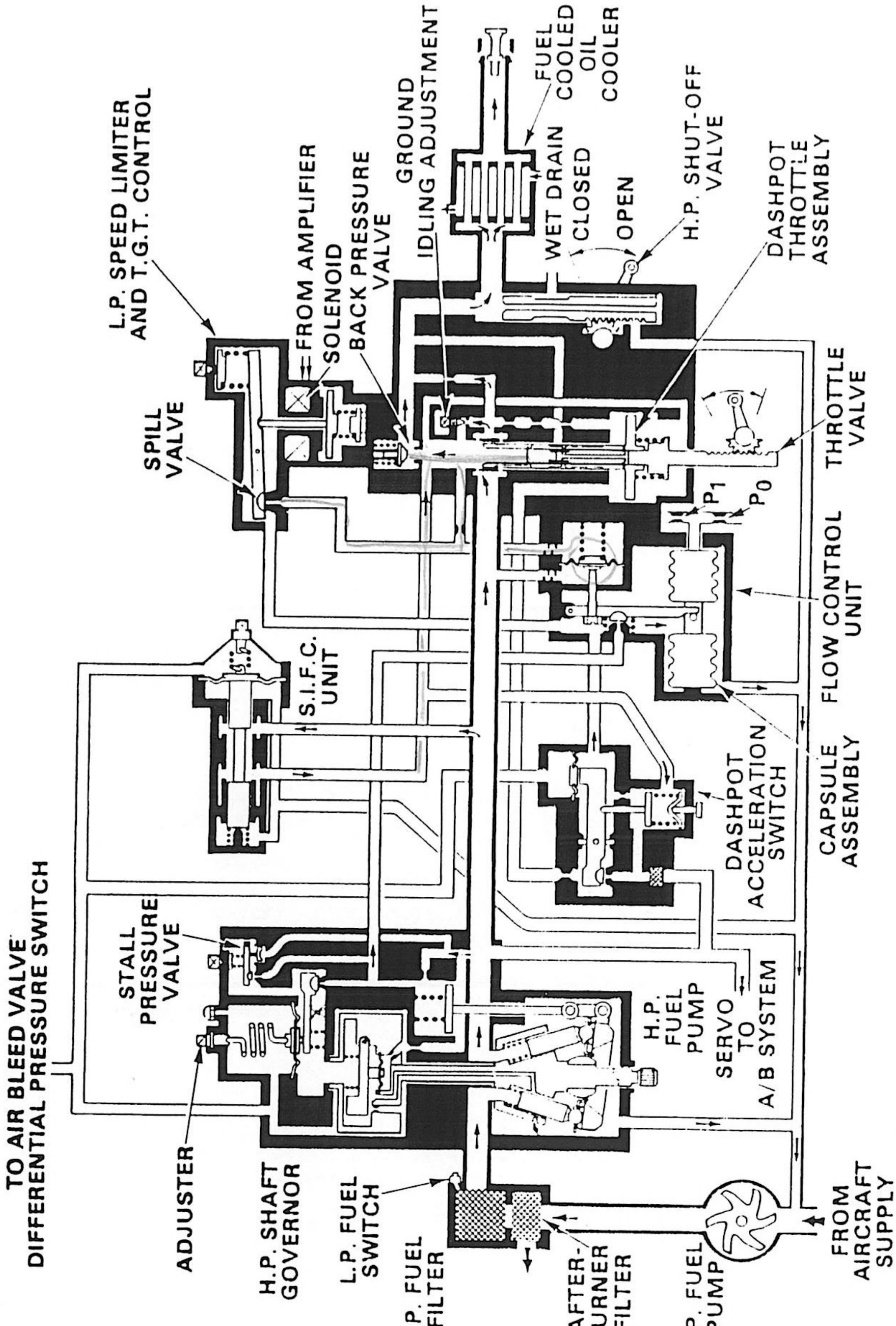


1 TUBE- $P_3 - P_1$ PROBE ANTI-ICING
2 TUBE- P_1 TO E.F.C.U – FIRST SECTION
3 TUBE- P_2 TO A/B F.C.U.– MEAN PRESSURE
4 TUBE- P_1 TO E.F.C.U – FIRST SECTION
5 TUBE- P_1 TO E.F.C.U.– THIRD SECTION
6 TUBE- P_6 TO A/B F.C.U.– SECOND SECTION
7 P_6 PROBE CONNECTION
8 TUBE- P_3 TO No.1 CATALYST
9 L.P. COOLING AIR OUTLET AND OVERHEAT DETECTOR SWITCH
10 TUBE- P_6 TO A/B F.C.U.– FOURTH SECTION
11 TUBE- P_2 TO A/B F.C.U.– SECOND SECTION
12 TUBE- P_3 TO A/B F.C.U.– SECOND SECTION
13 TUBE- P_2 TO A/B F.C.U.– AIR BLOWN SEAL
14 TUBE- BREATHER BALANCE
15 TUBE- P_2 TO A/B F.C.U.– FIRST SECTION

NOTE–
THIS ENGINE IS NOT SHOWN TO A SPECIFIC MODIFICATION STANDARD

ABBREVIATIONS
E.F.C.U. ENGINE FUEL CONTROL UNIT
A/B F.C.U. AFTERBURNER FUEL CONTROL UNIT

Location of air tubes and assemblies.
Underside view



ENGINE FUEL SYSTEM.

ROLLS-ROYCE/TURBOMECA.

ADOUR MK,s 811/815.

FUEL SYSTEM.

INTRODUCTION.

The system is required to:

1. Introduce fuel into the combustion chamber in a finely atomised spray to ensure efficient burning over the whole range of fuel flows from starting to max.dry.
   Refer to: A.FUEL SPRAY NOZZLES.
   B.PUMPING UNITS.

2. Provide pilot control of fuel flow.
   Refer to: PILOT CONTROL OF FUEL FLOW.

3. Enable pilot selected fuel flow to be over-ridden to prevent certain engine operating limitations being exceeded.
   Refer to: AUTOMATIC CONTROL OF FUEL FLOW.

4. Provide a completely automatic fuel schedule during engine starting.
   Refer to: STARTING FUEL FLOW METERING.

5. Provide pilot control of fuel flow to the spray nozzles for starting and stopping the engine.
   Refer to: HIGH PRESSURE SHUT-OFF VALVE.

OPERATION.

The system can now be studied by analysis of these requirements.

1A. The fuel must be conditioned for efficient burning by atomising into minute droplets.

This is achieved by spray nozzles supplied with fuel at a substantial pressure.

Eighteen fuel spray nozzles are mounted around the combustion chamber outer casing.

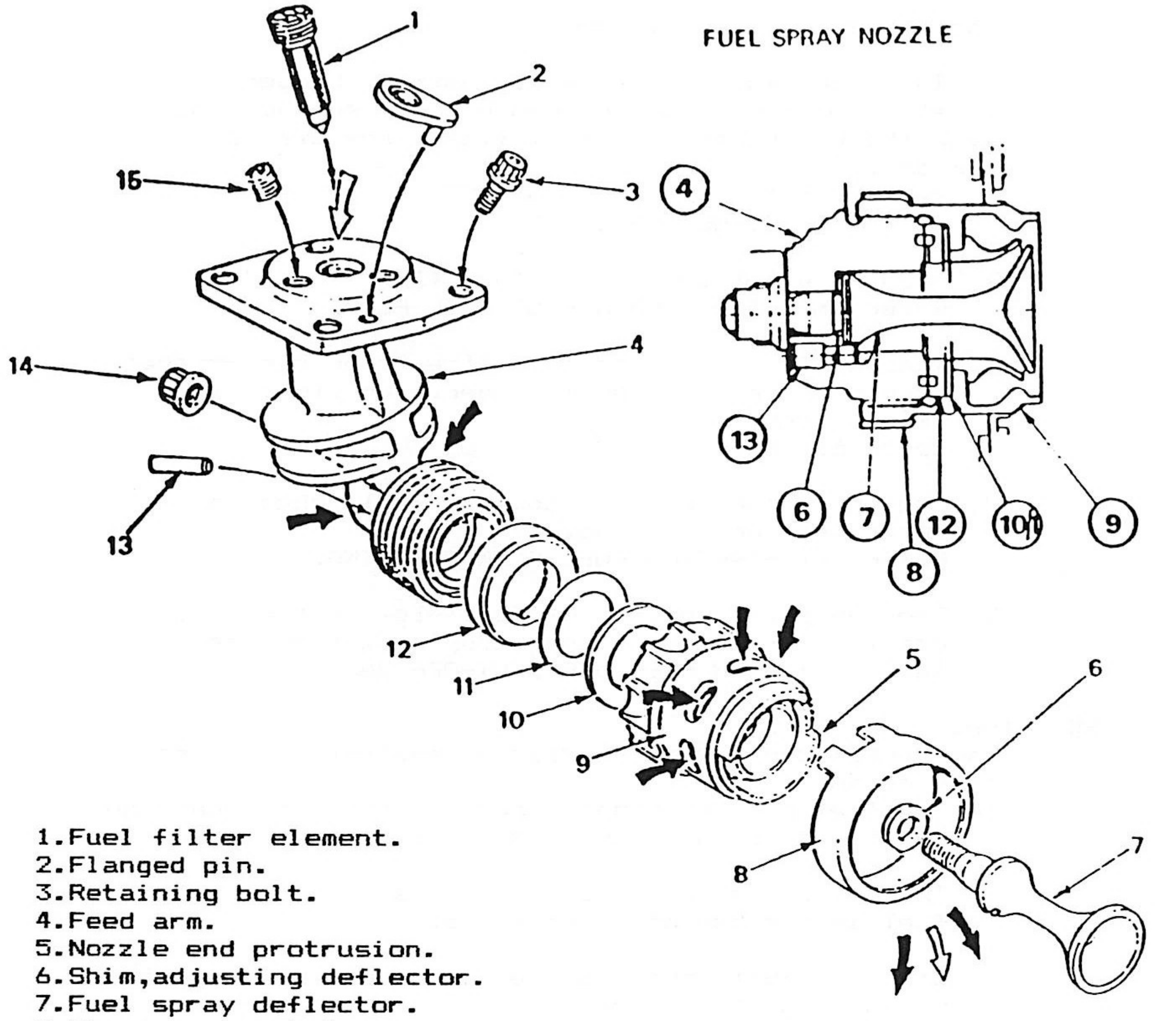
A drilling in the feed arm conveys fuel to a swirl chamber via tangential drillings which impart a swirl to the fuel as it enters.

Air also enters the swirl chamber from the combustion chamber primary zone via forward facing ports in the feed arm.

cont./

fuel system cont./

Most of the air passes through the centre of the fuel vortex and is deflected by a spreader plate to further break up the fuel cone into an atomised spray.



1. Fuel filter element.
2. Flanged pin.
3. Retaining bolt.
4. Feed arm.
5. Nozzle end protrusion.
6. Shim, adjusting deflector.
7. Fuel spray deflector.
8. Sleeve nut retainer.
9. Fuel spray nozzle.
10. Spacer.
11. Shim, adjusting-fuel spray nozzle.
12. Fuel spray swirler.
13. Pin.
14. Nut, fuel spray deflector.
15. Wire thread insert.

1B. PUMPING UNITS.

The necessary high fuel pressure required for good atomisation by the spray nozzles is provided by the Lucas High Pressure fuel pump.

To prevent cavitation within the HP fuel an LP or backing pump is located downstream of the HP pump.

A low pressure filter is interposed between the two pumps.To give warning of excessive filter blockage or LP pump failure a Low Fuel Pressure switch is positioned between the filter and the HP pump.This warning is an amber light on the CWP giving either a BP1 or BP2 caption.

Whilst the LP pump is a simple centrifugal,positive displacement pump,the HP pump is not.

a. HP FUEL PUMP.

An engine driven rotor carries seven spring loaded plungers loaded against a circular camplate.
The camplate is mounted on trunnions which permit its angle relative to the rotor to be varied.Variation of this angle regulates the 'stroke' of the plungers as the rotor is turned.
The pumping action takes place as the plungers rotate around the angled camplate;plungers that are extended draw in fuel through a semi-circular inlet port,and those being compressed deliver fuel through a similarly shaped outlet port.
Since for any given RPM the engine fuel requirement does not coincide with the max. pump output the pump stroke will have to be varied independently of RPM.
The variation in fuel flow to suit the engine requirements is effected by altering the camplate angle.
The camplate is moved by a servo piston which is subjected to pump delivery pressure on one side and a variable servo pressure plus a spring on the other.
The degree of servo pressure and therefore the camplate angle is governed by a spill valve in the Fuel Control Unit.(FCU).
The next step is to see how the spill valve is controlled to produce the engine fuel flow requirements.

2. PILOT CONTROL OF FUEL FLOW.

a. Basic Flow Schedule.

The requirement here is for the system to schedule a specific fuel flow for a given throttle lever position.

It has been previously explained that movement of the pump servo spill valve controls pump stroke, and therefore fuel flow,irrespective of RPM.

The spill valve is housed in the fuel flow control unit.(FCU).

In the FCU is a throttle valve,this is a sleeve which is positioned by pilots lever movement in a fixed perforated outer sleeve.

Movement of the pilots lever towards max.causes the sleeve to uncover more holes and thus increase the throttle valve area.

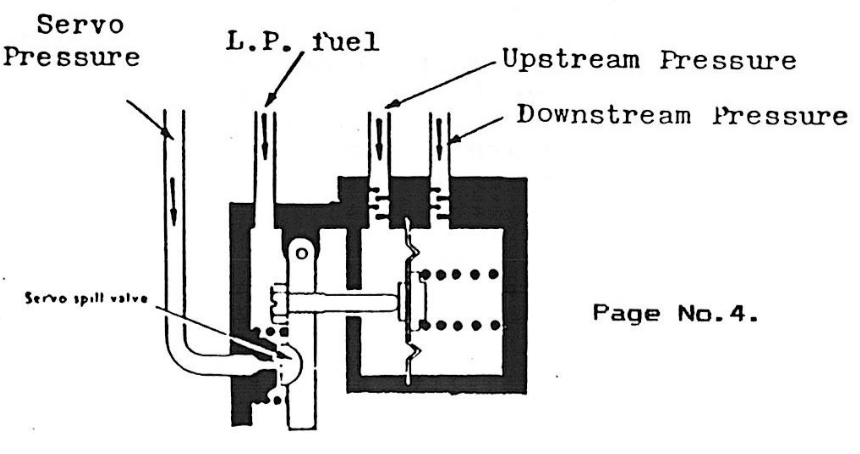
The principle of flow control is that pump stroke will be adjusted until the same differential pressure occurs at any selected area of the throttle valve.

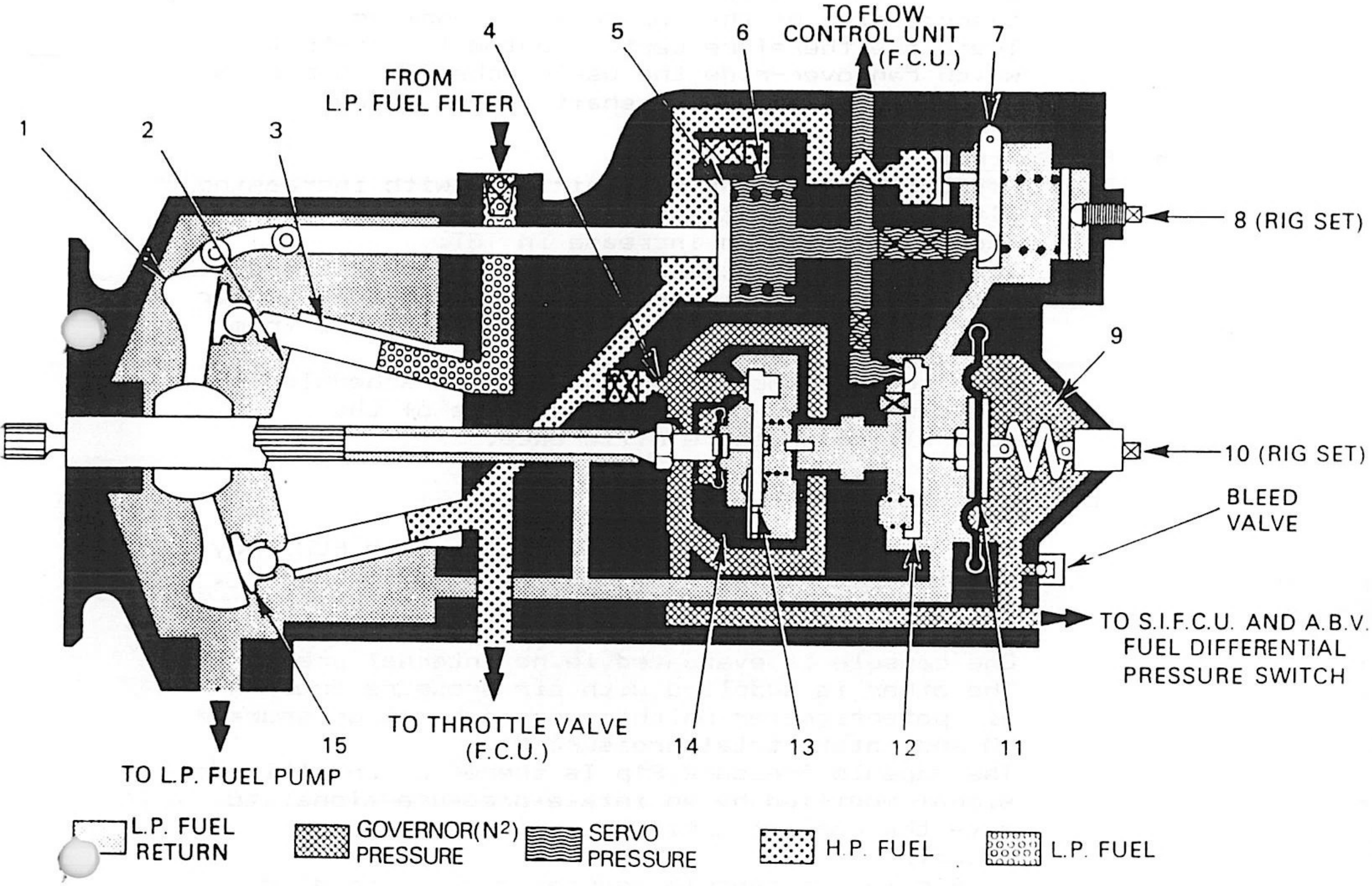
This gives a specific steady running fuel flow for any throttle position.

Fuel pressure upstream of the throttle valve is sensed on one side of a diaphragm and downstream pressure on the other
The force applied to the diaphragm by downstream pressure is augmented by a spring.
Movement of the diaphragm is transmitted to the pump servo spill valve by a pin.
The pump camplate angle will become stable when the total forces across the diaphragm are balanced

Upstream pressure = Downstream pressure + Spring force.

This then is the maximum flow schedule-determined by the rig set value of the spring.





1. CAMPLATE
2. ROTOR ASSEMBLY
3. PISTON
4. GOVERNOR RESTRICTOR
5. SERVO PISTON
6. SERVO ORIFICE
7. STALL VALVE LEVER ASSEMBLY
8. STALL VALVE ADJUSTER
9. OVERSPEED GOVERNOR
10. OVERSPEED GOVERNOR ADJUSTER
11. OVERSPEED CONTROL DIAPHRAGM
12. OVERSPEED LEVER ASSEMBLY
13. WEIGHTED LEVER
14. HYDRO-MECHANICAL GOVERNOR ROTOR
15. PISTON SLIPPER

HP FUEL PUMP.

3. AUTOMATIC CONTROL OF THE FUEL FLOW.

Under most operating conditions the maximum flow schedule will cause overheating of the combustion and turbine section of the engine,and overspeeding of the two shaft assemblies.
There are therefore certain automatic controls which can over-ride the basic schedule to prevent limitations of TGT and shaft speeds being exceeded.

a. TGT Control.

Reduction in engine mass air flow with increasing altitude and air temperature will,for a given fuel flow,cause an increase in TGT.
To prevent the maximum TGT from being exceeded two controls are incorporated.One receives an air pressure signal,the other a control signal from the amplifier which senses TGT.
Both controls modify the basic flow schedule in the same way,by reducing the value of the controlling pressure difference.

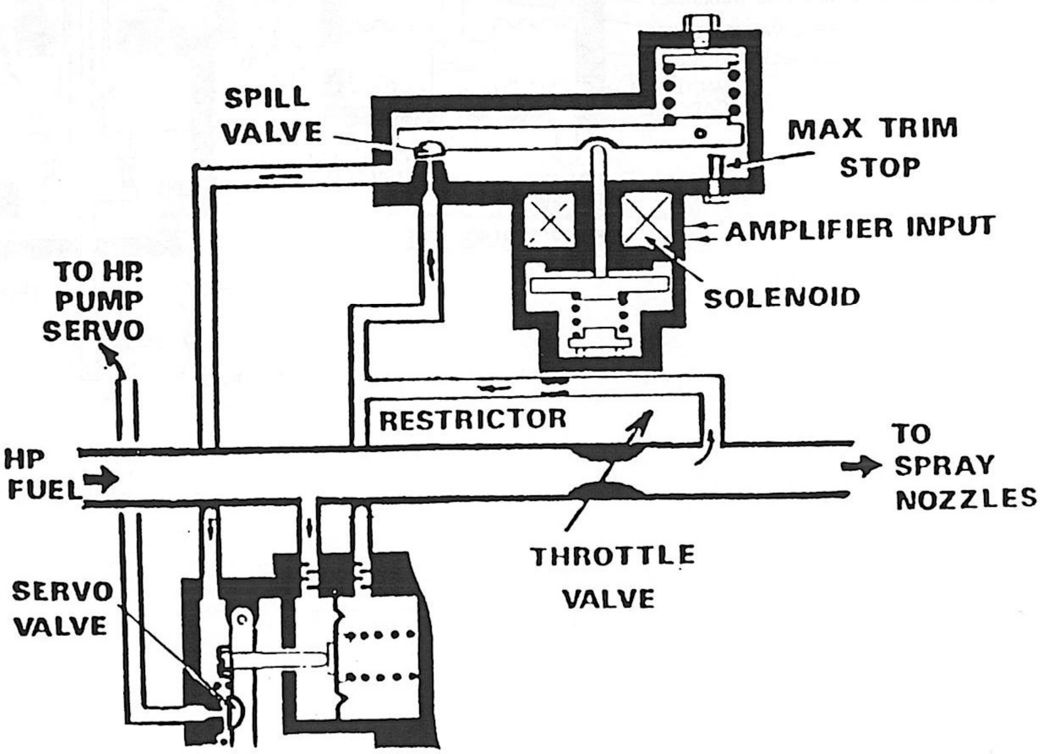
i. Altitude Compensation.

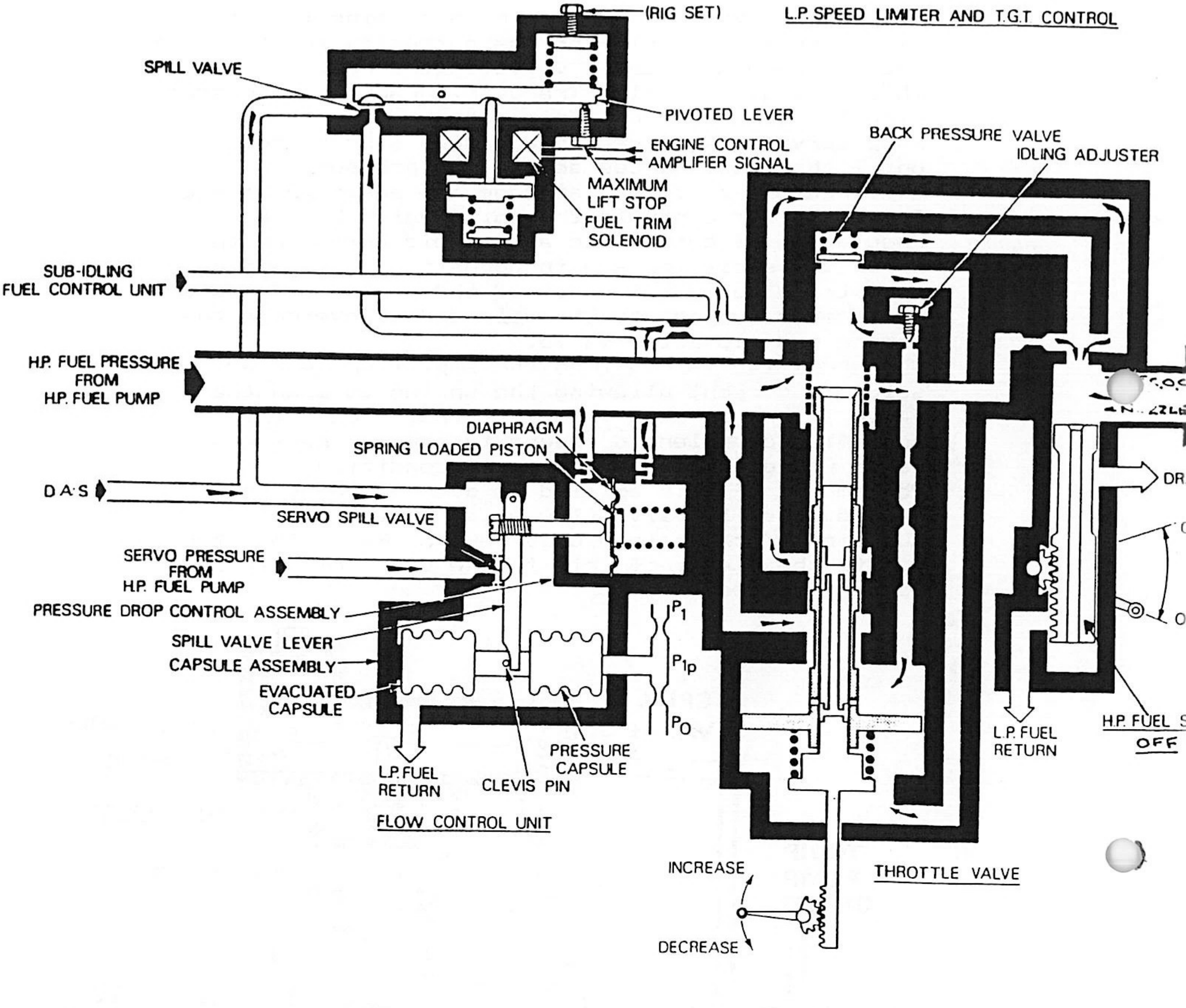
This is effected by two capsules in the FCU.They are interconnected by a central stem through which passes the free end of the spill valve lever.
One capsule is evacuated,ie.no internal pressure, The other is supplied with air pressure from an air potentiometer which senses ambient pressure P0 and intake total pressure P1.
The capsule pressure,P1p Is therefore an altitude signal modified by an intake pressure signal to give the correct altitude to forward speed matching.
As P1p in the capsule reduces with increasing altitude the evacuated capsule is allowed to expand.The spill valve opens above its steady running value and pump stroke decreases.
The system will stabilise when the pressure drop across the throttle valve once more equals the the total pressure balance across the pressure drop piston.
This however is now of a lower value since the pressure drop spring is now opposed by another force - the evacuated capsule spring effect.
The latter will progressively increase as altitude increases,thus decreasing the controlling pressure drop value,and therefore the fuel flow.

104% NL SPEED

ii. Amplifier Control. 640°C

To prevent excessive TGT with increasing intake temperature,the amplifier has authority to 'trim off' fuel by opening a spill valve in the FCU.
This will give a false (reduced) downstream pressure signal to the pressure drop control diaphragm.
Pump servo flow increases and pump stroke reduces until the total forces across the pressure differential control diaphragm are again in balance.
The amplifier controls the spill valve by the regulation of current to a solenoid acting on the spill valve pivoted arm in opposition to a spring.
When trimming is not required the amplifier supplies sufficient current to the solenoid to overcome the spring and close the valve.
When trimming is required the amplifier reduces solenoid current allowing the spring to open the valve.It can be seen from this that should the amplifier or solenoid reduce to zero current the valve would go to a 'fail safe' condition.
The amount of trim applied is determined by the degree of spill valve flow,which in turn is a function of the solenoid current.A 'Max.Trim' stop limits the amount of trim in the event of a failure to zero current.





FUEL CONTROL UNIT.

b. LP Shaft Speed Control.

The operation of the solenoid valve to control LP shaft speed control is identical to TGT control. It is the amplifier which detects the necessity to trim and subsequently reduce the solenoid current.

c. HP Shaft Speed Control.

A hydro-mechanical governor is incorporated in the fuel pump.It produces a fuel pressure which is proportional to pump (and therefore HP shaft speed). The difference between this pressure and backing pump inlet pressure is sensed across a diaphragm.At a value of pressure difference,determined by an adjustment on the pump casing,the diaphragm deflection will operate a spill valve which will bleed away pump servo pressure thus limiting pump stroke and therefore HP speed to its adjusted value.

d. Acceleration Control.

If fuel is introduced into the combustion chamber at too high a rate during acceleration,compressor surge will occur.
This is prevented by a dashpot throttle system. Broadly,this ensures that the throttle valve in the FCU opens at a rate which ensures an acceptable degree of overfuelling regardless of the rate of pilots lever movement.

Acceleration,Idling to Max.Dry.

As the cockpit lever is moved to Max Dry the plunger is moved from the position in Fig.1 to the maximum position in Fig.2.
This causes two simultaneous actions:

a. The stabilising bleed of fuel from the upstream pressure side of the dash-pot piston ceases.
b. The 'initial step flow' holes are uncovered.

The latter causes an immediate increase in fuel flow and the former results in a pressure drop across the throttle valve being sensed across the dash-pot piston.This determines the rate of throttle valve opening.
At a stage in the acceleration when the engine can accept a greater degree of overfuelling the second step orifice is uncovered and the rate of throttle valve opening increases.Ultimately the flow ports in the plunger once again become aligned with the ports in the sleeve,a bleed commences to downstream of the back pressure valve and no further movement of the servo piston and throttle valve takes place.As the throttle valve approaches this position the 'initial step flow' is shut off.

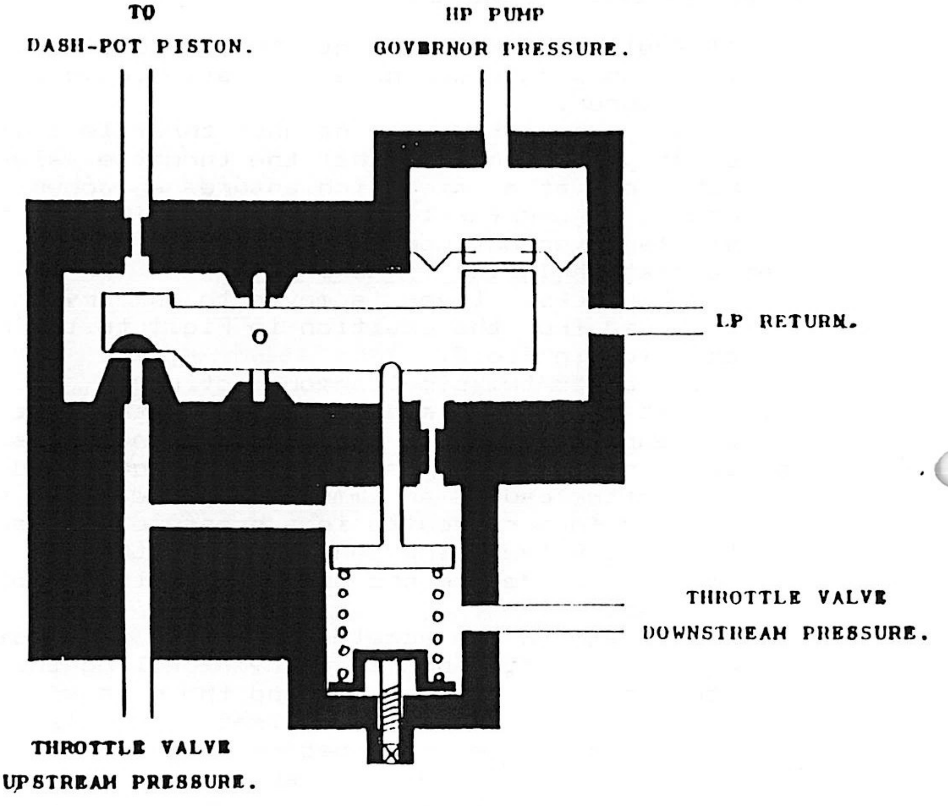
e. Dash-pot Acceleration Switch.

The switch consists of a hinged lever which operates a spill valve in response to movement of a diaphragm. The diaphragm senses governor pressure and LP fuel inlet pressure.

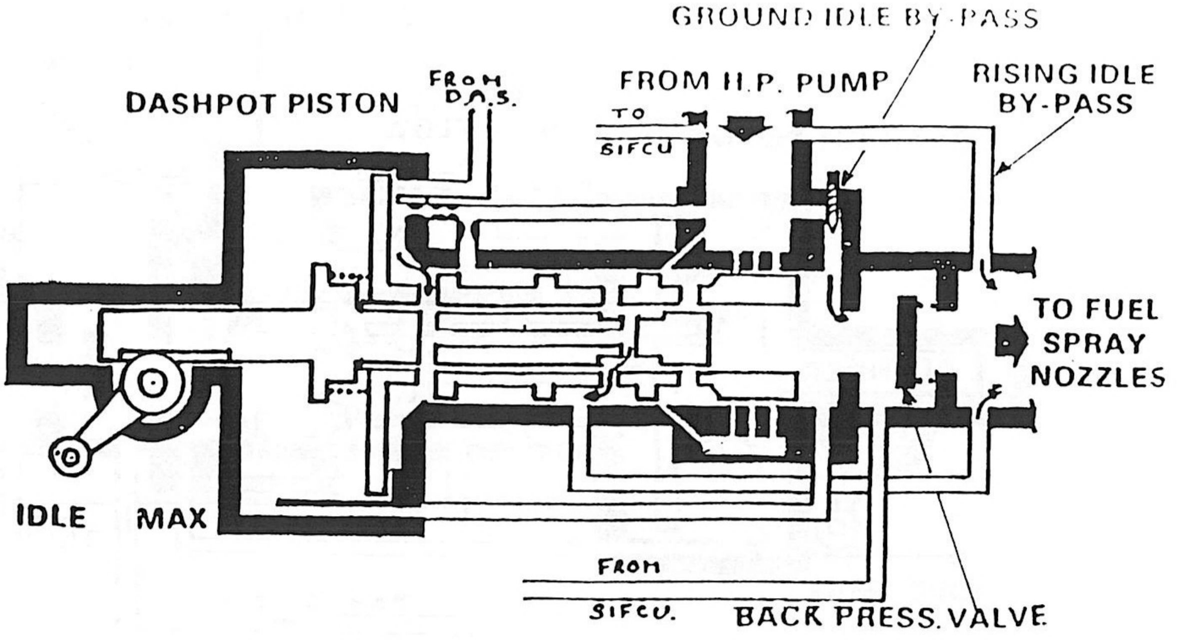
At a predetermined governor pressure,corresponding to a scheduled HP shaft speed,the spill valve opens and increases the throttle dash-pot operating pressure which then increases the rate of throttle valve opening.

Movement of the spill valve lever is opposed by a spring loaded piston which senses the pressure drop across the throttle valve.

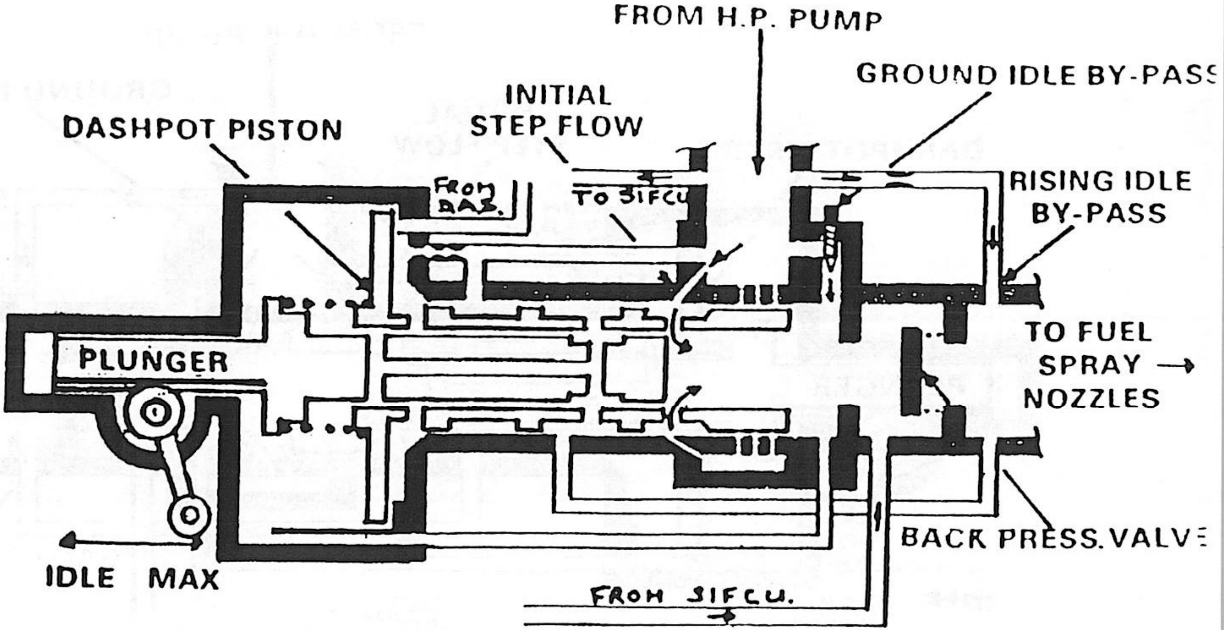
As the pressure drop decreases with increasing altitude,a higher governor pressure and therefore a higher shaft speed is required to overcome the spring pressure and operate the spill valve,thus engine acceleration time will increase with altitude.



DASH-POT ACCELERATION SWITCH.

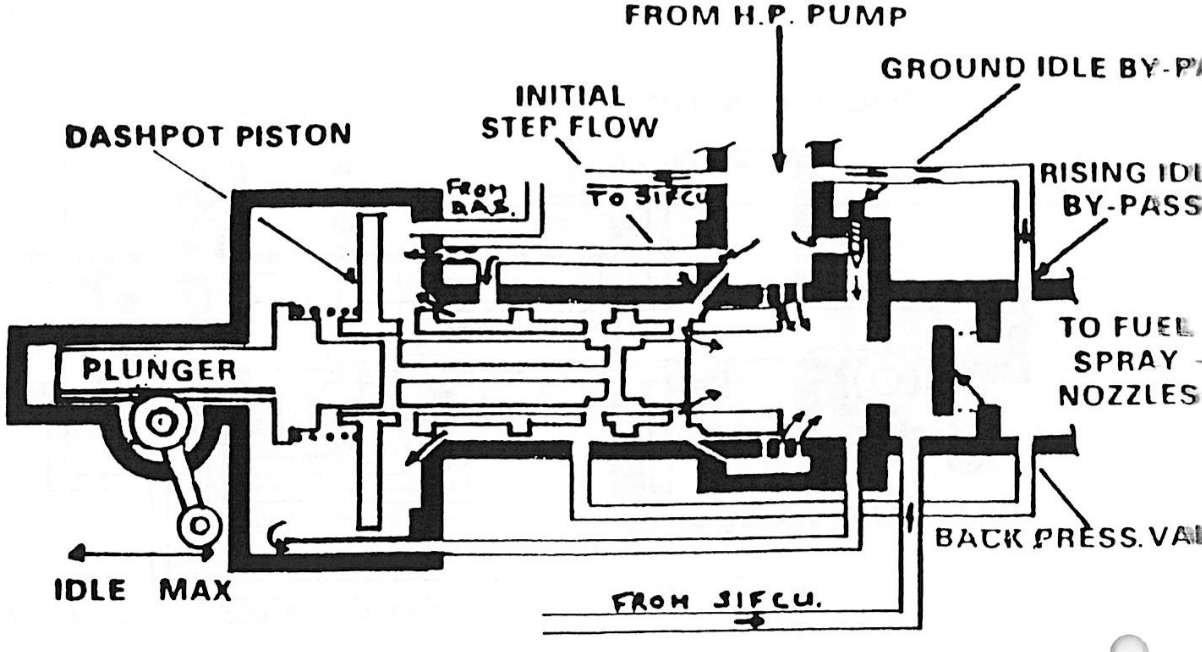


DASHPOT THROTTLE-IDLING

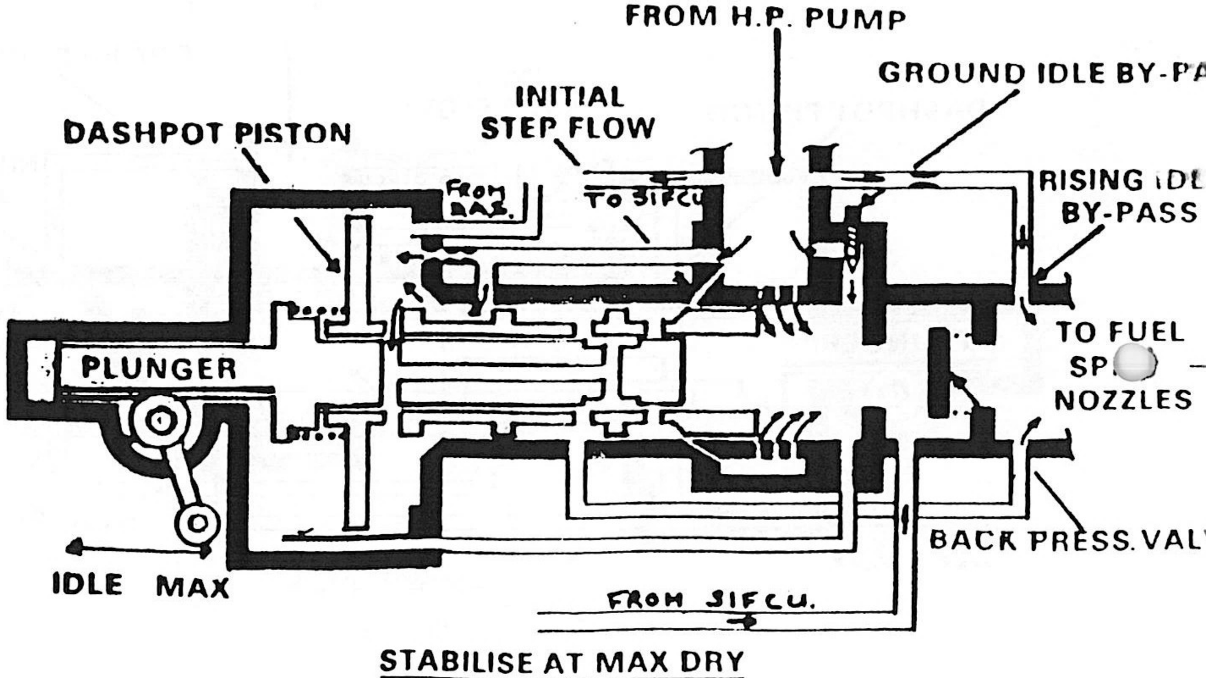


INITIAL STEP FLOW

DASH-POT THROTTLE.



SECOND STEP FLOW



STABILISE AT MAX DRY

DASH-POT THROTTLE.

f. <u>Fuel Pump Pressure Limitation.</u>

It is necessary to limit the delivery pressure of the HP fuel pump to a 'pre-set' value.
This is achieved by the Stall Pressure Valve,which senses pump delivery pressure against a spring.
Should pump pressure attempt to to exceed the pre-set value the valve opens to bleed pump servo to LP.
This prevents any further increase in pump stroke and therefore delivery pressure.

4. <u>STARTING FUEL FLOW METERING.</u>

During an engine start the main throttle valve is <u>CLOSED</u> and fuel is metered via three flow paths.

i. The Ground Idle By-pass.

ii. The Rising Idle By-pass.

iii. The Sub-idle Fuel Control Unit.(SIFCU).

The first two incorporate fixed orifices and the third a variable orifice.
The SIFCU consists of a small secondary throttle valve which is operated by a diaphragm subjected to the same fuel pressure difference as the HP fuel pump governor diaphragm.
With increasing NH the PD across the diaphragm increases progressively opening the throttle valve in the SIFCU.
However,at a pre-determined NH the valve will then reverse its action and reduce fuel flow with increasing NH until a satisfactory idling speed is obtained.
The interaction of these three flows can now be examined during the start cycle.
When a start is initiated the HP shut off valve is not opened until 20% RPM is achieved on the NH gauge.
By that time a metered flow has been achieved through the two idling by-passes by the pressure drop control system.The fuel however is being returned to LP by the hollow shut off valve.
When the shut off valve is opened this metered flow is supplied to the nozzles and ignition occurs.
At approximately 20% RPM ,NH, the proportional PD across the SIFCU diaphragm causes the metering valve to progressively open and fuel flow increases.
At approx. 45% RPM ,NH, the SIFCU metering valve commences to close and when the total metered flow falls to the nominal idling value the engine stabilises.

5. <u>HIGH PRESSURE SHUT OFF VALVE.</u>

Movement of the cockpit lever to the 'STOP' position operates the HP shut off valve and the following actions occur:

i. HP fuel is shut off from the spray nozzles.

ii. HP fuel is diverted from the nozzles through the hollow valve back to LP pump inlet.

iii. Residual fuel in the spray nozzle feed lines is directed to the wet drain manifold.

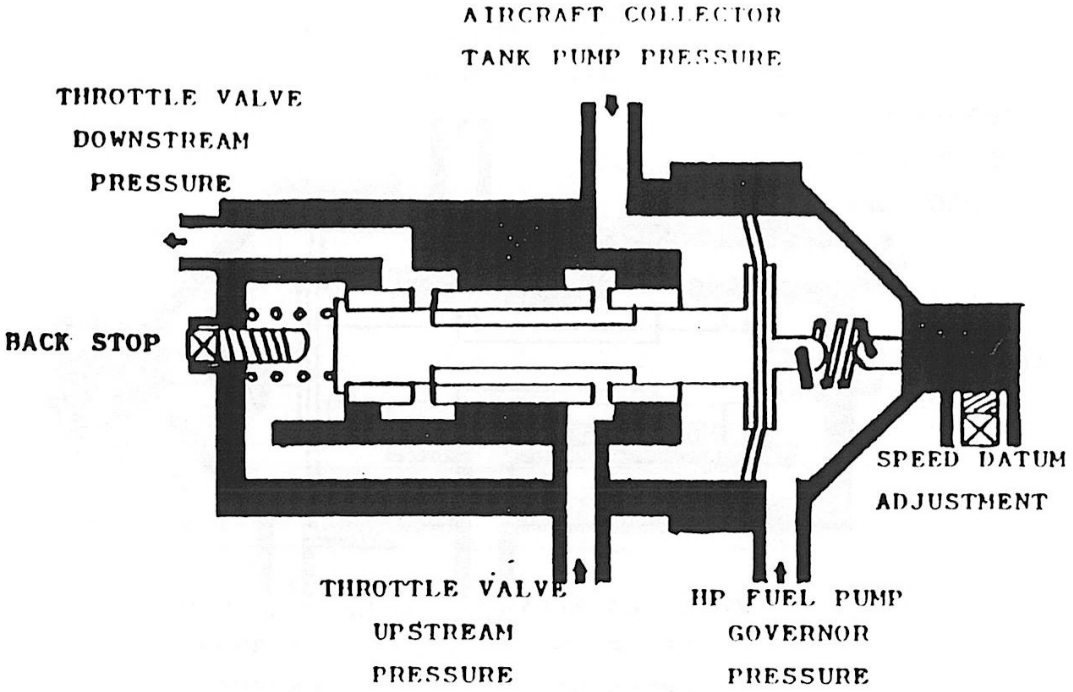
6. <u>ADDITIONAL FEATURES.</u>

After-burner filter.

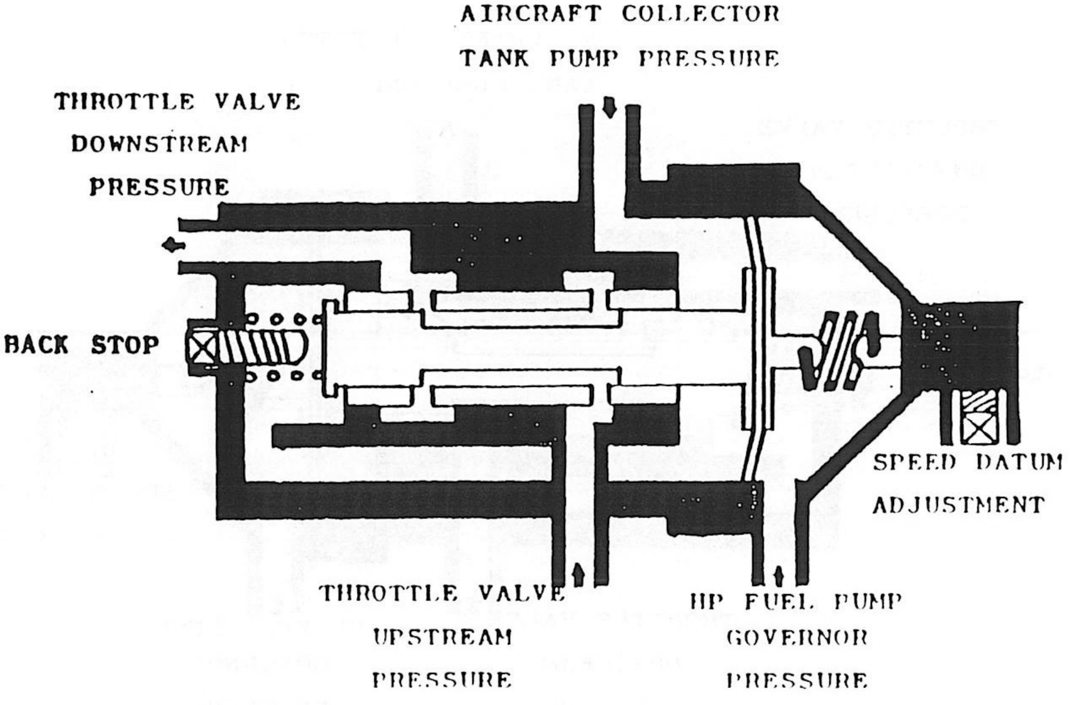
This filter is housed in the filters block,located on the rear underside of the engine,forward of the oil tank.
The filter is a wire cloth gauze strainer.Fuel supply to the after-burner fuel control unit passes through the strainer,and any contamination in the fuel is deposited on the external surface of the strainer.The fuel supply to the engine fuel system flows around the outside of the strainer and sweeps off some of this contamination which is then contained by the LP fuel filter.

Back Pressure Valve.

The back pressure valve is downstream of the throttle valve in the line to the main fuel spray nozzles. Since system pressure at high altitudes is low,the back pressure valve raises the pressure levels sufficiently to maintain satisfactory operation of the pump servo system and to ensure sufficient pressure is available for the after-burner servo tapping.

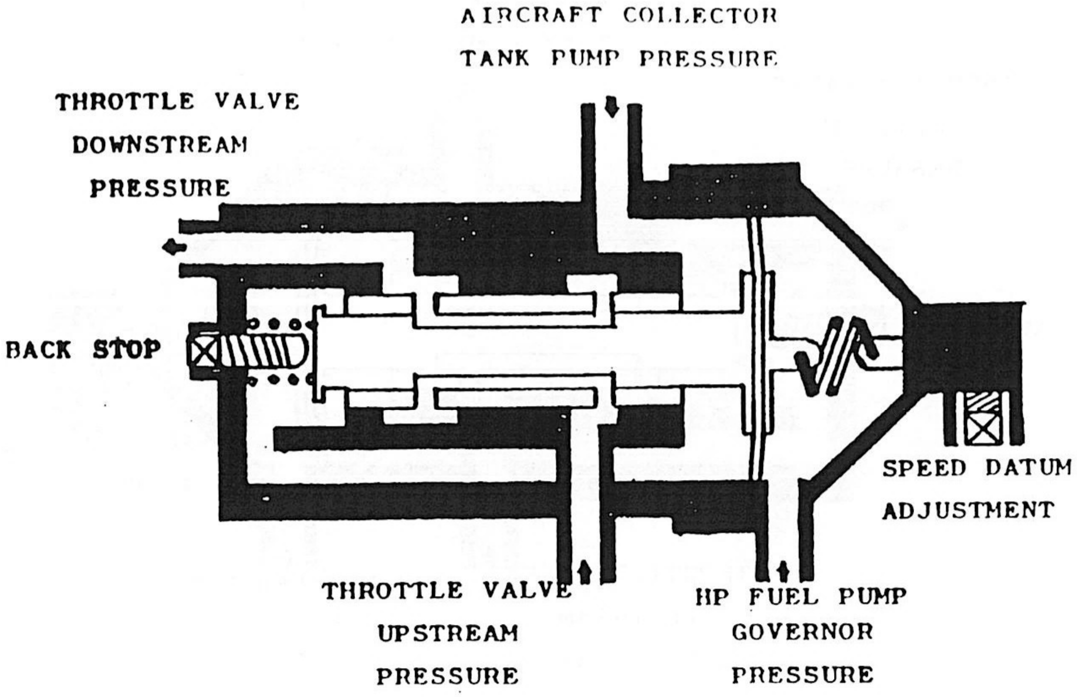


ENGINE STATIC.

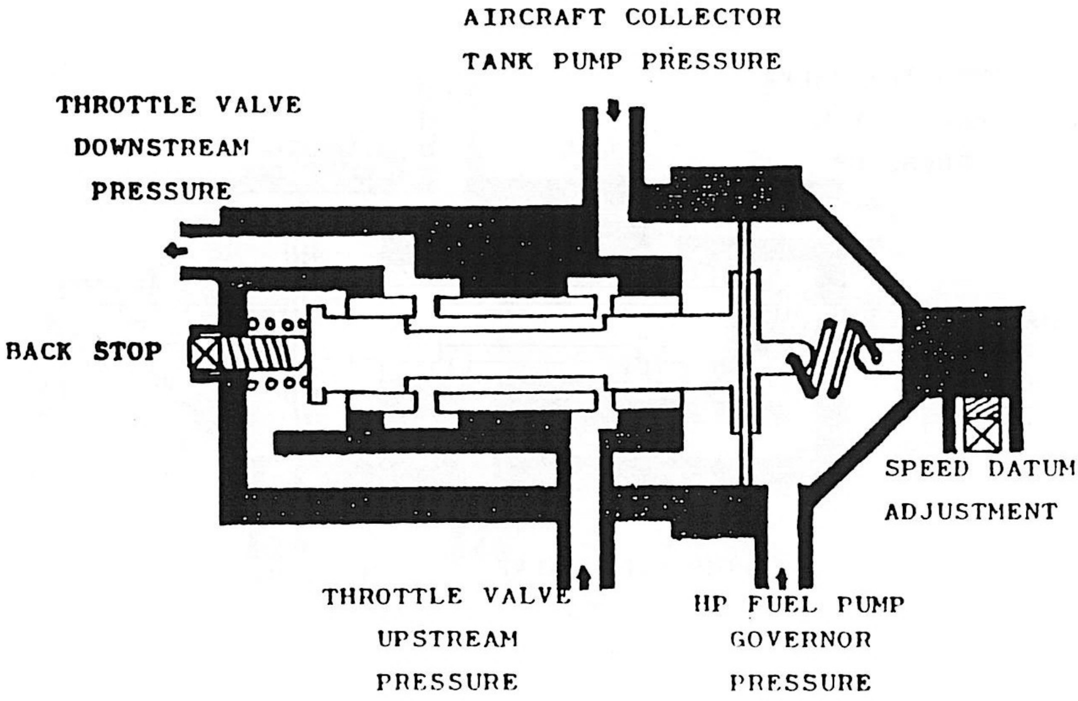


FLOW COMMENCING.

SUB-IDLE FUEL CONTROL UNIT.

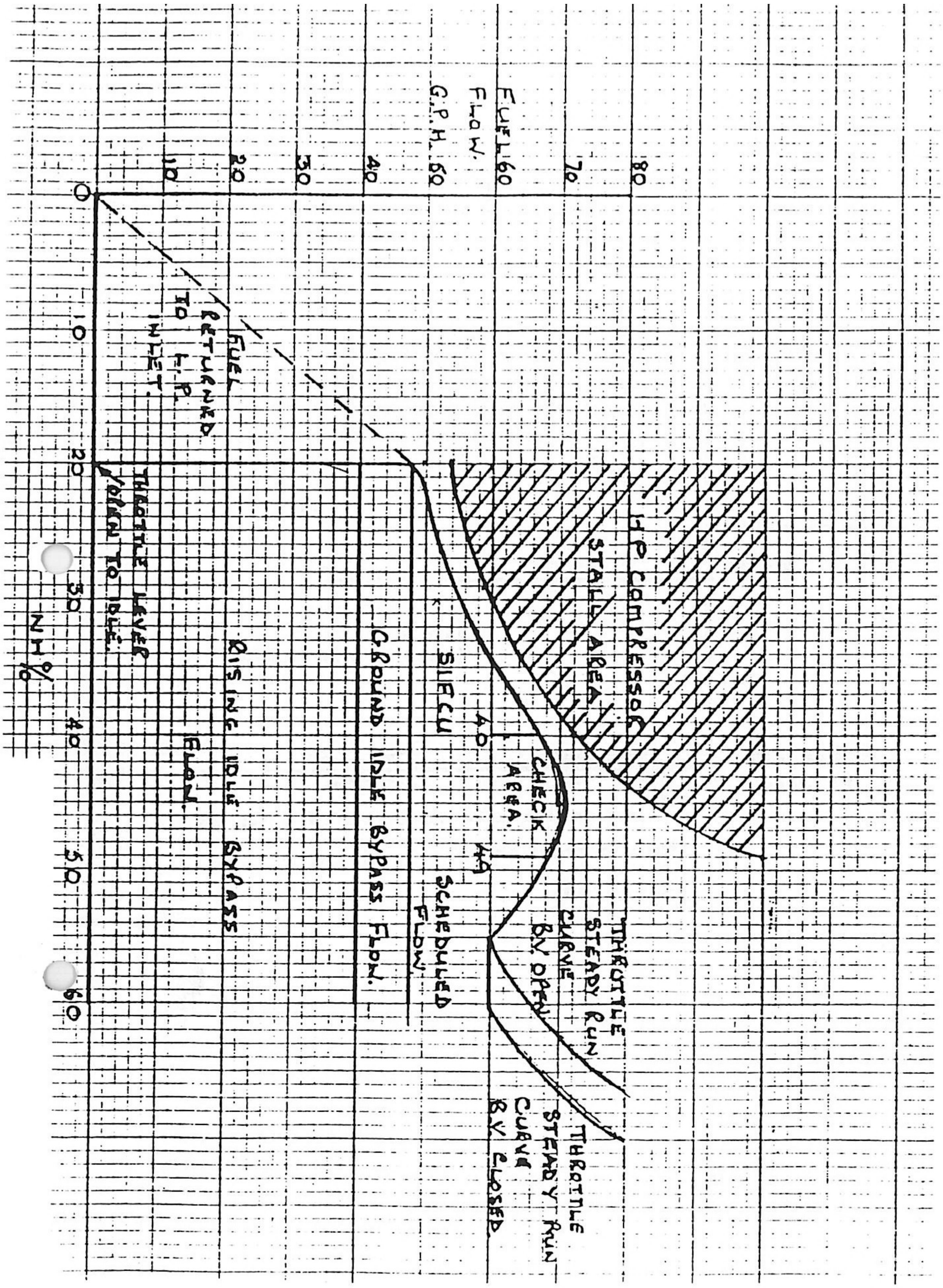


MAXIMUM FLOW.

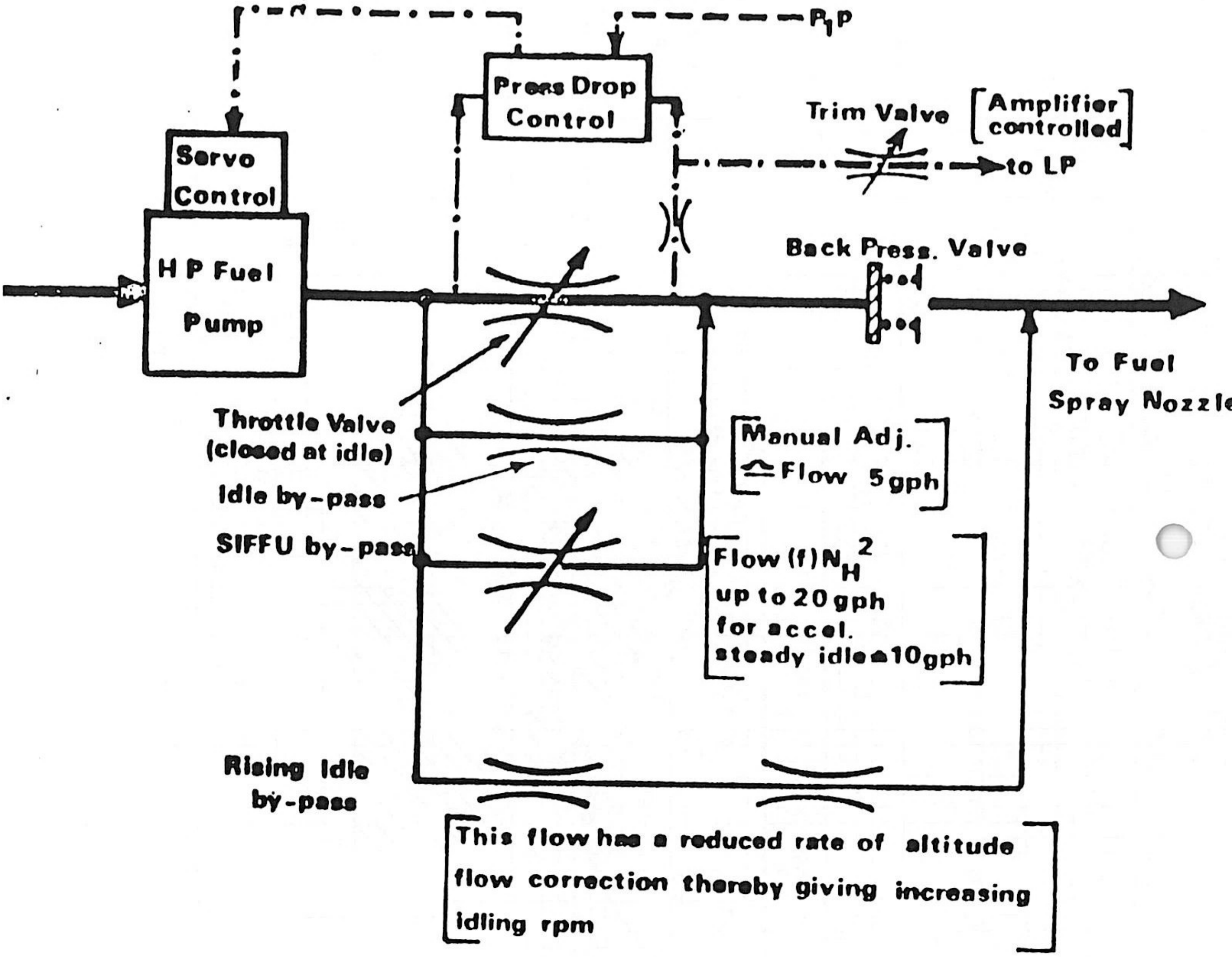


STABILISED IDLING.

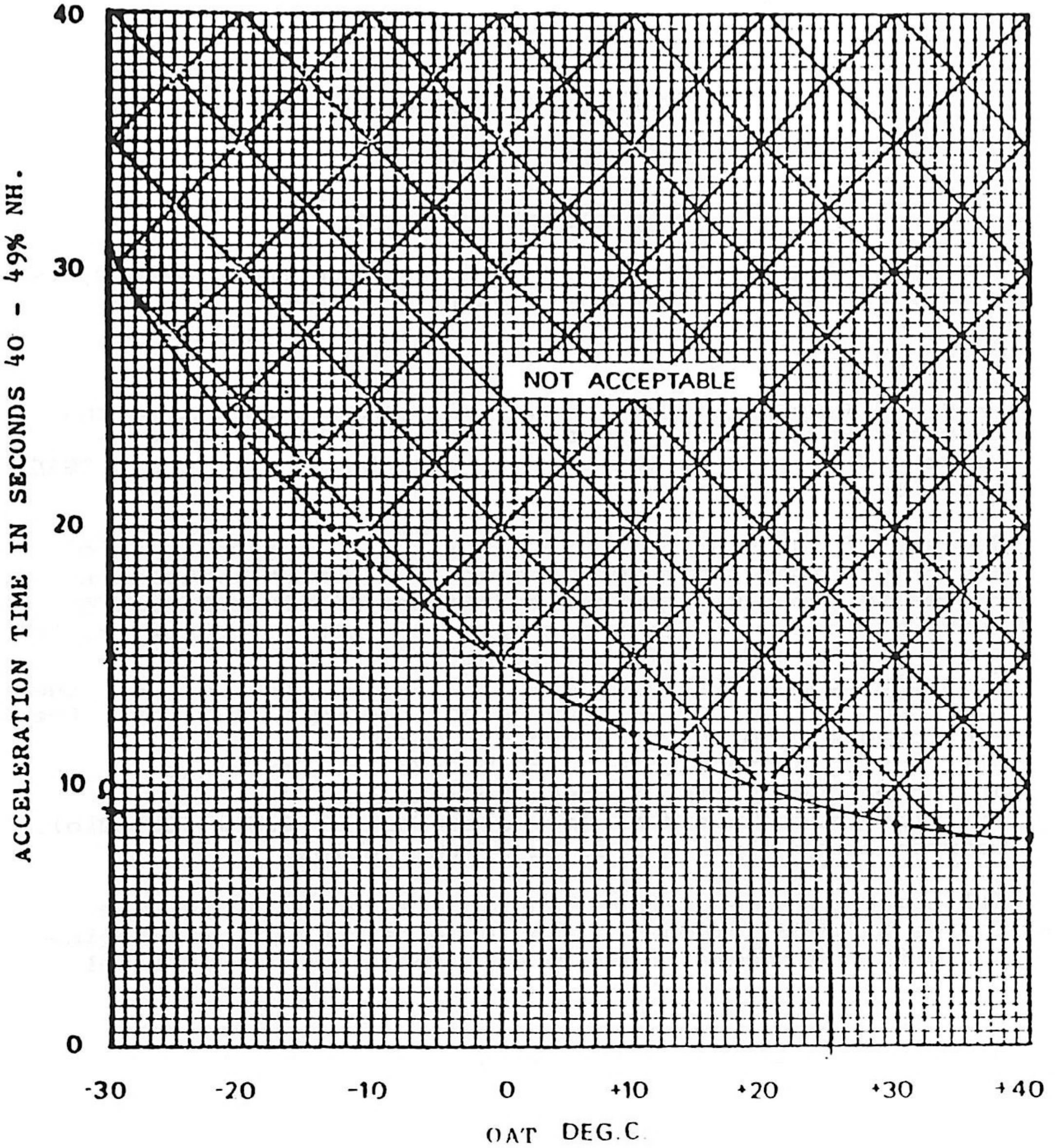
SUB-IDLE FUEL CONTROL UNIT.



STARTING FLOW CHARACTERISTICS.



<u>THROTTLE VALVE AND BY-PASS FLOWS.</u>



SIFCU SETTING CHART.

<u>ROLLS-ROYCE/TURBOMECA.</u>

<u>ADOUR 811/815.</u>

<u>FUEL SYSTEM SERVICING.</u>

The following servicing procedures are concerned with system checks and with unit removal and re-placement.

<u>Precautions.</u>

Before commencing work on the fuel system ensure that the throttle lever is set to 'STOP' to close the HP shut off valve and check that the LP cock switches are in the CLOSED position.

Because of the small differences in bolt lengths it is of the utmost importance that the correct length of bolts are fitted in the various pipes and flange fittings.Damage or leaks can occur if the wrong bolt is fitted.If doubt exists check the Part No. before fitting.
To avoid contamination of the fuel system,blank off all the apertures during removal and do not remove blanks until the serviceable item is ready for fitment.
All locking devices,joint washers and sealing rings disturbed during removal must be replaced.
All pipes must have a minimum clearance of 2.5mm (0.100in). between other pipes and parts of the engine.

All components requiring changing are obtained from the Engine Bay.U/S components should be returned to the Engine Bay with the requisite box,blanks and a repairable label.

Fuel Contamination Check.

At the recommended inspection periods a sample of fuel is taken via the LP filter drain plug.The procedure is simple and no special tools are required.
Ensure that the area around the plug is clean and that the throttle is fully rearward and the LP cocks are closed.
Unscrew the drain plug and collect a fuel sample into a suitable container.Renew the drain plug sealing washer and torque load the plug.
If after inspection of the fuel sample,the fuel is considered to be contaminated,remove all the contaminated fuel from the aircraft system.The LP and After-burner filter should be removed,cleaned and replaced.
Locate and rectify the source of contamination.Check system for leaks.

Fuel System Bleeding.

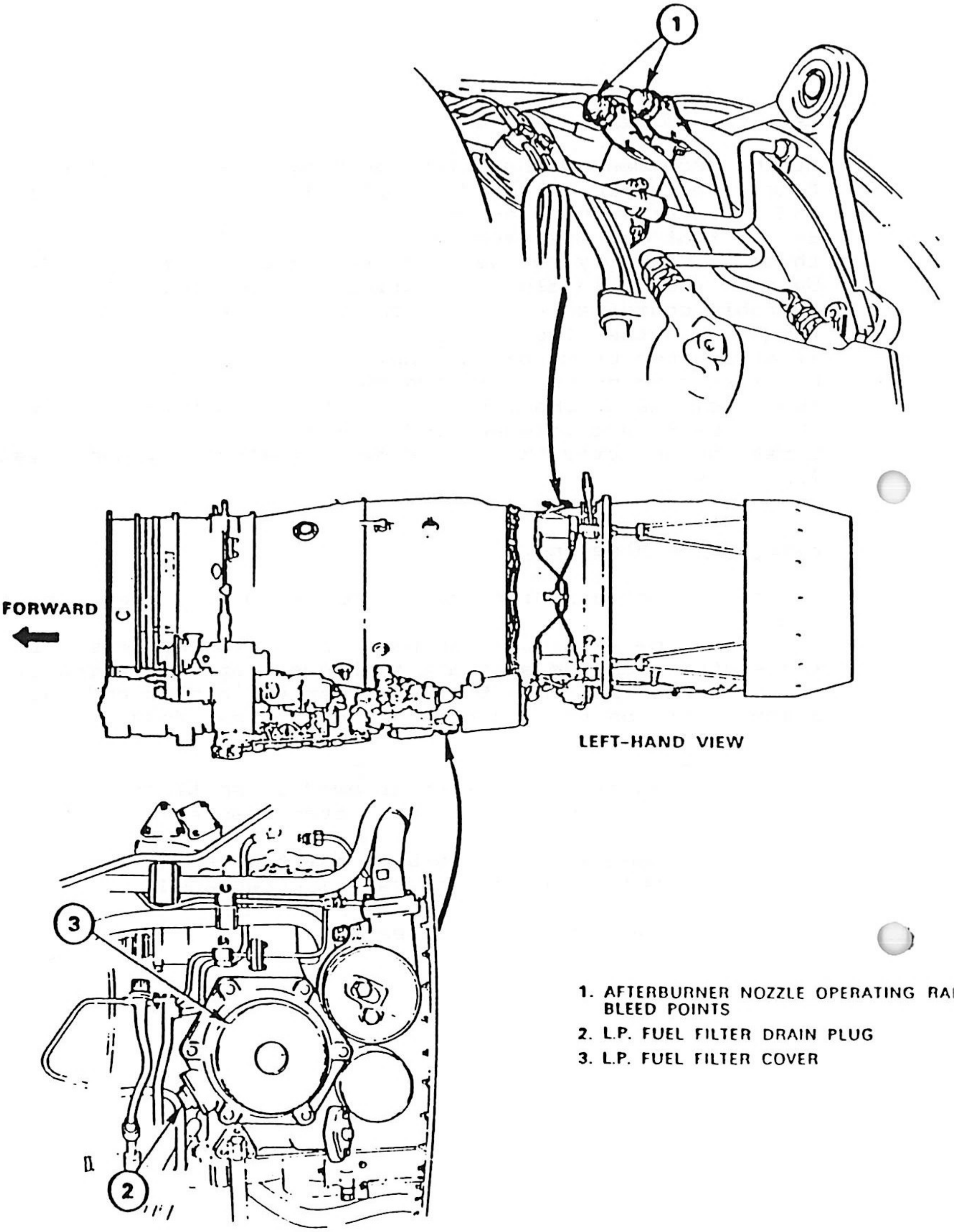
The purpose of bleeding the system is to remove air or inhibiting oil.
The procedure is simple and basically involves pressurising the system from the aircraft tank pumps and obtaining air and oil free fuel from the LP filter drain plug and the two bleed points on the after-burner nozzle ram feed lines.

Ensure that:

No oil or fuel is allowed to spill on to and soak into the exhaust collector insulation blanket.

Adequate fuel is bled off to ensure clean fuel and all relevant seals are replaced.

Check system for leaks.



1. AFTERBURNER NOZZLE OPERATING RA
   BLEED POINTS
2. L.P. FUEL FILTER DRAIN PLUG
3. L.P. FUEL FILTER COVER

FUEL SYSTEM BLEED POINTS.

The LP fuel Filter.

The filter assembly is readily accessible on the underside of the engine.

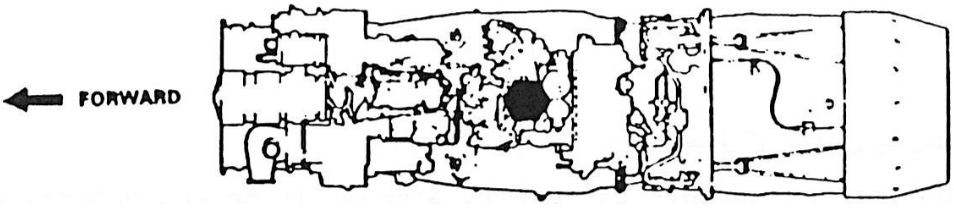
Ensure the LP fuel supply is off and drain the filter housing into a clean container,the filter can be cleaned by washing the element in clean fuel.The filter can be cleaned up to a maximum of three times and to identify the number of cleans the filter housing should be marked appropriately.

Never brush clean the element.

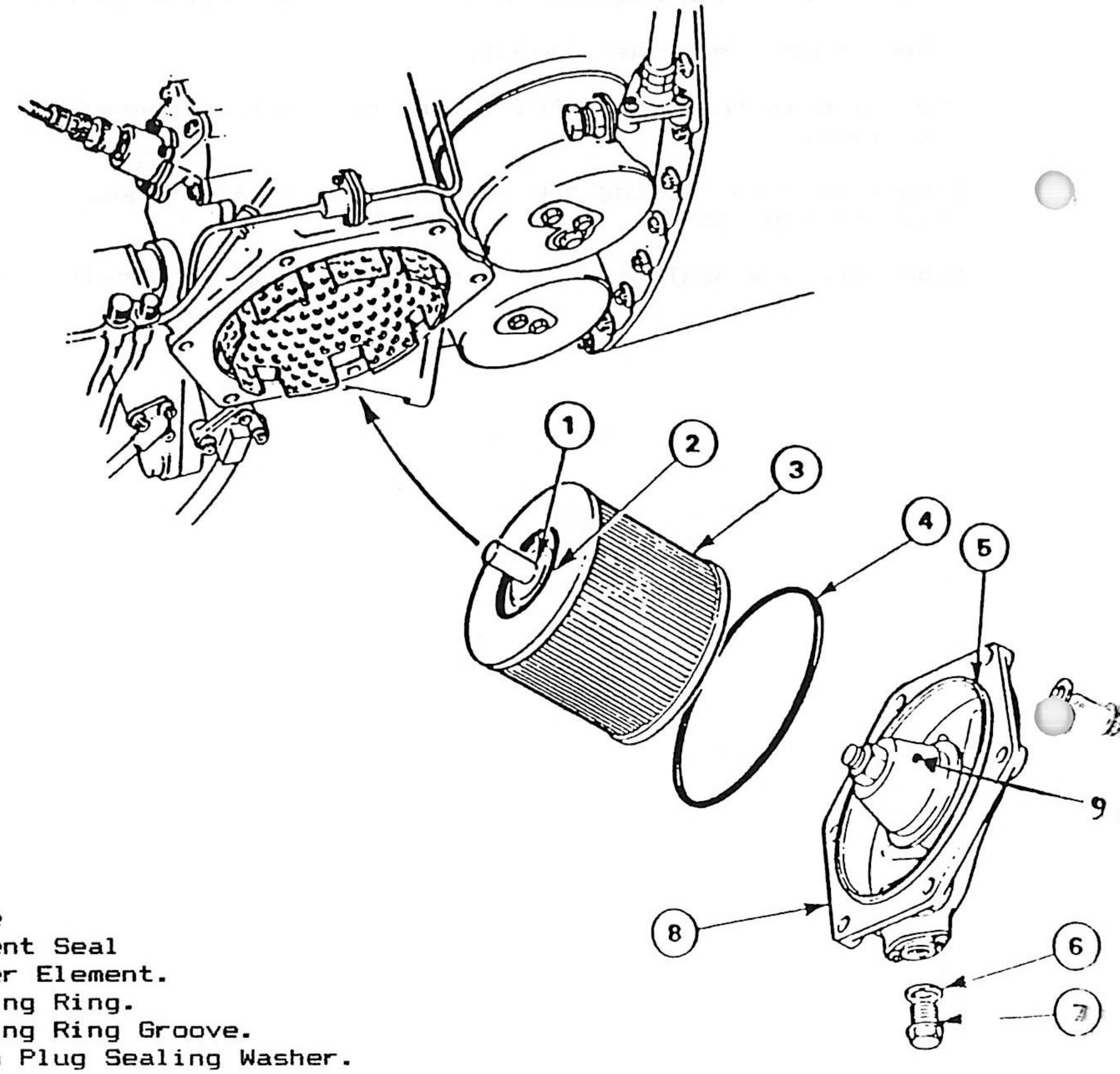
The valve in the top of the filter must not be opened during the clean.

Ensure when re-fitting the element that it fits squarely into its housing

Lubricate new sealing ring,torque load bolts and drain plug.



UNDERSIDE VIEW

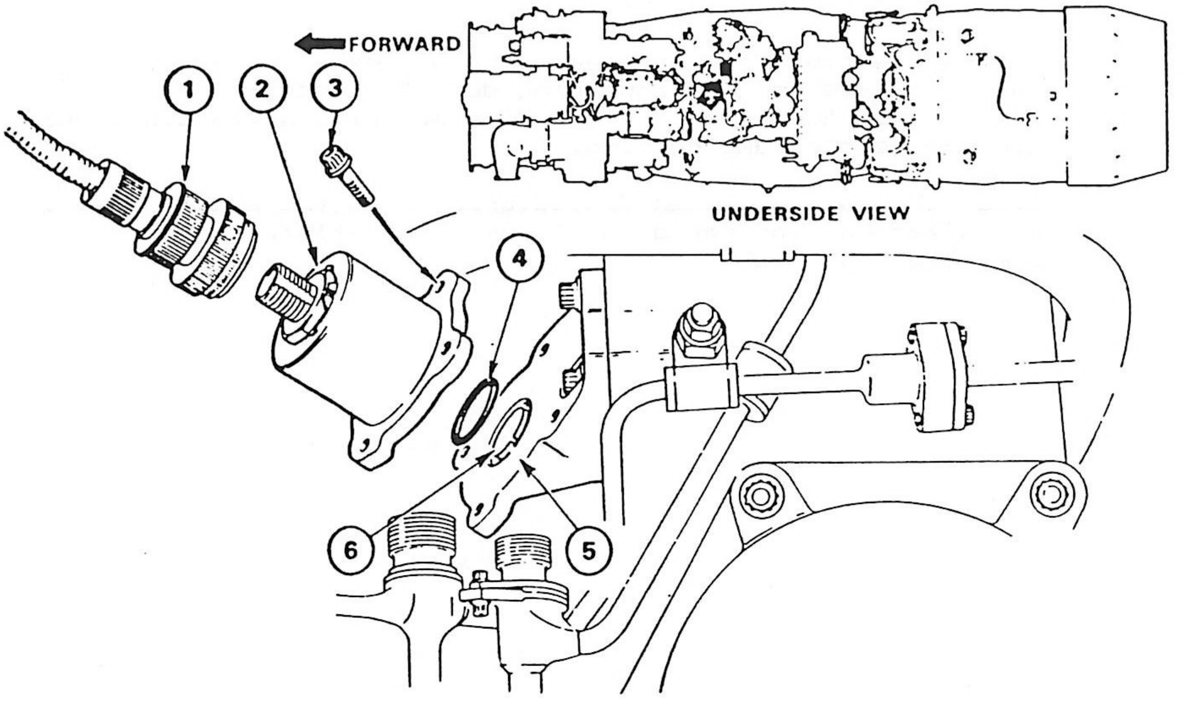


1. Valve
2. Element Seal
3. Filter Element.
4. Sealing Ring.
5. Sealing Ring Groove.
6. Drain Plug Sealing Washer.
7. Drain Plug.
8. Filter Cover.
9. Balance Hole.

LP FUEL FILTER.

LP Fuel Absolute Pressure Switch.

The removal and replacement is straightforward. Renew the sealing ring and replace the switch.
After replacement bleed the fuel system and check switch for operation on a ground run observing that the warning light goes out when the LP system is pressurised. Check for leaks.



1. Electrical Connection.
2. Fuel Low Pressure Warning Switch.
3. Securing Bolt.
4. Switch Sealing Ring.
5. Switch Mounting Bracket.
6. Seal Retaining Ring.

FUEL LOW PRESSURE WARNING SWITCH.

Low Pressure Fuel Pump. (Backing Pump).

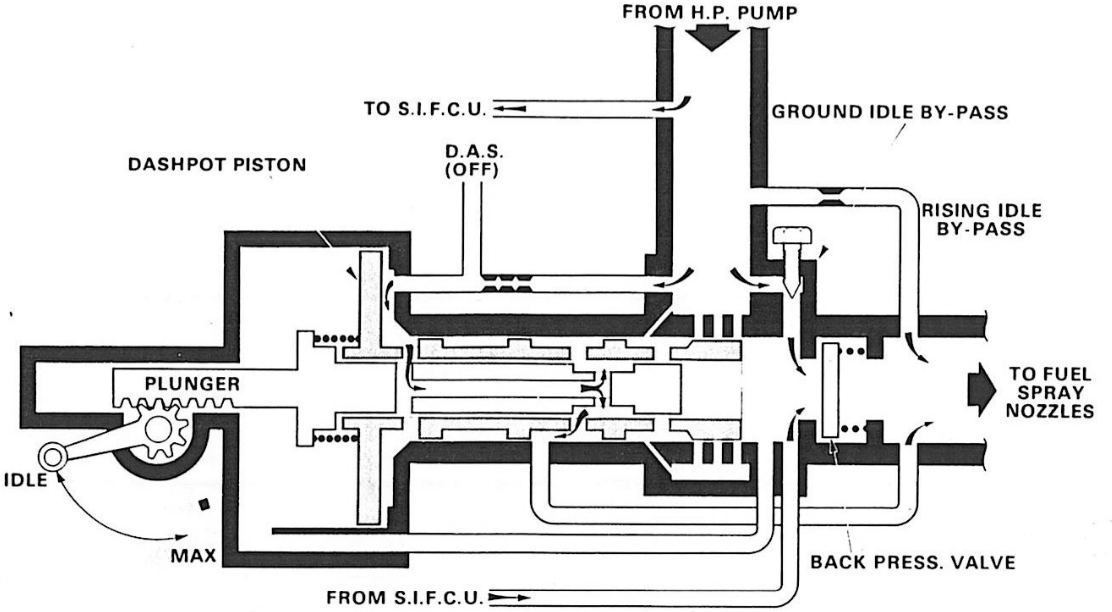
No special tools are required and the removal/fitment procedures are straightforward.

There are however one or two points that require special attention.

Before fitting the new LP pump its drive shaft should be cleaned with trichlorethane and coat the shaft and splines with a dry film lubricant.

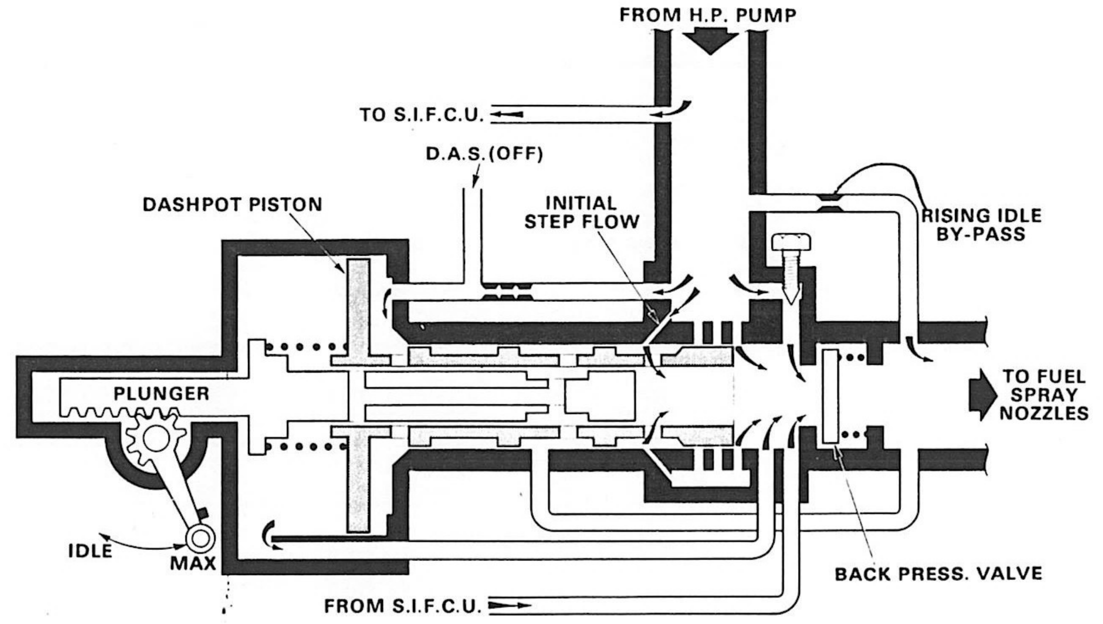
Ensure the pump mounting face sits squarely to the gear-box mounting face before tightening down the securing bolts.
Do not pull down the pump with its securing bolts since this can damage the pump bearing.

After the pump has been fitted,ground run the engine in the non after-burning range,check pump for satisfactory operation and leaks.



DASHPOT THROTTLE-IDLING

TA 3908



INITIAL RAMP FLOW

TA 3909

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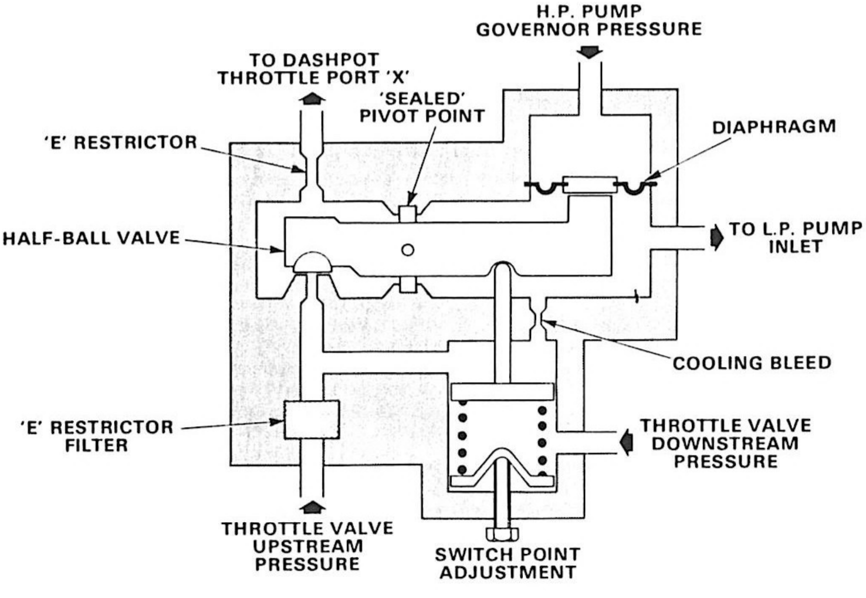
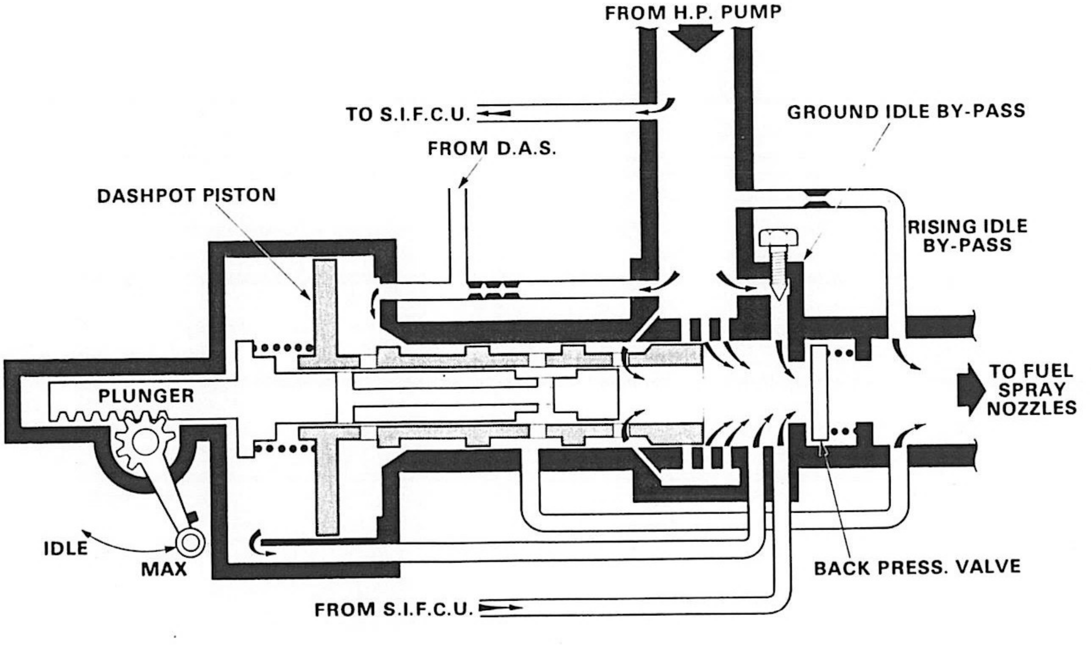


DASHPOT THROTTLE ACCELERATION SWITCH

TA 3903



SECOND RAMP FLOW

TA 3910

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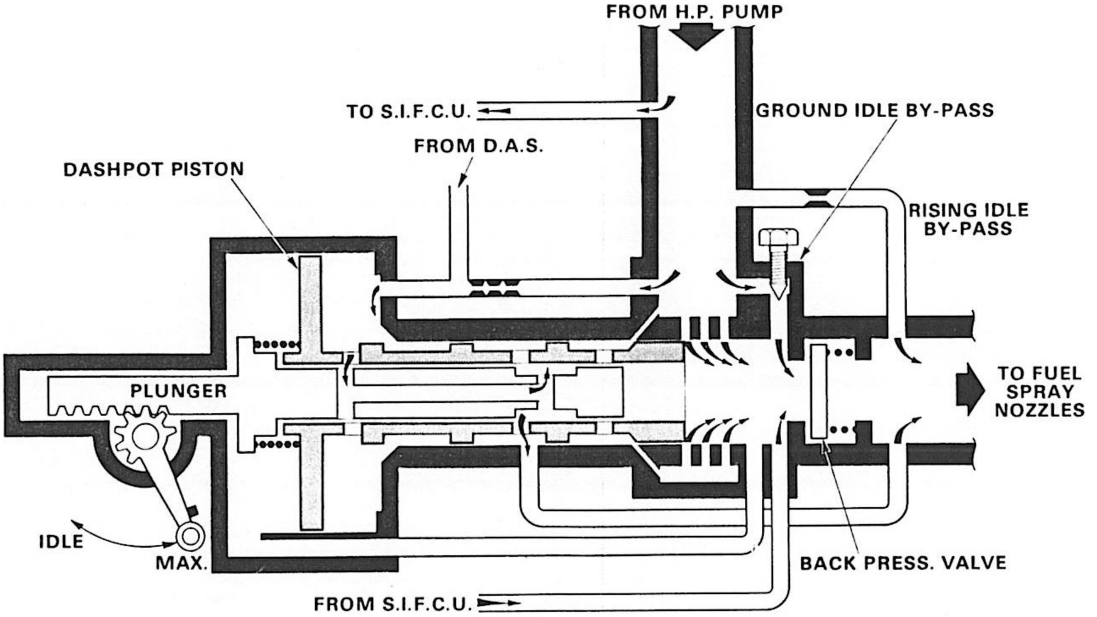
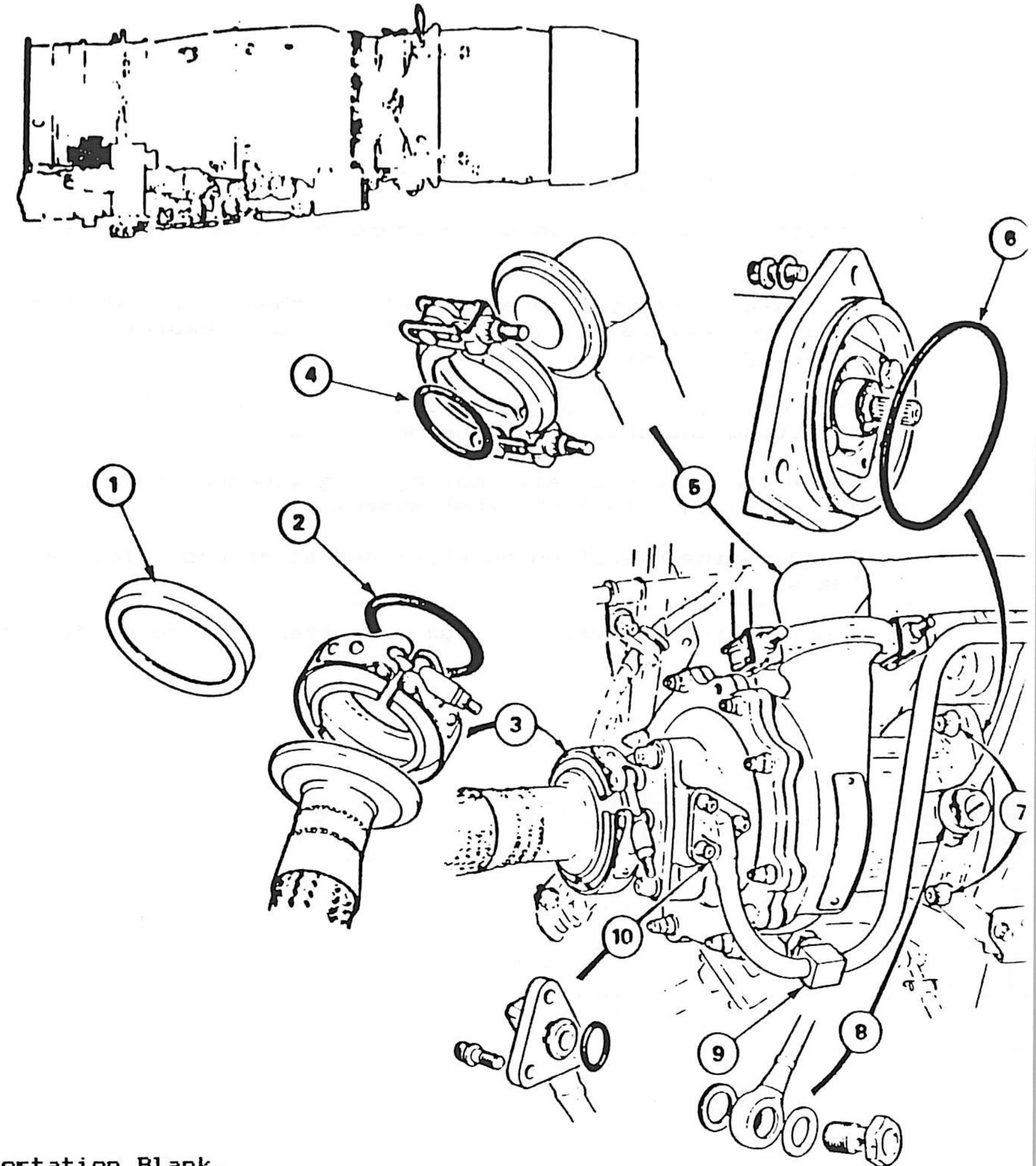


MAX FLOW

TA 3911



1. Transportation Blank.
2. Seal Ring Fuel Supply Pipe.
3. Fuel Supply Pipe Clamp.
4. Seal Ring,LP Fuel Pipe to Filter.
5. Pipe,LP Fuel Supply To Filter.
6. Seal Ring,LP Fuel Pump.
7. Pump Retaining Bolts.
8. Dry Drain Connection.
9. LP Fuel Feed Conn.To ABV.
10. Pipe,LP Fuel Feed Return To Pump Inlet.

LP FUEL PUMP.

Sub-idle Fuel Control Unit.(SIFCU).

Access to this unit on a starboard engine will necessitate engine removal.

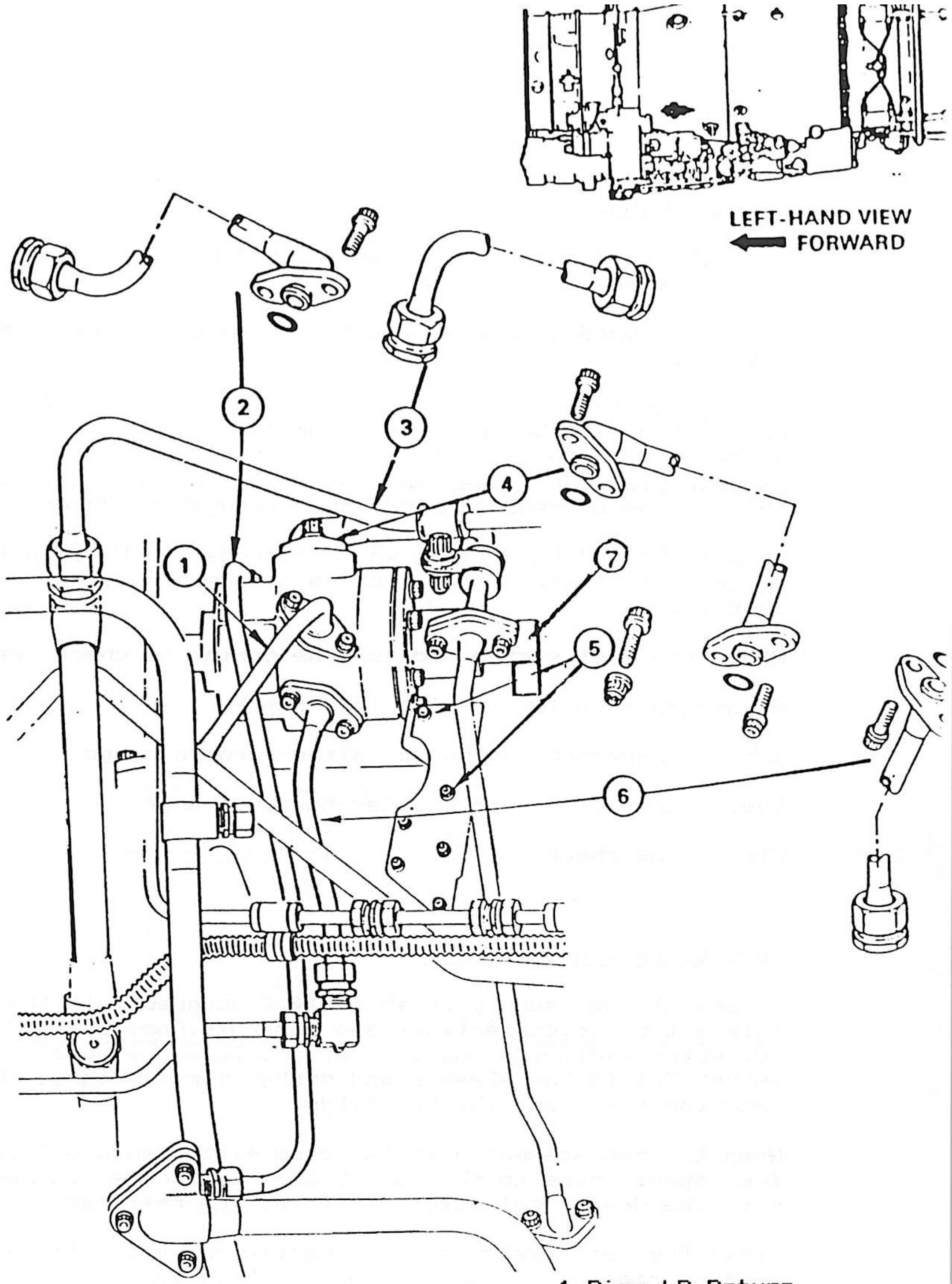
The unit is mounted on a bracket attached to the HP fuel pump.The unit is removed from the HP pump complete with its mounting bracket.

When replacing the unit fit its mounting bracket before refitting the bracket to the HP fuel pump.

Renew and lubricate all sealing rings,torque load as necessary and bleed the fuel system.

Check engine operation on start and at ground idle,check for leaks.

Check engine operation at Max,non after-burning condition.



1. Pipe,LP Return.
2. Pipe,Fuel Junction To SIFCU.
3. P3 Air Supply.
4. Pipe,SIFCU to FCU.
5. Securing Bolts.
6. Pipe,Governor to SIFCU.
7. Speed Datum Adjuster.

SUB-IDLE FUEL CONTROL UNIT.

HP Fuel Pump.

The SIFCU and the Reheat Arming Speed Switch need to be removed when replacing the HP pump.

On a Starboard engine access to the pump will require engine removal.

During the removal and re-installation of the HP fuel pump a considerable number of pipe connections are disturbed,careful attention should be paid to the clearance between pipes,and pipes and engine casings or components and the fitting of sealing rings and corrugated gaskets.

Ensure the 'V' band clamp which secures the HP pump to the HS gear-box is correctly located by the pin of the baulking bracket.

Bleed the fuel system and run the engine to check the pump.

At ground idle for initial leak check.

Engine operation in the non after-burning range

Engine operation in the after-burning range.

Final leak check.

Fuel Control Unit.(FCU).

Ensure LP fuel supply is shut off.Disconnect all the relevant pipes,connections and controls.Remove the drains collector manifolds and LP fuel absolute pressure switch.Retain the sleeves and bushes for the three FCU securing bolts and the P0 filter.

When the replacement unit is being fitted ensure that the fuel supply pipe to the Fuel Cooled Oil Cooler is refitted when the drains collector manifolds are refitted.

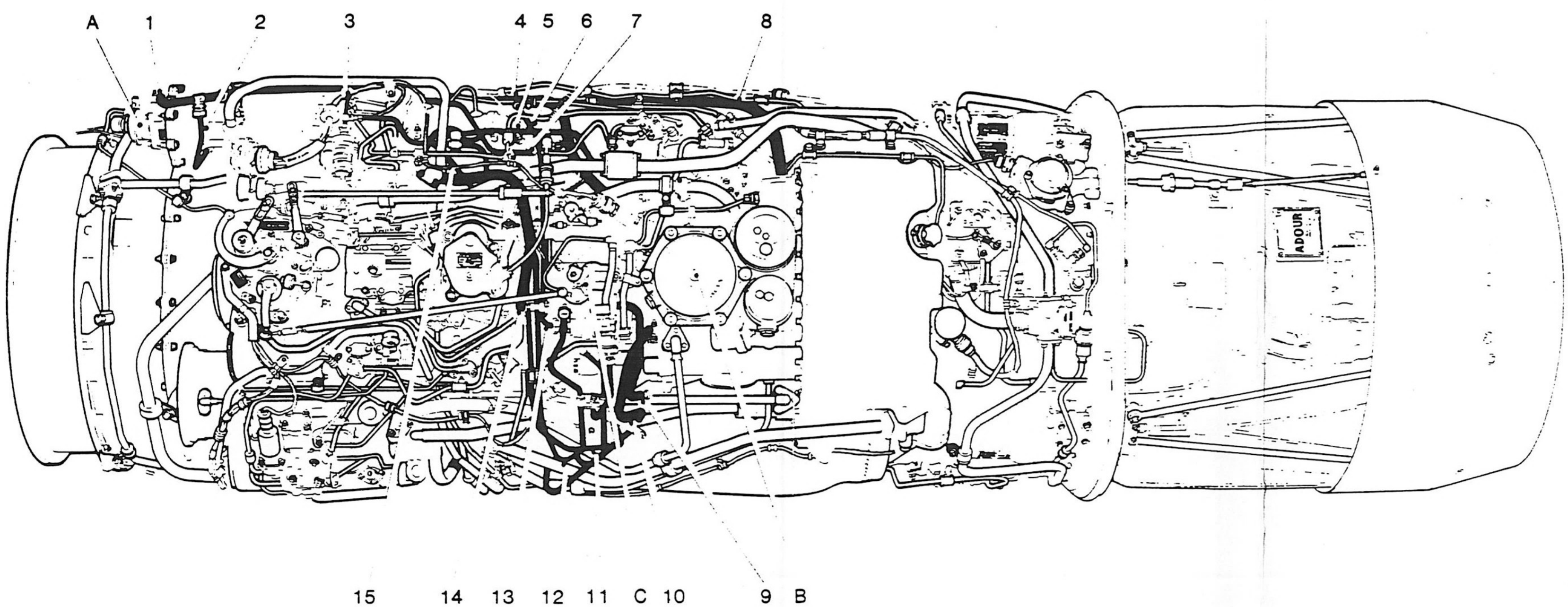
Bleed the fuel system,check throttle and shut off valve control rigging and ground run to check for:
Initial leaks.

Engine operation at ground idle.

Engine operation at Max.non after-burning range.

Acceleration and deceleration checks.

Stop engine and re-examine for leaks.

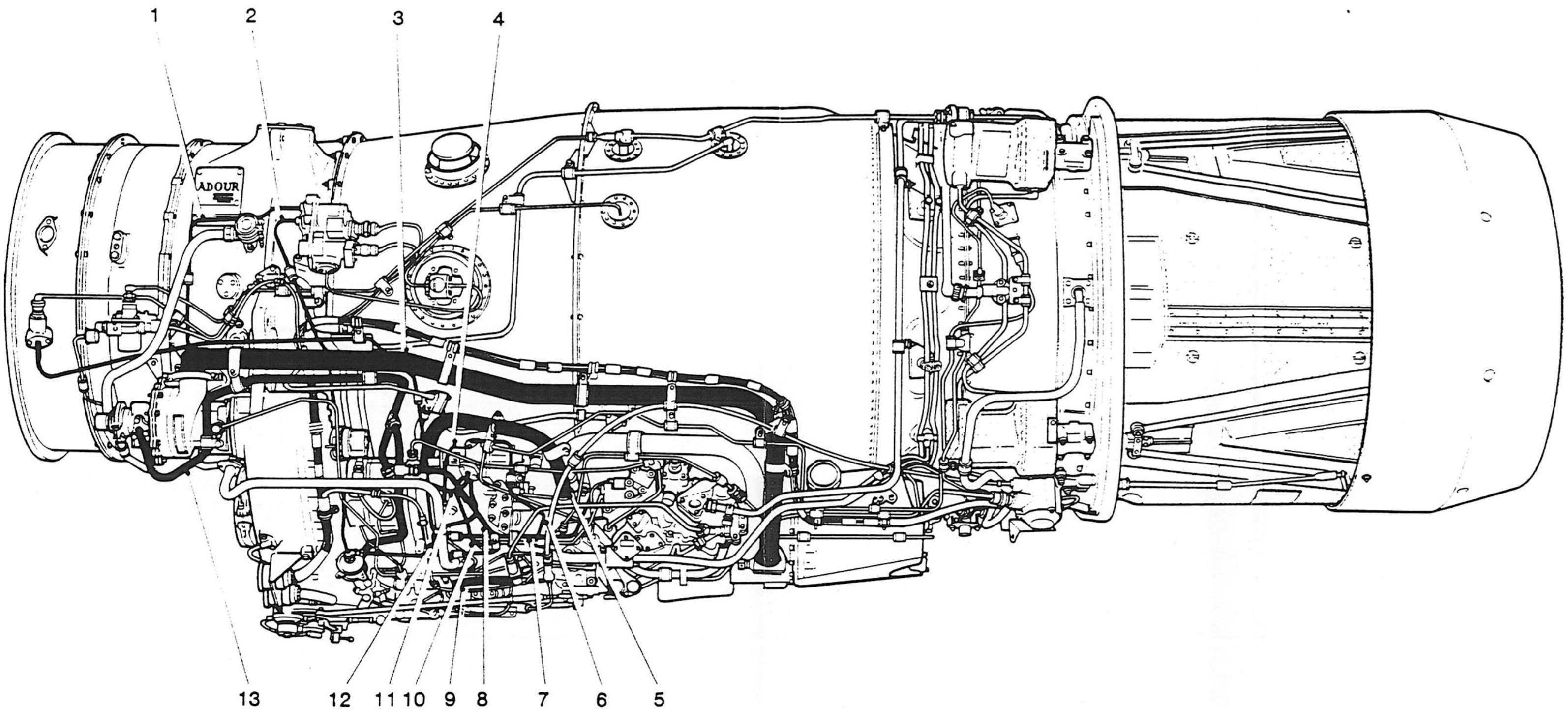


1 L P FUEL RETURN TUBE COLLECTION TUBE-TO-L P PUMP INLET
2 L P SIGNAL TUBE L P PUMP TO AIR BLEED VALVE DIFFERENTIAL PRESSURE SWITCH
3 H P N_2 SIGNAL TUBE H P PUMP TO AIR BLEED VALVE DIFFERENTIAL PRESSURE SWITCH
4 L P FUEL SUPPLY TUBE L P FILTER TO H P PUMP
5 P_1 AIR SUPPLY TUBE PROBE TO E F C U
6 FUEL SUPPLY TUBE, S I F C U TO E F C U
7 L P FUEL RETURN TUBE COLLECTOR TO L P PUMP
8 L P FUEL SUPPLY TUBE L P PUMP TO FILTER BLOCK
9 H P FUEL SUPPLY TUBE E F C U TO F C O C
10 H P FUEL SUPPLY TUBE F C O C TO MAIN MANIFOLD
11 FUEL TUBE D A S TO S I F C U
12 H P N_2 SIGNAL TUBE HP PUMP TO D A S
13 L P FUEL RETURN TUBE E F C U TO COLLECTOR
14 H P FUEL SUPPLY TUBE H P PUMP TO E F C U
15 H P FUEL SUPPLY TUBE, H P PUMP TO S I F C U
A L P FUEL PUMP
B L P FUEL FILTER
C E F C U

ABBREVIATIONS

L P	LOW PRESSURE
H P	HIGH PRESSURE
E F C U	ENGINE FUEL CONTROL UNIT
S I F C U	SUB - IDLING FUEL CONTROL UNIT
F C O C	FUEL COOLED OIL COOLER
D A S	DASHPOT ACCELERATION SWITCH

Engine fuel system tubes and units
Underside view



1. L.P FUEL SIGNAL SUPPLY TUBE. FUEL RETURN TUBE-TO-AIRBLEED - VALVE DIFFERENTIAL PRESSURE SWITCH
2. N_2 SIGNAL SUPPLY TUBE. H.P PUMP-TO-AIR BLEED VALVE DIFFERENTIAL PRESSURE SWITCH
3. L.P FUEL SUPPLY TUBE. L.P PUMP-TO-FUEL FILTERS BLOCK
4. H.P FUEL SUPPLY TUBE. H.P PUMP-TO-S.I.F.C.U.
5. L.P FUEL SUPPLY TUBE. FUEL FILTERS BLOCK-TO-H.P PUMP
6. FUEL SUPPLY TUBE. S.I.F.C.U-TO-E.F.C.U.
7. P_1 AIR SUPPLY TUBE P_1 PROBE-TO-E.F.C.U
8. L.P FUEL RETURN TUBE
9. H.P FUEL SUPPLY TUBE. H.P PUMP-TO-E.F.C.U
10. L.P FUEL TUBE. S.I.F.C.U. TO D.A.S
11. L.P FUEL RETURN TUBE. S.I.F.C.U-TO-L.P PUMP
12. N_2 SIGNAL SUPPLY TUBE. H.P PUMP-TO-S.I.F.C.U
13. L.P FUEL RETURN TUBE H.P PUMP-TO-L.P PUMP

ABBREVIATIONS

L.P	LOW PRESSURE
H.P	HIGH PRESSURE
S.I.F.C.U.	SUB IDLING FUEL CONTROL UNIT
E.F.C.U.	ENGINE FUEL CONTROL UNIT
D.A.S.	DASHPOT ACCELERATION SWITCH

Engine fuel system tubes and units. Left-hand view

ROLLS-ROYCE/TURBOMECA

ADOUR.811/815.

AFTER-BURNER SYSTEM.

INTRODUCTION.

The system is required to supply a substantial increase in thrust for short durations by the combustion of fuel in the exhaust section of the engine.
To provide this the system must provide:

1. FUEL BURNERS.
A burner system which will introduce into the gas stream fuel,in such a way as to ensure reliable ignition and efficient burning over the full range of selected fuel flows.

2. VARIABLE AREA NOZZLE.
A variable area exit nozzle to ensure that this further combustion process does not cause changes in gas pressure which could affect the operation of the engine.

3. CONTROL OF FUEL FLOW.
Cockpit control of the metering of fuel flow to obtain varying degrees of after-burning thrust.

4. CO-ORDINATION OF NOZZLE CONTROL WITH FUEL METERING.
Co-ordination of the nozzle area with fuel flow selection to ensure that a matching nozzle area is provided.

5. SEQUENCING.
To correctly sequence events when after-burning is selected,and to provide certain essential services when after-burning is cancelled.

We can now study the operation of the system by analysis of these requirements.

1. FUEL BURNERS.

These consist of the following sections:

a. The Vapour Gutters.

b. The Main Manifolds.

c. The Catalytic Igniters.
The complete burner assembly is carried on four radial support tubes which also act as fuel supply passages.

cont./

a. <u>The Vapour Gutters.</u>

These consist of four concentric annular channels of blunt 'V' nose section.

In each gutter a number of segmented pipes are fitted.Each pipe has outlet holes at right angles to the gas stream and a forward facing inlet into which hot gases can pass.

The fuel is atomised as it is discharged onto a splash plate,and slots in the forward face of the gutters admit hot gases to dilute and distribute the fuel/air mixture within the wake of the gutters.

Fuel is supplied via the top support pipe only.It is then directed into the central hub from where it passes radially outwards via pipes to the four vapour gutters.

b. <u>The Main Manifolds.</u>

This assembly consists of four circular concentric rings of tubing situated upstream of the vapour gutters and spaced to inject fuel into the space between the vapour gutters.

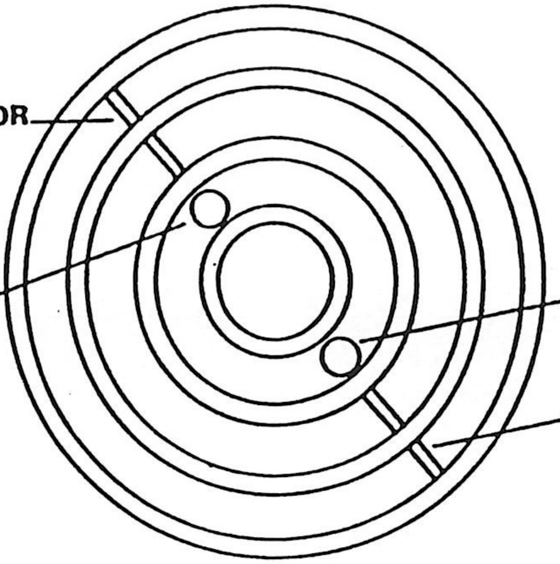
Fuel is supplied via the two horizontal support pipes.The left hand pipe (looking forward) supplies the outer manifold,with a restricted flow to the inner manifolds.The right hand pipe supplies the three inner manifolds.

c. <u>The Catalytic Igniters.</u>

Two catalytic igniters are mounted between the inner and the intermediate inner vapour gutters in diametrically opposed positions.(10 o'clock and 4 o'clock).

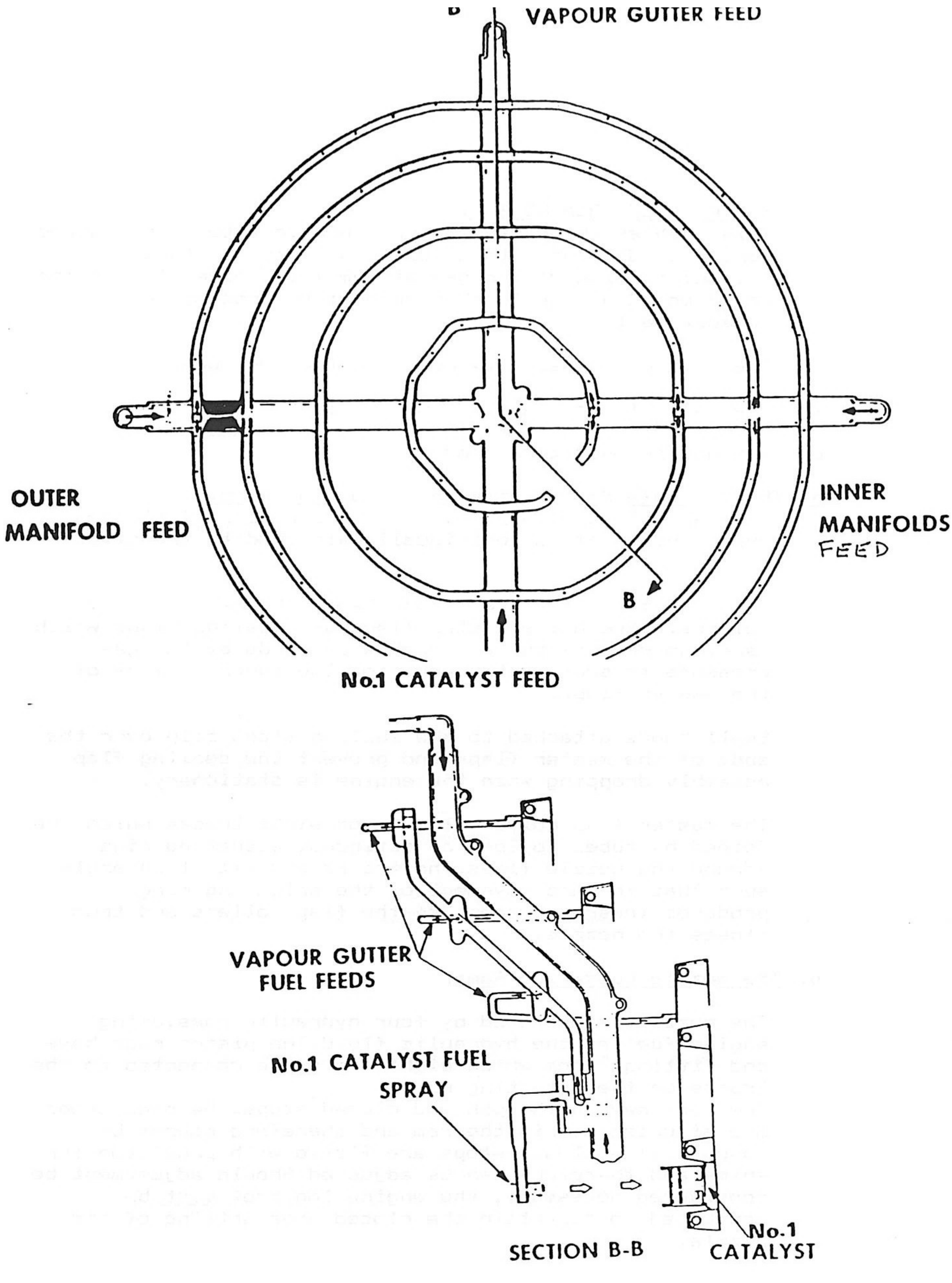
The igniters contain an element made of platinum/rhodium alloy.The passage of the fuel/air mixture over the element at normal engine temperatures promotes a reaction between fuel and oxygen and so initiates the combustion process which then spreads into the adjacent vapour gutters and via radial inter-connecters to the other vapour gutters.

The fuel supply to No.1 catalyst is via the lower support pipe,No.2 catalyst has a separate supply via the Part Throttle After-burner Solenoid.



VIEW FROM REAR

VAPOUR GUTTER AND CATALYTIC IGNITERS.



MAIN MANIFOLDS WITH VAPOUR GUTTERS REMOVED.

2. <u>THE VARIABLE AREA NOZZLE.</u>

This enables the engine to run,both in after-burning and normal conditions,with a nozzle area suited to the volumetric flow of the gas stream.This leaves the engine un-affected by the further combustion process in the exhaust section.

The unit can be sub-divided into two sections.

a. The variable area nozzle and actuating ring.

b. The nozzle operating rams.

<u>a. The Variable Area Nozzle and Actuating Ring.</u>

The variable area nozzle assembly consists of sixteen over lapping flaps individually attached to the pivot ring.

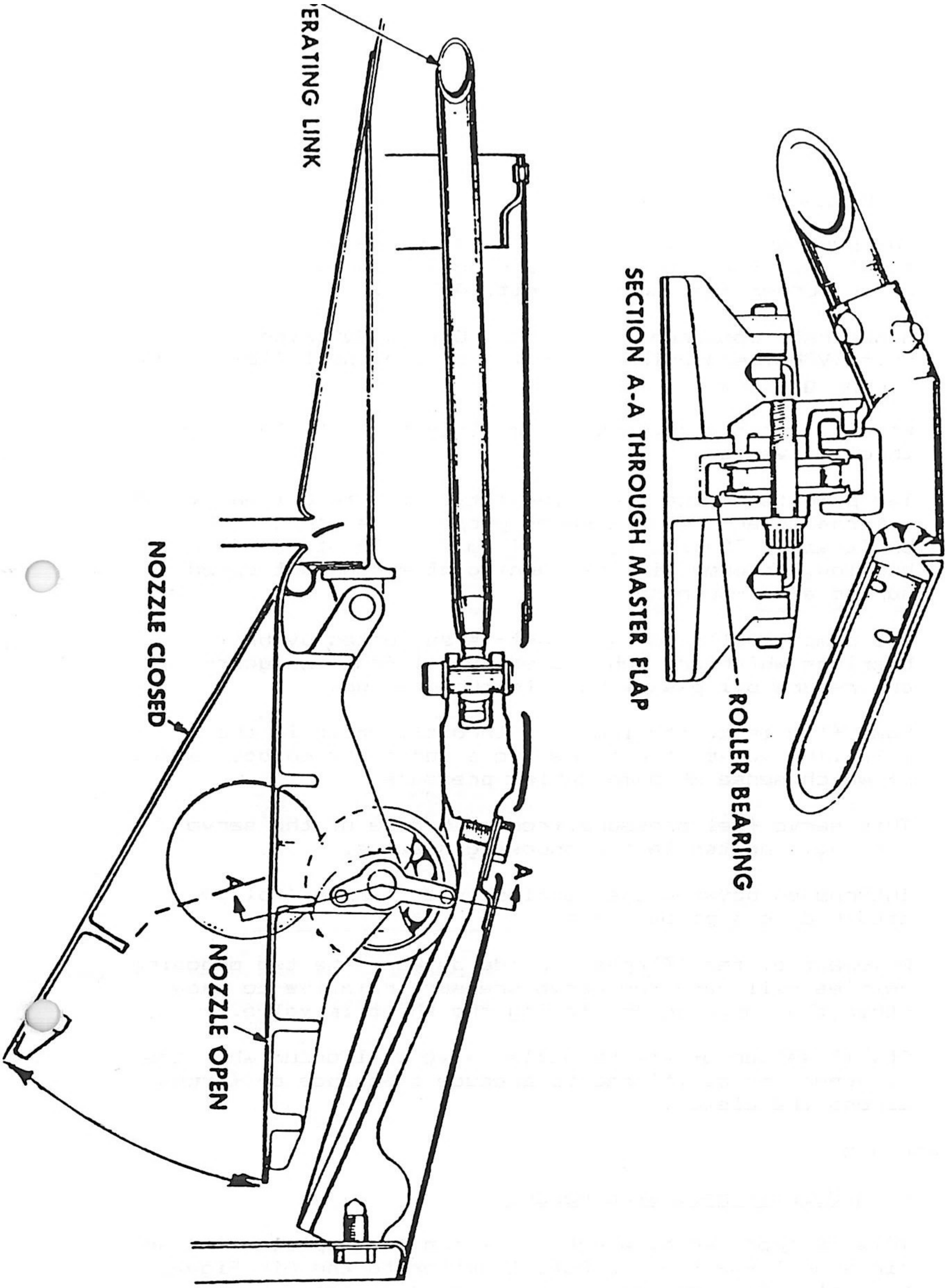
Eight of the flaps are termed Master Flaps and carry rollers.Between the master flaps are Sealing Flaps which carry no rollers but are pushed outwards by the gas pressure to seal at the edges on the inner surface of the master flaps.

Small hooks attached to the sealing flaps clip over the ends of the master flaps and prevent the sealing flap assembly dropping when the engine is stationary.

The master flap rollers locate on eight tracks which are joined by tubes to form an octagonal actuating ring around the nozzle flaps.The tracks are set at an angle such that forward movement of the actuating ring produces inward movement of the flap rollers and thus closes the nozzle.

b. <u>The Nozzle Operating Rams.</u>

The nozzle is operated by four hydraulic rams,using engine fuel as the hydraulic fluid.The piston rods have end fittings from which eight links are connected to the tracks on the actuating ring.
The rams have both open and closed stops.The open stops are situated within the ram and therefore cannot be adjusted.The closed stops are fitted with provision for shims and therefore can be adjusted.Should adjustment be considered necessary, the engine log.book <u>must</u> be consulted to ascertain the closed area setting of the nozzle.



VARIABLE NOZZLE ACTUATING MECHANISM.

3. <u>CONTROL OF FUEL FLOW.</u>

The pump and components concerned in the metering of the total fuel flow for after-burning are contained in the After-burner Fuel Control Unit.(ABFCU).

A separate component,The Vapour Gutter Metering Unit,(VGMU),schedules a portion of the total flow to the vapour gutters.

We will first examine the pump together with the inlet throttle valve.

The pump is of the centrifugal type and is driven by the external gear-box at a speed proportional to the HP shaft speed.Therefore,apart from Part Throttle After-burning,the pump will be running at a constant speed during after-burning.

The pump impeller drive shaft is supported by ball bearings which are lubricated by oil from the gear-box,return oil passes back to the gear-box.

Pump flow is controlled by a throttle valve in the inlet.The valve is attached to a servo-piston,both sides of which sense HP pump outlet pressure.

This servo fuel pressure,from each side of the servo piston,is ported to two opposing nozzles.

Interposed between the nozzles is a 'flapper' blade attached to a pivoted arm.

Movement of the 'flapper' blade between the two opposing nozzles will vary the servo pressure relative to each other,thus opening or closing the throttle valve.

Stabilisation of the throttle valve will occur when the 'flapper' is positioned to produce a balance of forces across the piston.

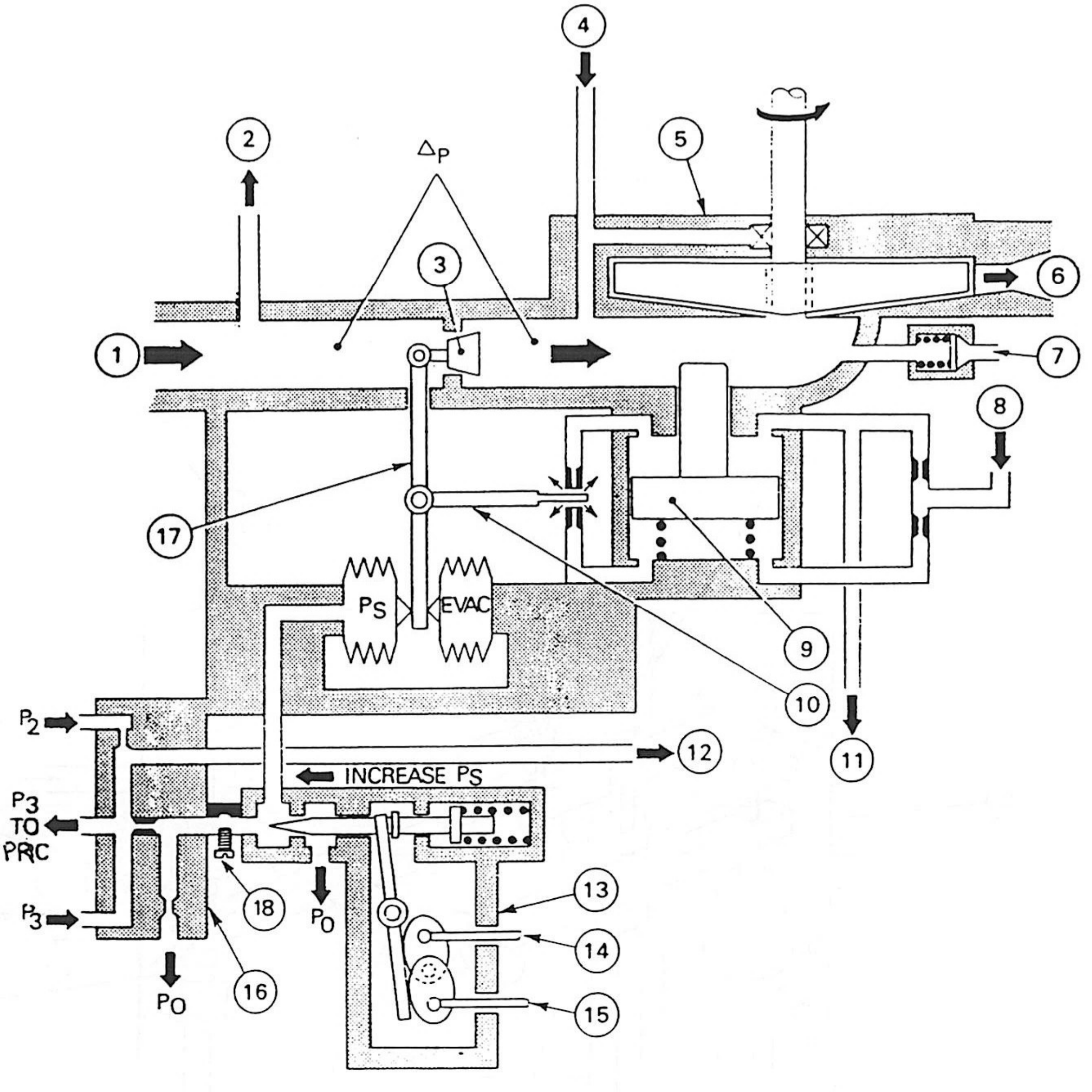
These are:

i. <u>A Cockpit Modulated Force.</u>

This is produced by a capsule which is supplied with an air signal,via the Air Potentiometer,to the Air Signal Generator.Air pressure modulation is achieved by a controlled spill to atmosphere.This is done by a profiled valve in the atmospheric vent orifice.The valve is moved in the after-burning range giving an increased capsule pressure for an increase in the degree of after-burning selected.

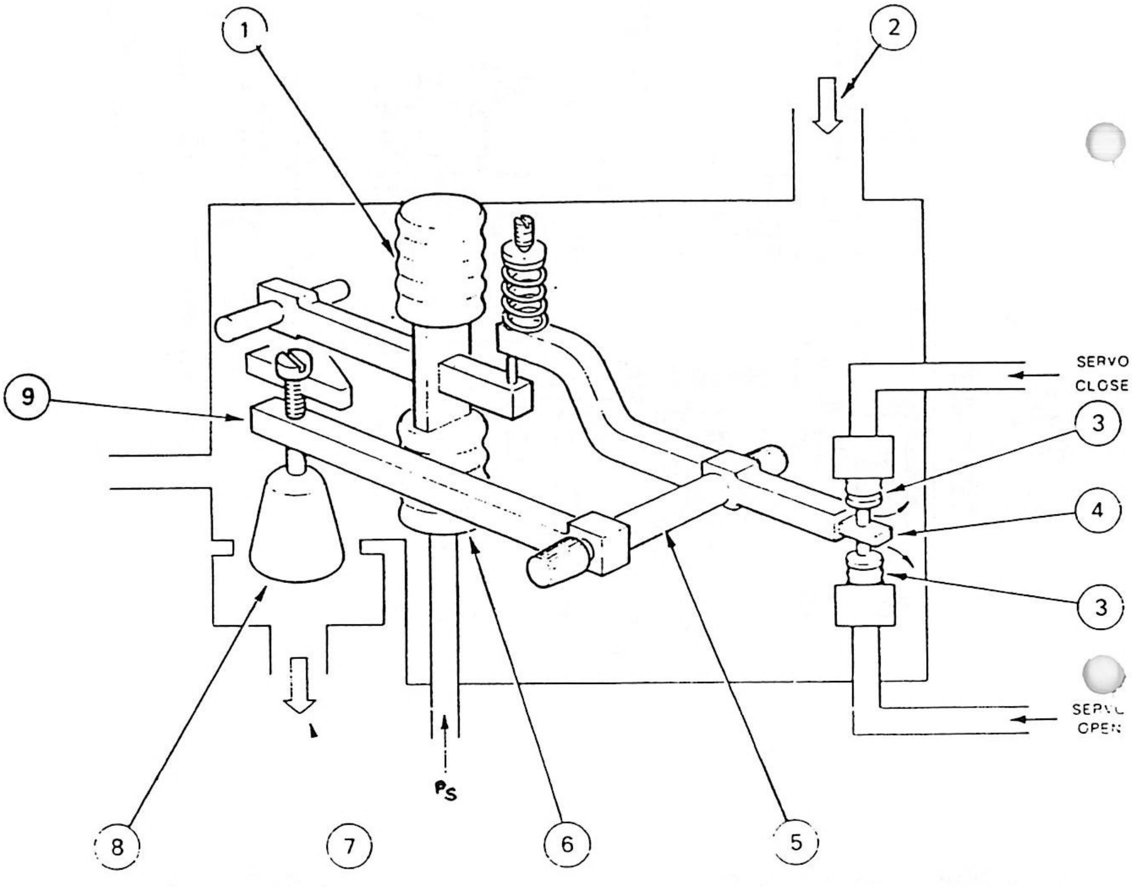
ii <u>An Evacuated Capsule Force.</u>

This opposes the modulated capsule force for altitude variation.



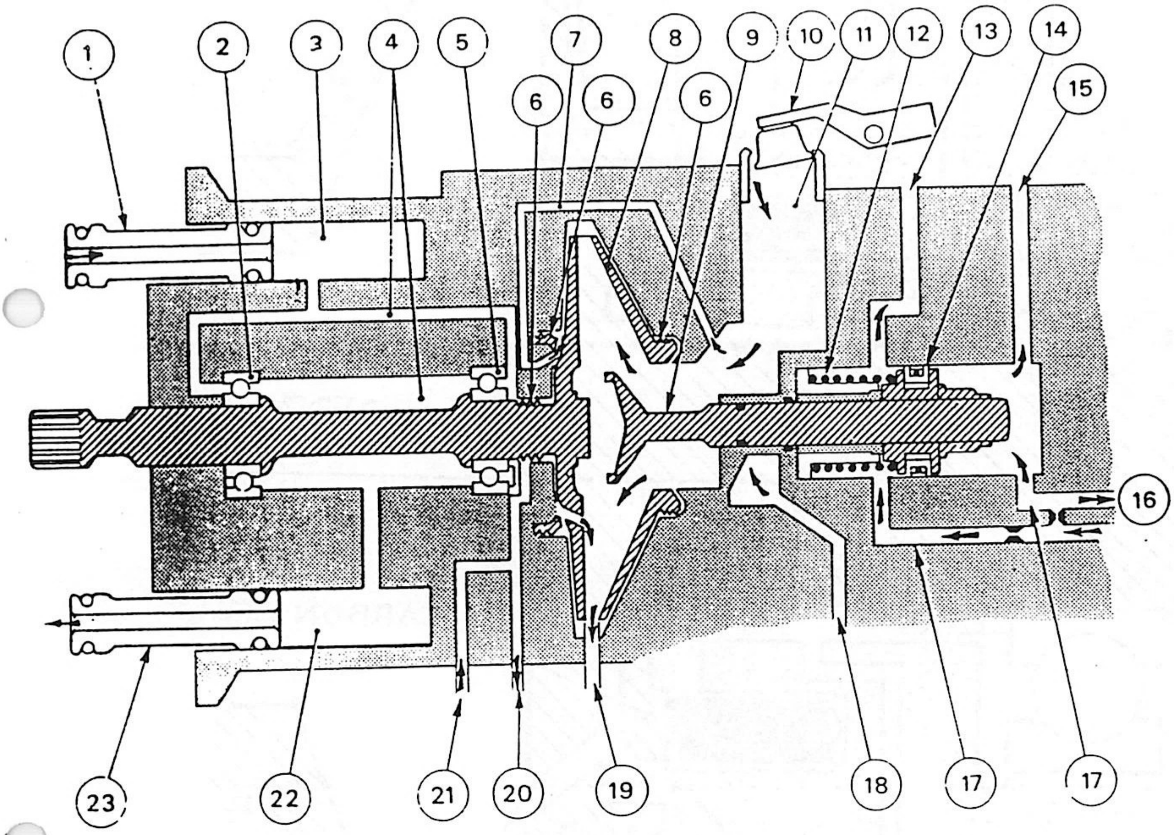
1. LP Fuel from Engine.
2. To Ejector Pump Shut-off Valve.
3. Flowmeter Plug.
4. LP Return from VGMU.
5. Vapour Core Pump.
6. To A/B, VGMU.
7. Non-return Valve.
8. HP Fuel Pressure.
9. Inlet Flow Control Servo Piston.
10. Flapper Blade.
11. To Circuit Control Valve.
12. P3 Pressure to VGMU.
13. Air Signal Generator.
14. Feed-back Link, Nozzle.
15. Throttle Control Link.
16. Air Potentiometer.
17. Beam Assembly.
18. PS Slope Setting.

INLET FLOW CONTROL, AIR GENERATOR, AIR POTENTIOMETER AND PUMP.



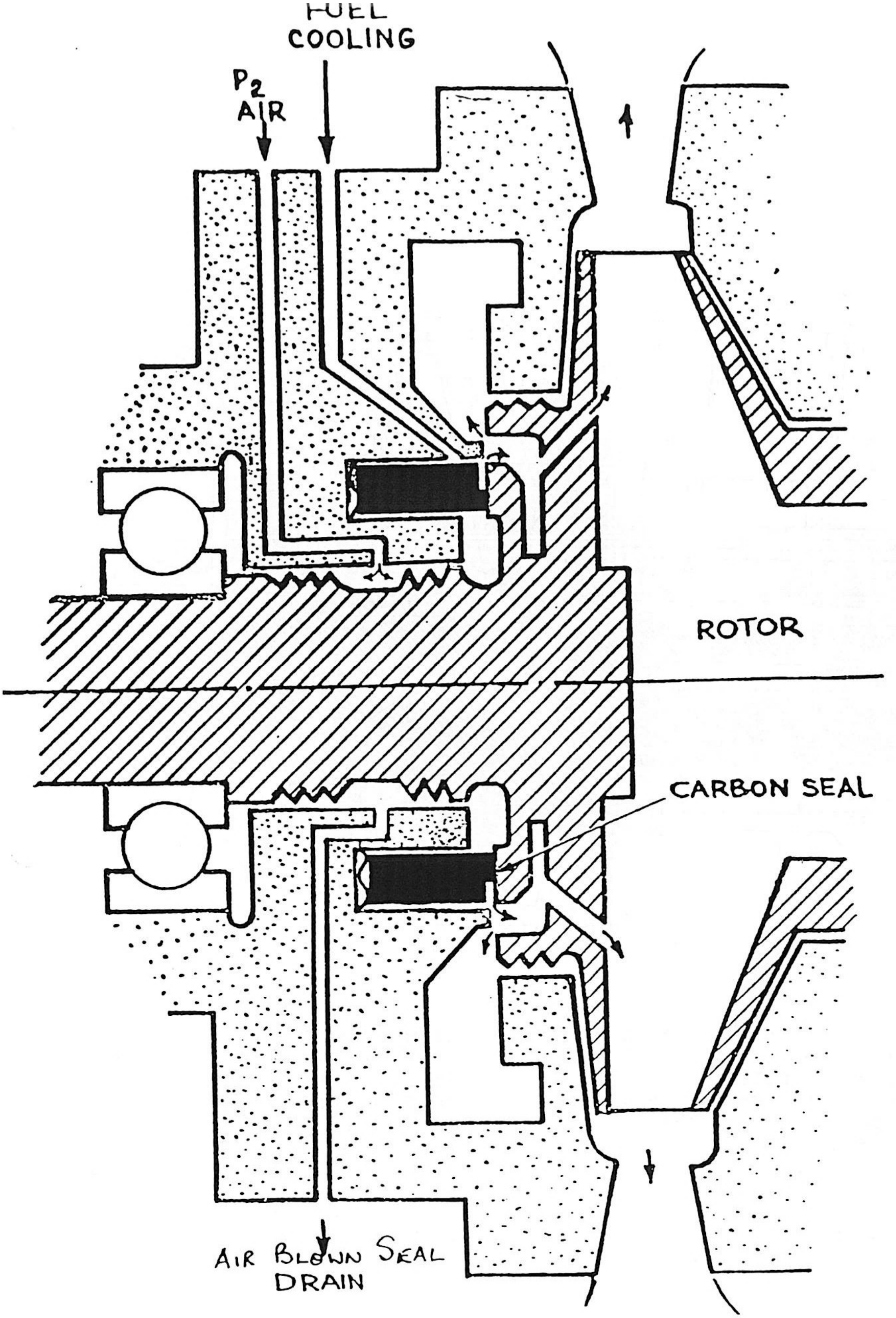
1. Evacuated Capsule.
2. LP Fuel Inlet.
3. Leak Orifices.
4. Flapper Blade.
5. Torsion Bar.
6. PS Capsule.
7. To Vapour Core Pump Inlet.
8. Flowmeter Plug.
9. Parallel Lever.

INLET FLOW CONTROL UNIT.



1. Oil Bobbin-From Gear-box.
2. Impeller Shaft Bearing.
3. Lubricating Oil.
4. Oil Ducts for Shaft Lubrication.
5. Impeller Shaft Bearing.
6. Labyrinth Seal.
7. Cooling Flow.
8. Centrifugal Impeller.
9. Throttle Valve.
10. Flowmeter Plug.
11. Fuel Inlet from LP Pump.
12. Shut Off Valve Spring.
13. HP Fuel Servo.
14. Inlet Flow Control, Piston.
15. Servo Fuel Outlet.
16. To Circuit Control Valve.
17. HP Fuel Pressure.
18. LP Fuel.
19. Vapour Core Pump Delivery.
20. Air Blown Seal Drain.
21. P2 to Air Blown Seal.
22. Oil Out Chamber.
23. Oil Bobbin-Return.

VAPOUR CORE PUMP AND INLET FLOW CONTROL UNIT.



CARBON SEAL COOLING FLOW.

iii. A Force Proportional To Fuel Flow.

This is produced by a conical plug positioned in an orifice at the fuel inlet position. The pressure drop across this plug is interpreted as a load on the 'flapper' beam via a torsion bar.

The operation of the flow control mechanism, when an increase in after-burner flow is selected is as follows:

a. The throttle modulated pressure increases when an increase is selected.

b. Balance of forces are now upset. The 'flapper' moves to restrict servo flow on the opening side of the pump servo piston and increases the flow from the closing side.

c. Throttle valve moves to increase fuel flow.

d. Force on conical plug increases.

e. 'flapper' is moved back to the central position where a balance of forces is once more obtained, the throttle valve is then stabilised.

VAPOUR GUTTER METERING UNIT.

The main requirement of this unit is to schedule a proportion of the total flow to the vapour gutters. A throttle valve is operated by a servo piston, with servo fuel pressure regulated by a 'flapper' valve in a similar way to the main fuel flow control.

However in this case After-burner Pump Outlet pressure is used to provide the servo system.

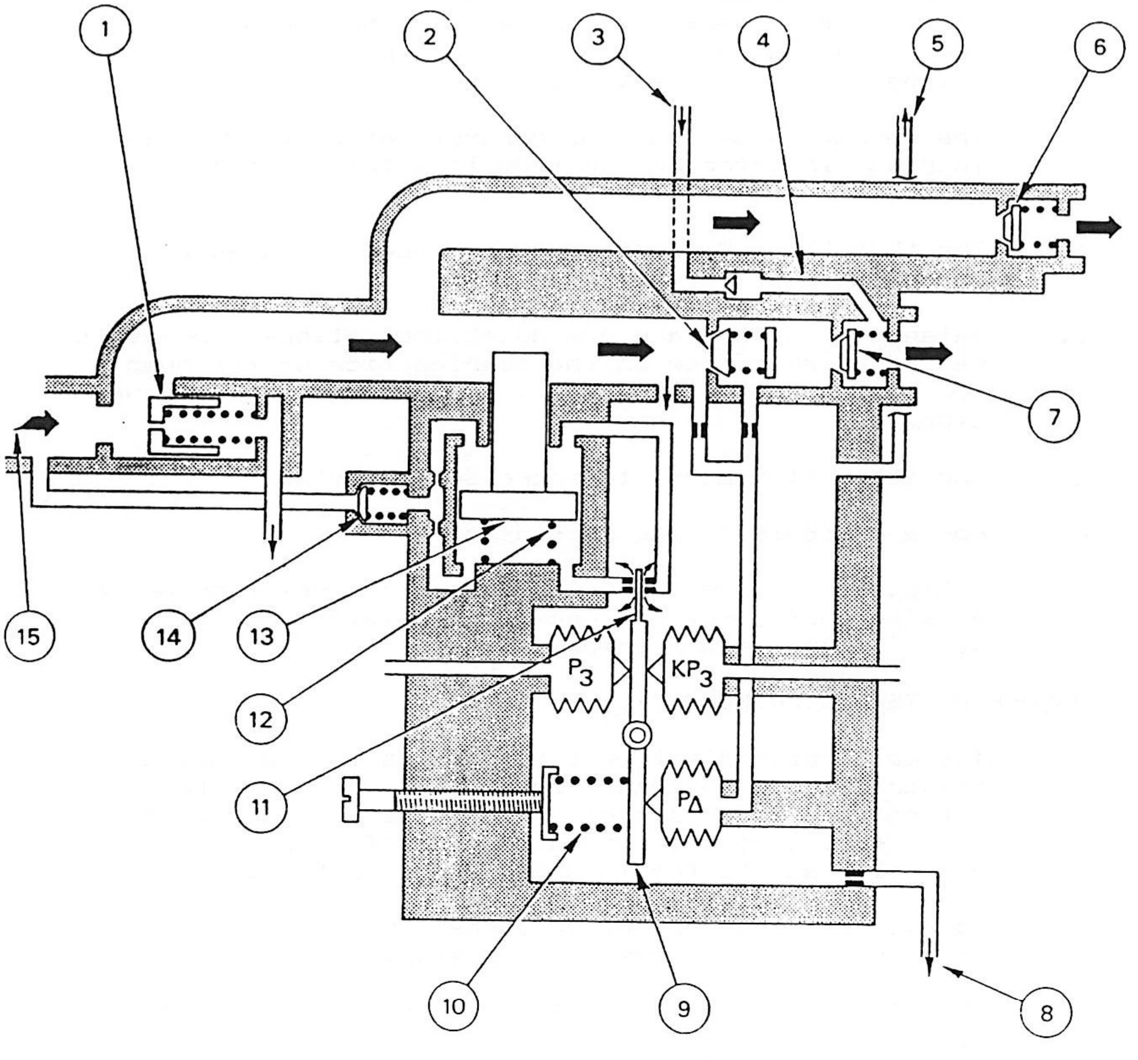
The 'flapper' beam is influenced by the following forces:

i. A capsule force, proportional to vapour gutter flow across a non return valve.

ii. A reference (spring) pressure.

111. Two capsules subjected to a modulated P3 pressure.

The geometry of the unit is such that with both air capsules and the fuel capsule and spring holding the beam in equilibrium, the vapour gutter flow is approximately 10% of the total flow at all flight conditions.



1.Pressure Augmenting Valve.
2.Vapour Gutter Metering Valve.
3.P3 Purge Air.
4.Air Purge Duct.
5.LP Return.
6.Main Manifold Check Valve.
7.Vapour Gutter Check Valve.
8.Return to Pump Inlet.
9.Lever.
10.Adjustable Spring.
11.'Flapper' Blade.
12.Throttle Valve Return Spring.
13.Vapour Gutter Throttle Valve.
14.Non-return Valve.
15.Fuel from Vapour Core Pump.

VAPOUR GUTTER METERING UNIT.

4. CO-ORDINATION OF NOZZLE CONTROL WITH FUEL METERING.

The rams which position the nozzle are operated by fuel pressure.

Within the ABFCU are components which control the fuel supply to the rams and co-ordinate nozzle area with fuel flow selection.

These components are:

a. The Nozzle Ram Control Valve.

This consists of a landed valve moving in a ported sleeve.The space between the two lands is supplied with fuel for ram operation.
Movement about the null position aligns the valve lands with ports in the valve housing to simultaneously direct HP fuel to one or the other side of the ram piston and provide a return to backing pump inlet via an external restrictor 'R' for the displaced fuel.

b. The Pressure Ratio Control Unit.

This component is responsible for moving the Nozzle Ram Control Valve.Servo fuel pressure across a piston attached to the valve is varied by a 'flapper' valve.

The servo system pressure is provided by the HP fuel pump outlet pressure.

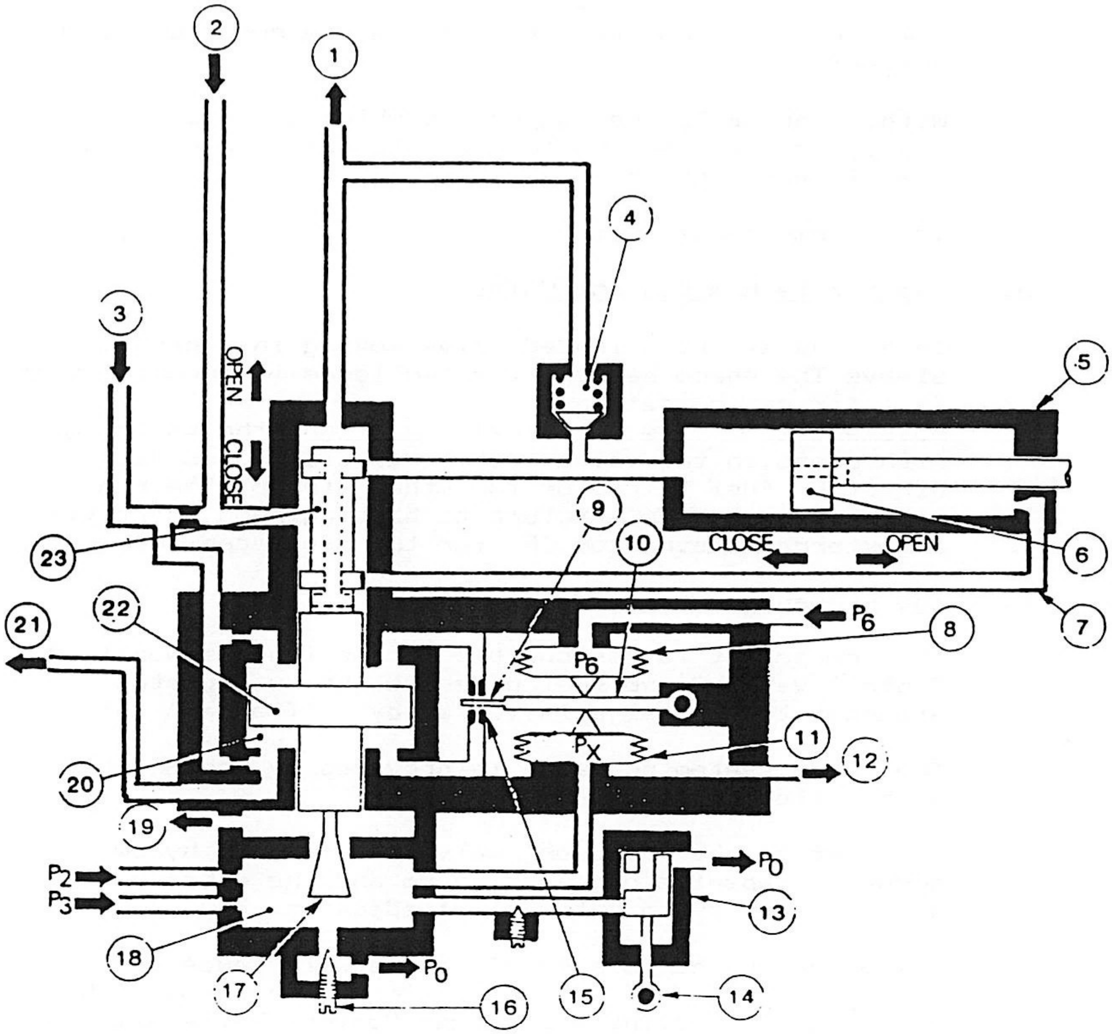
Movement of the 'flapper' valve is effected by two opposing capsules,one sensing P6 and the other a P2/P3 pressure set by an external PX adjuster.

Any error in the balance of forces will cause the 'flapper' to move from its null position between the opposing nozzles.The Nozzle Ram Control Valve will then move in the direction relative to the displacement,moving the nozzle and restoring equilibrium when the pressures in both capsules are equal.

c. The Nozzle Feedback Cam.

This is required as an over-ride to the throttle selection of fuel flow.It permits only a portion of the selected fuel flow to be available immediately.The remainder is then metered as a function of nozzle area increase

The cam is located in the Air Signal Generator and rotates on the same axis as the throttle cam.It is operated by the nozzle feedback linkage.



1.Return to VC Pump Inlet.
2.From VC Pump.
3.Main Engine Supply.
4.Ram Pressure Relief Valve.
5.Nozzle Ram.
6.Nozzle Ram Piston.
7.Ram Spill.(LP Return).
8.P6 Capsule.
9.Blade.'Flapper Valve'.
10.Lever.'Flapper Valve).
11.PX Capsule.
12.To LP Pump Inlet.
13.Pre-open Bleed Valve.
14.Nozzle Feedback Linkage.
15.Servo Nozzles.
16.PX Adjuster.
17.Conical Needle.
18.Air Potentiometer.
19.PX Vent.
20.Servo Chamber.
21.To Circuit Control Valve.
22.Nozzle Ram Servo Piston.
23.Spool Valve.

PRESSURE RATIO CONTROL UNIT AND NOZZLE RAM CONTROL VALVE.

With after-burning selected,the throttle cam rotates to the amount of after-burning required,however because at this time there is no nozzle movement the nozzle came remains in the AB 'OFF' position.The geometry of the system is such that when AB is selected the rams immediately begin to move towards the open position,this affects the nozzle cam which will also move and thus commencing fuel flow to the After-burner. Movement will cease when the lever in the Air Signal abuts the throttle cam at the selected degree of after-burning.

d. <u>Cockpit Indication Of Nozzle Position.</u>

A nozzle position signal is supplied to the cockpit.This is effected by a potentiometer which converts the mechanical movement into an electrical signal.
The cockpit gauge is actually sensing a change in electrical resistance as the potentiometer is moved and is marked off in equal graduations marked 1 - 10.

5. <u>SEQUENCING</u>.

When after-burning is selected it is essential that certain events are sequenced correctly.

Additional,on cancellation certain services are required within the system, eg.a cooling flow of fuel circulated through the main components.These requirements are met by various control valves.

a. <u>The Circuit Control Valve.</u>

This provides the following circuits with after-burning off.

i. The pump inlet throttle valve opening servo pressure is connected to the backing pump inlet holding the throttle valve closed.

11. The pressure augmenting valve bleed is closed off,holding the valve closed.

iii. The nozzle pressure ratio control valve is connected to the backing pump inlet,thus the valve is held in the nozzle closed position.

The valve is held in position to select the above services by spring pressure and HP fuel pressure.

When after-burning is selected the pressure is directed to oppose the spring and move the valve to reverse the circuits previously described.

cont./

The 'switching' of pressure is carried out by:

b. <u>The Throttle Selector Valve.</u>

The spool of this valve is moved sympathetically with the throttle cam in the air signal generator and is a two position ON/OFF valve.
The two positions are:

<u>A/B Selected.</u>
In this position the spring chamber of the circuit control valve is opened up to LP fuel pump pressure and HP fuel pump pressure is directed to the other end of the valve.

<u>A/B De-selected.</u>
The pressures across the valve are now reversed,HP fuel pressure is directed to augment spring pressure whilst the other end is opened up to LP.

c. <u>The Nozzle Selector Valve.</u>

The nozzle selector valve is operated by the nozzle feedback linkage.

This controls a cooling flow of fuel and correctly sequences the catalyst fuel flow on A/B selection.

<u>Cooling Flow.</u>

A supply of backing pump fuel is directed to the rear of the pump impeller.
It is then directed around the carbon seal,for lubrication and cooling,and passes into the impeller via a number of holes.
Since the pressure augmenting valve is closed(by the action of the circuit control valve)the fuel is directed from a second pump outlet connection to backing pump inlet via the nozzle selector valve and the pressure ratio control capsule chamber.

<u>Catalyst Flow.</u>

The nozzle selector valve also controls the catalyst fuel supply.The porting of this section of the valve is such that fuel is supplied to the catalyst when the nozzle is in the pre-open position.

d. <u>The Pre-open Bleed Valve.</u>

This is located on the PRCU section of the A/B FCU and with the nozzle closed it bleeds to atmosphere a proportion of PX.

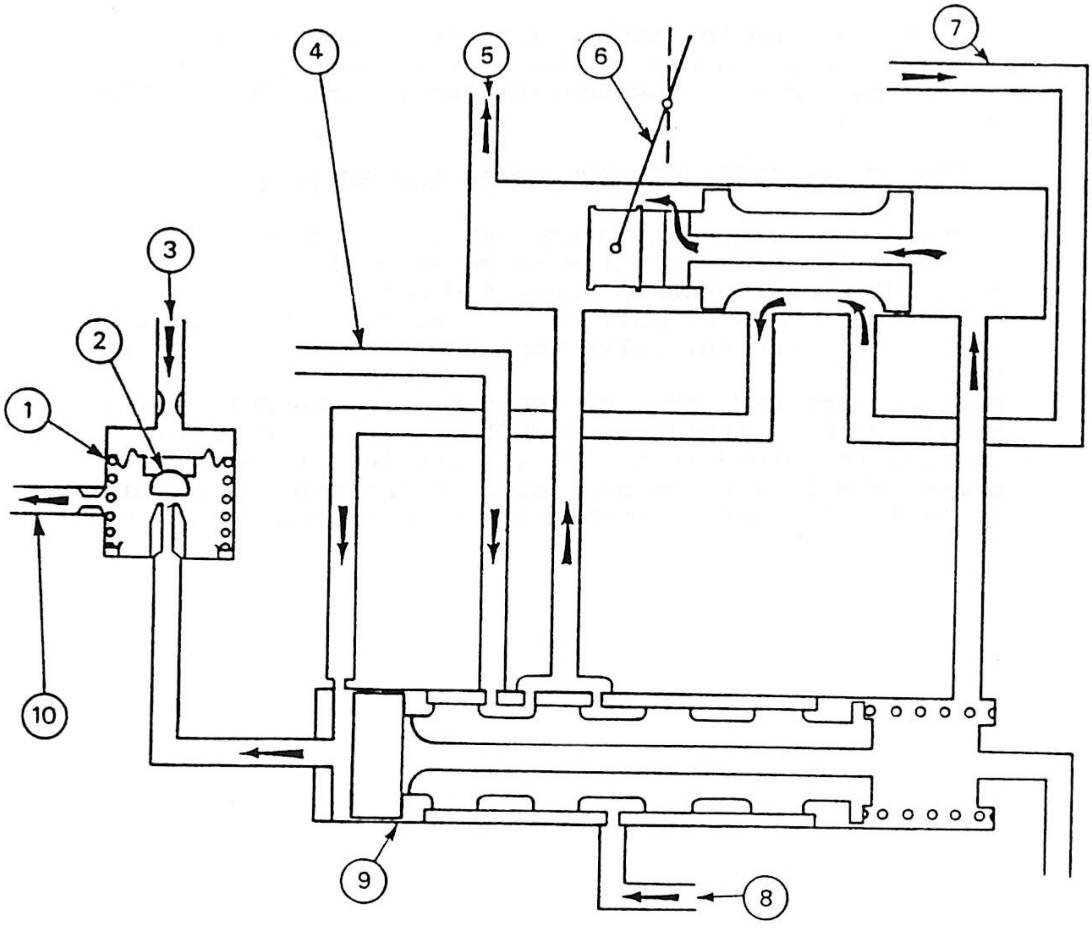
cont./

The bleed valve is connected to the feedback mechanism and therefore moves in conjunction with the nozzle. As the nozzle moves to the open position the pre-open bleed valve vent flow to atmosphere is progressively reduced and PX capsule pressure increases.The opening nozzle also causes P6 to fall and when the two pressures are equal (PX = P6) the 'flapper' valve of the PRCU will cause the nozzle to stabilise.This initial setting of the nozzle is known as 'The Pre-open Position' .At this position 'light up' of the after-burner will occur.

It follows from the above facts that as the feedback linkage is in control of the nozzle cam,then it is the nozzle cam that is responsible for the scheduled 'light up' fuel flow.

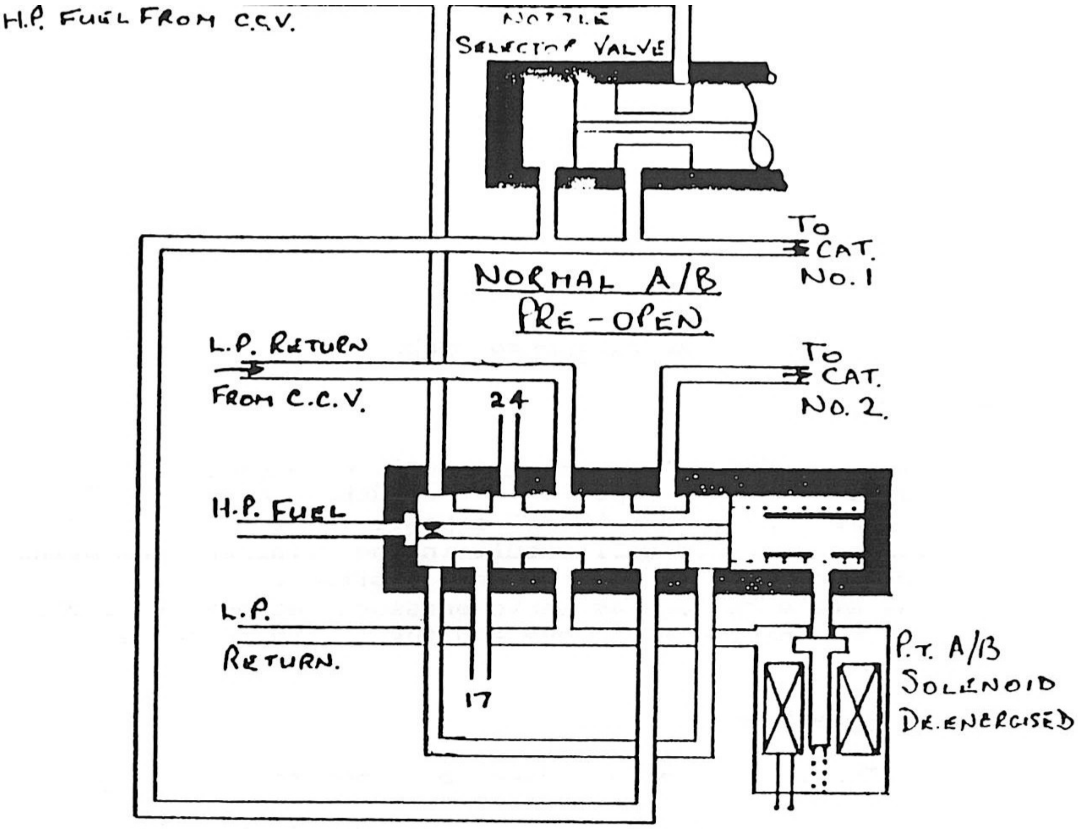
6. AFTER-BURNER SPEED CONTROLLED ARMING SWITCH.

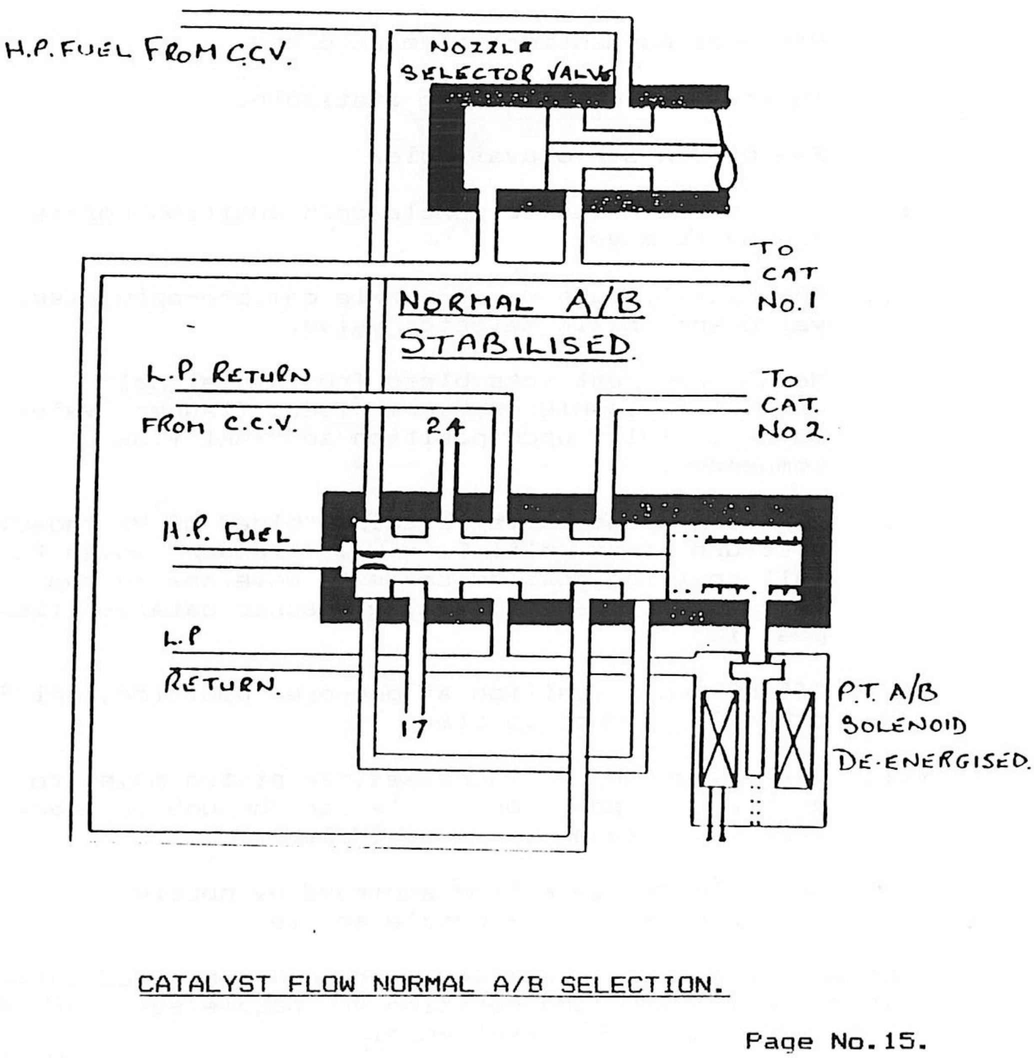
A speed controlled arming switch is fitted to the system to ensure that after-burning will not be available until after a pre-set RPM.
This is achieved by passing HP fuel from the back of the circuit control valve through the speed switch and back to LP.
At a pre-set RPM governor pressure will be felt on the speed switch diaphragm and deflect the diaphragm so closing the bleed to the LP side.At this time HP pressure will then be available to operate the circuit control valve and after-burning can commence.



1. Speed Switch.
2. Half Ball Valve.
3. Governor Pressure.
4. A/B Flow Control Servo.
5. Return to LP.
6. Throttle Lever A/B.'ON'.
7. HP Servo Inlet.
8. PRCU Servo Pressure.
9. Circuit Control Valve.
10. HP Fuel Return to LP.

<u>AFTER-BURNER SPEED CONTROLLED ARMING SWITCH.</u>





CATALYST FLOW NORMAL A/B SELECTION.

AFTER-BURNER OPERATION

SELECTION.

It will be noticed that while after-burning is not selected,the P6 capsule in the PRCU is receiving full P6 pressure whilst the PX capsule is being vented to atmosphere.This will result in the 'flapper' arm being held in the 'ram open select' position.
Therefore as soon as servo pressure becomes available the ram piston will move and the nozzle commence to open.

ON Selection:

i. Throttle selector moves to on position.

ii. Circuit control valve moves under fuel pressure.

Pressure Augmenting Valve unlocked.

Inlet flow control servo available.

Ram piston servo available.

iii. Ram piston moves to nozzle open position,nozzle begins to move

iv. Feedback linkage moves nozzle cam,pre-open bleed valve and nozzle selector valve.

v. Nozzle cam restricts bleed from air signal generator,capsule pressure rises,'flapper' valve moves to inlet open position and fuel flow commences.

vi. Pre-open bleed valve restricts bleed of PX capsule pressure rises until P6 = PX, 'flapper' moves to null position,nozzles cease to move,nozzle cam stops,nozzle selector valve reaches catalyst flow position.

vii. After-burner ignition at pre-open position,fuel flow scheduled by nozzle cam.

viii. After light up P6 increases,ram piston moves to nozzle open position,nozzle cam through feedback linkage increases fuel schedule.

ix. Throttle cam selection achieved by nozzle cam,capsule P6 = PX,nozzle stable.

After pre-open has been achieved,pre-open bleed valve moves to fully closed position and nozzle selector valve moves to cut off catalyst supply.

DE-SELECTION.

i. Throttle selector moves to 'OFF' position.

ii. Circuit control valve moves under fuel pressure.

a. Inlet flow control drops to LP value, spring closes inlet valve.

b. Pressure augmenting valve closes, held closed by locked in pressure.

c. Ram piston servo drops to LP value, ram piston moves to ram closed position.

iii. After-burner pump pressure rises, ram supply NRV opens, A/B fuel directed to ram closing position.

iv. Rams begin to close, return fuel pressure rises and restrictor 'R' chokes.

v. A/B pump inlet NRV 'X' opens, fuel is 'locked in' pump/ram circuit.

vi. Nozzle driven to closed position by 'locked in' fuel pressure.

vii. Feedback linkage operates nozzle cam, pre-open bleed valve and nozzle selector valve.

viii. Nozzle selector valve cooling flow port opens, pump pressure and flow fall to cooling flow value.

EMERGENCIES.

RAM SEIZURE.

Should a nozzle ram seize during operation a pressure relief valve will operate in the PRCU to prevent damage to the remaining ram operating arms.

'SLAM' SELECTION.

Should a 'slam' selection of after-burner be made, the normal ram selector restrictor 'U' becomes saturated and the ram supply check valve 'J' opens and the A/B FCU pump pressure is used to open the rams.

PART THROTTLE AFTER-BURNING.

This feature enables after-burning to be selected with the throttle in the Max.Dry position.

Selection is by a switch located on the port side canopy sill,the two switches are labelled 'MOD REHEAT' 1 and 2.Selection to the 'ON' position will also bring into operation a 'Detent' on the throttle quadrant,via a micro-switch,which will cancel Part Throttle After-burning if the throttle is closed beyond the 'Detent'.

With the engine running at Max.Dry the recommended position for selection of Part Throttle After-burning 'ON',the thrust obtained will be Minimum After-burning.Thrust may then be reduced over the micro-switch 'ON' range by closing the throttle lever until the detent is reached.Therefore the range of Part Throttle After-burning is from 2,000lbs thrust to Minimum After-burning.

Because the selector switch and the micro-switch are in series both must be closed for Part Throttle operation.

Part Throttle After-burner Operation.

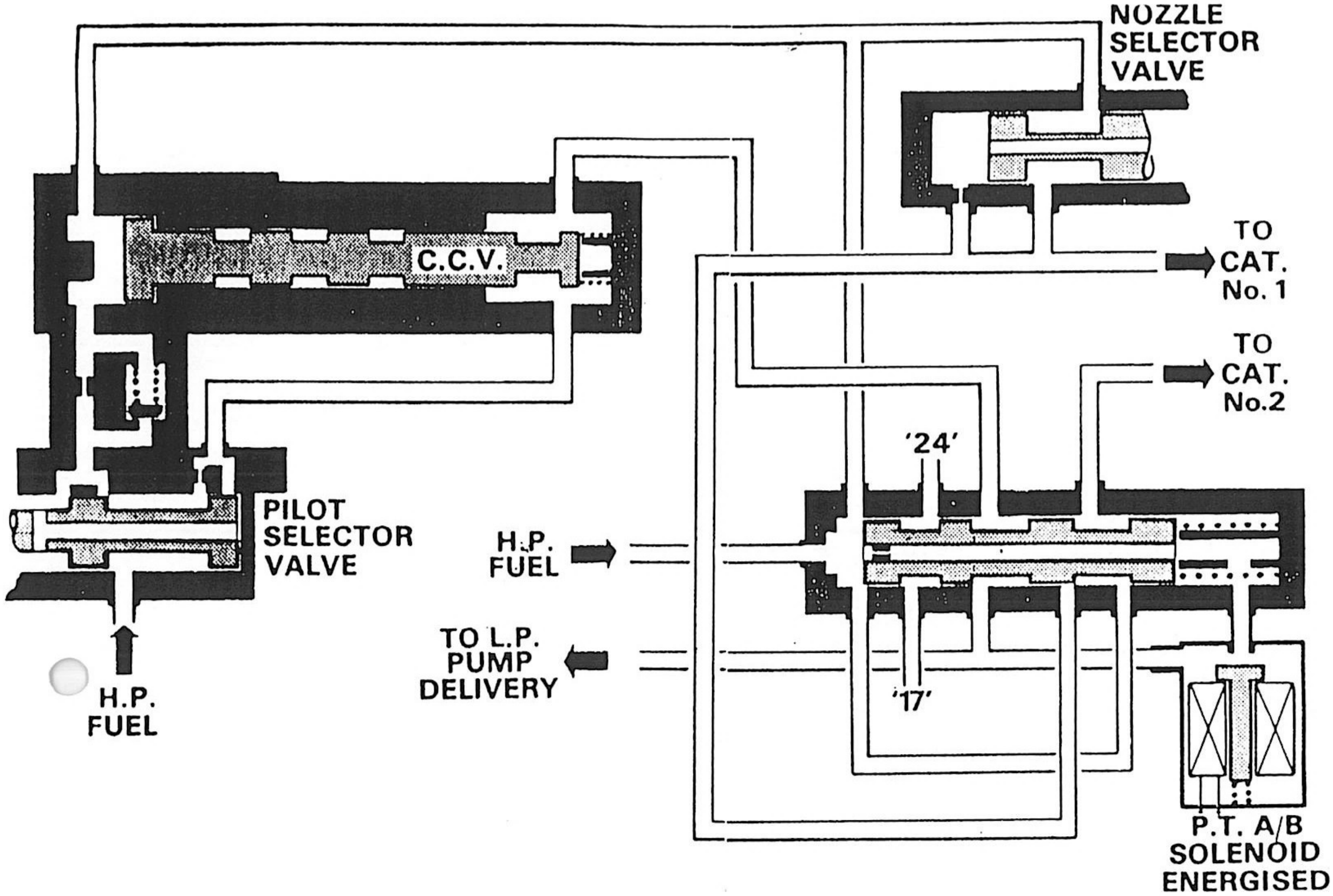
When the Part Throttle solenoid is energised the Part Throttle selector valve moves to set up the following:

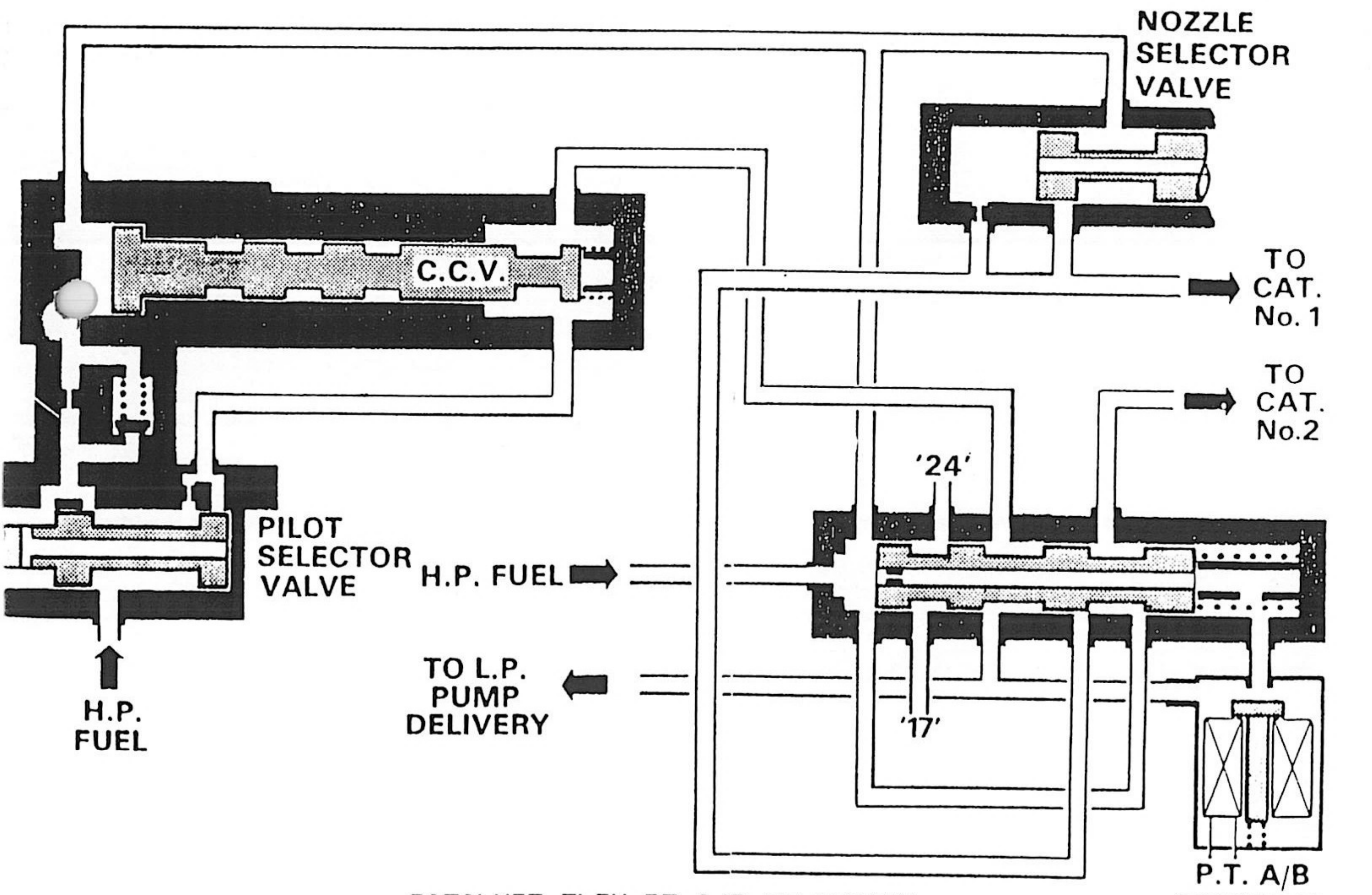
a. HP fuel is supplied to the 'unsprung' end of the Circuit Control Valve and the other end is ducted to LP pump delivery.
b. HP fuel is supplied directly to the No.1 catalyst via the Nozzle Selector Valve as in normal After-burner.
c. Fuel is supplied to the No.2 catalyst direct from the Part Throttle After-burner Selector Valve.this catalyst will therefore be in operation continually during PT.A/B operation.
d. Connections 17 and 24 are connected together to provide a by-pass around the Pressure Augmenting Valve on the A/B FCU.This prevents instability at low fuel flows.

After the supply from the PT A/B Solenoid has moved the CCV the light up of the After-burner will be exactly the same as in the normal mode.

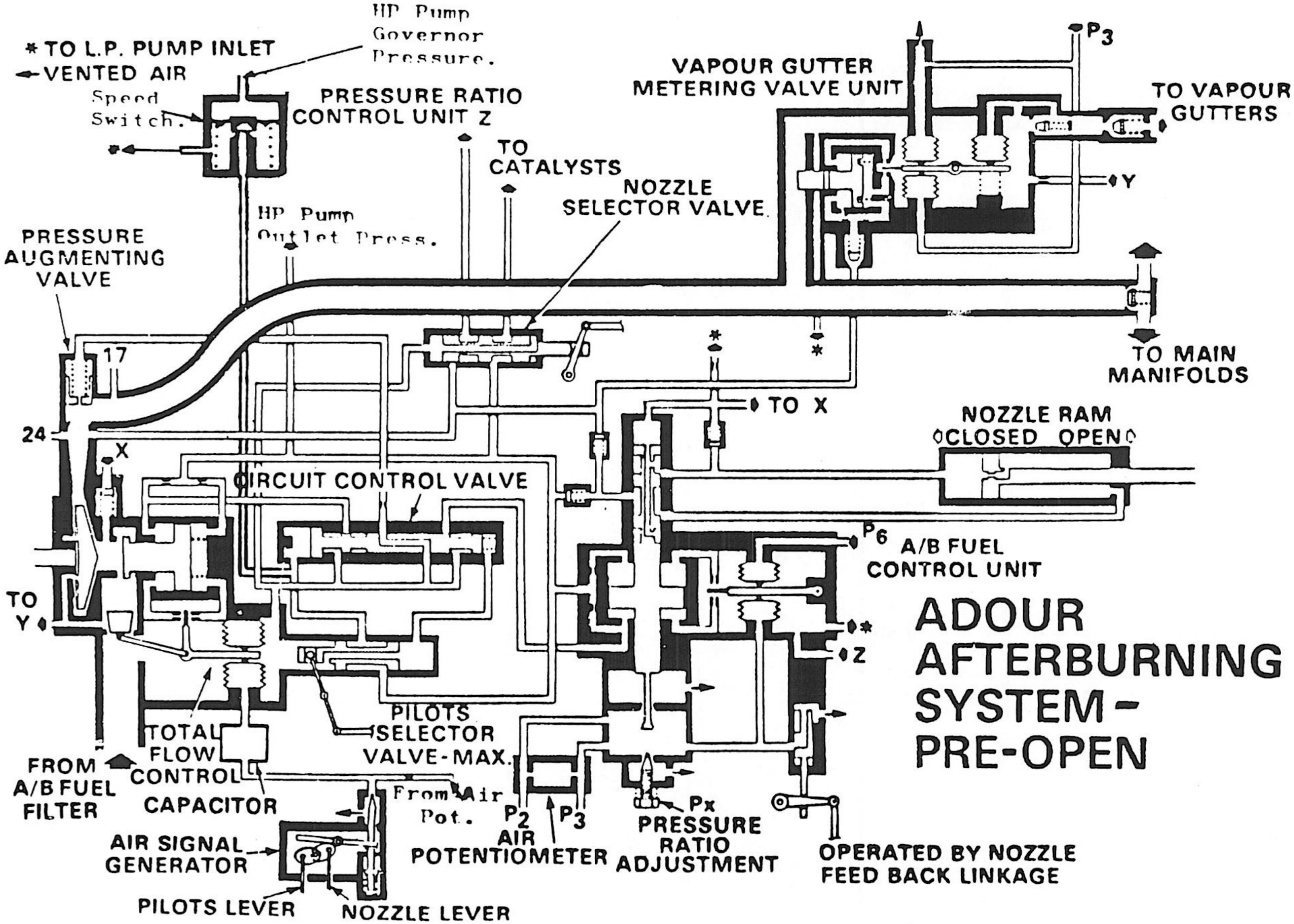
Min A/B is obtainable at Max,Dry because on de-selection from the normal mode the throttle cam will remain in the Min.A/B position.

Should the throttle lever be moved into the normal mode of A/B the only change will be that the throttle cam will now cause the A/B thrust to be modulated to the degree scheduled by the cam.
The sequencing of the catalysts for PT operation is,both 'ON' for light up,No.2 remains on during PT selection.





CATALYST FLOW PT A/B SELECTION.



ADOUR AFTERBURNING SYSTEM - PRE-OPEN

ROLLS-ROYCE/TURBOMECA.

ADOUR 811/815.

ENGINE DRAINS SYSTEM.

REQUIREMENTS.

1. Dry Drains.
   To collect fuel and/or oil from the interspace of a double seal to give an indication of seal failure.

2. Wet Drains.
   To collect drainage from certain areas which is functional and permissible within limits.

3. Air Blown Seal Drains.
   To collect the vent air from the External gear-box component drives which feature labyrinth seals pressurised by P2 air.Excessive fluid drainage would be indicative of drive shaft seal failure.

4. Nozzle Ram Drain.
   To collect fuel which would indicate a ram to piston seal failure.

5. Exhaust Collector Drain.
   To allow fuel to drain from the exhaust collector.

1. Dry Drains.
   The following components are connected to the dry drain manifold.

LP Fuel Pump. (1).	The interspace between the
HP Fuel Pump. (2).	double fuel/oil drive shaft seal.
A/B FCU. (3).	Capsule sealing ring interspaces and selector valves.
VGMU. (4).	Capsule sealing ring interspaces.

2. Wet Drains.

FCU. (16).	HP shut-off valve.
A/B FCU. (12).	Nozzle ram control valve.
By-pass ducting rear (11) & (9) with spring loaded valves which close when the engine is running.	Unburnt fuel drain following a wet start.

3. Air Blown Seal Drains

The following air blown seal drains are connected to the air blown seal drains manifold,by internal drillings and external tubes.

Starter Motor. (15).
AC Generator. (18).
Hydraulic Pump. (18).
A/B FCU (Pump Seal). (13).

A pressure balance tube (14) connects the manifold to the breather outlet so that the only pressure drop across the seals is that across the breather rotor.

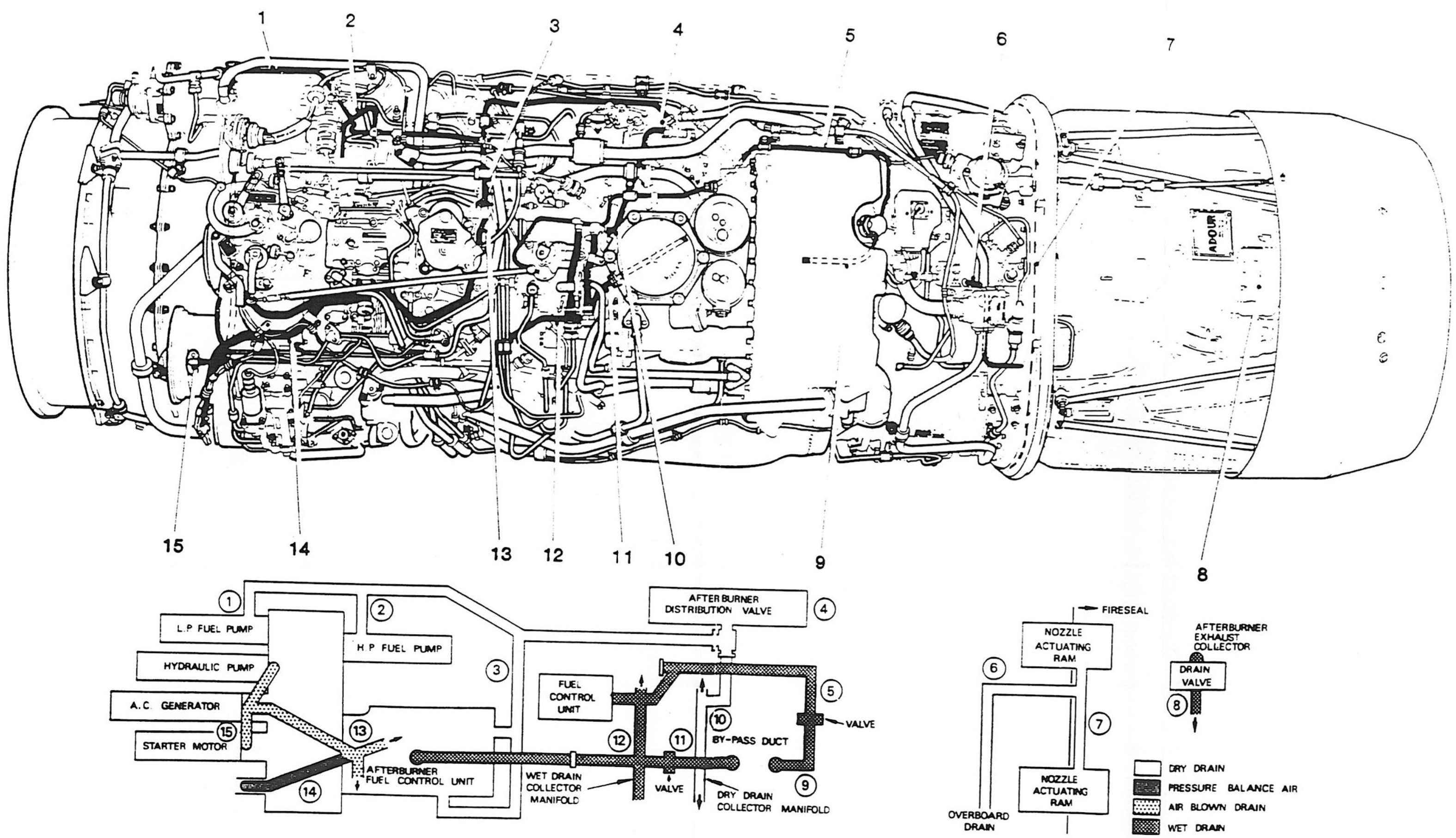
4. Nozzle Ram Drains.

The four nozzle ram drains are connected by a common drain (7) interconnecting each ram.The drain line (6) passes through the fireproof bulkhead and is connected to the keel.

5. Exhaust Collector Drain.

The exhaust collector is drained directly through a spring loaded drain valve (8).

For method and drain permissible amounts see relevant Servicing Manual.



Drains system. Tubes and location

ROLLS-ROYCE/TURBOMECA.

ADOUR 811/815.

TEST EQUIPMENT.

INTRODUCTION.
Two main pieces of test equipment are used during servicing and fault diagnosis.
Associated with these are various leads,cables and minor pieces of ancillary equipment.
In broad terms the functions of the equipment can be classified as follows.

1. Test Set 'A'.
   Used to provide checks on speeds and temperatures on the engine and its control systems.

2. Test Set 'D'.
   The Dawes Roughness Measuring Set is used to obtain a measure of engine vibration intensity.

We can now analyse in more detail the function of each test set.

TEST SET'A'.

This is used to check and/or set all engine control parameters.
The checks can be broken down into two categories.

Static checks.

Engine running checks.

Static Checks.

The static checks prove the control function of the amplifier and also the control of the T2 compensator when the engine is static.These checks must be made before an engine run after the following:

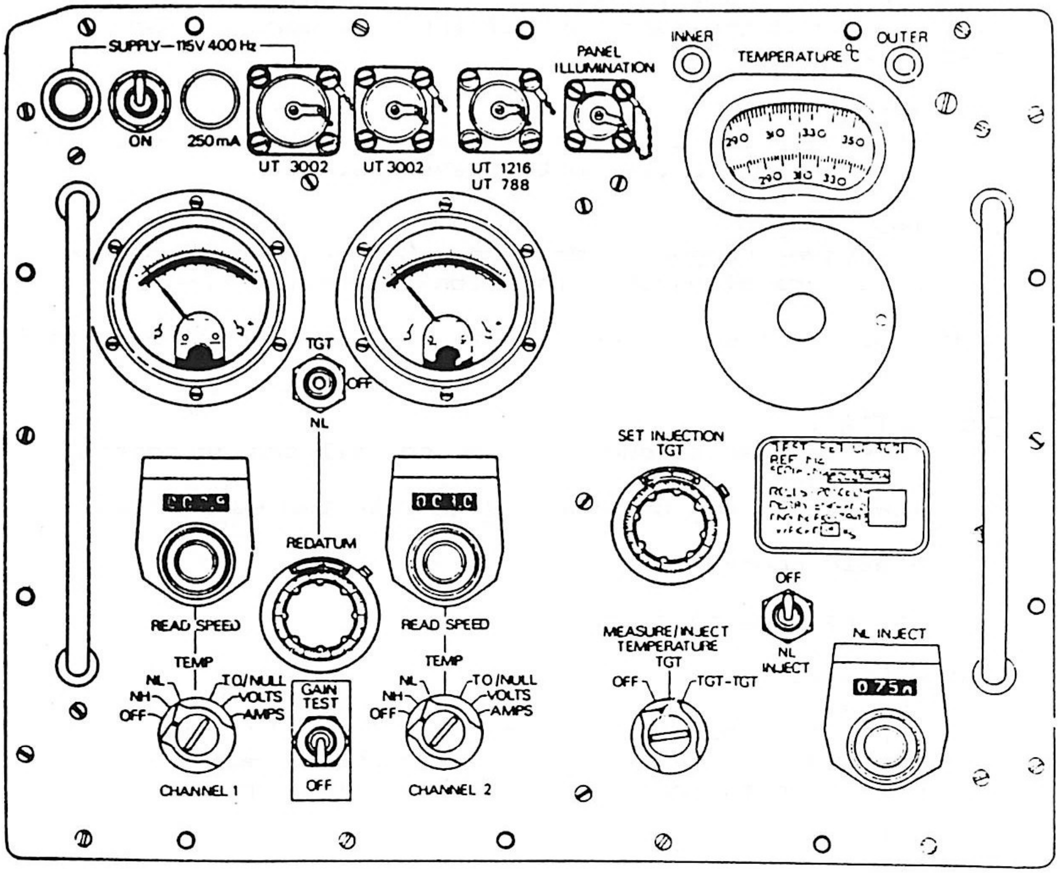
After an engine change.

After a control amplifier change.

Amplifier checks for fault diagnosis.

After replacement of any component that could affect the operation of the amplifier. (FCU change).

These checks will prove that the amplifier will subsequently control engine parameters during engine running.
Details of the checks to be carried out may be found in the relevant Servicing Manual.


SUPPLY—115V 400 Hz
ON
250mA
UT 3002
UT 3002
UT 1216
UT 788
PANEL
ILLUMINATION
INNER
TEMPERATURE °C
OUTER
TGT
OFF
NL
SET INJECTION
TGT
REDATUM
READ SPEED
TEMP
NL
NH
OFF
TO/NULL
VOLTS
AMPS
CHANNEL 1
GAIN
TEST
OFF
READ SPEED
TEMP
NL
NH
OFF
TO/NULL
VOLTS
AMPS
CHANNEL 2
MEASURE/INJECT
TEMPERATURE
TGT
OFF
TGT-TGT
OFF
NL
INJECT
NL INJECT

<u>TEST SET 'A'.</u>

Engine Running Checks.

Test Set 'A' is used during ground checking to provide an accurate measurement of NL,NH,TGT and also that the amplifier is in fact controlling Max. engine parameters via the current supplied to the fuel solenoid.
The figures also provide the basics for a 'PRCU Setting Check' or more commonly termed 'Working Line'.

PRCU Setting Check.

When after-burning is selected it is essential that it does not cause any excessive back pressure which could affect the compressors and turbines.

This requirement is met by the Pressure Ratio Control Unit in the A/B FCU which controls the nozzle area via four rams.

On selection of after-burning the PRCU increases the nozzle area and subsequently controls it,in the majority of cases,to obtain an exhaust collector pressure slightly lower than that obtained in the DRY condition.

This is known as 'under restoration' and will in fact cause a slight increase in shaft speeds in after-burning due to the increased pressure drop across the turbines.

It is this change in shaft speeds,within a tolerance band,that is used initially to set the PRCU on the test bed.
Because all engines have been run and tested on the test facility here the PRCU setting check is now only used for fault diagnosis.

On the initial test bed run a PRCU setting chart is produced which is then incorporated in the engine log book.
The chart consists of two engine working lines:
a. An 'unlit' working line,which is produced by plotting NL against NH as the fuel flow is reduced from the Max.Dry value.This has nothing to do with the after-burning system and is purely a 'DRY' engine characteristic.

b. A 'lit' working line.Again NL is plotted against NH but with the after-burner lit.The engine flow is reduced in this case by using Part Throttle After-burning.

To eliminate the effect of air intake temperature variation, the speed values of the setting chart are non-dimensional ie,NL and NH values divided by the square root of T1(Degrees K) existing when the readings were taken.

It follows therefore that on subsequent in service checks the same procedure must be adopted,the NH and NL values obtained on a check must be divided by /T(oK) before comparison with the chart.
Conversion tables in the Servicing Manual are provided for this purpose.

<u>PRCU Setting Check Procedure.</u>

This check is made in service when it is required to prove that the PRCU section of the A/B FCU is functioning correctly in maintaining the engine working pressures throughout the engine within acceptable limits when after-burning is in operation.

If the engine speed changes are outside the permitted tolerance then an adjustment is made on the PX adjuster,which will move the A/B lit working line relative to the unlit line.

PX - OUT
P6 - REDUCES.   UNDER RESTORED ENGINE.

PX - IN
P6 - INCREASES   OVER RESTORED ENGINE.

<u>Ground Run Procedure.</u>

1. With Test Set 'A' connected,start engine,ensure all air offtakes and accessory loads are at a minimum.Ensure PT A/B is not selected and measure NL and NH speeds at 96.5%,98.5% and at Max.Dry record the speed values after stabilisation at each speed setting.

2. Advance the throttle to the Max. A/B position,allow the engine to stabilise,then record NL and NH speed values.

3. Select PT A/B and after stabilising at each setting record speed values at 98.5% and 96.5% respectively.

4. Using conversion chart provided convert all readings into values of NL and NH.
/T1 /T1

These readings may now be plotted on the PRCU setting chart obtained from the engine log book.

After plotting and drawing in the lines obtained from the ground run the following procedure is adopted:

Take the corrected figure for the Max A/B 'lit' and on the NH line of the graph and project it upward to
/T1
intersect both the log book and the ground run working lines.

Where the Max.A/B 'lit' projected line crosses the log book 'lit' and 'unlit' lines project a line across the graph to the NL upright.subtract the lower figure from /T1 the higher,this will give a figure known as Datum Delta 1.

Use the same procedure.this time using the ground run working lines and the figure achieved will be known as Actual Delta 2.

The next step is to determine,if any,how much PX adjustment is required.

Subtract Actual 2 from Datum 1,or vice versa,if the difference is not more than 0.050 no PX adjustment is required.

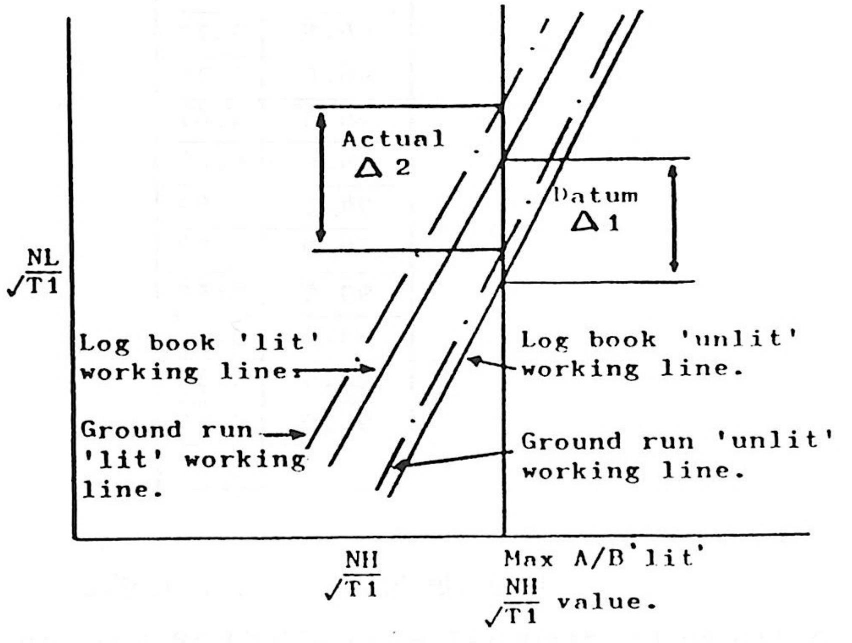
If the figure obtained is greater than 0.050 then PX adjustment should be carried out in the following manner:

If Actual 2 is a higher figure than Datum 1 then the answer is considered to be minus and the PX adjuster is screwed IN.

If Actual 2 is a lower figure than Delta 1 then the answer is considered to be positive and the PX adjuster is screwed out.

NOTE: Only small adjustments are required.

At all times whilst calculating the PX adjustment from the working line graph the log book graph must be used and not one from a previous ground run.



ESTABLISHING PX ADJUSTMENT.

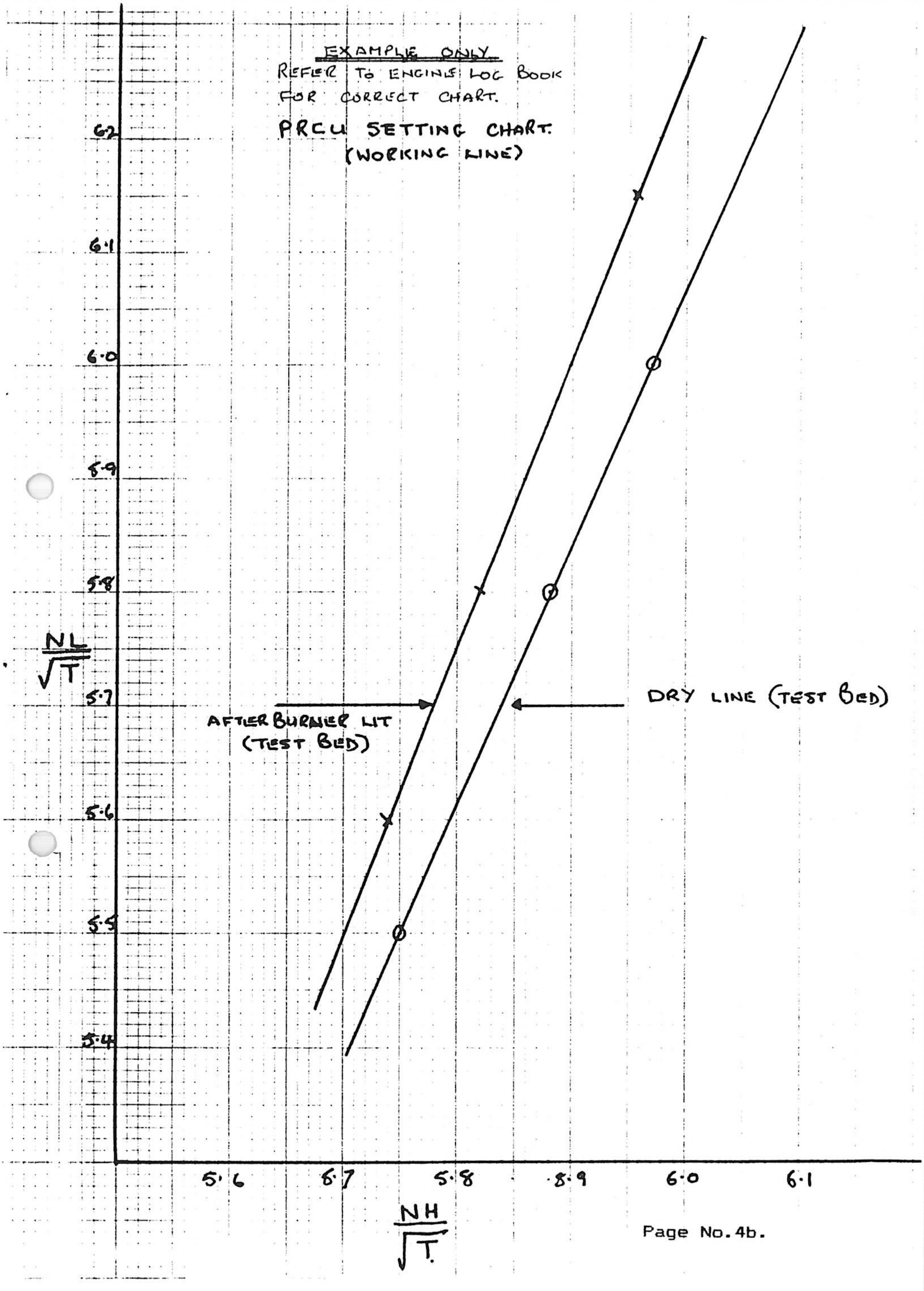
SIMPLIFIED CONVERSION CHART.

Only one temperature figure is given,on the full chart a range of eleven different temperatures are given per page.

105.0	6.23
104.5	6.20
104.0	6.17
103.5	6.14
103.0	6.11
102.5	6.08
102.0	6.05
101.5	6.02
101.0	5.99
100.5	5.96
100.0	5.93
99.5	5.90
99.0	5.87
98.5	5.84
98.0	5.82
97.5	5.79
97.0	5.76
96.5	5.73
96.0	5.70
95.5	5.67
95.0	5.64
94.5	5.61
94.0	5.58
93.5	5.55
93.0	5.52
92.5	5.49
92.0	5.46
	+11

Outside Air temperature ØC.

Estimate to obtain values of RPM/T1 (ØK) for intermediate RPM values.


EXAMPLE ONLY
REFER TO ENGINE LOG BOOK
FOR CORRECT CHART.
PRCU SETTING CHART.
(WORKING LINE)
6·2
6·1
6·0
5·9
5·8
5·7
5·6
5·5
5·4
NL / √T
AFTERBURNER LIT
(TEST BED)
DRY LINE (TEST BED)
5·6
5·7
5·8
5·9
6·0
6·1
NH / √T

JAGUAR ENGINE INSTALLATION GROUND RUN PROFORMAE

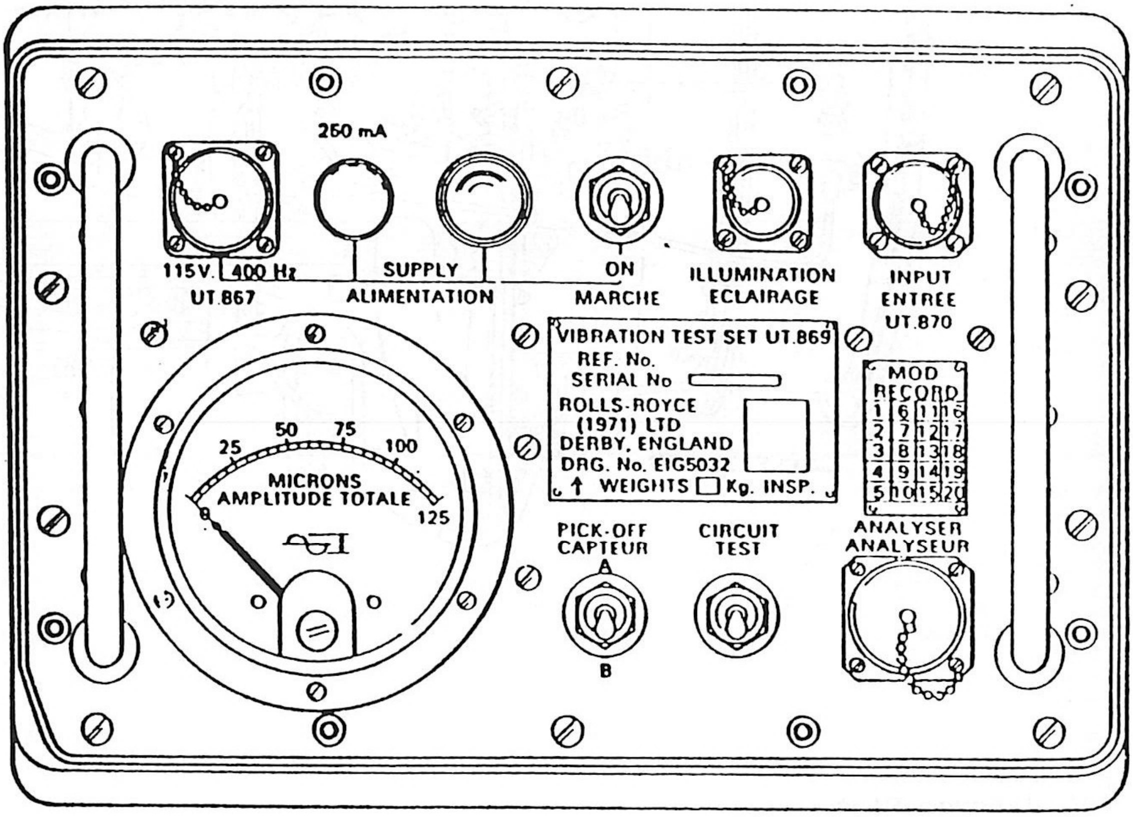
ADOUR NO.1234... A/C No.567.. POSITION..PORT. DATE.22/8/85 OAT.11

	Initial Start	2nd Start Eng Hot
LP Rotation light, Time to light	Secs	Secs
Time to Starter cut out	Secs	Secs
Time to 50% NH	Secs	Secs
Time from 40% NH to 49% NH	Secs	Secs
Oil pressure light out by 50% NH		
Max TGT during start, Max 650°C	°C	°C
Bleed valve closed at	% NH	% NH

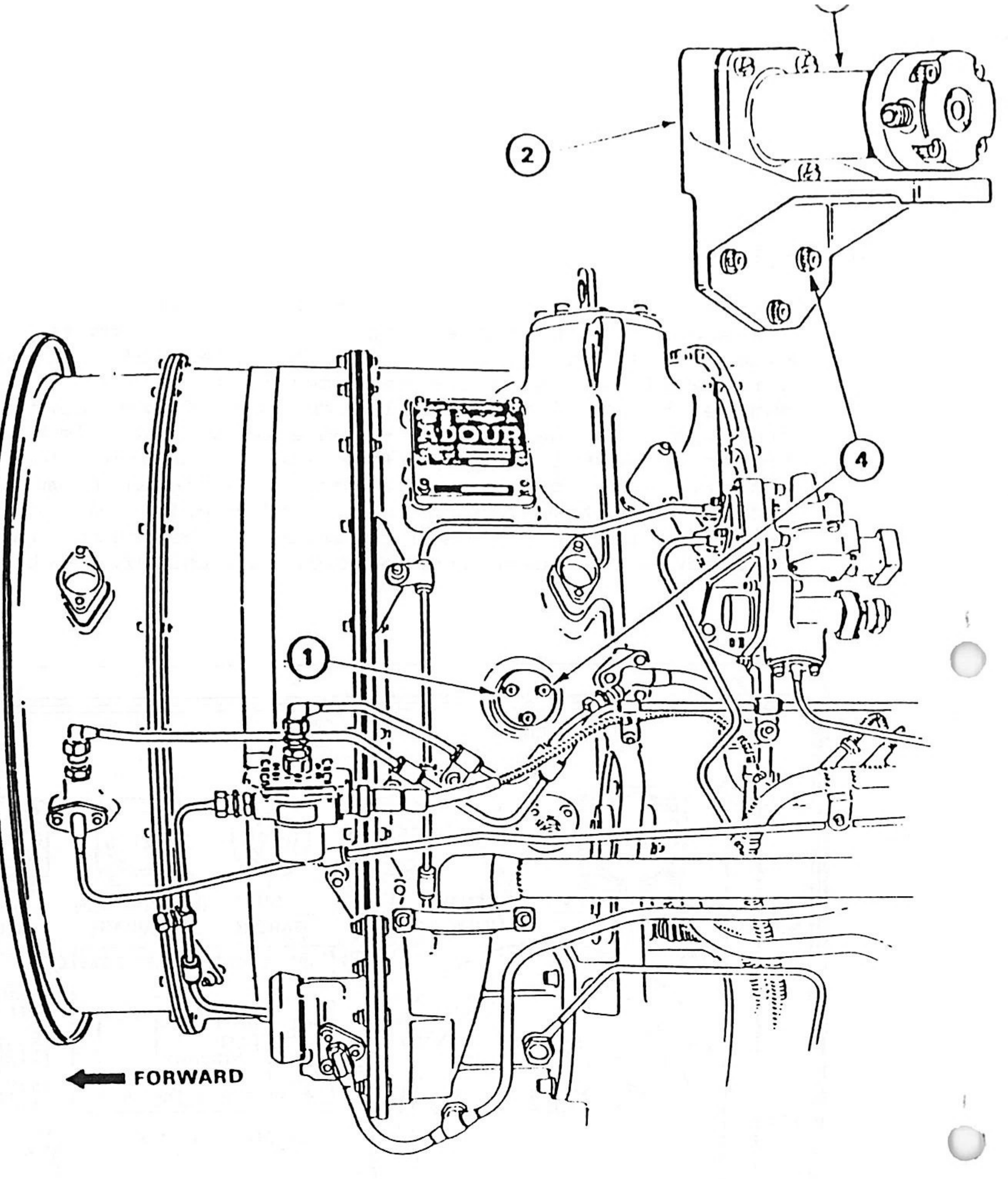
CONDITION	COCKPIT				TEST SETS					CALCULATED	
	% NH	TGT	Fuel Flow	NP I	% NH	% NL	TGT	Amp	Vib	NH T1°K	NL T1°K
INITIAL START											
Idle B/V open											
Idle B/V closed											
P.T.R. OFF											
70% NH									35		
80% NH									52		
96.5% NH					96	92.2	530	40	57		
98.5% NH					98.5	97.0	585	40	54		
Max dry					100	100.5	640	20	43		
Max reheat					99.8	103	640	20			
P.T.R. ON											
98.5% NH					96.8	97.0	585	40			
96.5% NH					95.5	94.0	530	40			

TEST SET 'D'.

This set along with the engine mounted vibration transducers enables the total engine vibration to be read direct from a meter.It is this piece of equipment which will determine the serviceability of the engine.The complete assembly consists of two inductive pick-ups - one per engine - whose outputs are fed via a filter network to an amplifier.The output from the amplifier is displayed on a meter.the signal from one pick-up at a time can only be displayed.The 'A' or 'B' switch on the box is used to switch transducers. The unit takes its power from a source on the aircraft.



TEST SET 'D'.



1. Cover Plate.
2. Bracket.
3. Transducer.
4. Securing Bolts.

VIBRATION PICK-UP ASSEMBLY.

FITTED TO MODULE 03.

ROLLS-ROYCE/TURBOMECA.

ADOUR 811/815.

INSTRUMENTATION.

The instrumentation covered in this section is the instrumentation covering the main engine handling parameters.

The main engine handling parameters are:

Turbine Gas Temperature.(TGT).

HP Shaft Speed.(NH).

There is no cockpit indication of NL (LP Shaft Speed) except for 'LP Correct Rotation' lights during starting,but provision is made to measure NL during engine check out and fault diagnosis,using Test Set 'A'.The instrumentation covered in this section is:

1. Engine Pyrometry System.
    a. Thermo-couple and Harness.

    b. Thermo-couple junction box.

2. Shaft Speed Indication.
    a. HP Shaft Tachometer Generator.

    b. LP Shaft Speed Probes.

1. ENGINE PYROMETRY SYSTEM.

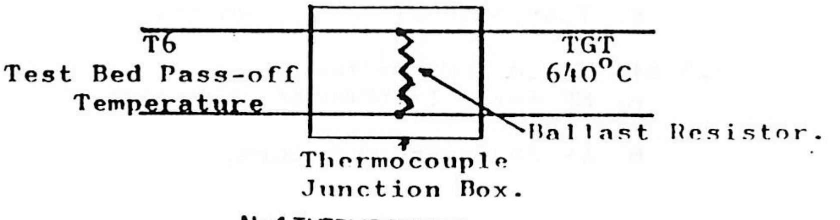
a. Thermocouples and Harness.

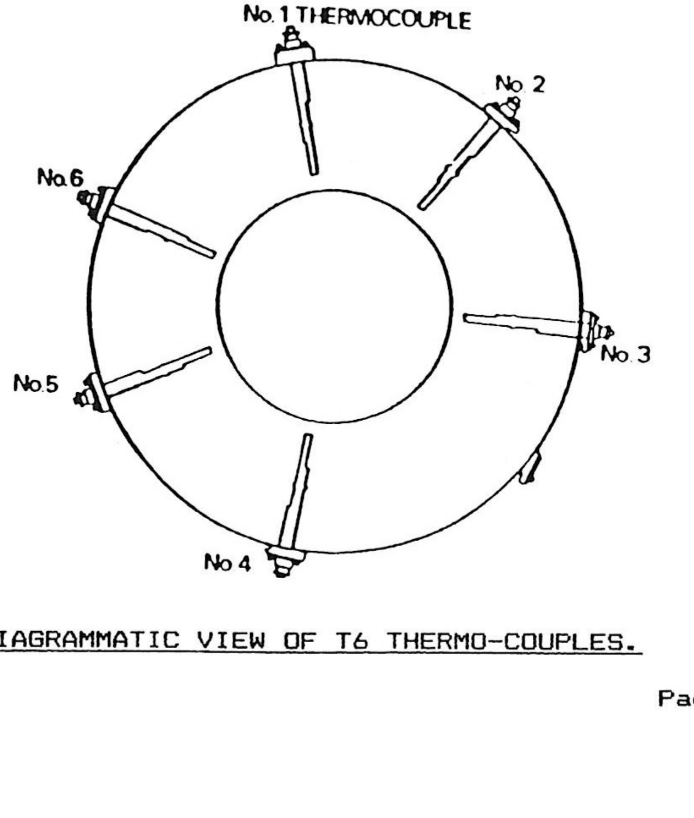
Six double element probes are located in the gas stream leaving the turbines.

Wired in parallel,the mean output of the twelve readings is supplied to a thermo-couple junction box.Here this value,which is known as T6, is ballasted and the output is termed TGT.(Turbine Gas Temperature).

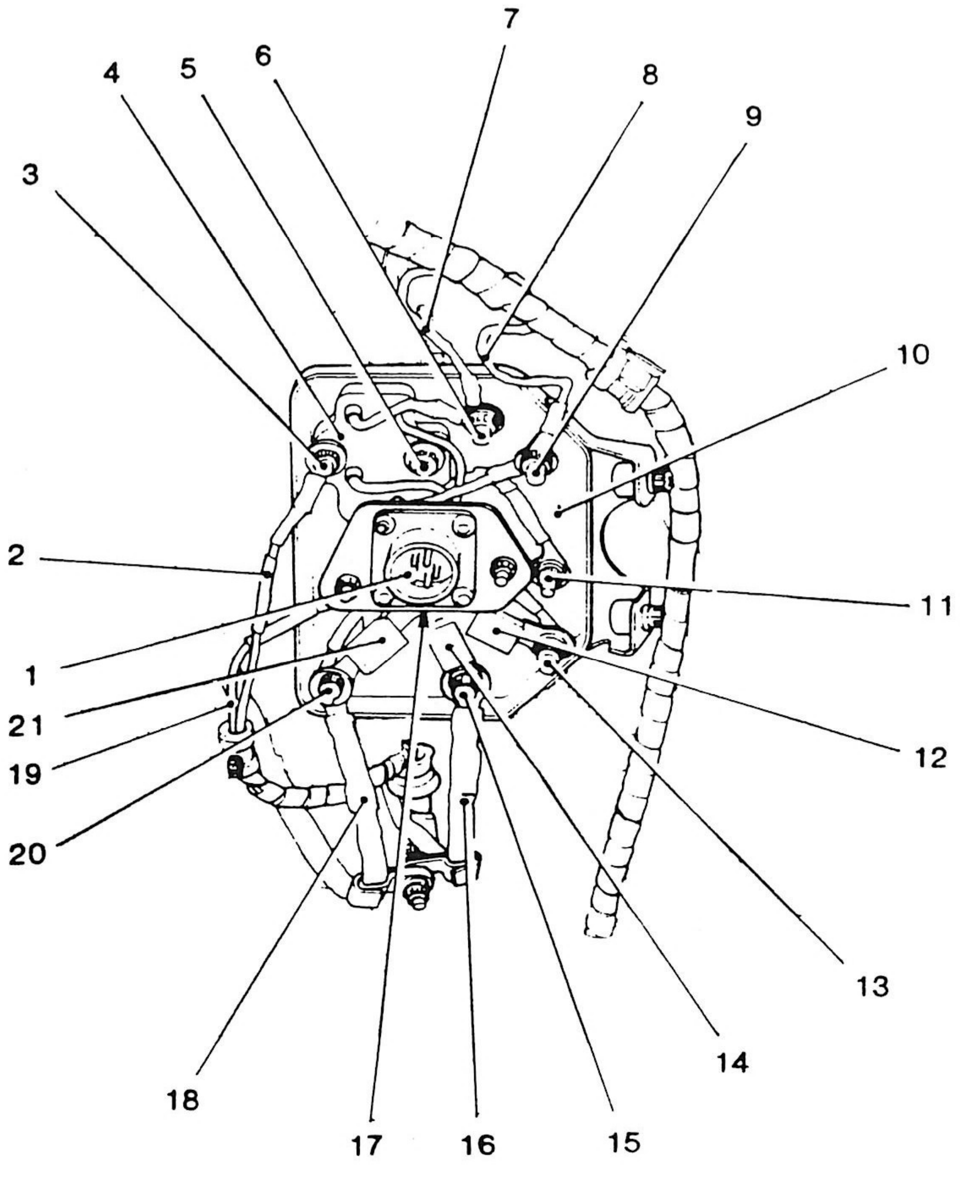
Both the thermo-couples and harness are colour coded.Red for positive (Nickel Chromium) and Blue for negative (Nickel Aluminium).

It follows that as the harness is located before the test point and the test point after the the ballast resistor,the harness cannot be proved serviceable by using the test box.





DIAGRAMMATIC VIEW OF T6 THERMO-COUPLES.



THERMO-COUPLE JUNCTION BOX.

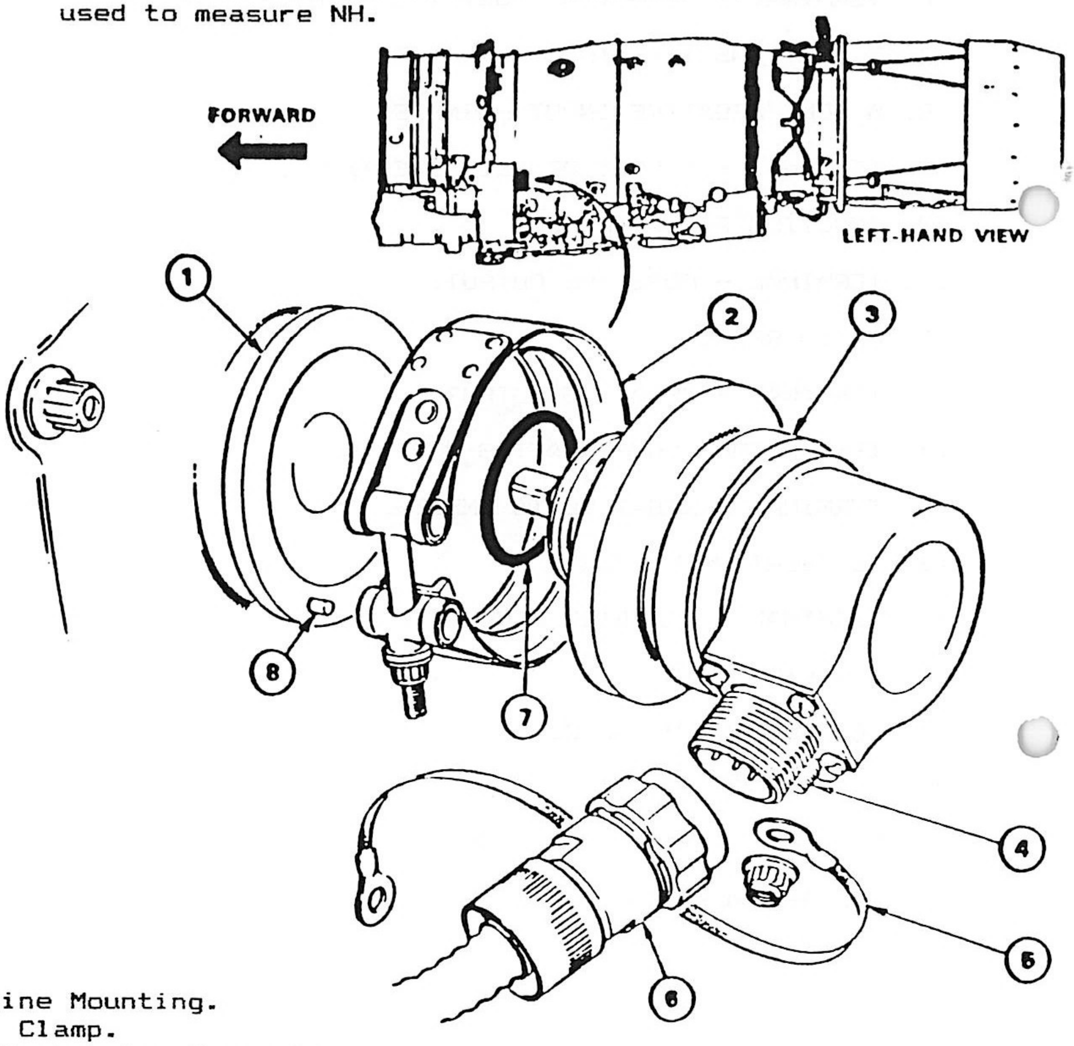
1. JUNCTION BOX TEST POINT.
2. T2 HARNESS POSITIVE INPUT.
3. TERMINAL - T2 POSITIVE INPUT.
4. COLD BRIDGE.
5. COLD BRIDGE MOUNTING STUD.
6. TERMINAL - 5 VOLT DC POSITIVE INPUT.
7. 5 VOLT POSITIVE INPUT HARNESS.
8. 5 VOLT NEGATIVE INPUT HARNESS.
9. TERMINAL - 5 VOLT DC NEGATIVE INPUT.
10. JUNCTION BOX ASSEMBLY.
11. TERMINAL - POSITIVE OUTPUT.
12. RATIO RESISTOR.
13. TERMINAL - NEGATIVE OUTPUT.
14. TEMPERATURE COMPENSATING RESISTOR.
15. TERMINAL - NEGATIVE T6 INPUT.
16. T6 NEGATIVE HARNESS.
17. TERMINAL - RESISTOR COMMON.
18. STACKING POINT.
19. T6 POSITIVE HARNESS.
20. T2 HARNESS NEGATIVE INPUT.
21. TERMINAL - POSITIVE T6 INPUT.
22. BALLAST RESISTOR.

2. SHAFT SPEED INDICATION.

a. HP Shaft Tachometer Generator.

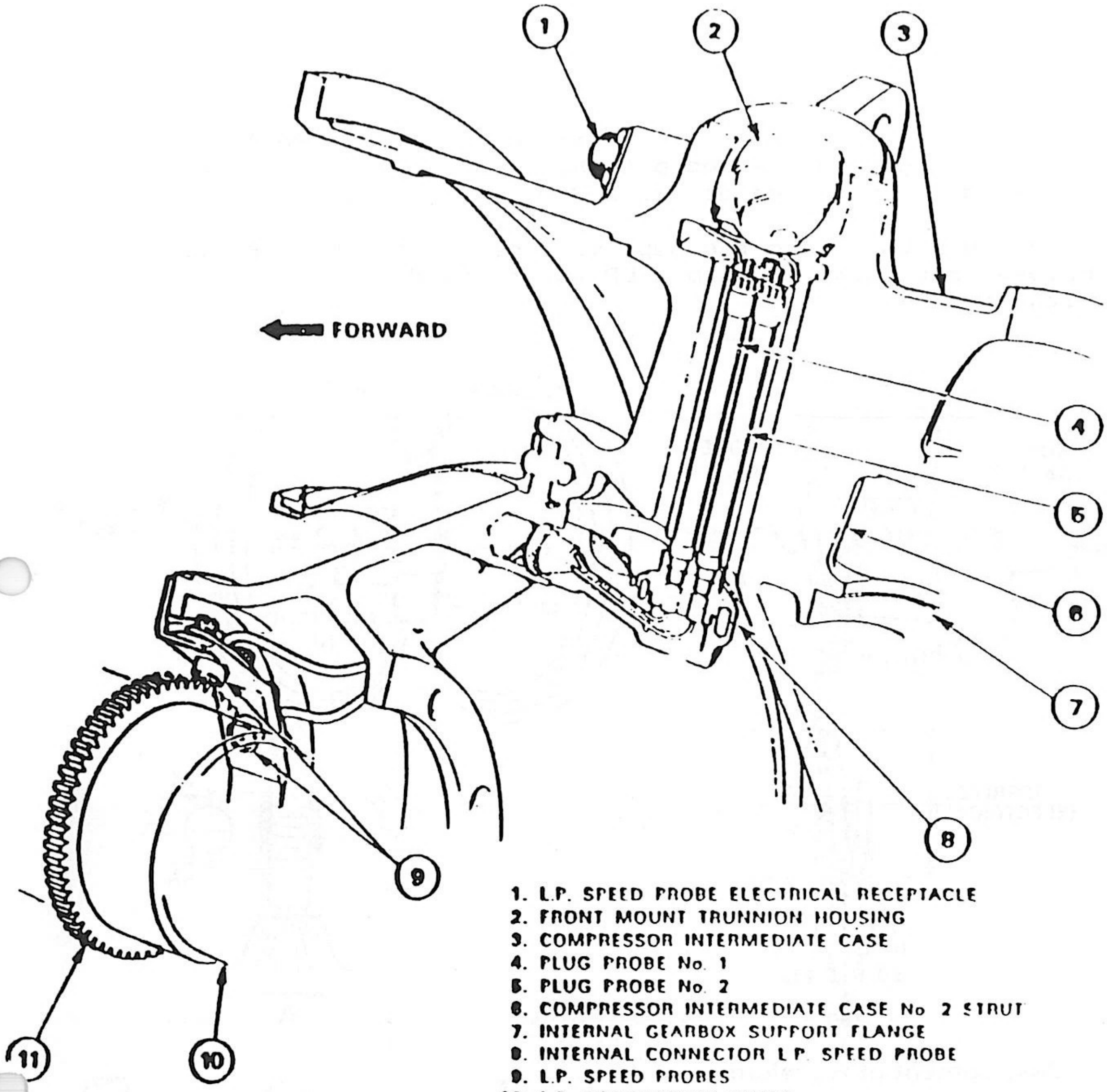
This component is fitted to the rear face of the external gearbox at the upper port side position.

An electrical signal proportional to NH is transmitted to the cockpit percentage gauge via the general service harness,and also to the aircraft remote test point,from where test set 'A' can be used to measure NH.



1.Engine Mounting.
2.'V' Clamp.
3.HP Tachometer Generator.
4.Earthing Post.
5.Earthing lead.
6.Electrical connection.
7.Seal Ring.
8.Dowel.

HP TACHOMETER GENERATOR.



1. L.P. SPEED PROBE ELECTRICAL RECEPTACLE
2. FRONT MOUNT TRUNNION HOUSING
3. COMPRESSOR INTERMEDIATE CASE
4. PLUG PROBE No. 1
5. PLUG PROBE No. 2
6. COMPRESSOR INTERMEDIATE CASE No. 2 STRUT
7. INTERNAL GEARBOX SUPPORT FLANGE
8. INTERNAL CONNECTOR L.P. SPEED PROBE
9. L.P. SPEED PROBES
10. L.P. COMPRESSOR SHAFT
11. PHONIC WHEEL

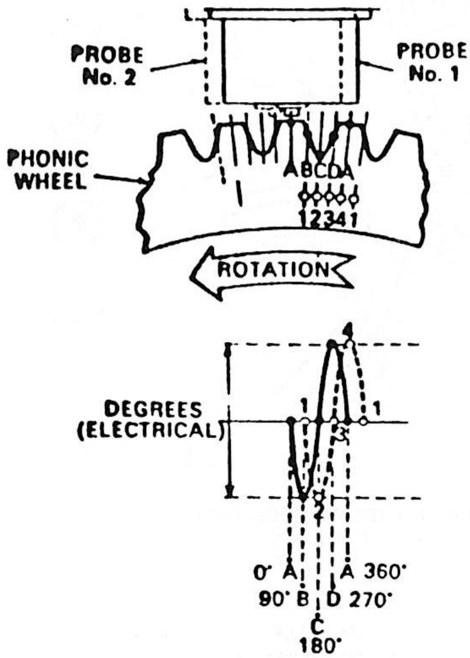
LP SHAFT SPEED PROBES.

Two probes are fitted in the internal gear-box around the periphery of a phonic wheel. Two frequencies proportional to speed signals are supplied to the amplifier via a drilling in the intermediate casing.

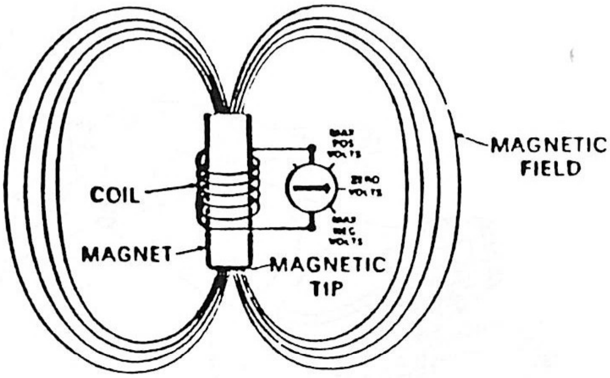
An output from the amplifier to the aircraft ignition circuit will permit the ignition relay to be energised when the LP shaft speed reaches 100 RPM in the correct direction during a start.

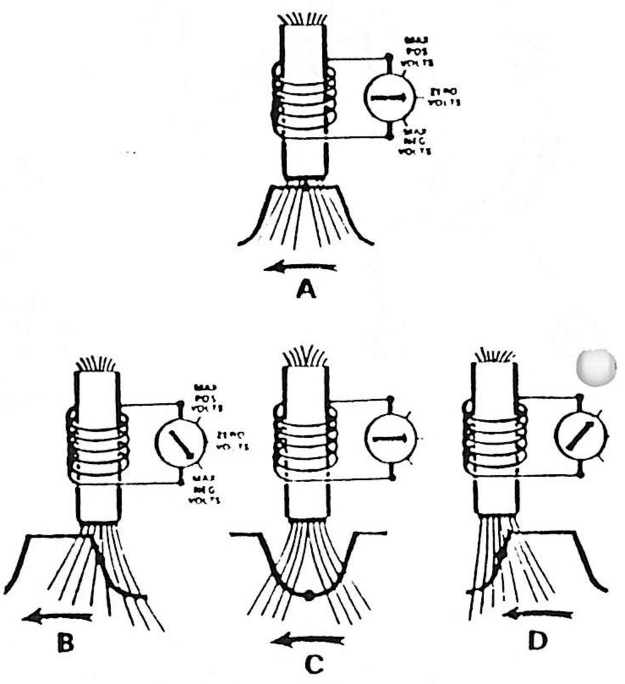
A contact of this relay also switches on the LP shaft rotation light in the cockpit. The light will go out when the relay is de-energised at the end of the starting cycle.

A second output from the amplifier passes to the aircraft remote test point to enable LP shaft speed to be measured with test set 'A'.



Development of waveform





Variation of flux path

Note:
While both No. 1 and No. 2 speed probes send back a combined signal to the amplifier – it can be seen that No. 2 speed probe is mounted 90 electrical degrees out of phase with No. 1 probe, – see development of waveform diagram, the fact is used in indicating the direction of rotation.

PROBE WAVE GENERATION.

b. Maximum NL Control.

The 'Comparator' circuit is also supplied with a maximum datum value of NL and an actual speed signal from the LP shaft signal probes.As with TGT control,trimming is commanded should the actual signal attempt to exceed the datum value.

Only one parameter can be in control at any one time,the one with the greatest error taking control.

It can be seen from above that the fuel solenoid adopts a 'fail safe' position.Should current to the solenoid fail at any time then the solenoid will go to full trim and therefore preventing either TGT or NL parameters to be exceeded.A pre-set backstop is provided in the solenoid to prevent over trim.

2. Over-ride the Engine Ignition.
THe amplifier has the authority to prevent the energising of the ignition relay in the engine starting circuit until the LP shaft has reached a minimum of 100 RPM in the correct direction of rotation.
The necessary input signals of NL are received from the LP shaft speed probes.

COCKPIT INDICATION.

a.LP Shaft Rotation Light.

The signal of NL used to withhold ignition is also used to illuminate a cockpit light (GREEN) when the LP shaft has reached a minimum of 100 RPM in the correct direction of rotation.

During a start sequence the light will go out when the ignition relay is de-energised.

General.
An electrical connection from the amplifier is taken to an aircraft remote test point. This is a Test Set 'A' connection point and is found on the keel panel secured by two screws.
The amplifier uses two power supplies,115V 400Hz AC and 28V DC.The latter is switcheable from the cockpit to immobilise the amplifier if required,but the LP shaft rotation light would be inoperative and normal ignition (not relight) would be isolated.

b. <u>Maximum NL Control.</u>

The 'Comparator' circuit is also supplied with a maximum datum value of NL and an actual speed signal from the LP shaft signal probes.As with TGT control,trimming is commanded should the actual signal attempt to exceed the datum value.

Only one parameter can be in control at any one time,the one with the greatest error taking control.

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THe amplifier has the authority to prevent the energising of the ignition relay in the engine starting circuit until the LP shaft has reached a minimum of 100 RPM in the correct direction of rotation.
The necessary input signals of NL are received from the LP shaft speed probes.

<u>COCKPIT INDICATION.</u>

a.LP Shaft Rotation Light.

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During a start sequence the light will go out when the ignition relay is de-energised.

<u>General.</u>
An electrical connection from the amplifier is taken to an aircraft remote test point. This is a Test Set 'A' connection point and is found on the keel panel secured by two screws.
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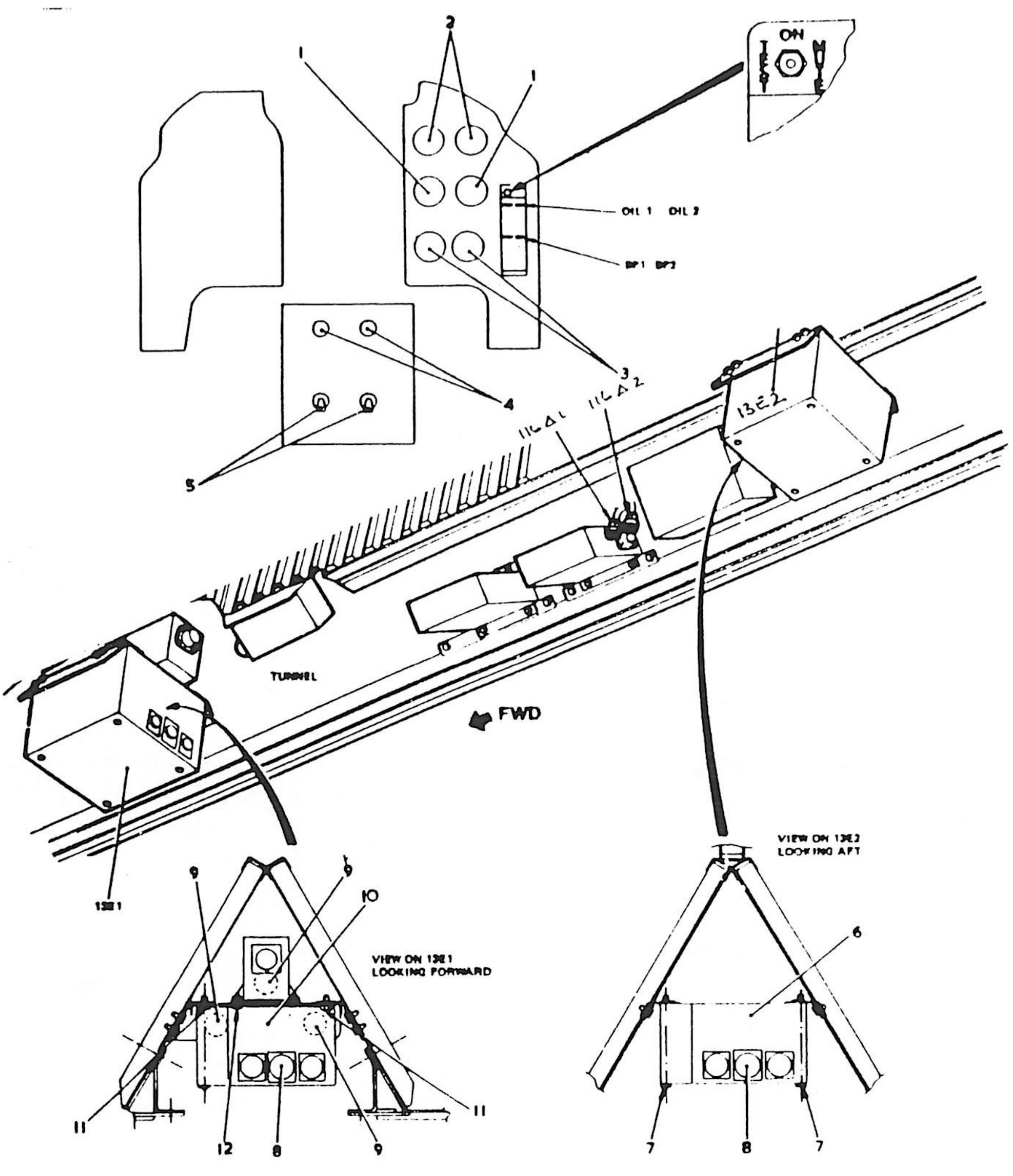


1. TGT Indicator.
2. Tachometer.(NH).
3. Nozzle Position Indicator.
4. Correct Rotation Light.
5. TGT Amplifier Switch.
6. No.2 Engine Amplifier.
7. Attachment Bolt.
8. Electrical Sockets.
9. Spigot.
10. No.1 Engine Amplifier.
11. Attachment Bolt.
12. Attachment Bolt.

INDICATORS AND AMPLIFIERS.

ROLLS-ROYCE/TURBOMECA

ADOUR 811/815.

ENGINE AND AIRCRAFT CONTROLS.

1. Control Rigging and Setting.

General.

When carrying out control rigging and checking certain general rules and cautions need to be observed as follows:-

a. Movement of the cambox input arm opens the HP Shut Off Valve,ensure that the LP cock switches are in the 'OFF' position.

b. The control stop clearances must be checked with the engine as cool as possible.

c. All maximum and minimum stops on components are rig set and must not be adjusted in service.

d. The FCU and SOV arms feature Messerschmidt adjusters and must not be adjusted in service.

e. Rigging pins should not be forced into their respective holes.

f. When rigging or checking the A/B FCU control linkage check the alignment marks on the cambox output arm to ensure that the clutch has not been dis-engaged.

g. To prevent damage to the A/B FCU the LP pumps must be 'OFF' and the nozzle must not be moved when rigging pin UT 1008 is fitted.

2. ENGINE CONTROL SYSTEM.

The power output of the engine is controlled by manually selecting and automatically regulating the engine and after-burning fuel flows.
Manual selection is by a lever in the cockpit.
This lever is mechanically connected to a cambox mounted on the under-side of the engine,which causes cockpit lever movement to operate the engine high pressure shut off valve,the engine fuel control unit and the after-burner fuel controls in their correct sequence..

In order to prevent the engine operating limitations to be exceeded the manual controls can be over-ridden by the automatic control system.
With the throttle lever set in the Max.Dry position the engine will be normally controlled under the influence of the control amplifier.

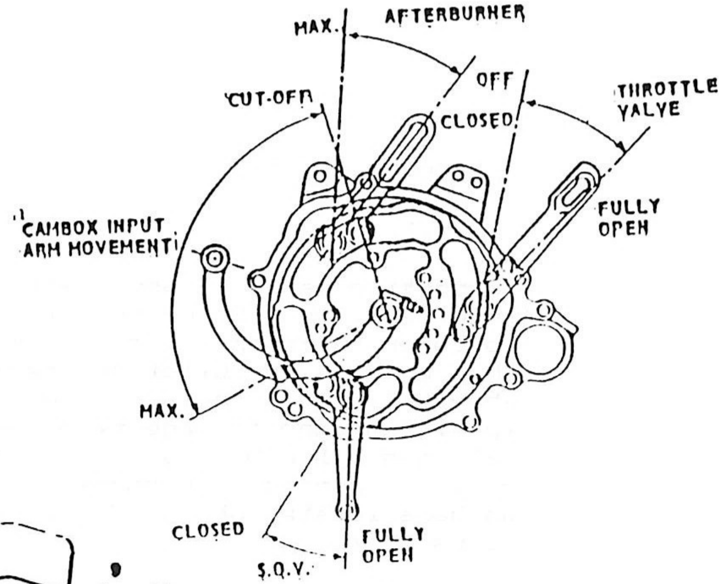
3. CAMBOX.

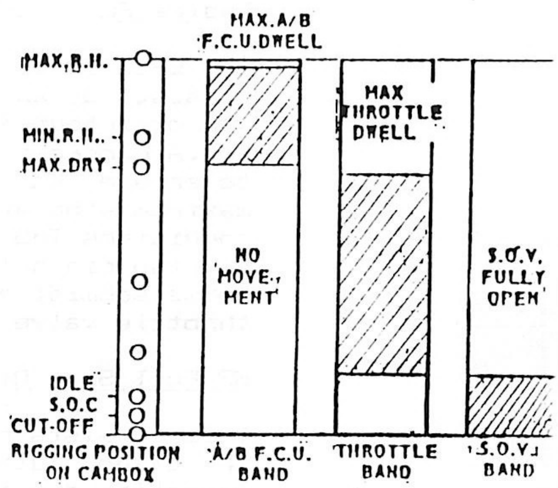
The cambox is bolted to the underside of the high speed gear-box and consists of a housing and cover assembly containing a camplate and shaft assembly,and three cam followers.The shafts carrying the camplate and cam followers are supported in ball bearings housed in the cambox housing and cover.

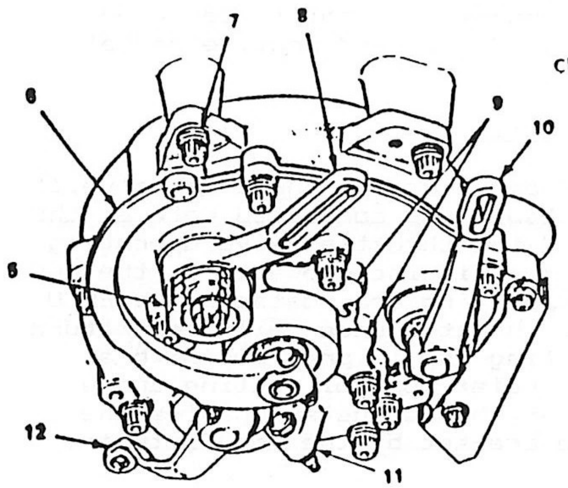
The camplate has three profiled cam tracks cut into it.Roller followers,attached to the cam follower shafts,run in cam tracks.To prevent backlash between the cam tracks and followers a second roller,secured to a pivoted follower arm,runs underneath the main roller.The roller fasteners are spring loaded apart on to the opposite sides of the cam track.

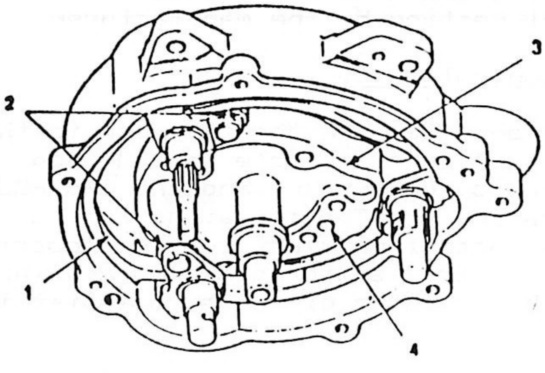
The input arm is located and secured to the camplate shaft by an eccentric pin,which passes through the arm and along a slot in the shaft.
Internal stops are provided at the Shut Off and Max A/b positions and an external stop is provided at the Max A/B position.The external stop is provided in case of failure of the Max A/B internal stop.

The cam housing cover is provided with six holes for rigging pins.The holes are marked and align with holes in the camplate for control setting.The rigging positions are:-Cut Off,SOV,Min A/B,Max.Dry,Idle and Max.A/B.When not in use these holes are covered by two cover plates.









1. Cam Track.
2. Roller Followers.
3. Camplate.
4. Rigging Holes.
5. A/B FCU Clutch.
6. Cambox Input Arm.
7. Mounting Bolt.
8. A/B FCU Output Arm.
9. Rigging Hole Covers.
10. Throttle Valve Output.
11. Cambox Input Arm Stop.
12. SOV Output Arm.

<u>CAMBOX - INTERNAL LAYOUT.</u>

4. CONTROL RIGGING.

General.
The EFCU and SOV output arms are attached to their respective cam follower shafts in a similar manner to the input arm.The A/B FCU output arm is splined to its cam follower shaft and incorporates a clutch mechanism. This enables the pilot to operate the EFCU and SOV should the after-burner mechanism fail and the torque loading on the linkage rise above a certain value.The EFCU and A/B FCU output arms are slotted and serrated at their control rod connection points.Serrated washers locate their rod ends and provide radial adjustment.

Engine Fuel Control Unit.

The EFCU control rod operates the throttle valve.It consists of an adjustable rod connected between the cambox output arm and the throttle valve operating arm.A compression spring is incorporated in the rod to ensure that the operating arm contacts the EFCU maximum stop at full throttle under all temperature conditions.The operating arm is provided with a rigging pin hole,to assist control setting,and a Messerschmidt adjuster.This adjuster enables the throttle valve to be pre-set by the manufacturer.

HP Fuel Shut Off Valve.

This consists of an adjustable rod connected between the cambox output arm and the SOV operating arm.The operating arm is provided with a rigging pin hole,to assist control setting and a Messerschmidt adjuster,for initial setting by the manufacturer.

After-burner Fuel Control Unit.

The A/B FCU control operates the throttle cam in the A/B FCU and consists of an adjustable control rod connected between cambox output arm and the A/B FCU manual control operating arm.The operating arm is crankedd and relays control movement to the throttle selector valve via a fixed length rod.The operating arm is provided with a rigging pin hole,to assist in control setting.

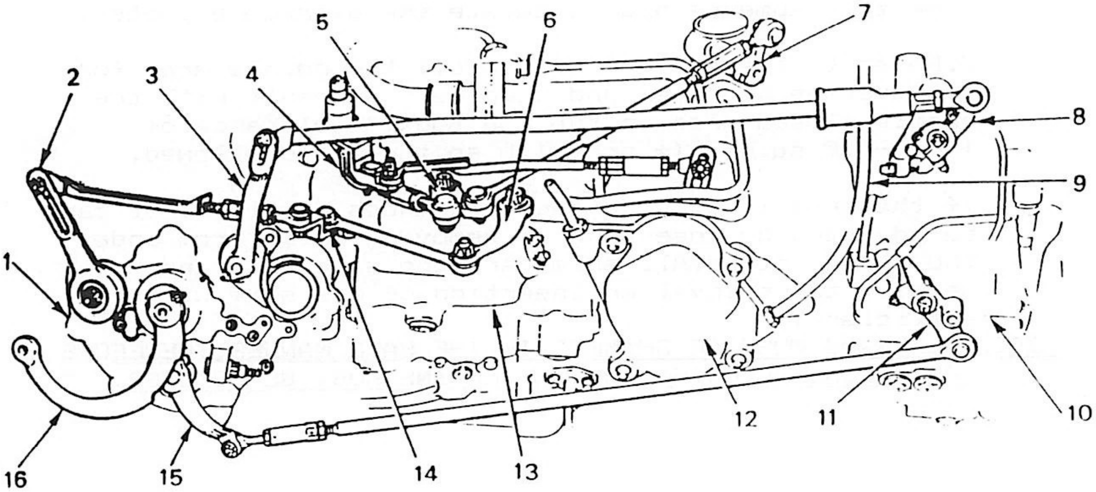
After-burner Feedback Mechanism.

When after-burner operation is required the latch on the throttle lever mechanism must be operated to allow the selection to be made.(With the exception of PTR)This will set the engine control linkage to the required position which will light up the after-burner unit.

However the operation of the normal engine must not be disturbed and normal pressures throughout the engine must be maintained.To avoid any interference between the engine and after-burner operation a feed back mechanism is provided.This will correct the fuel supply and nozzle position to match the engine performance and maintain the engine operating conditions within limitations.

5. CONTROL RIGGING.

Full details of control rigging and checking can be found in the relevant Servicing Manual.
All clearances for stop to lever are also in the Servicing Manual with the exception of three.
The three exceptions are to be found in the Engine Log Book and are: A/B FCU Max.Stop, Nozzle Open and Closed Stops.



1.Cambox.
2.A/B FCU Output Arm.
3.Throttle Valve Output Arm.
4.A/B FCU Feedback Arm.
5.A/B Nozzle Selector Arm.
6.Throttle Selector Valve Arm.
7.Pre-open Bleed Valve Arm.
8.Throttle Valve Arm.
9.A/B Nozzle Feedback Linkage.
10.Engine Fuel Control Unit.
11.SOV Arm.
12.Feedback Linkage Control Box.
13.A/B FCU.
14.A/B FCU Manual Control Arm.
15.SOV Output Arm.
16.Cambox Input Arm.

ENGINE CONTROLS.

6. NOZZLE AREA.

Checking and Setting.

General.
The nozzle closed area is set by the manufacturer. As it is a function of the performance of the engine, therefore,when any component is changed which can affect the area the nozzle area must be checked.Those components which,when changed,can affect the nozzle area are the nozzle actuating rams and the nozzle actuating ring.The area for each nozzle is quoted in each Engine Log Book.

Procedure.

Tools: Vernier Caliper,609.6 mm. (24 inch).

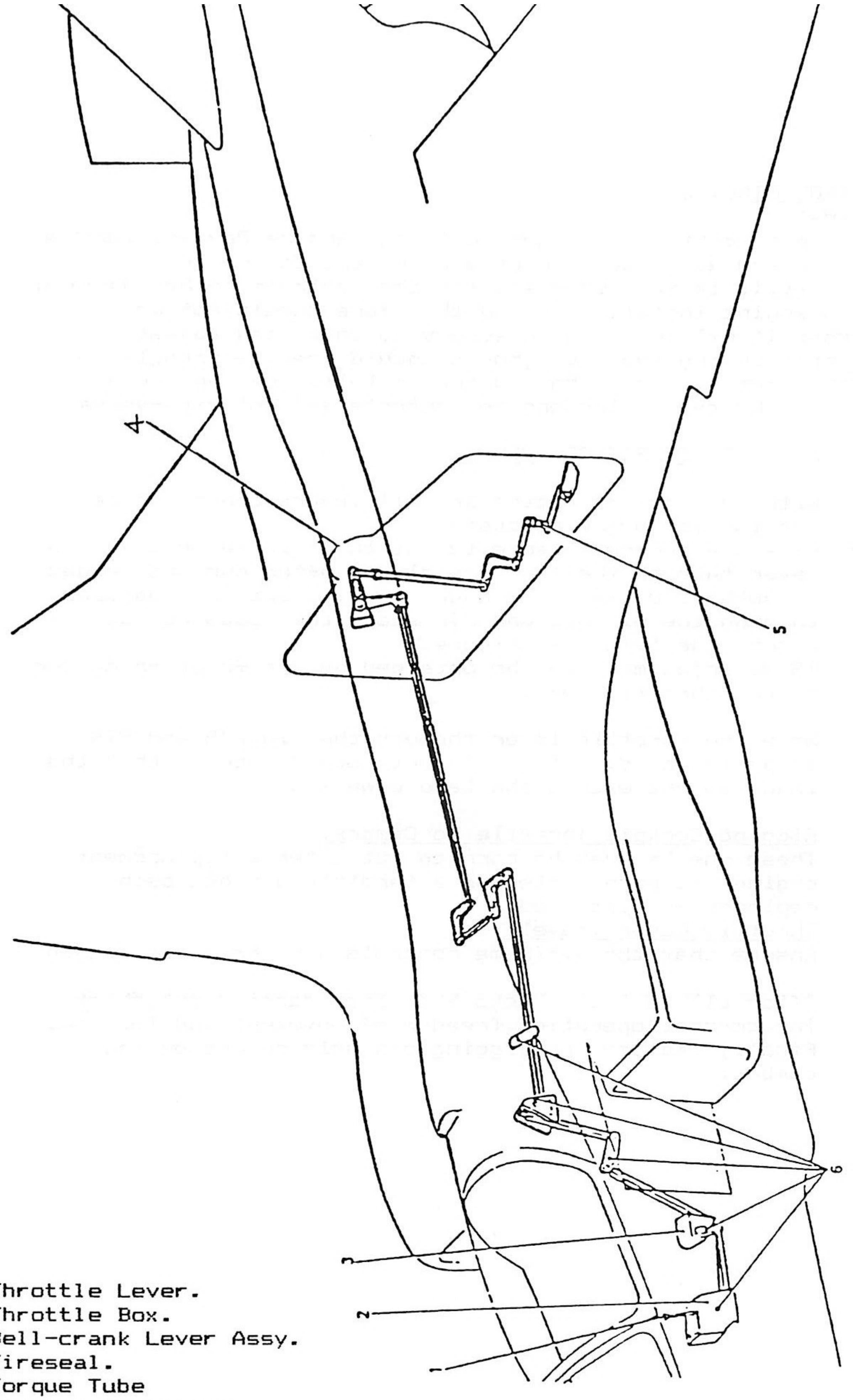
1.Manually close the nozzle and check that the nozzle closed stops are firmly seated.

2.Measure the nozzle diameter between the four pairs of master segments and calculate the average diameter.

3.Refer to the graph and read off the nozzle area for the average diameter and compare the result with the nozzle closed area in the Log Book.A tolerance of + or - 10 sq.cm. (+ or - 1.5 sq,ins.). is allowed.

If the area is outside the tolerances permitted it can be adjusted by inserting or removing shims from under the closed stops.All shims are the same size,and usually the removal or insertion of one shim will be sufficient.

NOTE. ALL RAMS MUST BE SHIMMED IN THE SAME MANNER,THEREFORE ON AN INSTALLED ENGINE THE ENGINE MUST BE REMOVED.



1. Throttle Lever.
2. Throttle Box.
3. Bell-crank Lever Assy.
4. Fireseal.
5. Torque Tube
6. Rigging Positions.

THROTTLE CONTROL LAYOUT.

CONTROL RIGGING.

General.

The engine controls are set-up in the Engine Bay and further checked and adjusted if necessary on the Engine Test Facility.It is not necessary for the controls to be adjusted on an engine installation and therefore should not be touched.It will only be necessary to check and adjust controls during fault diagnosis,should they be wrongly set. It therefore follows that during installation the cockpit controls be set to the engine controls and not vice-versa.

7. RIGGING COCKPIT CONTROLS.

With the engines fitted and all levers connected carry out the following checks:-
Attach a spring balance to the throttle lever,move the lever through the full normal and after-burning ranges in both directions,and check that,except when passing through the Min.A/B and PTR stops,the loads do not exceed the laid down figure.
(Some adjustment can be obtained by the friction damper on the throttle box).

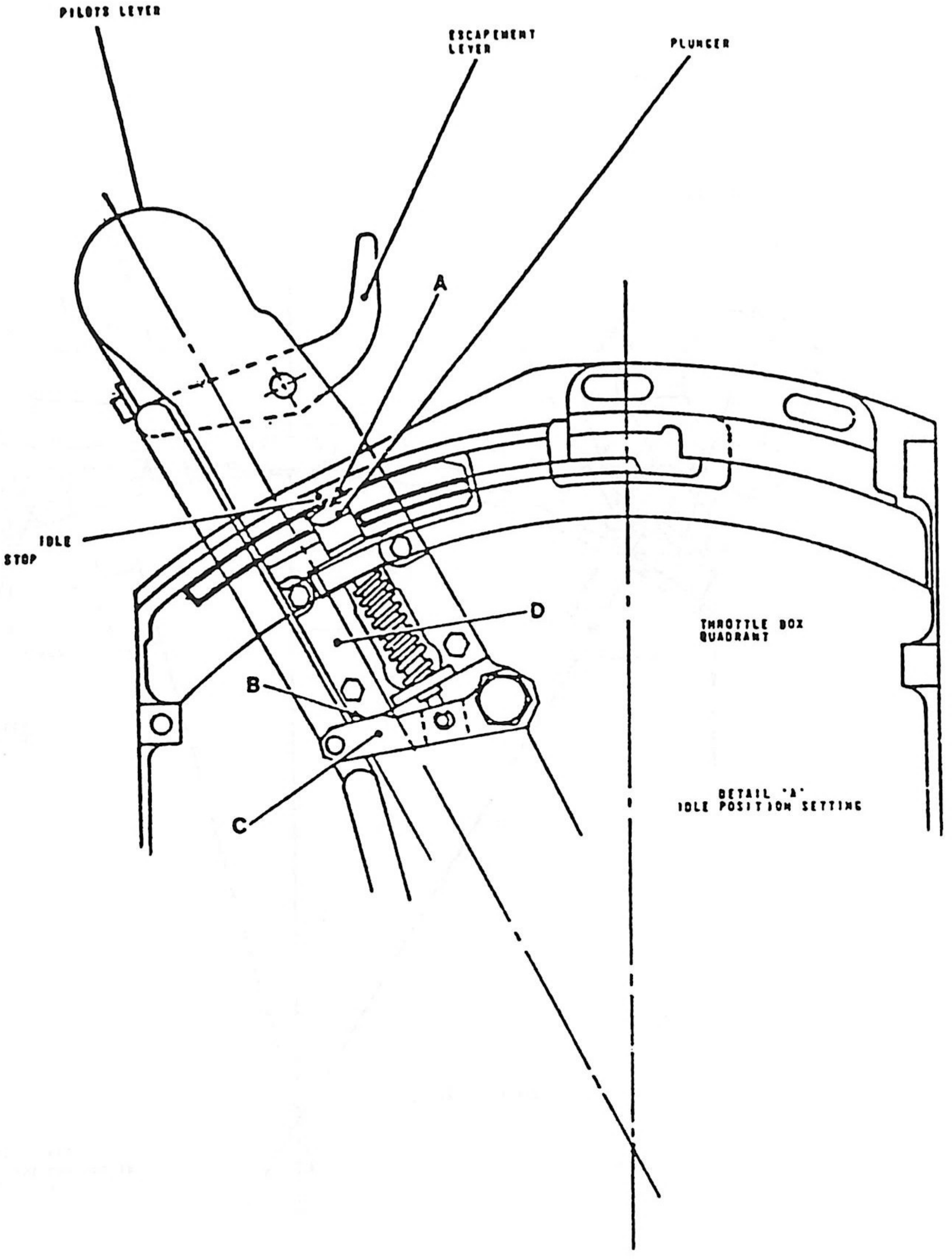
Move the throttle lever through the Min.A/B and PTR stops in the direction of shut-down,and check that the loads do not exceed the laid down figure.

Rigging Cockpit Throttle To Cambox.

These checks must be carried out after a replacement engine has been fitted or a throttle box has been replaced or disturbed.

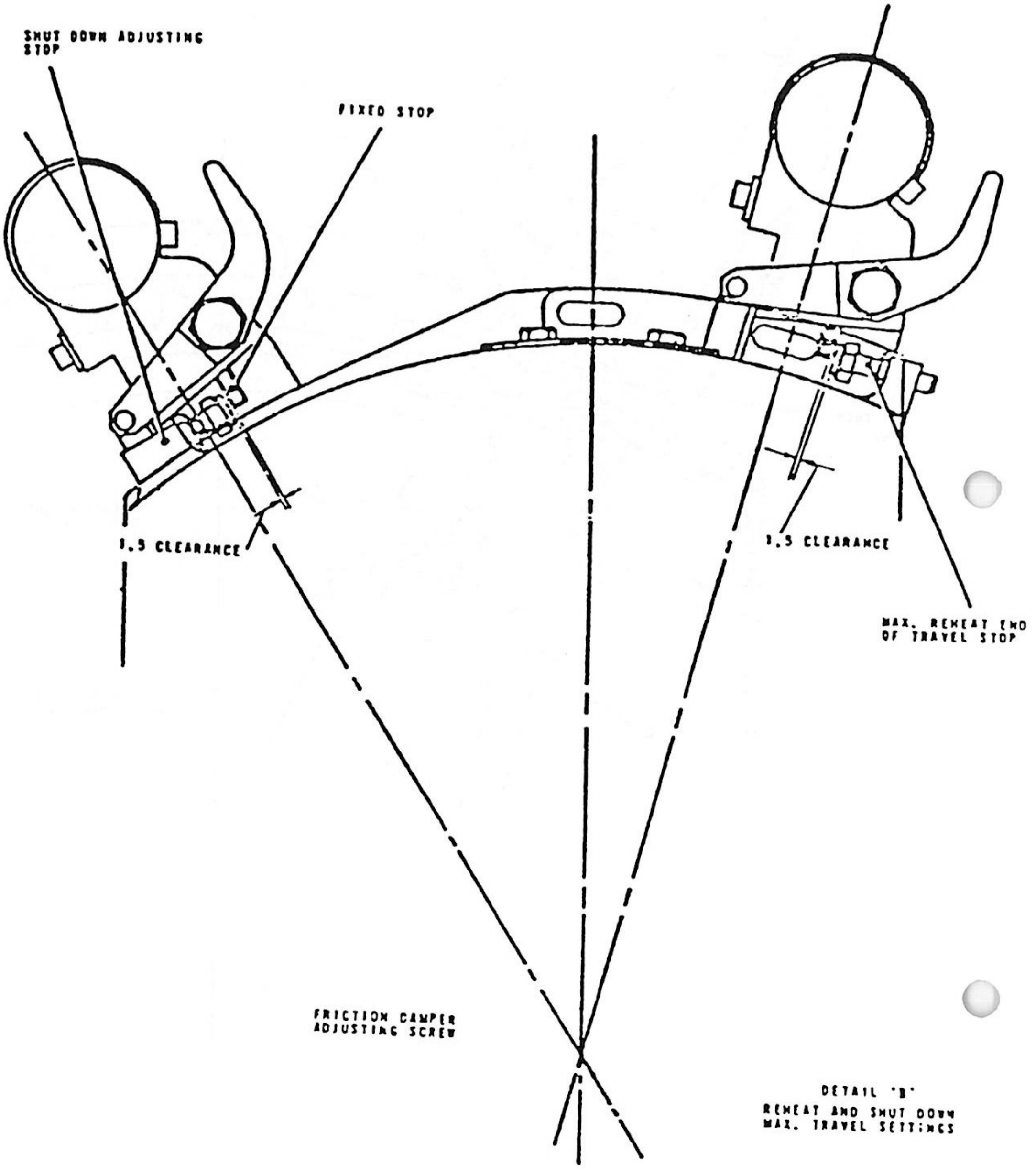
1. Throttle Lever Travel.
   Ensure that the airframe controls are correctly rigged.

2. After all control checks have been carried out,check for correct operation,freedom of movement and locking. Finally replace the rigging pin hole covers on the cambox.



<u>Rigging the Idle Stop.</u>
Rig pin the cambox to the idle position,the idle stop in the cockpit is a fixed stop,to adjust the throttle position either lengthen or shorten the input lever at the cambox.The idle setting check is the first check carried out.

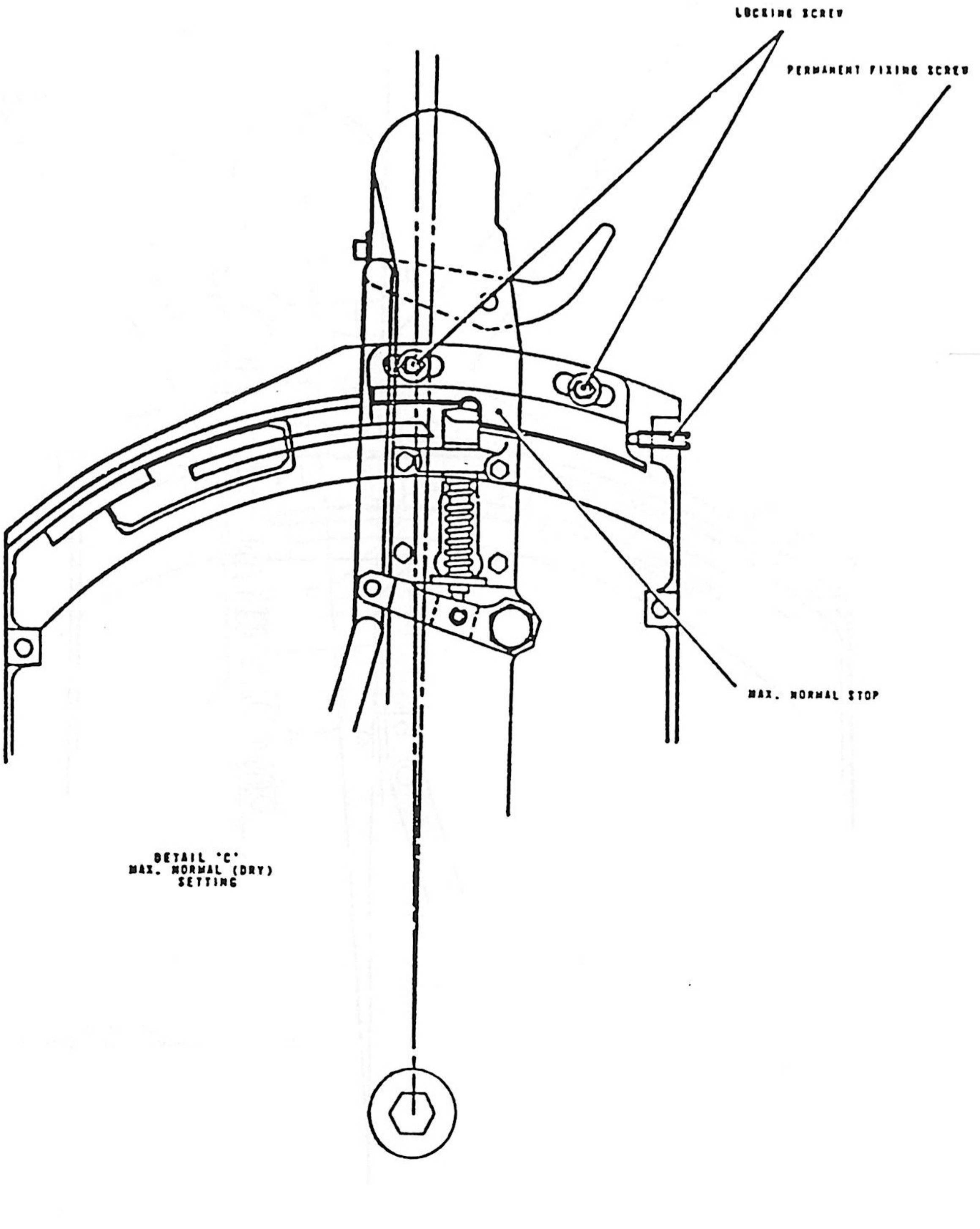
<u>IDLE POSITION SETTING.</u>



<u>Rigging the Cut-off Position.</u>
Rig pin the cambox in cut-off,check that the clearance between the screw of the shut-down stop on the throttle box and lever is 1.5mm.

<u>Rigging the Max A/B Stop.</u>
Rig pin the cambox in Max A/B ,check that the clearance between the screw of the Max A/B stop on the throttle box and the lever is 1.5mm.

<u>MAX A/B & SHUT-DOWN MAX. TRAVEL SETTINGS.</u>

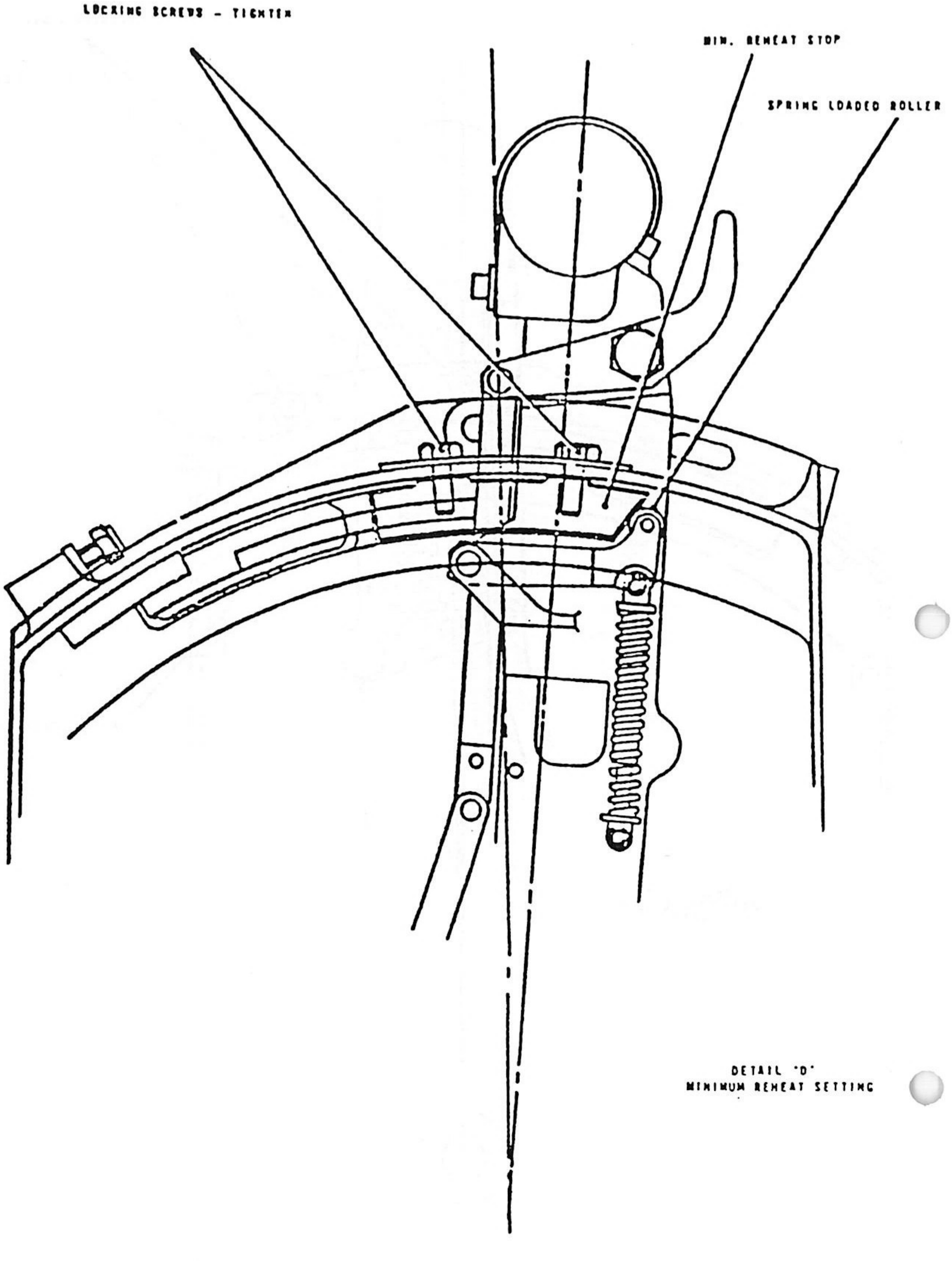


DETAIL 'C'
MAX. NORMAL (DRY)
SETTING

<u>Rigging the Max Dry Stop.</u>

Slacken the screws of the Max Dry stop and unscrew the permanent fixing screw at the forward end of the throttle quadrant. Rig pin the cambox in Max Dry, move the stop until it abuts the plunger on the throttle lever, tighten the locking screws and screw in the permanent fixing screw until it abuts the stop.

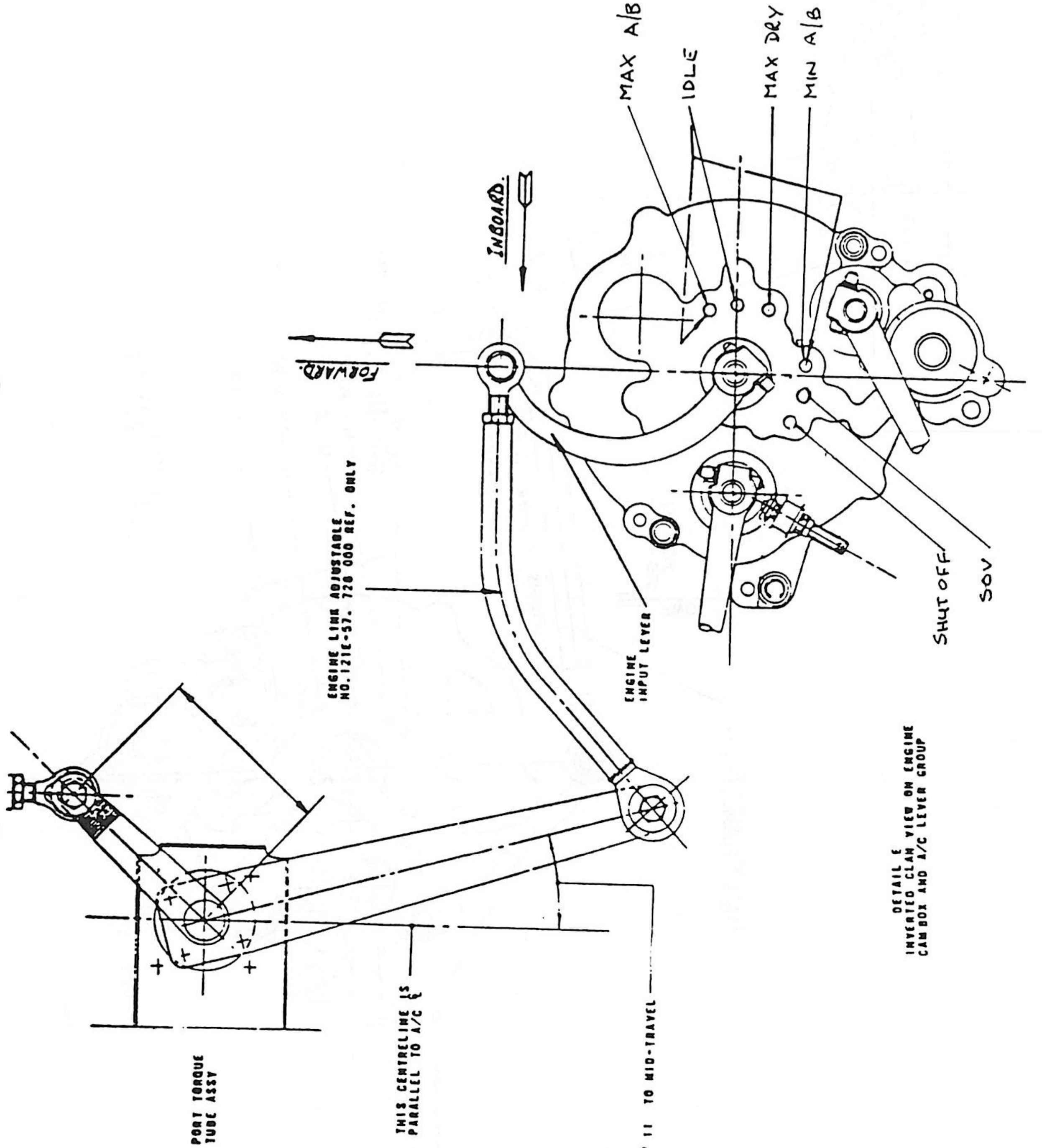
<u>MAX.DRY SETTING.</u>



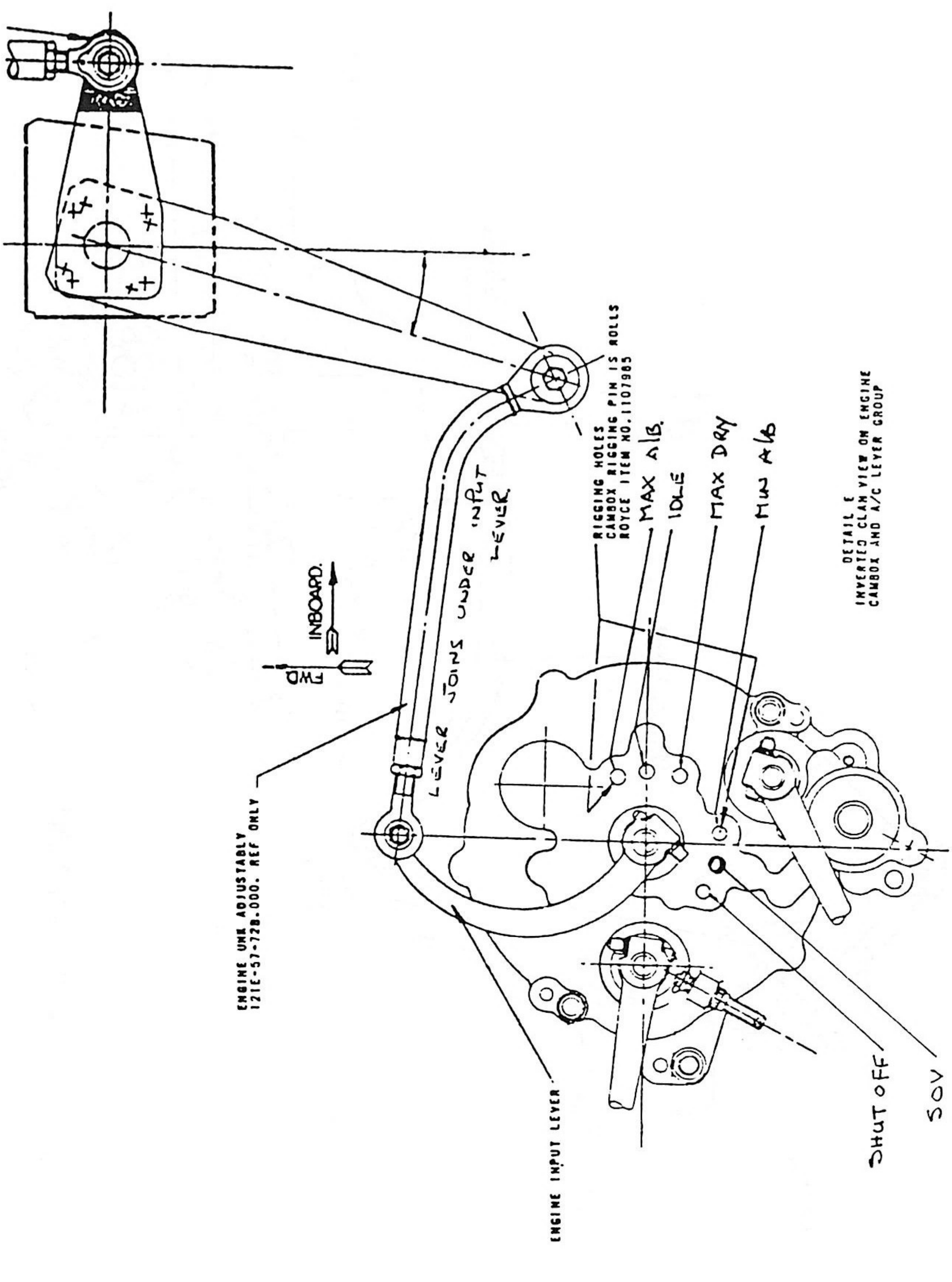
DETAIL "D"
MINIMUM REHEAT SETTING

<u>Rigging the Min.A/B Stop.</u>
Slacken the locking screws on the Min A/B stop on the throttle box,rig pin the cambox in Min.A/B,move the stop until it abuts the roller on the throttle lever,tighten the locking screws.

<u>MIN A/B SETTING.</u>



INVERTED PLAN VIEW ON ENGINE CAMBOX
AND AIRCRAFT LEVER GROUP. (PORT).



INVERTED PLAN VIEW ON ENGINE CAMBOX
AND AIRCRAFT LEVER GROUP.(STBD).

ROLLS-ROYCE/TURBOMECA.

ADOUR 811/815.

FIRE PROTECTION SYSTEM.

Introduction.

1. General.

2. Detection.

3. Suppression.

4. Testing.

5. Servicing.

1a. General.

Two types of fire detection are in current use on the aircraft:

a.Point Detection.

b.Graviner Fire Wire.

When the modification programme is complete all aircraft will be fitted with the Graviner type fire detectors.

For fire protection purposes the two propulsion units are isolated by a vertical firewall and each bay is divided by a radial firewall into fire zones. Provision is made for indication of overheat conditions within either the engine or a specific fire zone.

b. Fire Zones.

Each propulsion unit bay is divided into two zones by a titanium fireseal of channel construction.The seal is in two parts,one part on the fuselage within the engine bay and the other part on the engine door.With the engine door closed the seal abuts on the fireseal mounted on the engine.The vertical firewall is lined with a corrugated titanium web and the engine bay roof and rear face of the forward bulkhead protected by a pre-fabricated insulating blanket.

c. Fireseals.

A circular fireseal assembly is attached to the exhaust assembly and divides the propulsion unit into two zones.Zone 1 is the forward zone and contains all possible sources of leakage of inflammable fluids with exception of the nozzle dry drain manifold which ends in Zone 1 after passing through the fireproof bulkhead.

A square shaped channel around the outer periphery of the engine houses a fireproof sealing ring.The sealing ring is a fabricated assembly of fireproof material which maintains contact with the airframe fireseal thus preventing gas leakage at this point.

d. Fire Warning System.
There is a detection system in each of the four fire zones on the aircraft,the unmodified type being the point detection system which relies on a resistance change in the circuit and the modified Graviner type which relies on a capacitance change in the circuit. Both systems send a signal to a detector unit,one for each zone,which illuminates the appropriate fire warning lamp,operates the attention getter and the audio warning.

e. Engine Overheat Warning.
To provide indication of engine internal overheat a detector probe is fitted in the cooling air outlet. This senses the the temperature of the cooling air, should the temperature exceed 400 degrees C.a RED warning lamp on the CWP,either ENG.OH1 or ENG.OH2,will illuminate.In this instance the engine at fault must be shut down.

f. Engine External Protection.
The exterior of the engine in Zone 1,because of the by-pass duct,is relatively cool compared with the exterior of a straight flow gas turbine.The by-pass duct protects external components from excess heat and ducts in the engine door create an airflow over the exterior of the engine thus dissipating any excess heat.The units in Zone 2 are protected by an insulation blanket fitted around the exhaust collector.In the event of fluid leakage,except for ruptured pipes,the engine incorporates a drains system which carries any leaks through pipes to the engine bay door bottom mount panel.

2a. Detection System.
Either detection system consists of four sub-systems,one to each fire zone.The pint detection system consists of a chain of detectors linked by a fire resistant cable,a control unit and one fire warning lamp.Each detector chain is routed round the associated fire zone and connected to a detector unit in the keel tunnel.The control unit is connected to the associated warning lamp on the starboard forward console in the cockpit.The detectors,with the exception of those in the tail unit rear fairing,are of the low temperature type designated 7W and operate at 350 degrees C.Those in the tail fairing are designated 8W and operate at 500 degrees C.

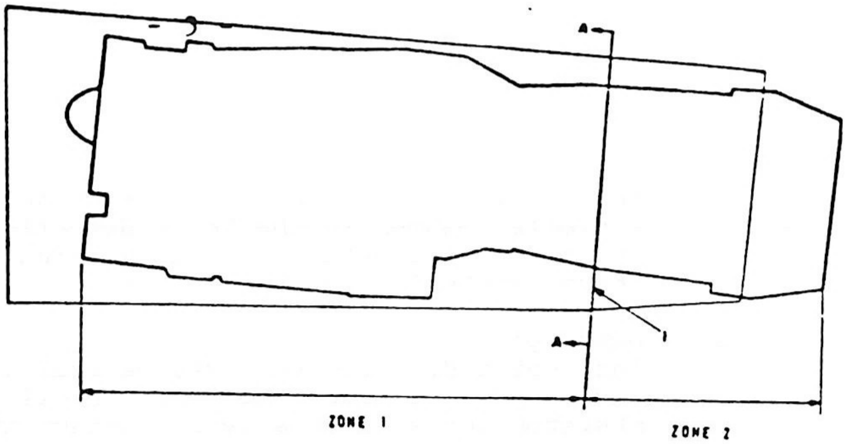
The Graviner Fire Wire system runs around each zone in a similar manner to the Point detection system and apart from the detector boxes,sensing a capacitance change,works in the same manner.

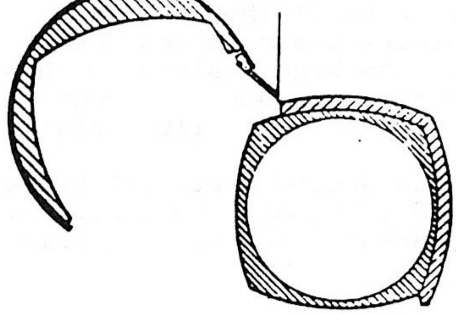
b. Detectors.

Each point detector consists basically of a bi-metal strip and a resistor.The strip normally by-passes the resistor and are normally in contact thus providing a low resistance path for the current.If the operating temperature is exceeded the strips separate and the current then must pass through the high resistance thus causing a current drop in the detector box.This drop will activate the detector box which will illuminate the appropriate warning lamp.
In the Graviner Fire Wire system excess heat will cause a capacitance change in the wire,this will be sensed by the detector box and the appropriate fire warning lamp will be lit.

c. Control Units.

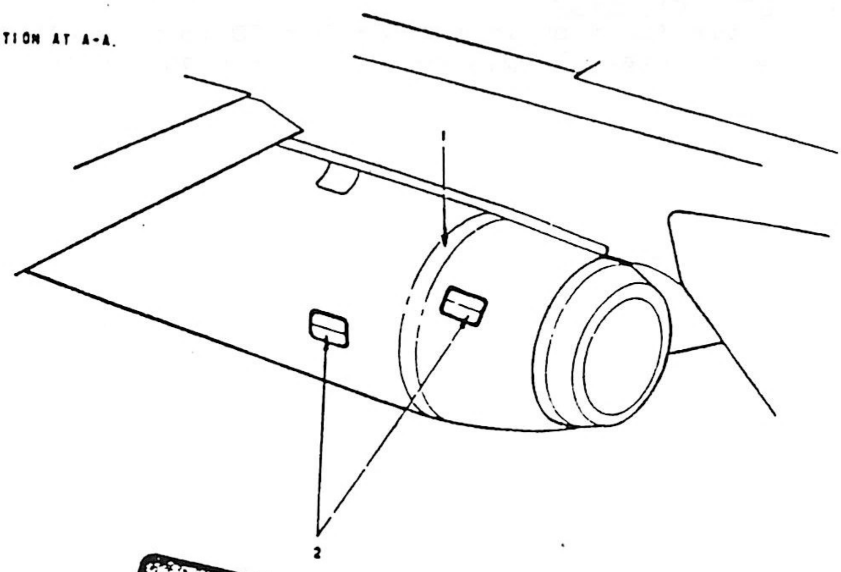
THeir function is to switch a 28 volt supply to the appropriate lamp,attention getter and audio warning.

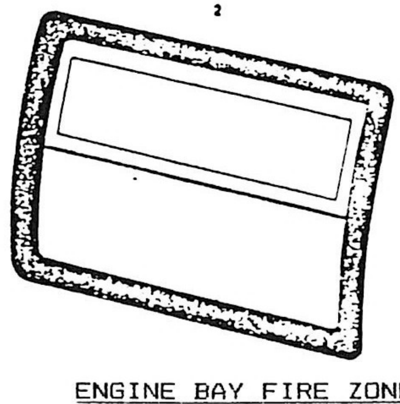




SECTION AT A-A.

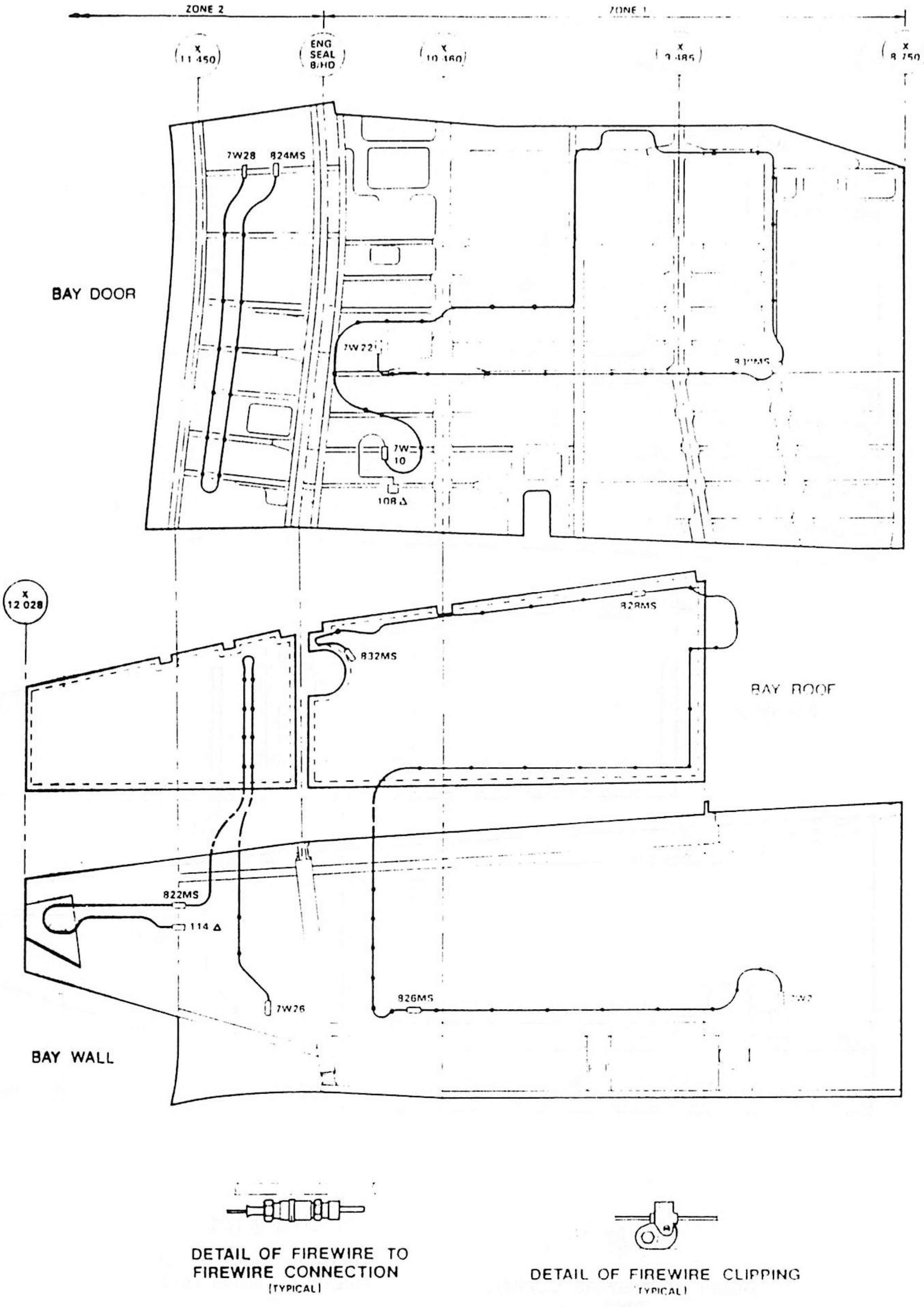
With the engine bay door removed the fire detection circuit will be broken. To carry out ground runs the circuit must be re-made.



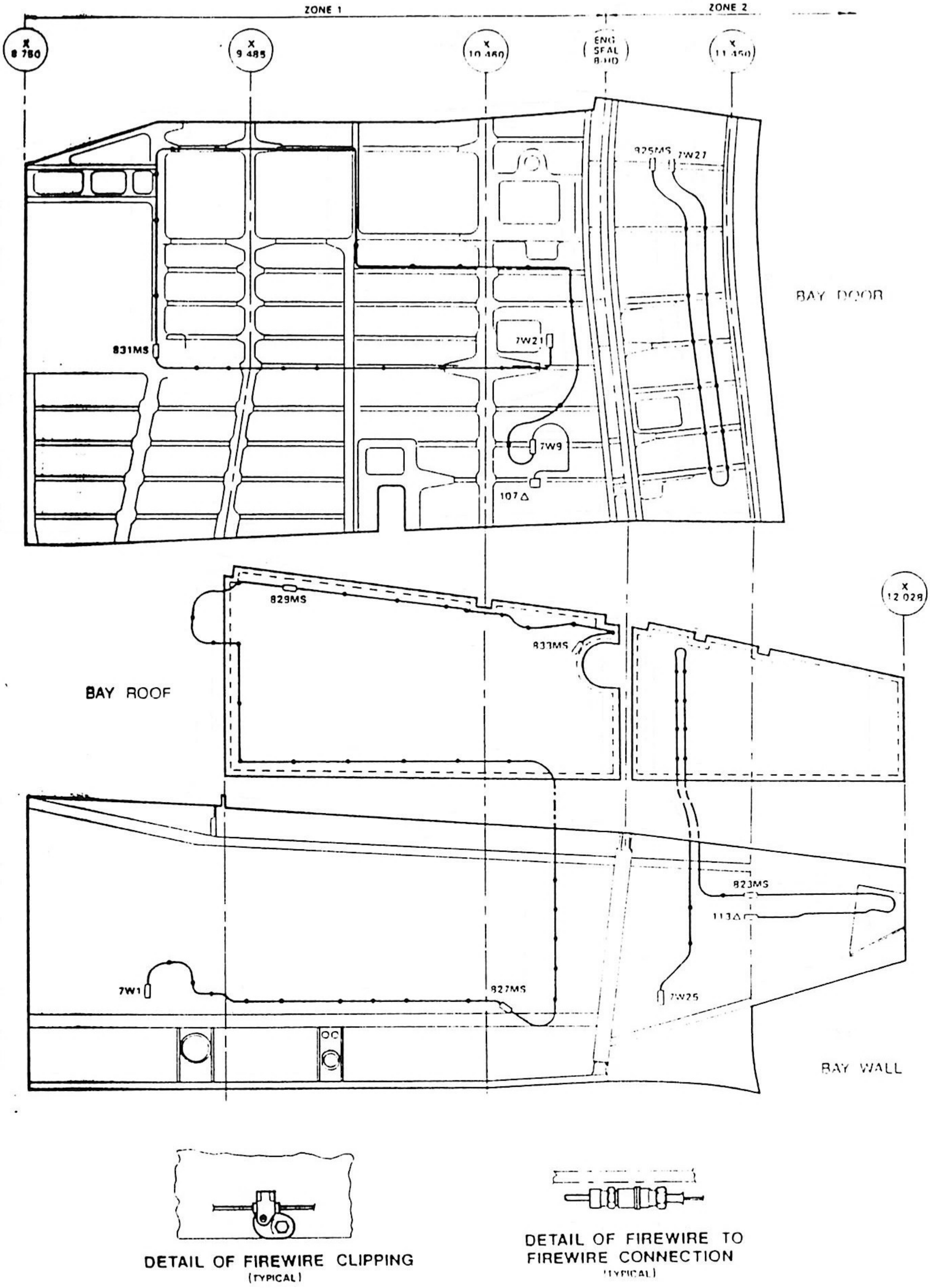


1. Fire Seal.
2. External access.

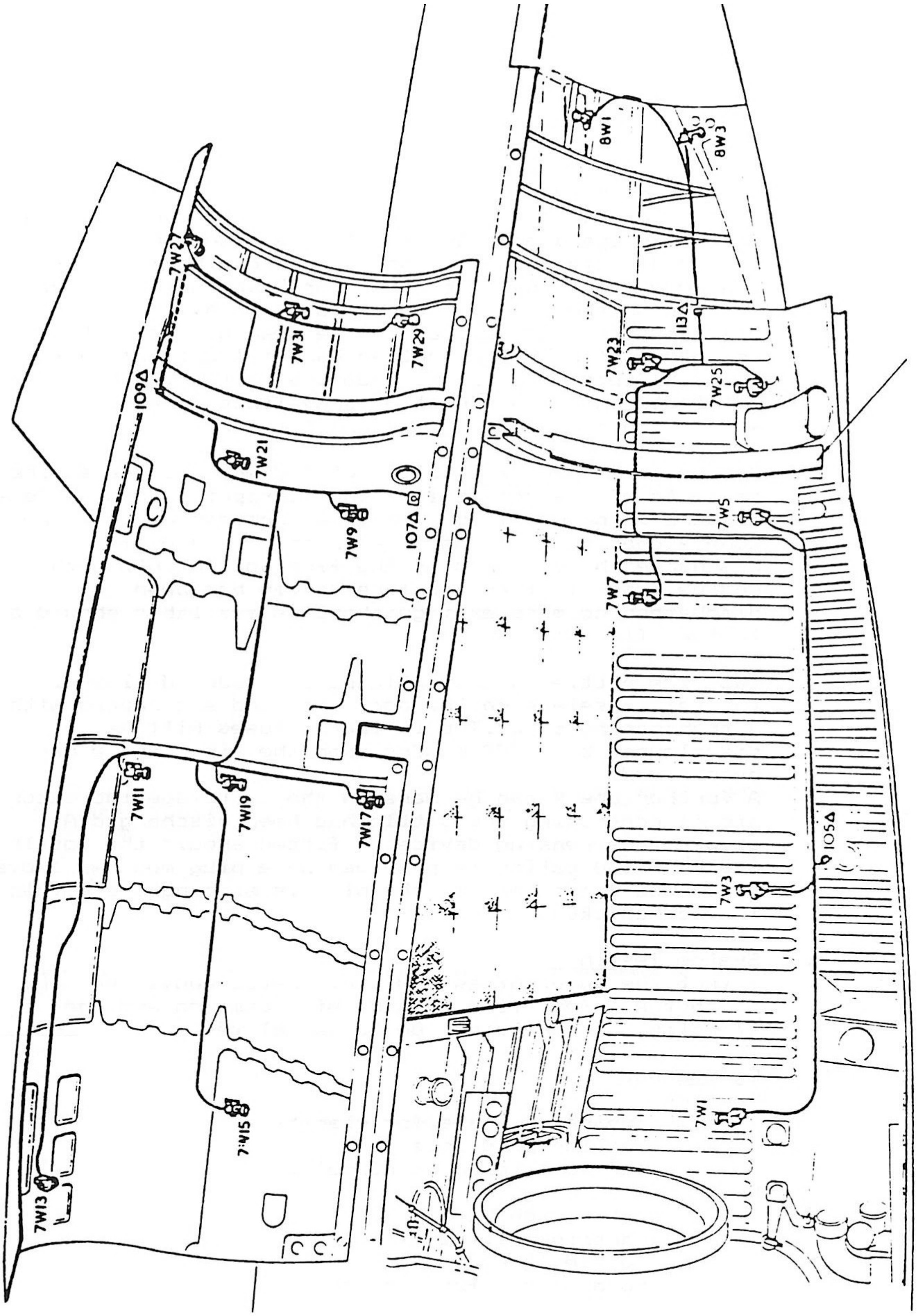
ENGINE BAY FIRE ZONES.



Routeing of the Firewire loops No 1 engine



Routeing of the Firewire loops No.2 engine



DETECTOR LOCATIONS.

3. <u>Fire Suppression.</u>

Fire suppression is provided by a 6lb.BCF dual headed cartridge operated automatic fire extinguisher situated in the tail fuselage on the starboard side.The system can be operated by either Port or Stbd.indicator/push buttons on the stbd.forward console or by the manually operate fire/crash switch at the rear of the port side console,lifting the operating bar will automatically fire the bottle.Pipelines from the extinguisher terminate in two perforated spray lines running fore and aft in each engine bay ZONE 1.

Operation of the fire button will discharge the entire contents of the bottle into the appropriate engine Zone 1,there is no provision for fire suppression in either Zone 2,operation of the fire/crash switch will discharge the contents of the fire bottle into both engine Zones 1.After the fire bottle has been discharged no more extinguishant is available should a further fire occur.

Two fire bottle indicator fuses are mounted flush in the tail fuselage on the port side and are capped with a transparent cover.The indicator fuses will be discoloured by a RED powder when the fire bottle has been fired.

A further check can be made on the cartridge indicator pin,if protruding the bottle has been discharged,A temperature sensing device is fitted should the bottle overheat.Indication is provided by a plug mounted above the fused indicators.If the plug is missing the bottle must be checked.

4. <u>System Testing.</u>

Select the mute/on/test switch,located above the CWP, to test.All four fire warning will come on and the attention getter.Select ON to cancel test.

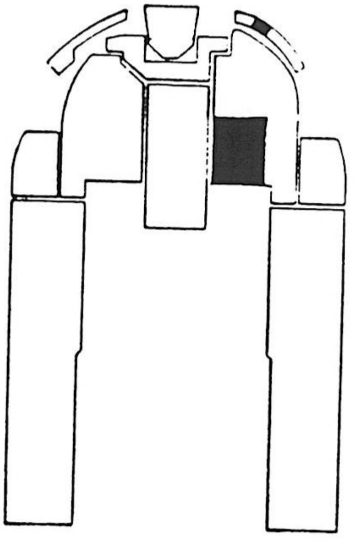
5. <u>Servicing.</u>

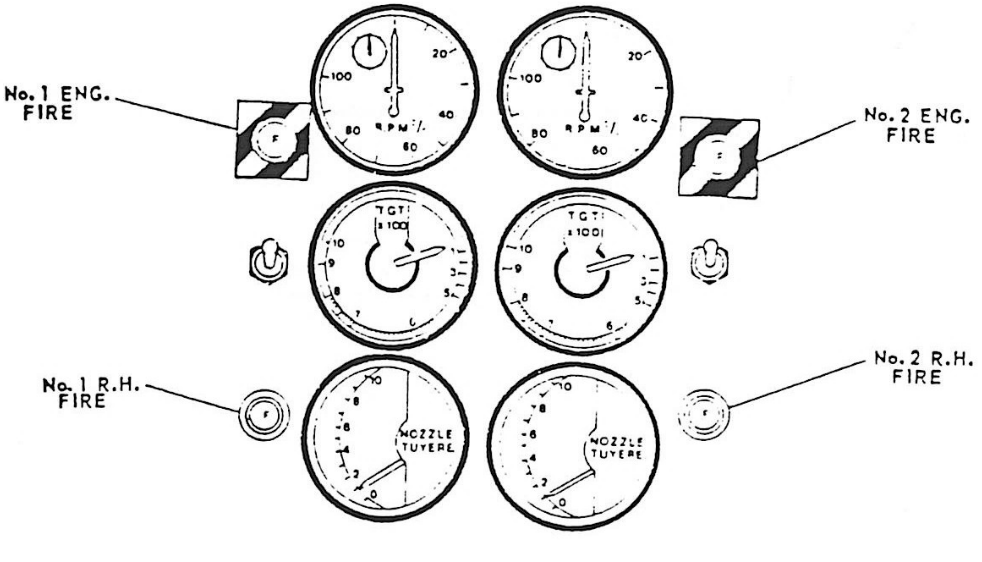
Routine.

- Indicator fuses for clarity.
- Sealing plug intact.
- CWP test to check circuit.

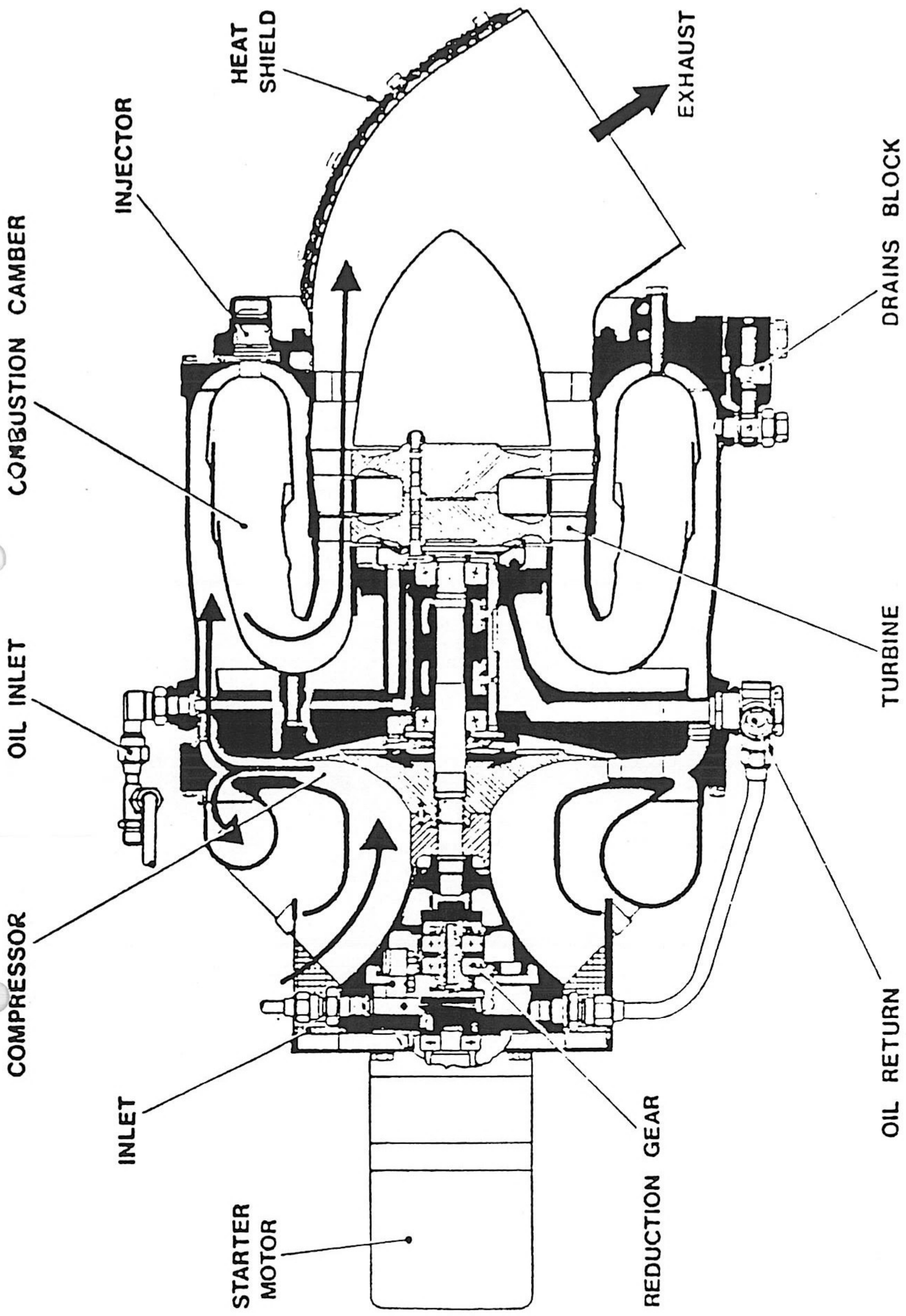
Periodic.

- Test weigh bottle.
- Cartridge life.
- Bottle life.
- Spray lines for blockage.





CONTROLS AND INDICATORS.



AIR GENERATOR. SCHEMATIC.

ROLLS-ROYCE/TURBOMECA.

ADOUR MK.811/815.

ENGINE STARTING.

CONTENTS.

1.Introduction.

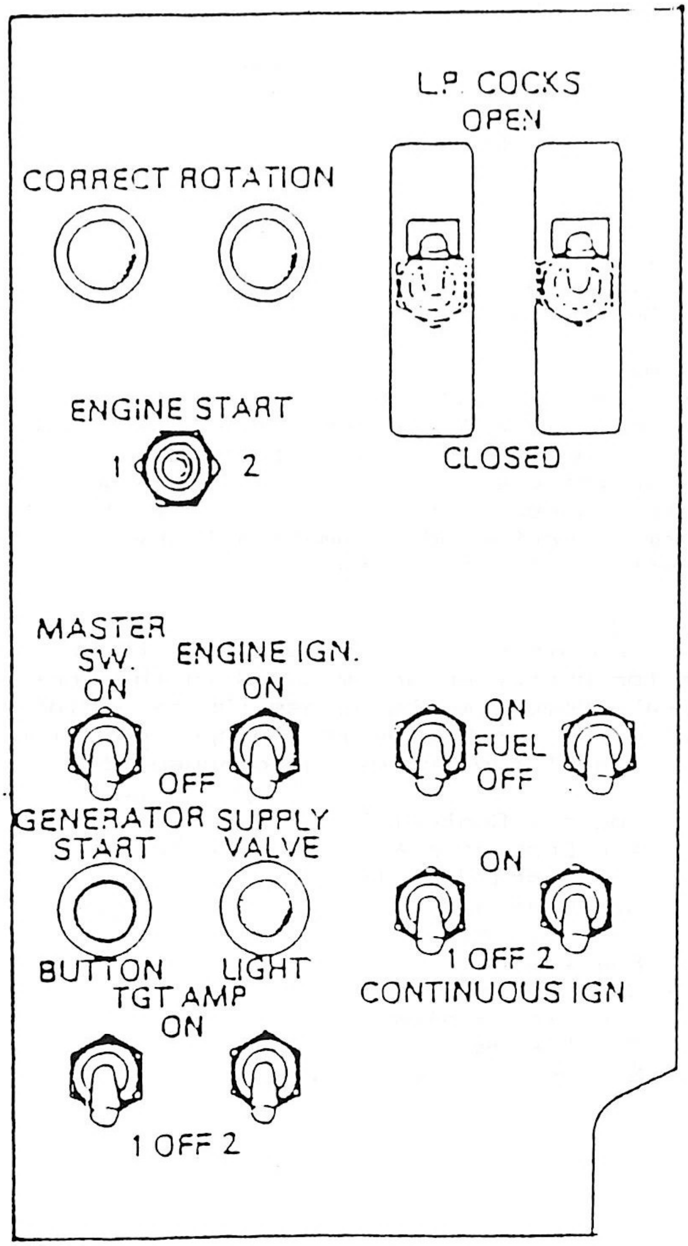
The starting system consists basically of a Micro-turbo Air Generator - a small gas turbine engine - which is automatically controlled once initiated.
Air,bled from the compressor,is fed to the main engine turbo starter on operation of the cockpit start switch.The whole system is protected automatically by speed and pressure switches in the system.

2.Air Generation.

The Micro-turbo Air Generator,complete with the various components for operation,are mounted in the Port and Stbd.air brake compartments.Access for servicing is obtained with the air brakes in the open position.The system consists of the following components:-

a.Cockpit Control Panel.
b.Air Generator Electric Starter
and Speed Detector.
c.Air Generator.
d.Fuel System.
e.Purging Unit.
f.Oil System.
g.Ignition System.
h.Air System.
i.Electronic Control Box.

CONTROL BOX
23K



ENGINE CONTROLS AND INDICATORS.

a. Cockpit Control Panel.

The cockpit control panel is situated on the centre lower console. The switches on this panel control the Air Generator Start System and the Main Engine Start System. Located on the control panel are the following:-

Engine Start Switch	1/OFF/2.
Ignition Switch.	ON/OFF.
Air Generator Start Master Switch.	ON/OFF.
Air Generator Start Button incorporating operating light.	
Air Valve Open Indicator.	AMBER.
TGT Amplifier Switches.	ON/OFF.
Continuous Ignition Switches.	ON/OFF.
LP Cock Switches.	OPEN/CLOSED.
LP Pump Switches.	ON/OFF.
Correct Rotation Lights, Port/Stbd.	Green.

b. Electric Starter Motor and Speed Detector.

The starter motor is a very robust unit designed to withstand high speeds whilst on and off load. Integral with the starter motor is a speed detector consisting of a phonic wheel and a speed sensing probe. The starter motor is attached to the inlet side of the AIr Generator and drives through a gear chain forming part of the Air Generator.

The starter motor receives its power supply from the aircraft battery to drive the Air Generator.
Once the Air Generator has reached self-sustaining speed, 69% RPM, the electrical supply to the motor is cut off and the starter motor then becomes driven by the Air Generator and takes the part of a speed detector. The output from the phonic wheel and sensor to the electrical control box is therefore maintained. This signal to the control box is fed to the fuel spill valve which governs the Air Generator at its correct speed to meet the demands for air supply.

c. Air Generator.

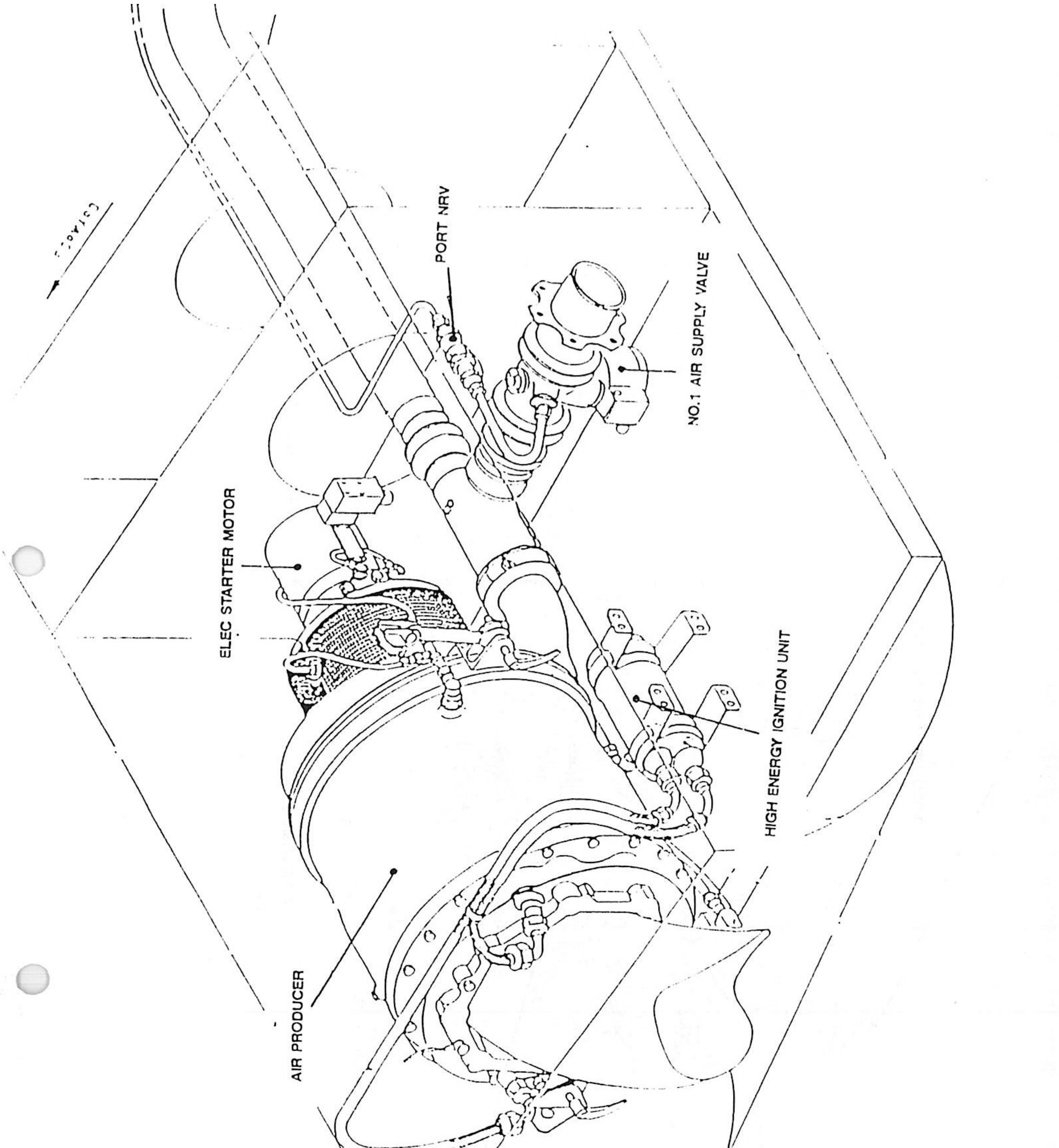
The Air Generator is a small gas turbine engine with a centrifugal type compressor driven by a two stage axial flow turbine. The combustion chamber is of the folded annular type fitted with eight burners and two igniters. Air is compressed at a maximum rate of 72Kg/Min. with a bleed of approximately 25Kg/Min. to atmosphere via the discharge valve or direct to the Adour turbo-starter when a start is initiated. The remaining air is passed to the combustion chamber for the normal function of a gas turbine engine.

The rotor is driven by the starter until 69% RPM.is reached.At this point the control box cuts out the starter and the ignition.

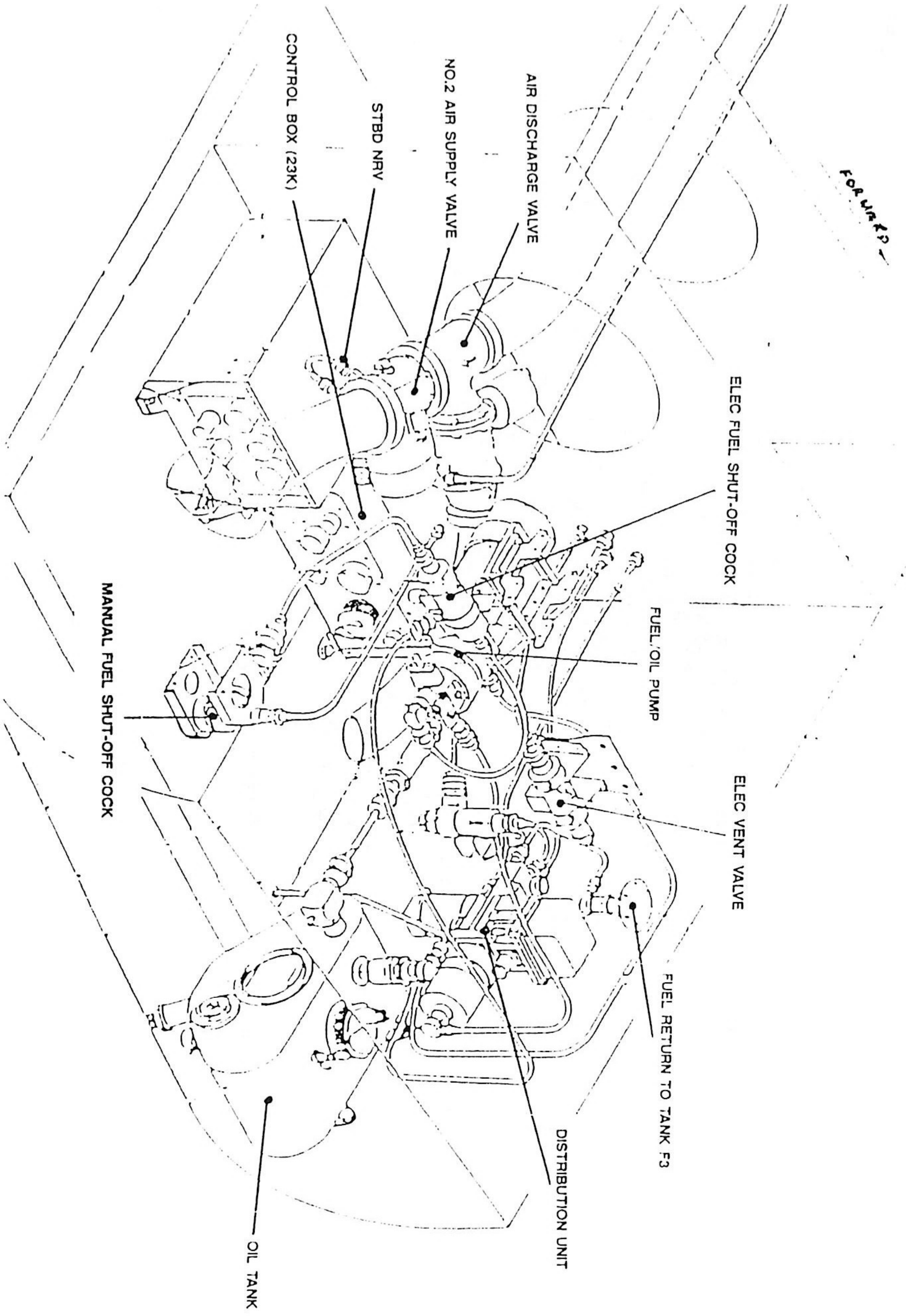
The Air Generator continues to accelerate up to idle speed,85% RPM.,under the influence of the spill valve where it is controlled by the control box.
When supplying air to No.1 or No.2 engine turbo-starter the spill valve will increase the fuel flow and subsequently control the Air Generator at 100% RPM.When the Adour reaches self-sustaining speed,39% RPM.,air will be shut off to the starter and the Air Generator returns to idling speed.
On completion of No.1 and No.2 engine starting sequence the control box will shut down the Air Generator.In the event of a single engine start and the master switch is not set to the OFF position the Air Generator will be shut down after ten minutes continuous running.In this event no further starts of the Air Generator should be attempted until a period of thirty minutes has elapsed.

The operating RPM's of the Air Generator are as follows:-

Idling Speed	85%	43,600 RPM.	FOR STARTS
Max Speed	100%	51,300 RPM.	
Overspeed	110%	56,400 RPM.	
Self Sustaining	69%	35,000 RPM.	



COMPONENTS LOCATED IN PORT A/B BAY.



<u>COMPONENTS LOCATED IN STBD.A/B BAY.</u>

d. Fuel System.

The Air Generator is controlled by a fully automatic fuel system which is supplied from the No.2 engine LP fuel line,before the LP cock.The system consists of the following components:-

Mechanical Cock.

The mechanical cock is used for ground servicing only and must be locked to the FULLY OPEN position during normal use.

LP Fuel Filter.

The LP fuel filter is a normal wire mesh filter giving a filtration of 50 microns.

Fuel Shut-off Cock.

The fuel shut off cock can be considered as a normal LP cock in the system,it is solenoid operated,through the electrical control box,and will energise to 'OPEN' when the start is initiated.The solenoid valve will de-energise to 'CLOSED' when any of the following occur:-
The Start Master is selected to off.
No.1 and No.2 engines have started.
Should the oil pressure fail to attain its correct value within 20 seconds.
Should the oil pressure fail at any time during running.
After 10 minutes continuous running.

Fuel Pump.

The fuel pump is a 28V DC electrically driven dual purpose spur gear pump.ie.fuel and oil pump.Normal fuel operating pressure is 4 to 10 bars (58 to 145 psi) which is fed direct to the fuel distribution unit.The fuel pump maximum outlet pressure is controlled by a pressure relief valve housed in the pump body.

Fuel Distribution Unit.

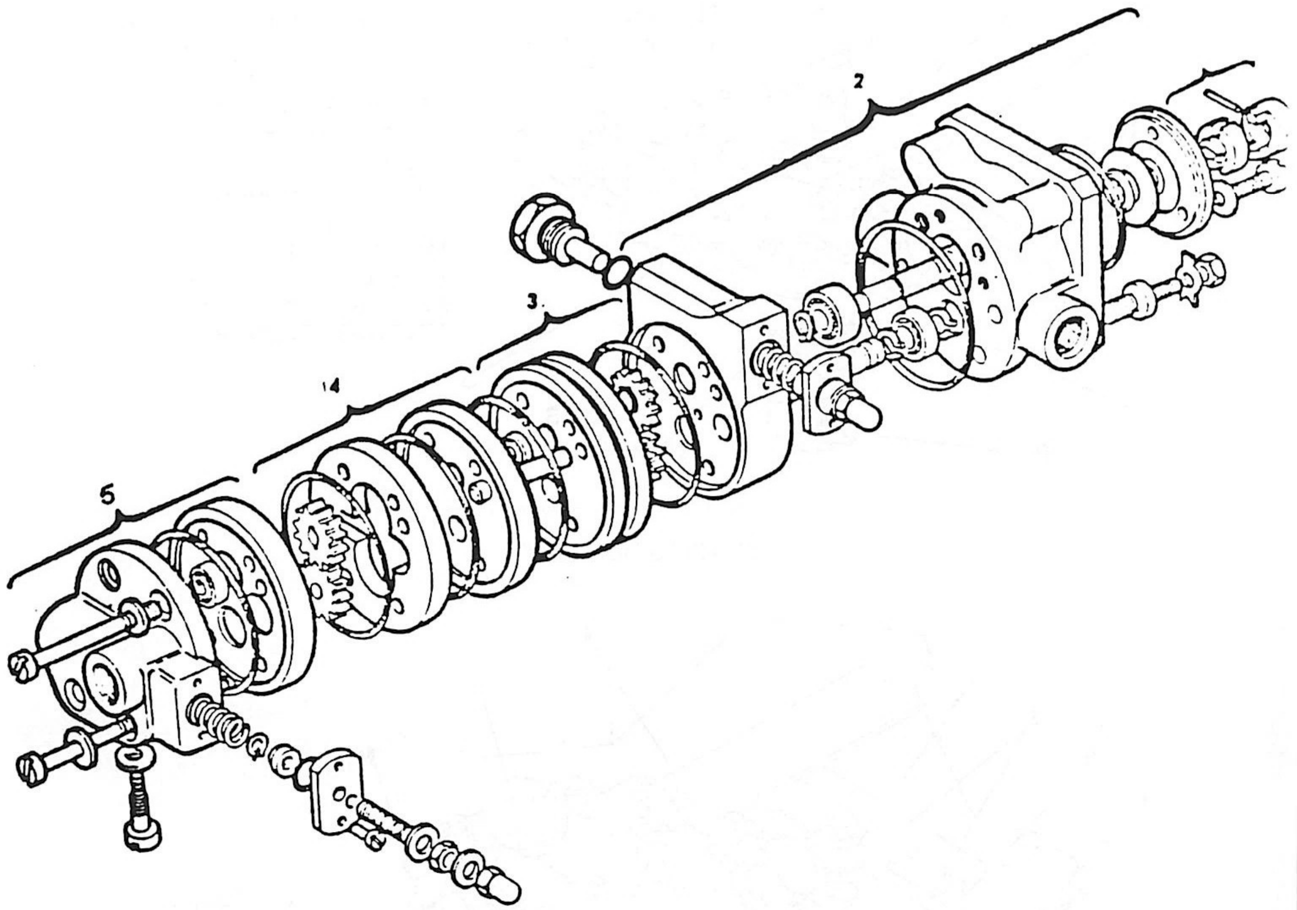
The fuel distribution unit consists of three components.two of which are fuel control and the third oil pressure control.The fuel components carry out an independent operation which affects the performance of the other.The oil pressure switch built into the unit controls the oil pressure during starting and subsequent running.The other two components are the Filter/Regulator valve and the Spill Valve.
Fuel enters the distribution unit via the Filter/Regulator valve where it is controlled under the influence of the Spill Valve.

Fuel Distribution Unit.(Operation).

On pressing the Air Generator start button an electrical supply is placed on the Spill Valve from the electrical control box,when the latter has received a signal from the speed detector fitted to the starter motor.
During the initial starting stage the Spill Valve will demand an increased fuel pressure to the burners to allow acceleration conditions to exist. This is done by reducing the amount of fuel allowed to spill from the burner line to the F3 fuel tank. This causes a back pressure to be created in the burner lines resulting in increased fuel available to the burners.
The back pressure is sensed by the Filter/Regulator which allows a greater pressure from the fuel pump to flow to the distribution unit and burner lines to maintain acceleration conditions.When the Air Generator reaches idling speed the electrical control box adjusts the electrcal supply to the Spill Valve.
This adjustment increases the rate of spill to the F3 fuel tank from the burner line therefore decreasing the fuel pressure at the burners to a point where constant speed conditions are maintained.The Filter/Regulator will re-adjust the supply to the Distribution Unit to meet the new condition.
For Adour engine start it is necessary to increase the speed of the Air Generator.This is to ensure that sufficient volume and pressure is available to drive the Adour turbo-starter to its correct speed. When the Adour starter switch is operated the electrical control box increases its output to the Spill Valve which causes burner pressure to increase and accelerate the Air Generator.The Air Generator accelerates to 100% RPM and controls at this speed in the same manner as described above.On completion of the Adour start the Air Generator will return to idle speed.(85% RPM).

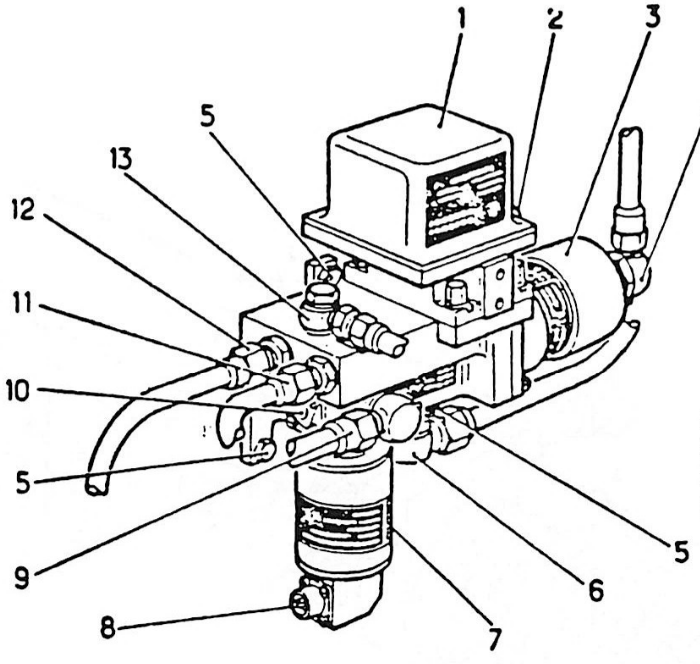
e.Fuel Purging Unit.

The Fuel Purging Unit is mounted on the base of the Air Generator and forms,in effect,an automatic HP shut-off valve.The Unit carries out its task through the operation of a pressure sensing valve and small ball valves.When starting P2 pressure is fed from the compressor to the pressure valve which which closes the fuel drain valve and allows fuel to the burners and spill line.When the Air Generator is shut-down the pressure valve opens the drain valve allowing the burner gallery to drain to atmosphere.



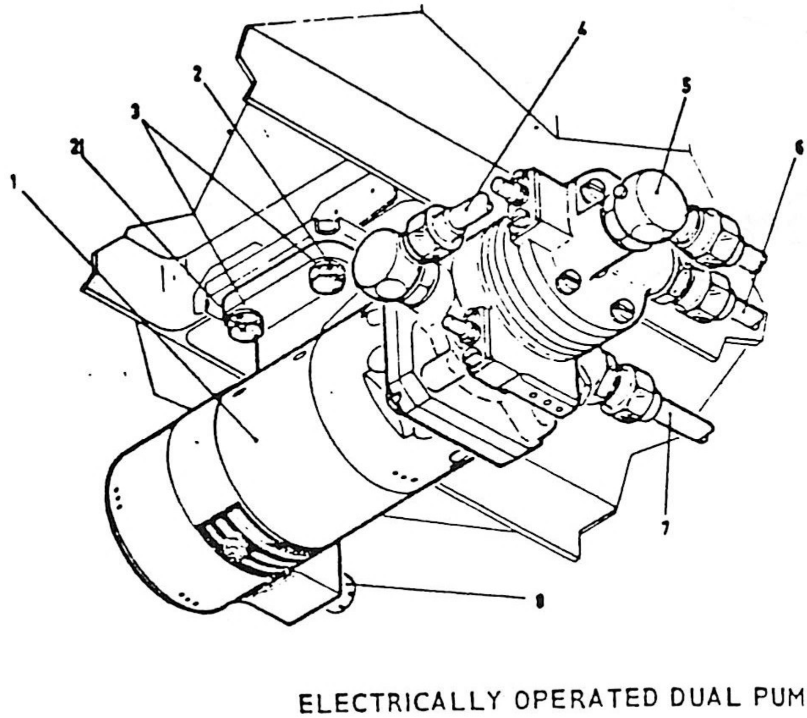
1. Motor/Pump Coupling.
2. Pump Body & Relief Valve.
3. Oil Pump.
4. Fuel Pump.
5. End Plate.

DUAL FUEL/OIL PUMP - PRINCIPAL PARTS.



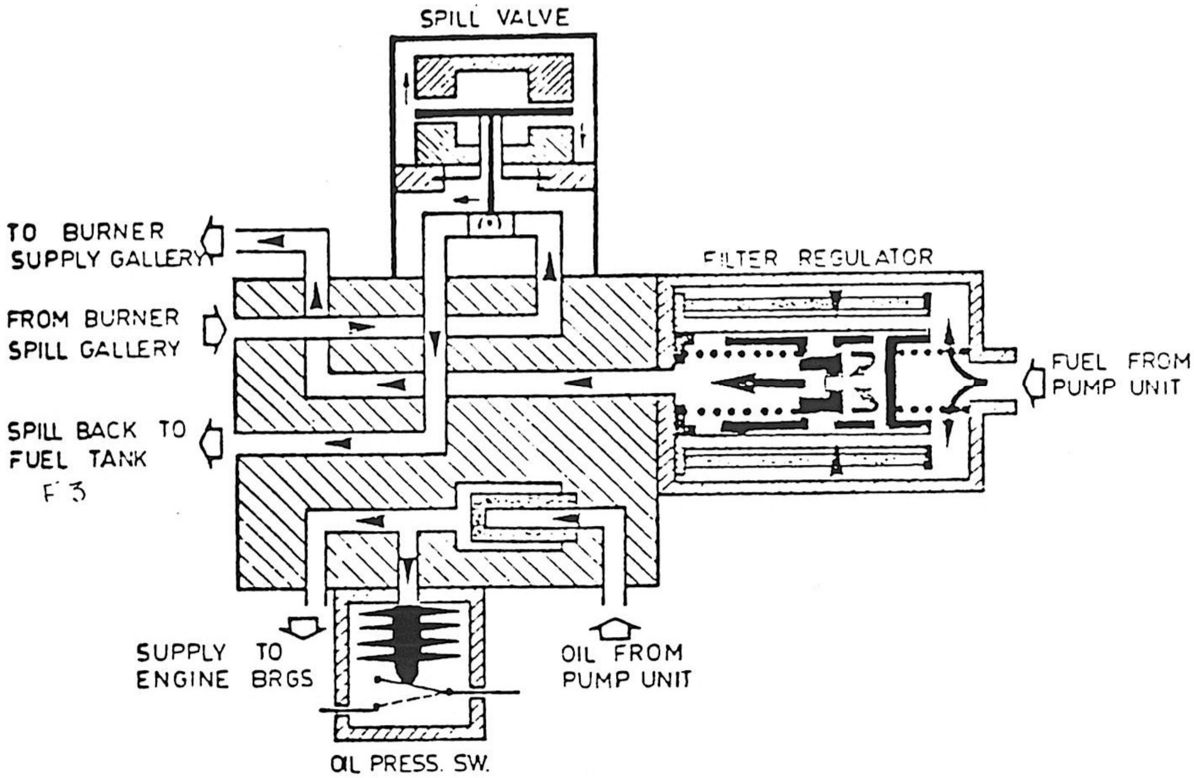
1. Spill Valve.
2. Elect.Connection.
3. Filter/Regulator.
4. Fuel Inlet.
5. Securing bolt.
6. Oil Inlet.
7. Oil Pressure Switch.
8. Elect.Connector.
9. Oil Outlet.
10. Oil Filter.
11. Fuel Return to F3.
12. Fuel Spill from Burners.
13. Fuel Supply.

DISTRIBUTION UNIT

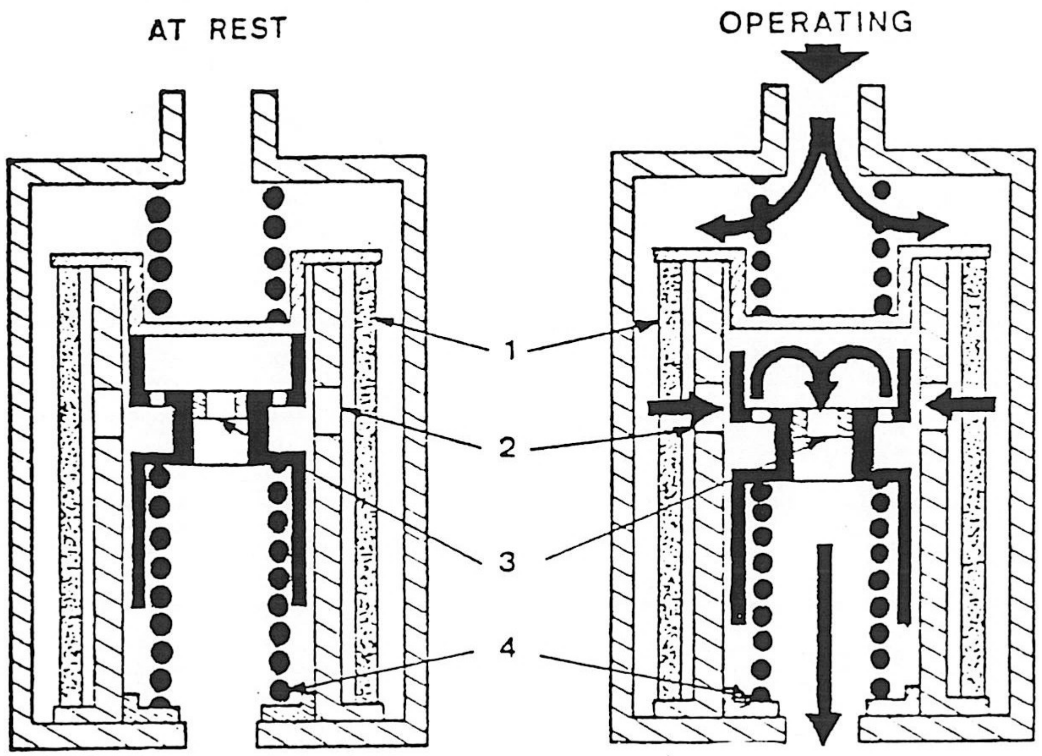


1. Pump.
2. Securing Bolts.
3. Washers.
4. Oil Inlet.
5. Fuel Inlet.
6. Fuel Outlet.
7. Oil Outlet.
8. Elect.Connection.

ELECTRICALLY OPERATED DUAL PUMP.



DISTRIBUTOR BLOCK DUCTING SCHEMATIC.



1. FILTER ELEMENT.
2. SLEEVE PORT
3. PLUNGER ORIFICE.
4. SPRING.

FILTER - REGULATOR FUNCTIONAL SCHEMATIC.

f. Oil system.

The Air Generator is lubricated by a re-circulating oil system. Oil is drawn from the oil tank and delivered by the second stage of the Fuel/Oil pump via the pressure switch in the Distribution Unit to the electrical starter motor reduction gearing and the main rotor bearings. the pressure switch operates at a value of 0.95 + - 0.15 bar, (13.36 + - 1.10 psi). In the event of the oil pressure not reaching this value the Air Generator will close down after 20 secs.

A 35 micron filter is housed in the Distribution Unit adjacent to the pressure switch to ensure cleanliness of the oil.

g. Ignition System.

A normal 28V DC High Energy Igniter unit is used in the Air Generator. The unit is energised and de-energised simultaneously with the starter motor. The output from the HT coil is fed to two igniter plugs, via screened wiring, in the combustion chamber.

h. Air System.

The air system directs air pressure from the compressor of the Air Generator to the Adour Turbo-starters. The flow is directed by operation of electrical and pneumatic controlled air valves. When the Air Generator is running in the off-load condition, air is passed to atmosphere via the discharge valve. The system consists of the following components:-

i. Air Vent Valve.
ii. Two Non-return Valves.
iii. Discharge Valve.
iv. Two Starting Turbine Supply valves.

i. Air Vent Valve.

The Air Vent Valve is electrically operated its purpose is to ensure the correct function of the Discharge Valve with a positive action. Under off-load conditions the valve is de-energised 'OPEN' by the electrical control box. This 'OPEN' position allows only ambient air pressure to the underside of the Discharge Valve enabling it to remain open, and compressor air pressure is vented to atmosphere. On selection of Adour start the electrical control box energises the Vent Valve to 'CLOSED' and opens the Turbine Supply Valve. Air pressure is allowed into the Vent Valve line and directed to the underside of the Discharge Valve moving it to the closed position. Air Generator output is then available at the Adour Turbo-starter.

ii. Two Non-return Valves.
The two non-return valves are fitted into the Air Vent Valve line to the Discharge Valve. The purpose of these valves is to ensure that air pressure, which is bled into the line to close the Discharge Valve during an engine start, is not passed inadvertently to the turbo-starter of the other engine.

iii. Discharge Valve.
A pneumatically operated valve which is controlled by the action of the Air Vent Valve. The Discharge Valve closes and opens respectively when the Air Vent Valve is energised or de-energised. As a correct function of the Discharge Valve is essential to ensure engine start a pneumatic switch is operated whenever the valve closes to illuminate the air valve open light (AMBER) on the starter control panel in the cockpit.

iv. Starting Turbine Supply Valves.
The two electrically opened Turbine Supply valves are located in the trunking leading to the turbo-starter from the Air generator. The selection of an engine start will energise the relevant valve to the ~OPEN~ position. When the engine has reached self-sustaining speed, 39% RPM, The valve will be de-energised closed.

i. Electrical Control Box.
The unit controls through electrical and electronic components the whole function of the starter automatic systems. It also monitors the system and will close down the Air Generator should any faults occur.

Faults Leading to Close Down.
Incorrect or no speed signal from Air Generator starter within 1.5 seconds.
69% RPM not exceeded within 20 seconds.
110% RPM exceeded at any time.
After 10 minutes running time.
Insufficient oil pressure within 20 seconds, or loss of oil pressure at any time.
- Terminate Adour start if 39% RPM is not achieved within 30 seconds.
Will not allow a second engine start until the first has completed its cycle.

Exceptionally the Air Generator will continue to run if the No.1 or No.2 engine start sequence has been selected within a 30 second period prior to the completion of the 10 minute limit.

Air Generator Start Sequence.

The Air Brakes must be in the 'OPEN' position before the Air Generator can be started.With the generator start master switch selected to 'ON' an electrical supply is made available to the start button.Operation of the start button causes the following sequence of operations:-

An electrical supply is fed to the starter motor and ignition unit from the aircraft battery.

When the speed sensor,in the starter motor, is rotated an electrical signal is relayed to the control box.This signal is increasing as the starter motor gains speed.When of sufficient value the control box will energise the fuel cock to the 'OPEN' position and start the fuel/oil pump.

If the oil pressure reaches the correct value the oil pressure switch in the distribution unit closes and the start is continued.

The fuel pump output is controlled by the spill valve and filter /regulator in the distribution unit,which is influenced by the control box.As the generator increases its speed the speed detector output continues to rise,this ensures that the control box maintains a supply to the spill valve to increase the fuel pressure supply to the burners.

Acce leration conditions therefore exist in the fuel system.The air generator will accelerate to 69% RPM self-sustaining speed where the control box will cut out the starter motor and ignition.

The air generator will continue to accelerate to its idling speed of 85% RPM.At this point the control box,on receiving a signal from the speed detector, will reduce the value of electrical supply to the spill valve allowing it to open and bleed more fuel from the spill line.This action causes the burner pressure to reduce to a value which will ensure constant speed conditions of 85% RPM.

3. ADOUR START SYSTEM.

Description.

The Adour turbo-starter is mounted on each engine, on the forward stbd.side of the HS Gear-box., and is supplied with air pressure, to initiate a start, by the Air Generator.

The Adour start system consists of the following components:-

i. Turbo-starter.
ii. Speed detector Unit.
iii. Correct Rotation Detector.
iv. AC and DC Igniter Units.

i. Turbo-starter.

The turbo-starter is a radial flow turbine consisting of a centripetal type turbine disc. The starter is coupled to a planet type reduction gear driving a quill drive through a sprag clutch. Air is supplied to the inlet where it passes through a volute chamber into the turbine. Rotation is transferred from the turbine, through the reduction gear, to the HS gear-box and thence by a drive to the internal gear-box where it drives the HP compressor. The Turbo-starter will drive the Adour to self-sustaining speed of 39% RPM where the air supply will be cut to the starter, the sprag clutch will dis-engage, and the turbine end of the starter will come to rest.

ii. Speed Detector Unit.

The speed detector unit is basically a magnetic core contained in a metal casing. It is positioned in the turbo-starter with the core facing the periphery of a phonic wheel which is attached to the clutch housing and rotates at the speed of the shaft. The alternate teeth and gaps on the wheel, by distortion of the magnetic field, induces in the coil an intermittent signal. The frequency of the signal is directly proportional to the rotational speed of the wheel and therefore to the speed of the turbo-starter shaft. When the Adour has reached self-sustaining speed the signal from the speed detector will be fed to the control box and the air supply to the turbo-starter will be shut off. The Air Generator will return to idling RPM.

iii. Correct Rotation Detector.

The LP compressor correct rotation detection is provided by a Hobson Speed Probe system. Two magnetic probes are situated in the forward LP compressor bearing housing with a phonic wheel rotating with the LP compressor shaft.

The probes are positioned 90 electrical degrees out of phase. This factor is used to indicate correct rotation in the control amplifier. When the amplifier identifies the correct rotation signal a green light is illuminated on the cockpit start panel and the ignition relay is armed.

iv. AC and DC Igniter Units.

Two igniter units are used in the ignition system. The AC and DC igniter units operate on conventional lines and are both controlled by the ignition switch on the cockpit start panel.

There are four operating positions.

1. Both unit are energised for a start using external power supply.

2. DC ignition only if an internal (Battery) start is carried out.

3. AC ignition only with continuous ignition in use.

4. Both units energised for re-light conditions.

SYSTEM PROTECTION.

In the event of an engine failing to start the start sequence will be terminated after 30 seconds.

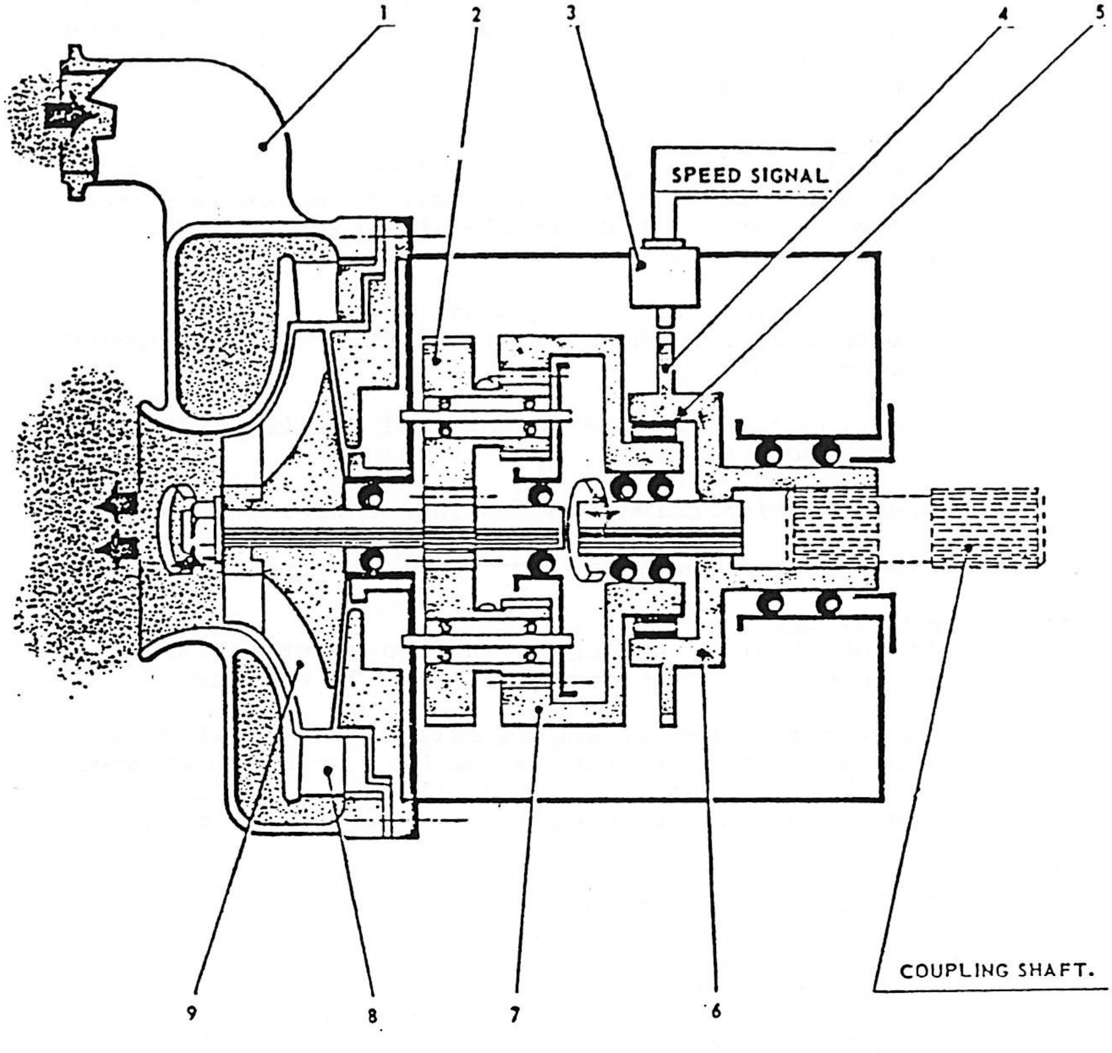
In circumstances of engine seizure the quill drive from the turbo-starter to the HS gear-box will shear and the turbo-starter speed will rise quickly to 39% RPM where a normal shut down of start will occur.

DRY RUNNING.

1. Start Air Generator.
2. HP shut-off cock closed.
3. Ignition switch off.
4. Open LP cock.
5. Select engine start, 39% RPM will not be achieved, so start sequence will run for 30 seconds.

WET RUNNING.

As above but during the 30 second cycle open HP shut-off cock until fuel can be seen in the exhaust collector.



1. Volute.
2. Planet Pinions.
3. Speed Probe.
4. Phonic Wheel.
5. Sprag Clutch.
6. Clutch Housing.
7. Annulus Assembly.
8. Turbine Nozzle.
9. Turbine Wheel.

ADOUR TURBO-STARTER.

ADOUR START SEQUENCE.

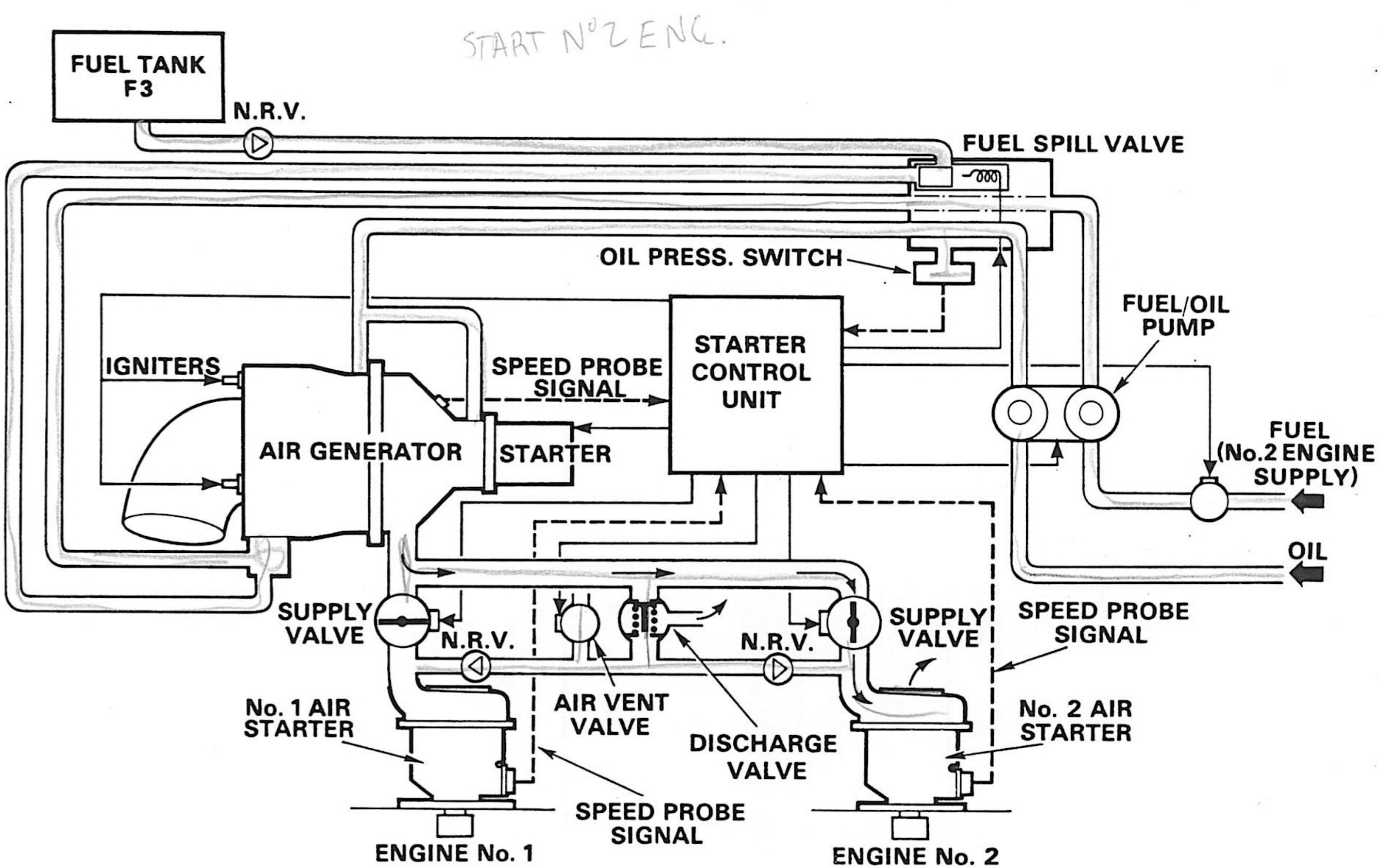
The Air Generator must be running at stabilised RPM before an engine start sequence can be commenced.The engine throttle should be in the closed position. Select LP cocks 'OPEN~ ignition switch 'ON' and LP pump switches 'ON'.Select engine start and hold for two seconds the selection will be held on electrically through relays.

The following sequence will take place:-

1. The Air Generate will accelerate to 100% RPM.
2. The Air Vent Valve will close and the turbine supply valve to the engine selected will open.
3. The Discharge Valve will close and the Air Valve light will illuminate.
4. The turbo-starter will rotate the HP compressor and speed detector.
5. The action of the air flow passing to the HP compressor will also rotate the LP compressor.
6. The correct rotation detector signal will be fed to the control amplifier and if correct will illuminate the light on the start panel.The igniter units will also be energised at this stage.
7. At 20% RPM the throttle should be opened to the idle position.

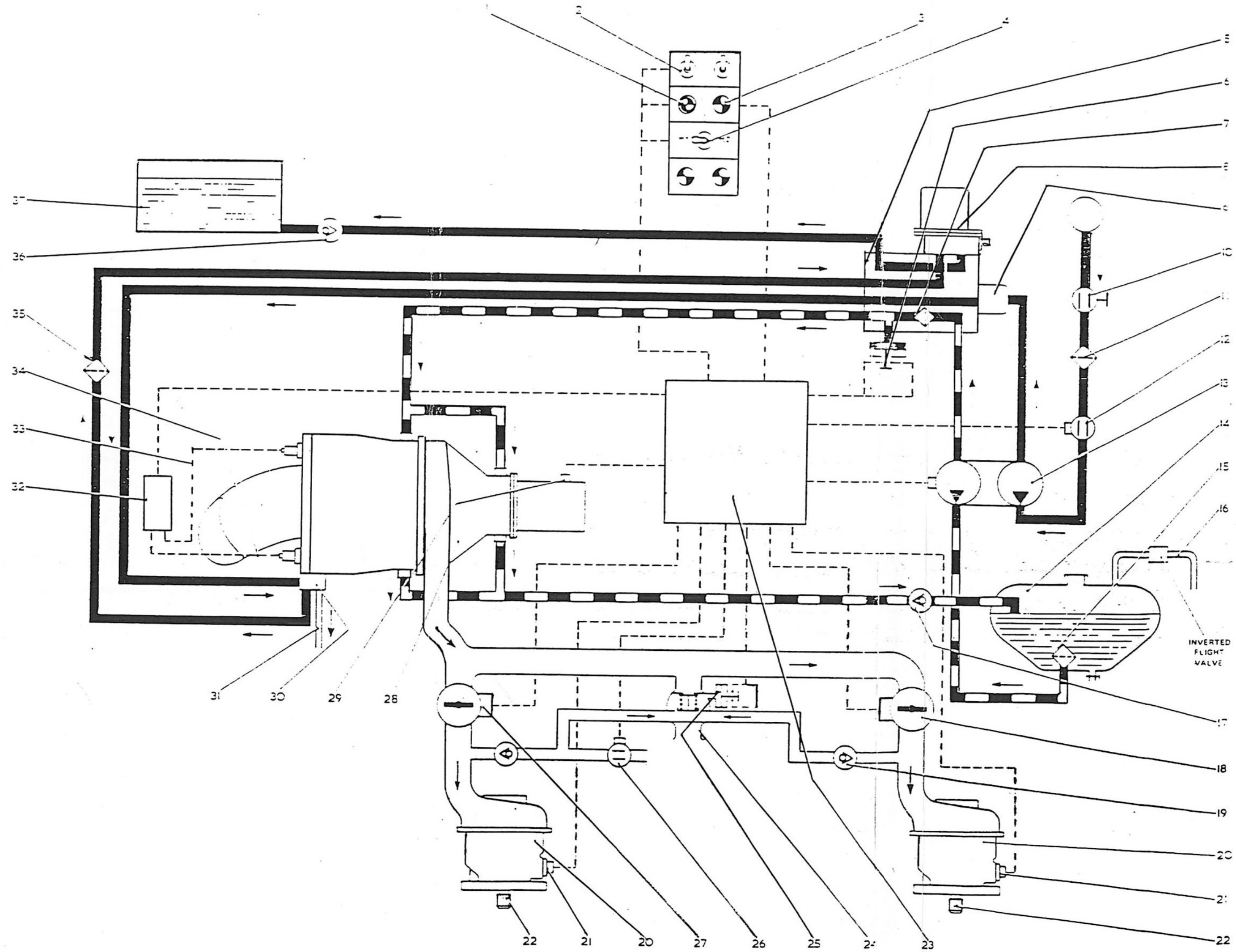
The engine will 'Light Up' and accelerate to idling speed.When reaching 39% RPM the speed detector output electrical signal to the control box will reach the shut-down datum - at this point the air supply valve will close,the air vent valve open,the discharge valve open and the Air Generator will return to idling speed.

NOTE: The starting sequence is precisely the same for both engines,except that after a successful start on both engines the Air Generator will be shut down automatically and not return to idle.



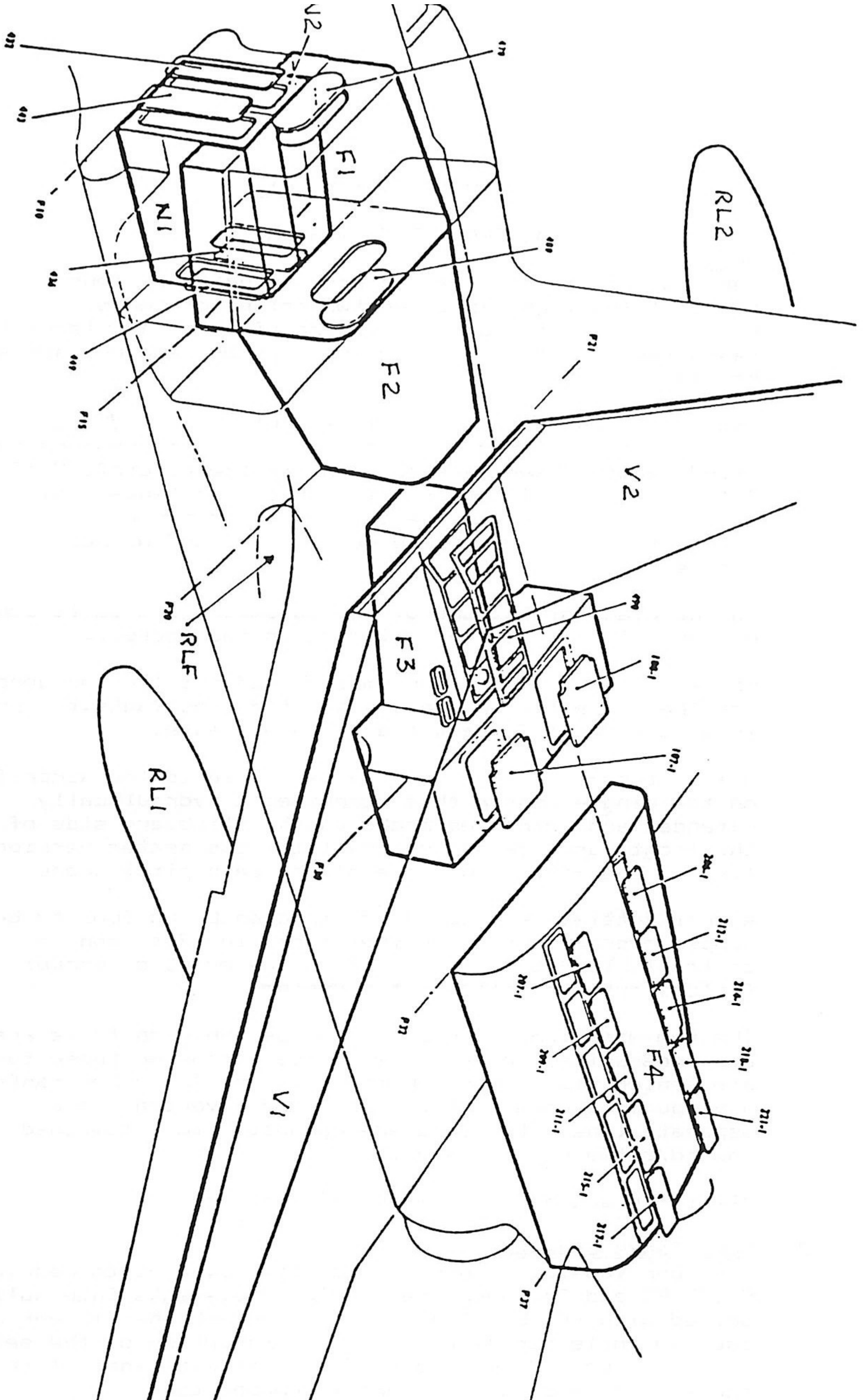
ENGINE STARTING SYSTEM (JAGUAR)

1. AIR GENERATOR START PUSH BUTTON SWITCH (3K
2. AIR GENERATOR START SWITCH (2K
3. AIR VALVE OPEN LAMP (8K
4. ENGINE START SWITCH (NO.1 AND NO.2) (4K
5. DISTRIBUTION UNIT (33K)
6. OIL PRESSURE SWITCH } DISTRIBUTION UNIT
7. OIL FILTER }
8. SERVO VALVE }
9. REGULATOR FILTER
10. MANUALLY-OPERATED COCK (56K
11. SUPPLY FUEL FILTER (51K
12. ELECTRICALLY-OPERATED SHUT OFF VALVE (30K
13. ELECTRICALLY OPERATED DUAL PUMP (31K
14. OIL TANK (52K
15. TANK OIL FILTER
16. OIL TANK AIR VENT PIPELINE
17. OIL NON-RETURN VALVE (72K
18. STARBOARD SUPPLY VALVE (29K2
19. AIR NON-RETURN VALVE (54K)
20. STARTER (27K
21. STARTER SPEED DETECTOR
22. SPLINED DRIVE SHAFT (58K
23. STARTER UNIT (23K)
24. RELIEF VALVE (32K)
25. AIR PRESSURE SWITCH
26. ELECTRICALLY-OPERATED AIR VENT VALVE (53K
27. PORT SUPPLY VALVE (29K1
28. AIR GENERATOR } AIR GENERATOR
29. SPEED DETECTOR }
30. DRAIN BLOCK }
31. DRAIN }
32. AIR GENERATOR IGNITION UNIT (27K
33. REAR H.E. CABLE ASSEMBLY (53K2
34. FRONT H.E. CABLE ASSEMBLY (53K1
35. RETURN FUEL FILTER (57K
36. FUEL NON-RETURN VALVE (50K
37. FUEL TANK F2



AIR SYSTEM
FUEL SYSTEM
OIL SYSTEM
ELECTRICAL CIRCUIT

Starting system – diagrammatic



DIAGRAMMATIC LAYOUT OF TANKS.

JAGUAR MK.S(O) & (B).

AIRCRAFT FUEL SYSTEM.

1. General.

Fuel is contained in two integral wing tanks,four integral fuselage tanks and two collector tanks. Provision is made for the fitting of three jettisonable tanks,two on the under wing inner pylons and one beneath the fuselage.

The fuel feed system is entirely automatic,fuel being transferred from the tanks,by pumps or air pressure in a pre-determined sequence to maintain the aircraft C of G. All the fuel is fed to the two collector tanks from where it is pumped to the engines.Under normal circumstances N1 will feed No.1 engine and N2 No.2 engine.

In the event of failure of the automatic system it can be manually operated by switches in the cockpit.

Pressure re-fuelling is normally used but for emergency use there are filler caps on the two wing tanks,the port forward side of F1 tank and the drop tanks.

A flight re-fuelling facility is fitted to the aircraft, on the single seater this comprises a hydraulically extended and retracted probe on the starboard side of the front fuselage and on the later two seater version a fixed probe fitted in place of the main pitot probe.

A fuel jettison system is provided enabling fuel to be dumped overboard via the fuel feed line.Jettison is controllable from the cockpit,in the event of cockpit failure,automatically by the system.

The two wing tanks,forward fuselage and drop tanks are air pressurised to assist with fuel transfer,these tanks are vented via the pressurisation line.The other tanks have pumps to assist transfer and are vented via a separate line.Both lines are connected to a combined inward/outward vent valve.

All tanks are provided with water drains.

2. Fuel Tanks General.

The four fuselage tanks are identified,front to rear,as F1,F2,F3 and F4.These are all integral tanks internally sealed with PRC.Located directly beneath the F1 tank are the two collector tanks N1 and N2,these are of the self-sealing type and are provided with access panels fore and aft for access to internal components.
The two wing tanks are also of integral construction and are identified as V1 (Port) and V2 (Stbd).
The drop tanks are identified as RL1(Port),RL2(Stbd) and RLF(Fuselage).

The tanks are grouped and gauged as follows:-

F1,N1 and N2.........Front Group.

F2 and F3............Centre Group.

F4...................Rear Group.

V1,V2,RL1,R12 and RLF all use magnetic indicators which show the following:-

Black................Full.

Cross-hatched........Feeding or partially full.

White................Empty.

Fuselage Tanks.

F1. The front fuselage tank is formed between Frames 10 and 15.Access is via the nose wheel bay behind the battery.

F2. This tank is formed between Frames 15 to 20.Access is gained to the tank is through F1.

This tank is formed between Frames 21 to 30.Because F2 and F3 act as one tank,F2 taking fuel from the wings and drop tanks and F3 delivering fuel to the collector tanks, they are generally known as F2/3.

F4. This tank is formed between Frames 32 to 37.A clack valve is located at Frame 35,this is to allow fuel to flow from front to rear only.Access is via panels on the spine.

Mainplane Tanks.

V1,V2. These tanks are separated at the centre and form two tanks,fuel is transferred by air pressure via a non-return valve to tank F2.

Drop Tanks.

RL1,RL2 and RLF. Either one two or three of the tanks can be fitted.Fuel feed is through the wing tanks and via a transfer valve (TRL) to the F2 tank.

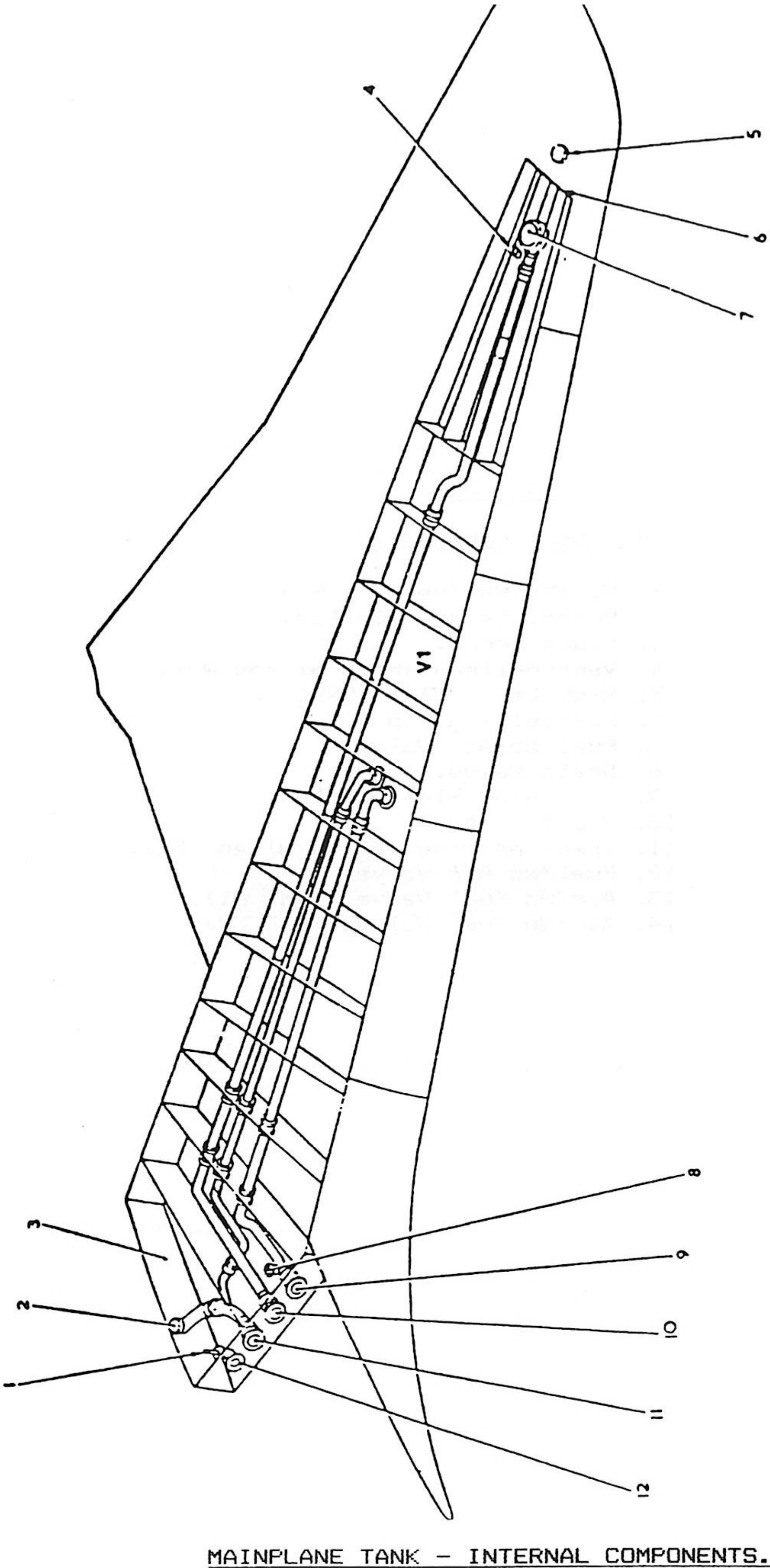
MAINPLANE TANKS.

COMPONENTS.

1. High Level Float Switch.
2. Pressurisation Pipe (V1,V2,RL).
3. Mainplane Root.
4. Low Level float Switch.
5. Drain Valve.
6. Rib No.13.

FUE BLOCK N/O AIR

7. Fuel/No Air Valve.
8. Filler Cap.
9. Re-fuel and Transfer Pipe.(External Tank).
10. Refuel and Transfer Pipe.(V1 and V2).
11. Pressurising Air Connection.
12. High Level Float Switch Access.



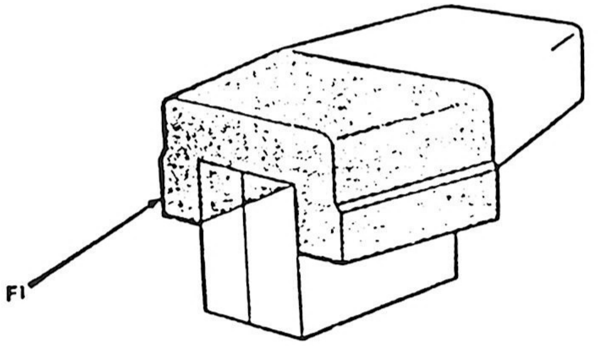
MAINPLANE TANK – INTERNAL COMPONENTS.

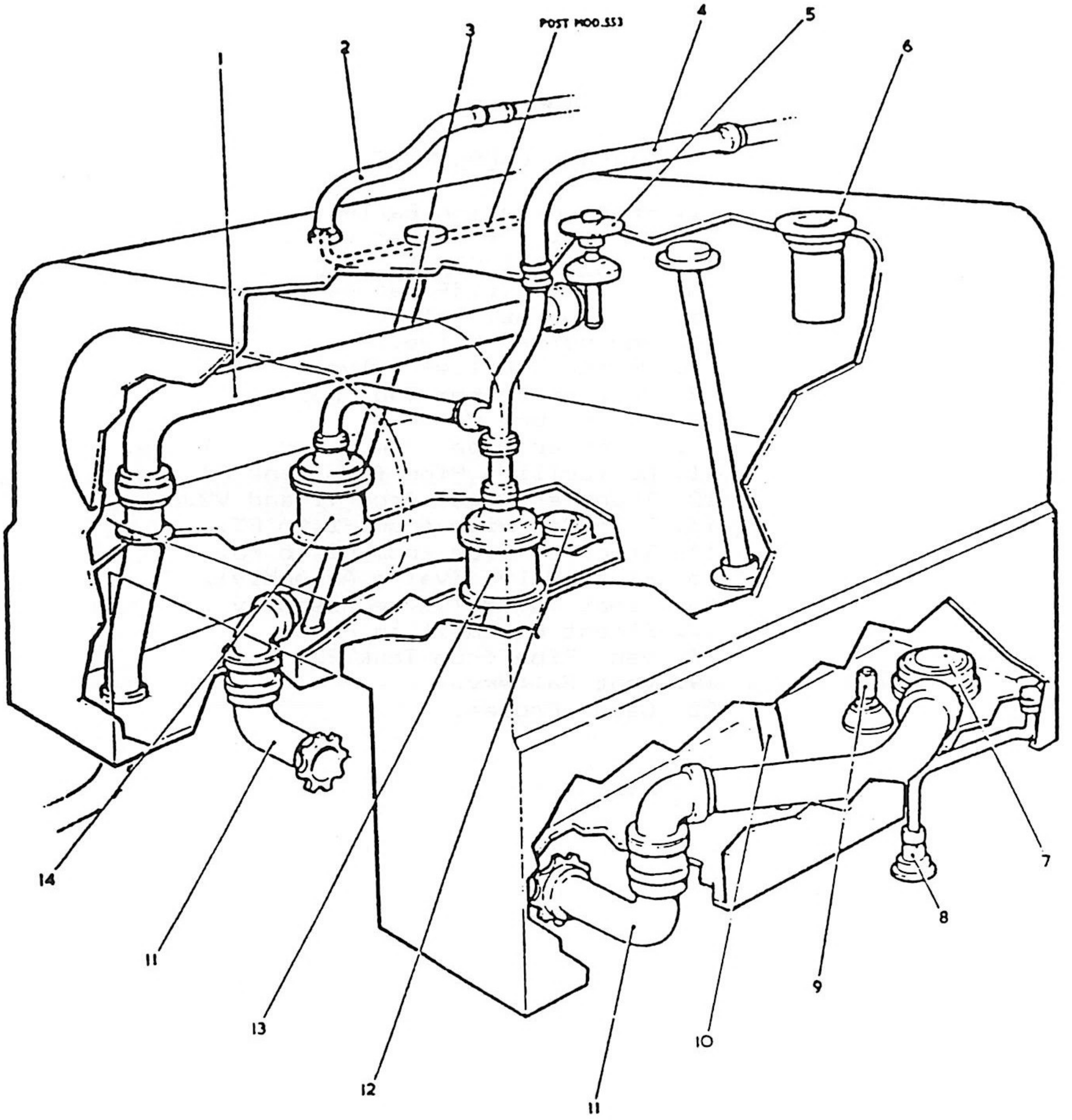
TANK F1.

INTERNAL COMPONENTS.

1. Flight Re-fuelling Pipe.
2. Pressurisation Gallery.
3. Gauge Probe.
4. Vent Gallery.(From N1 and N2).
5. High Level Float Switch.
6. Re-fuelling Cap.
7. Fuel/No Air Valve.
8. Drain Valve.
9. Low Level Float Switch.
10. Gauge Probe.
11. Transfer Pipe.(F1 to N1 and N2).
12. Fuel/No Air Valve.
13. Air/No Fuel Valve.(Tank N1).
14. Air/No Fuel Valve.(Tank N2).

REFUELING AIR TO ESCAPE





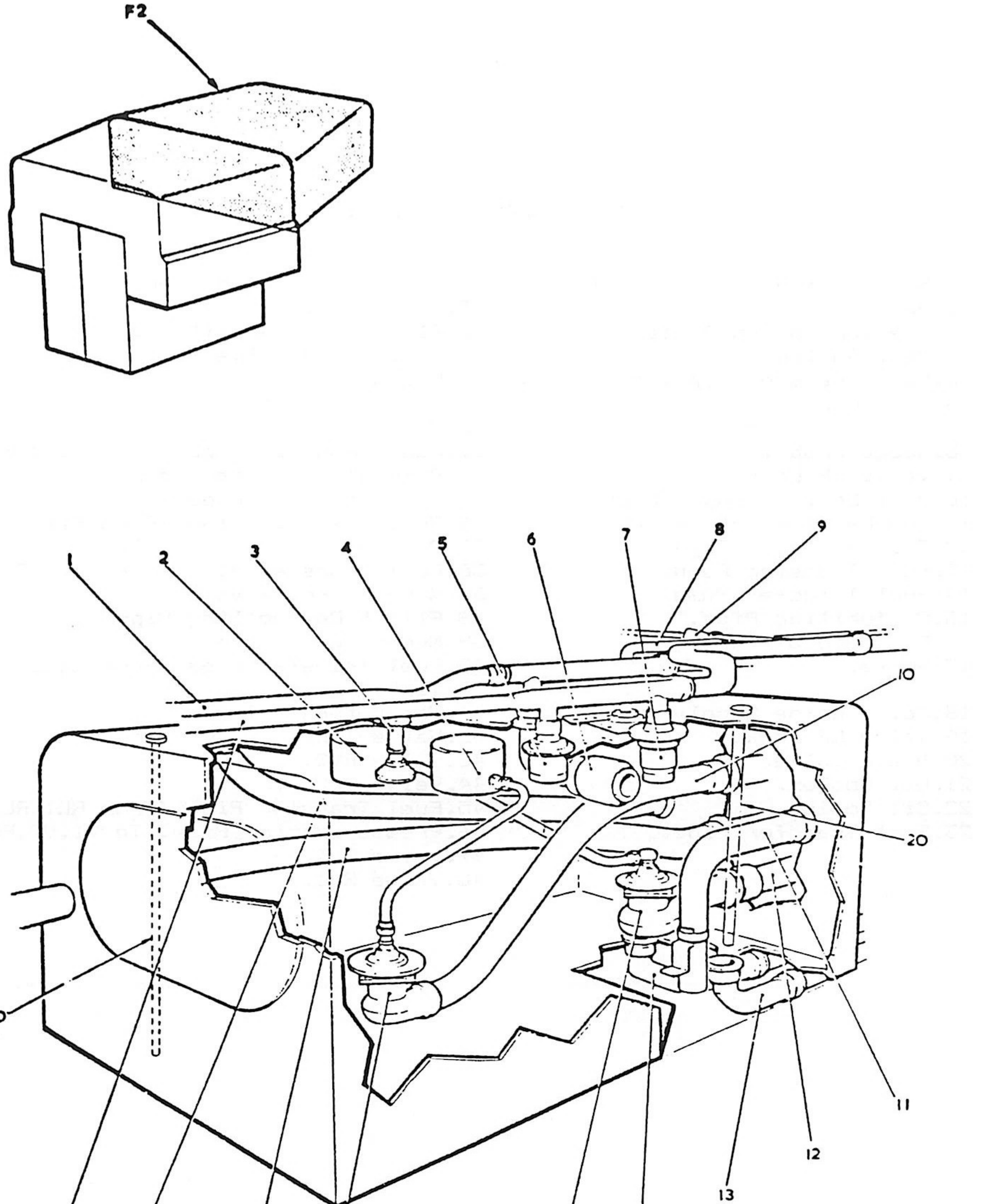
TANK F1 INTERNAL COMPONENTS.

TANK F2.

INTERNAL COMPONENTS

1. Pressurisation Gallery.
2. Float Valve.(Float Assembly).
3. High Level Float Switch.
4. Float Valve.(Float Assembly).
5. Air/No Fuel Valve.
6. Non-return Valve.
7. Pressure Relief Valve.
8. Vent Pipe from Tank F3.
9. Non-return Valve.
10. Transfer Pipe from External Tanks.
11. Re-fuelling Pipe from Tank F3.
12. Transfer Pipes from V1 and V2.
13. Transfer Pipe from F2 to F3.
14. Transfer Pipe from F2 to F3.
15. Float Valve.(Valve Assembly).
16. Float Valve.(Valve Assembly).
17. Flight Re-fuelling Pipe.
18. Vent Pipe from Tank F2.
19. Vent Gallery.
20. Gauge Probes.

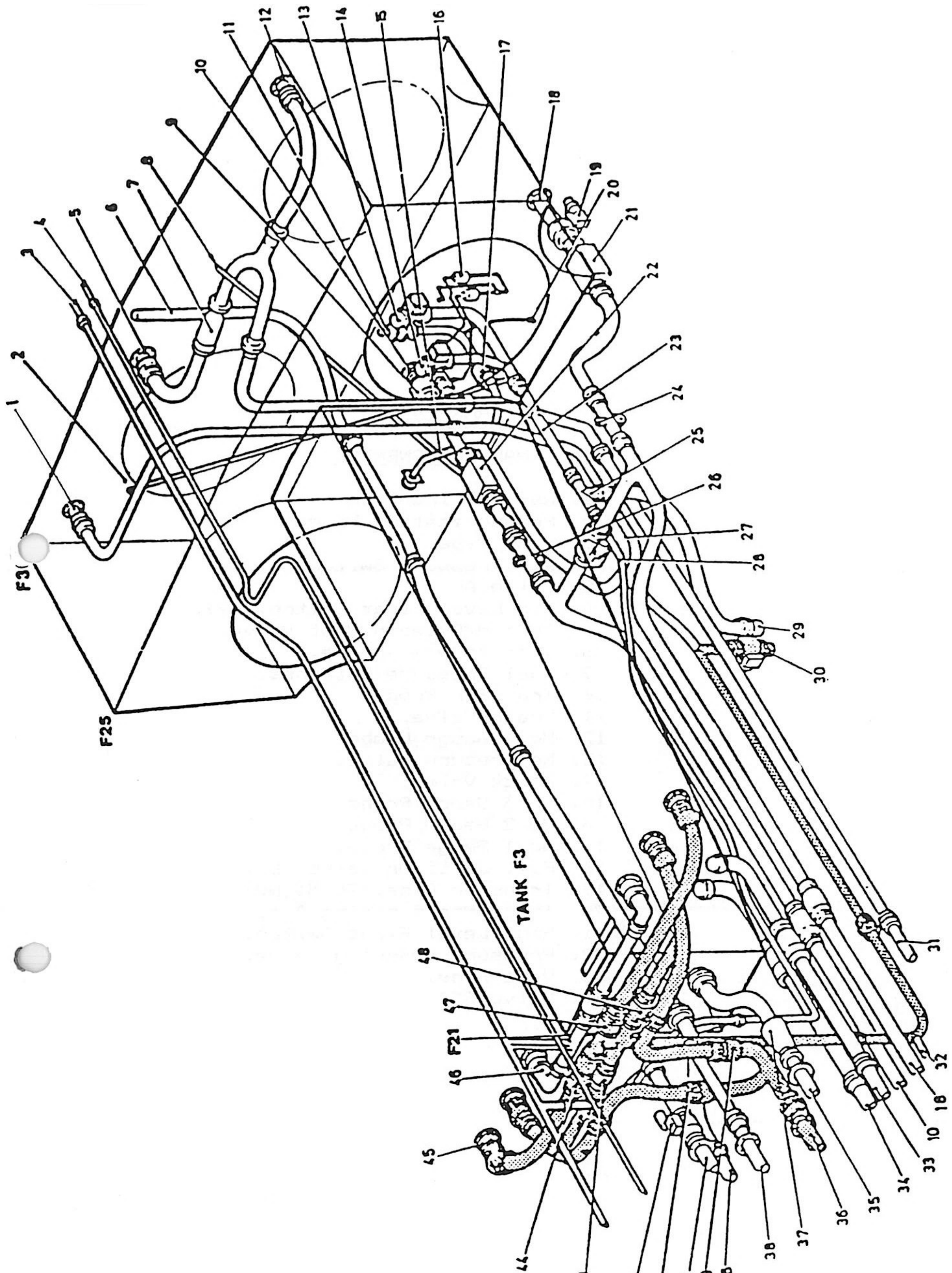
FEED'S
F2 - WING TANKS
DROP "



TANK F2 INTERNAL COMPONENTS.

TANK F3 INTERNAL COMPONENTS.

1. Re-fuelling Pipe. (To F4).
2. Gauge Probe.
3. Pressurisation Gallery.
4. Vent Gallery.
5. Fuel Transfer Pipe. (From F4).
6. Vent Pipe.
7. Non-return Valve.
8. Gauge Probe.
9. Valve LP Cock.
10. No.2 Engine Supply Pipe.
11. Low Level Float Switch.
12. Fuel Jettison Pipe.
13. Fuel Transfer Pump.
14. Fuel Transfer Pump.
15. Re-fuelling Pipe.
16. Pressure Switch.
17. Valve.
18. No.1 Engine Supply Pipe.
19. Valve LP Cock.
20. Drain Valve.
21. Oil Cooler.
22. Oil Cooler.
23. Fuel Transfer Pipe.
24. Flowmeter Transmitter.
25. Tee Piece.
26. Flowmeter Transmitter.
27. Cross-feed valve.
28. Pressurisation Pipe.
29. Pressurisation Pipe. (To RLF).
30. Valve RLF.
31. Fuel Transfer Pipe. (To N1 and N2).
32. Re-fuelling Pipe. (To N2).
33. Fuel Transfer Pipe. (From F2).
34. Fuel Transfer Pipe. (From F2).
35. Re-fuelling Pipe. (To F2).
36. Fuel Transfer Pipe. (From V1,V2).
37. Non-return Valve.
38. Flight Re-fuelling Pipe.
39. Non-return Valve.
40. Fuel Transfer Pipe. (From External Tanks).
41. Non-return Valve.
42. Valve TRL.
43. Valve RV2.
44. Valve RL2.
45. Fuel Transfer Pipe. (From RL1,RL2).
46. Pressurisation Pipe. (To V1,V2,RL1,RL2).
47. Valve RL1.
48. Valve RV1.

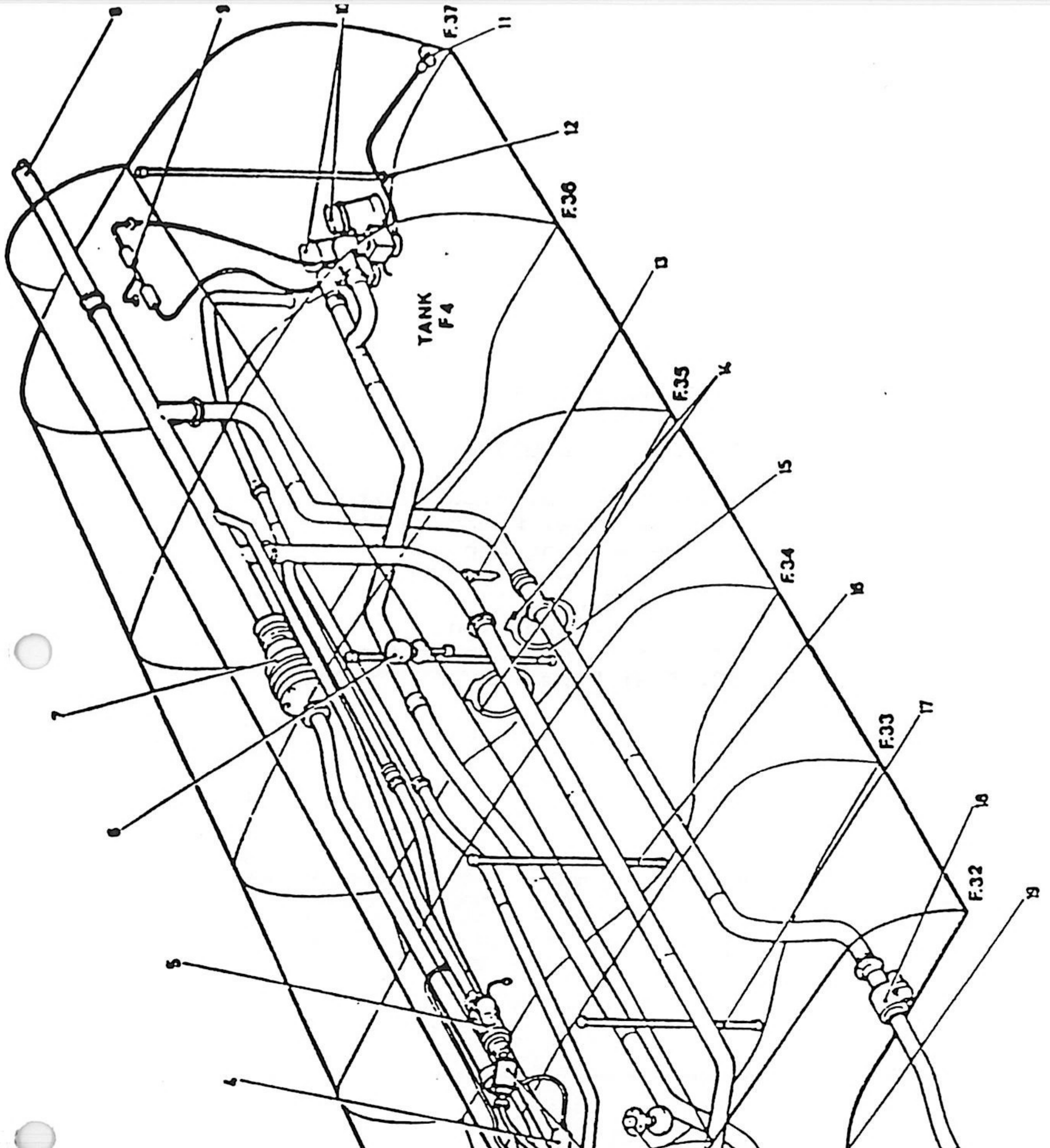


TANK F3 INTERNAL COMPONENTS.

TANK F4

INTERNAL COMPONENTS.

1. Re-fuelling Pipe
2. Pressurisation Pipe.
3. Vent Pipe.
4. Air Pressure Switch.
5. Valve AL.
6. Mid Level Float Switch.(M2).
7. Inward/Outward Vent Valve.
8. Vent to Atmosphere.
9. Fuel Pressure Switches.
10. Transfer Pumps.
11. Drain Valve.
12. No.4 Gauge Probe.
13. Non-return Valve.
14. Clack Valve.
15. No.3 Gauge Probe.
16. No.2 Gauge Probe.
17. No.1 Gauge Probe.
18. Fuel Jettison Valve 'D'.
19. Transfer Pipe.(To N1,N2).
20. Input,Pressurising Air.
21. High Level Float Switch.
22. Pressure Reducing Valve.
23. Vent Pipe.
24. Valve RF4.

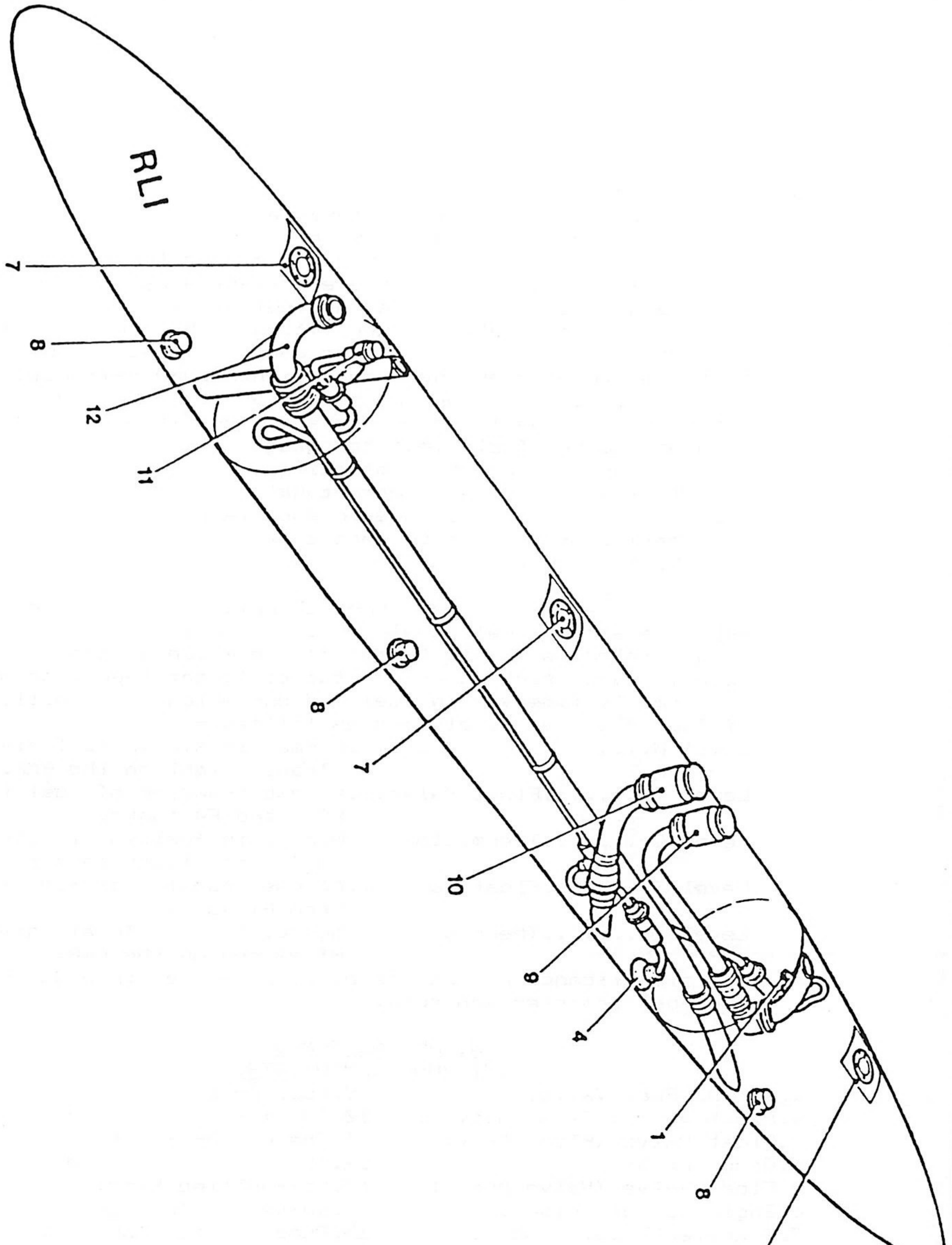


<u>TANK F4 - INTERNAL COMPONENTS.</u>

EXTERNAL FUEL TANKS

INTERNAL COMPONENTS.

1. High Level Float Switch.
4. Low Level Float Switch.
7. Refuelling Cap.
8. Drain Valve.
9. Air Connection.
10. Fuel Connection.
11. Electrical Connection.
12. Fuel Pipe.



EXTERNAL TANKS - INTERNAL COMPONENTS.

Collector Tanks.

N1.(Port) N2.(Stbd) - These tanks are identical and are located on the underside of F1 between Frames 10 and 15. They are formed by the structure and take the form of self-sealing bag tanks.They are protected by fibre glass and plastic material as are the fuel pipelines in the vicinity of the tank.They are fitted with a pump in each tank which supplies fuel to the engines,ie.N1 to No.1 engine,N2 to No.2 engine,should either pump fail both engines can be fed from one pump via a crossfeed valve IR. The switch can be found on the starboard forward console adjacent to the fuel flowmeter gauge.

Also in the tank are the following:-

Two Float Valves.(One in each tank).

Two Air/No fuel valves.(One in each tank).

Six Thermistors.(Three in each tank).

Fuel Gauging units.

The two float valves and three thermistors give five separate sensed fuel levels in each tank.

A thermistor is an electrical device which senses a fuel level.In each tank there are two different types,One which is normally immersed in fuel and one which is normally out of fuel.The five levels are as follows:-

Level 0........Thermistor....Normal in air.In fuel gives a 'Trans' light on the FMP.

Level 1........Float Valve...Allows transfer of fuel from F2-3 and F4 tanks.

Level 2........Thermistor....Normal in fuel.In air gives an 'Inter' light on the FMP.

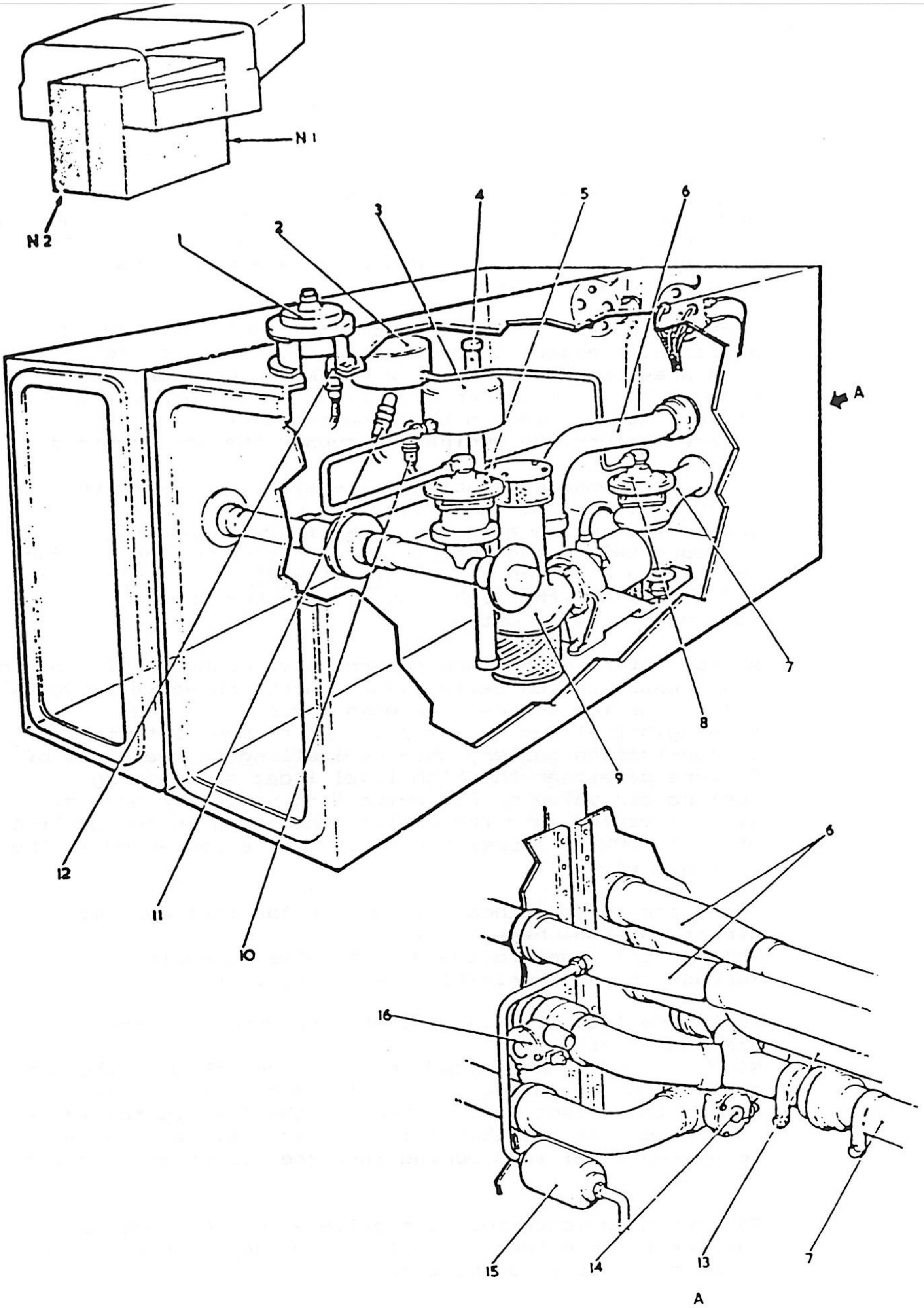
Level 3........Float Valve...Allows transfer of fuel from From F1 to N1.

Level 4........Thermistor....Normal in fuel.In air gives a N1,N2 red on the CWP.

The significance of each level will be explained during the fuel transfer sequence.

N1 AND N2 TANKS.
INTERNAL COMPONENTS.

1.Air/No Fuel Valve.	9.Fuel Pump.
2.Float Valve.(Float Assy.).	10.Thermistor.(Level 4).
3.Float Valve.(Float Assy.).	11.Thermistor.(Level 2). WARNINGS
4.Gauge Probe.	12.Thermistor.(Level 0).
5.Float Valve.(Valve Assy.).	13.Re-fuelling Pipe.
6.Engine Supply Pipes.	14.Valve IC.(Interconnect).
7.Transfer Pipe.(From F3 & F4).	15.Pump Pressure Switch.
8.Float Valve.(Valve Assy.).	16.Valve N.(Transfer Valve).



TANK N1 – INTERNAL COMPONENTS.

3. <u>Tank Pressurisation and Venting.</u>

The external tanks,wing tanks and F1 tank are pressurised to 5 psi.Tank F1 is pressurised to ensure fuel transfer to tank N1,the externals and wings are pressurised to ensure transfer to F2

Pressurised air is tapped from each engine at the P2 position,it passes through a non-return valve and is fed to a pressure reducing valve where the pressure is reduced to the required figure.The non-return valve will prevent air passing to the opposite engine in case of engine failure.One engine can supply the air required.

From the pressure reducing valve air is taken to the air pressure valve 'AL',this valve allows the tanks to de-pressurise during a re-fuel.The air is tapped to a pressure switch and then to the tanks requiring pressure. The pressure switch illuminates the RED air light on the FMP.at low RPM the light may flicker but should go out on opening of the throttle.

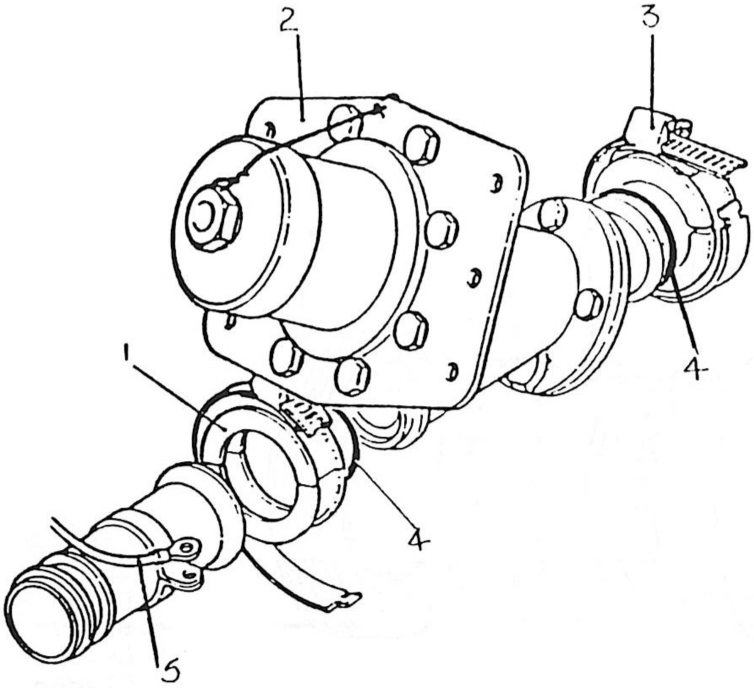
A pipe fitted with a non-return valve connects F2 tank to the pressurisation gallery.The non-return valve prevents pressurisation of the tank when the engines are running,but allows excess pressure to vent into the pressurisation gallery when re-fuelling.In the event of failure of either the high level float switch,wing fuel/no air valve or F3 re-fuelling valve,air or fuel will be vented into the gallery.Operating in conjunction with the NRV is a pressure relief valve,connected to the vent gallery.

There are three methods of venting the fuel system:-
Direct to atmosphere.
Through the inward/outward vent valve assembly.
Through the pressurisation valve 'AL'.

During re-fuel F1,V1,V2,RL1,RL2 and RLF are vented to atmosphere via valve 'AL'.
N1,N2 and F2-3 are vented to atmosphere through the vent gallery.An air/no fuel valve in the top of each tank closes to prevent fuel venting if the fuel to the tanks continues past the shut off level.The valves also close to prevent fuel loss during inverted flight or negative 'G' conditions.

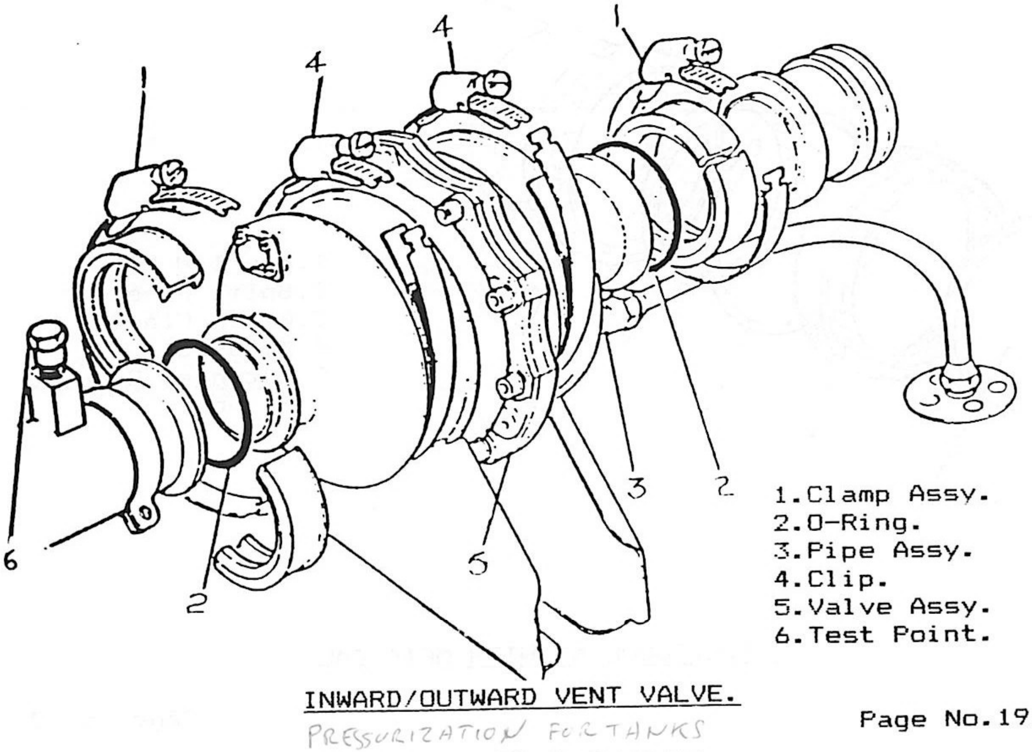
F4 tank also vents into the gallery and the vent line carries a non-return valve to allow fuel to drain back from the gallery to the tank.

A ram air non-return valve in the system allows air into N1 and N2 tanks to prevent them collapsing during a rapid descent.



1. Forward Clamp Assy.
2. Attachment Plate.
3. Rear Clamp Assy.
4. Seal.
5. Bonding Lead.

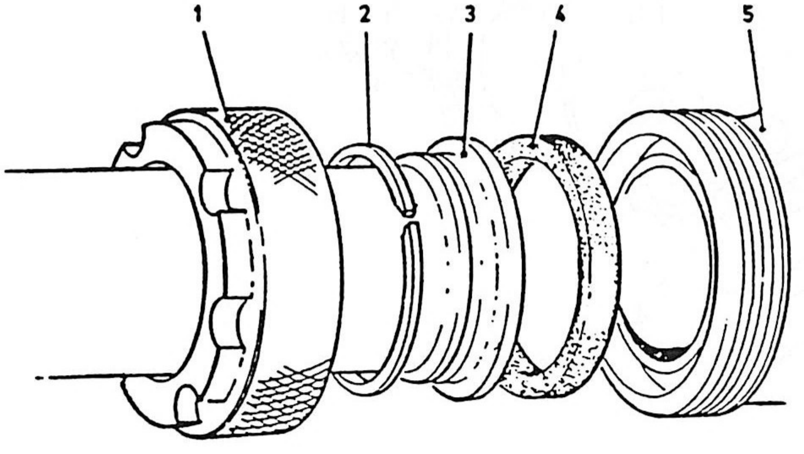
PRESSURE REDUCING VALVE.



1. Clamp Assy.
2. O-Ring.
3. Pipe Assy.
4. Clip.
5. Valve Assy.
6. Test Point.

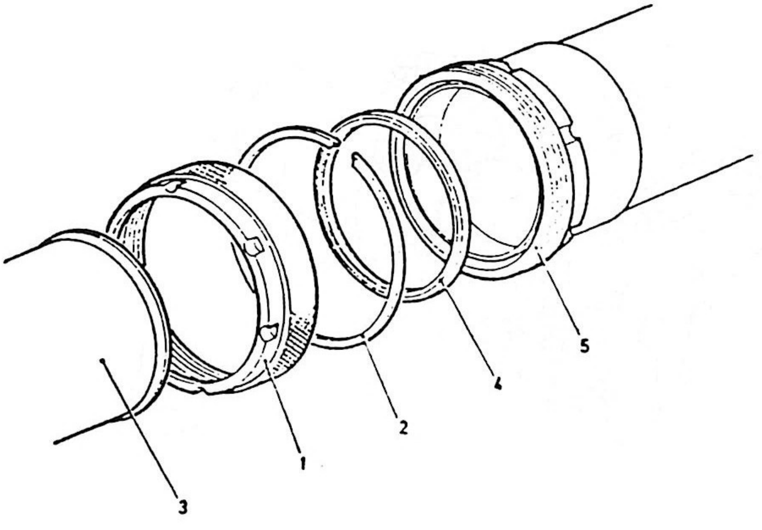
INWARD/OUTWARD VENT VALVE.

PRESSURIZATION FOR TANKS AT DIFFERENT ALTITUDES



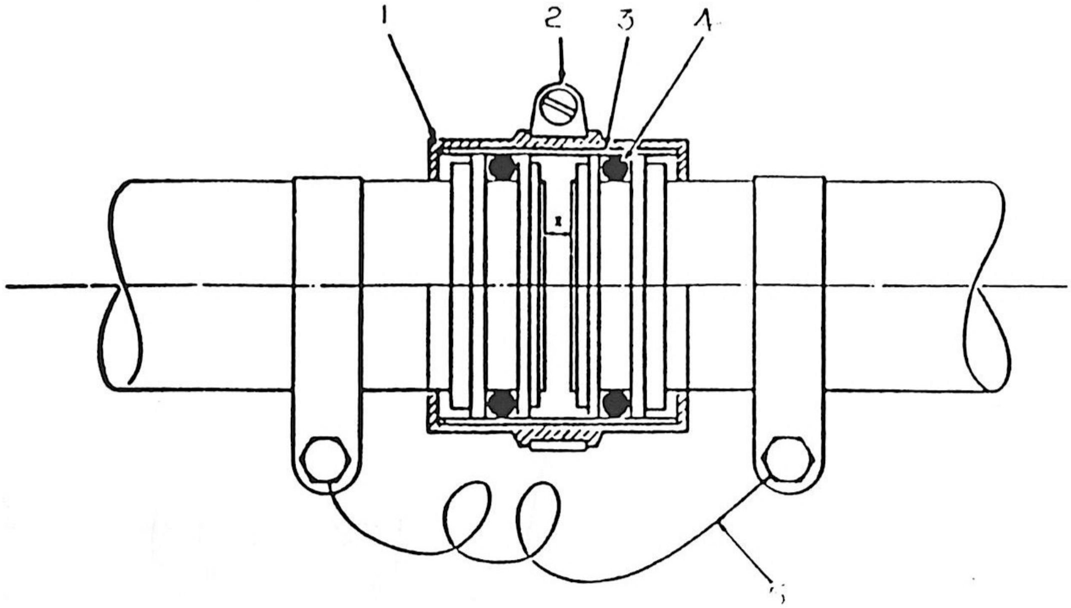
1. Knurled Nut.
2. Split Ring.
3. Plain Flange.
4. Seal.
5. Extended Grooved Flange.

H.T.E.COUPLING.



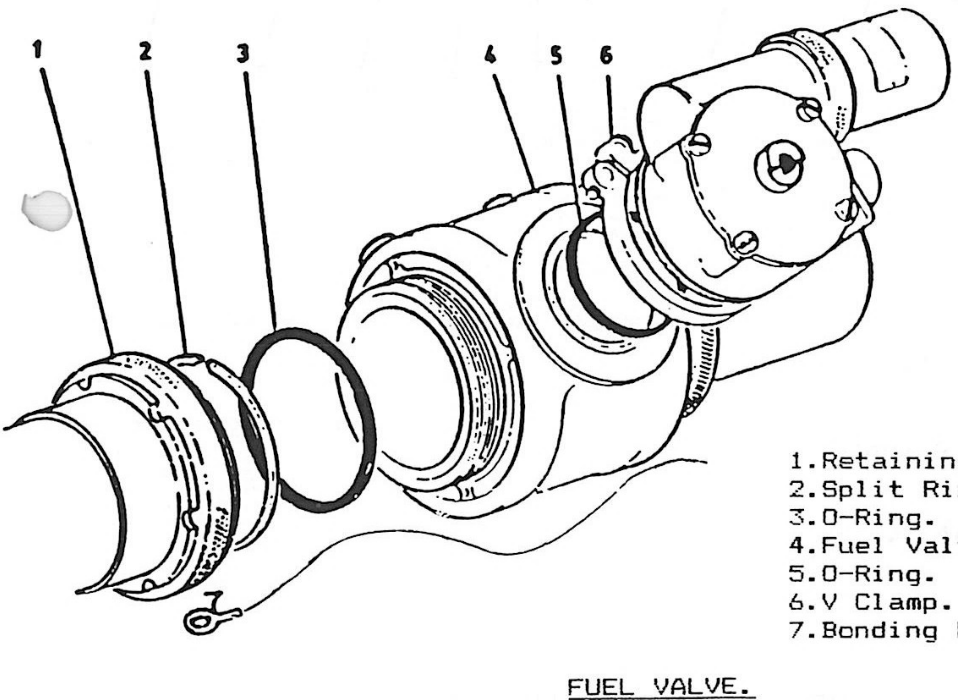
1. Knurled Nut.
2. Split Ring.
3. Plain Flange.
4. Metaseal.
5. Extended Grooved Flange.

H.T.E.COUPLING WITH METASEAL.

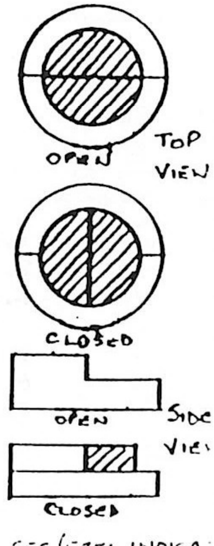


1. Half Collar.
2. Clip.
3. Sleeve.
4. O-Ring.
5. Bonding Lead.

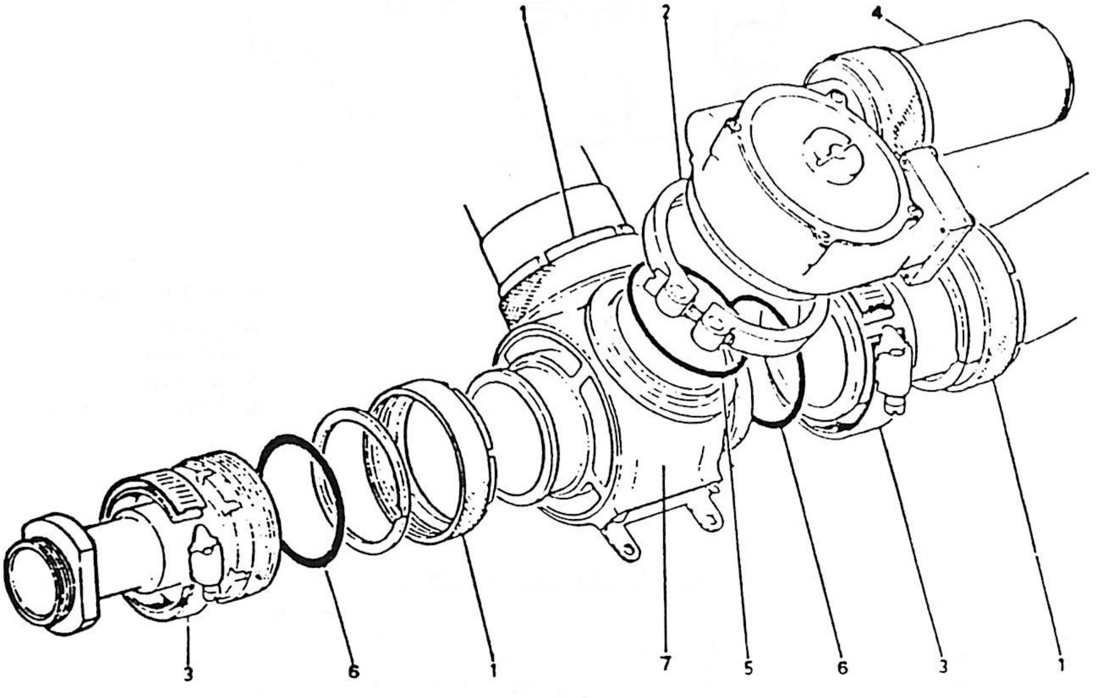
FLEXIRAC COUPLING.



1. Retaining Nut.
2. Split Ring.
3. O-Ring.
4. Fuel Valve
5. O-Ring.
6. V Clamp.
7. Bonding Lead.



FUEL VALVE.



1. Retaining Nut.
2. V Clamp.
3. Clips.
4. Electrical Actuator.
5. O-Ring.
6. O-Rings.
7. Valve Assembly.

PRESSURISATION VALVE 'AL'.

4. Fuel Valves.

Fuel valves,basically similar in construction,comprise a ball housing with an internal ball fitted between bearings.An actuator is fitted to the ball housing,one end of its shaft terminating in a tongue which engages with a slot in the drive spindle of the valve.The other end of the shaft protrudes through the actuator housing to provide a SEE/FEEL indication,the position of the indicator corresponding to the attitude of the valve.

'In Line' the valve is OPEN.

'Across' the valve is CLOSED.

The actuator comprises a DC split field,series wound, motor and gear train fitted in a housing.It is secured to the ball housing by a 'V' clamp which is torque loaded and wire locked on fitment.
The range of movement of the valve is 90 degrees determined by a limit switch shutting off the motor at each end of the movement range.A mechanical stop is incorporated in case of limit switch failure.

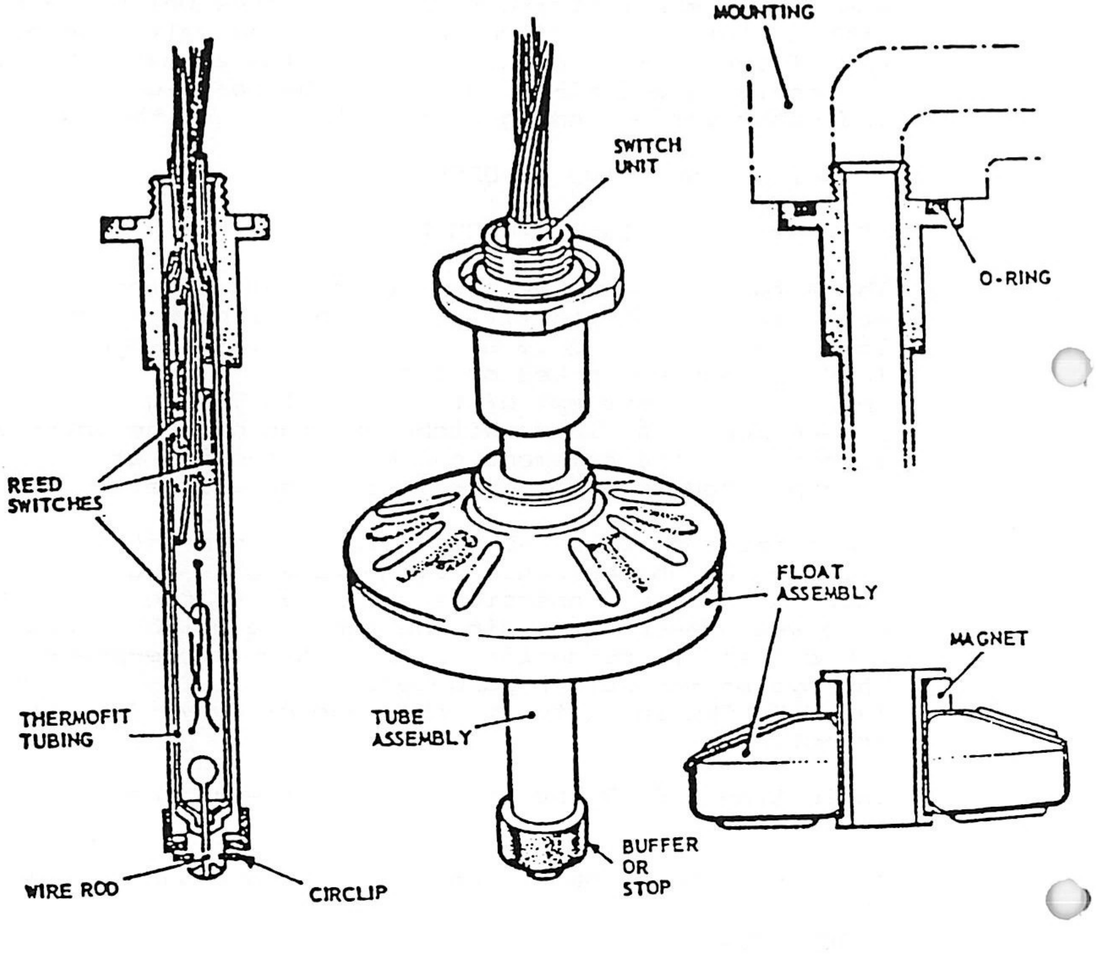
The exception to the above is the pressurisation valve 'AL' ,although the basic movements are as above.
There are three connections on the valve,one of which receives pressurising air and two more which direct the air either to pressurise the system or to de-pressurise the system for refuel purposes.
The SEE/FEEL indicator in the case of valve 'AL' is read as follows:-

Indicating CLOSED the system is in the de-pressurised mode.

Indicating OPEN the system is in the pressurising mode.

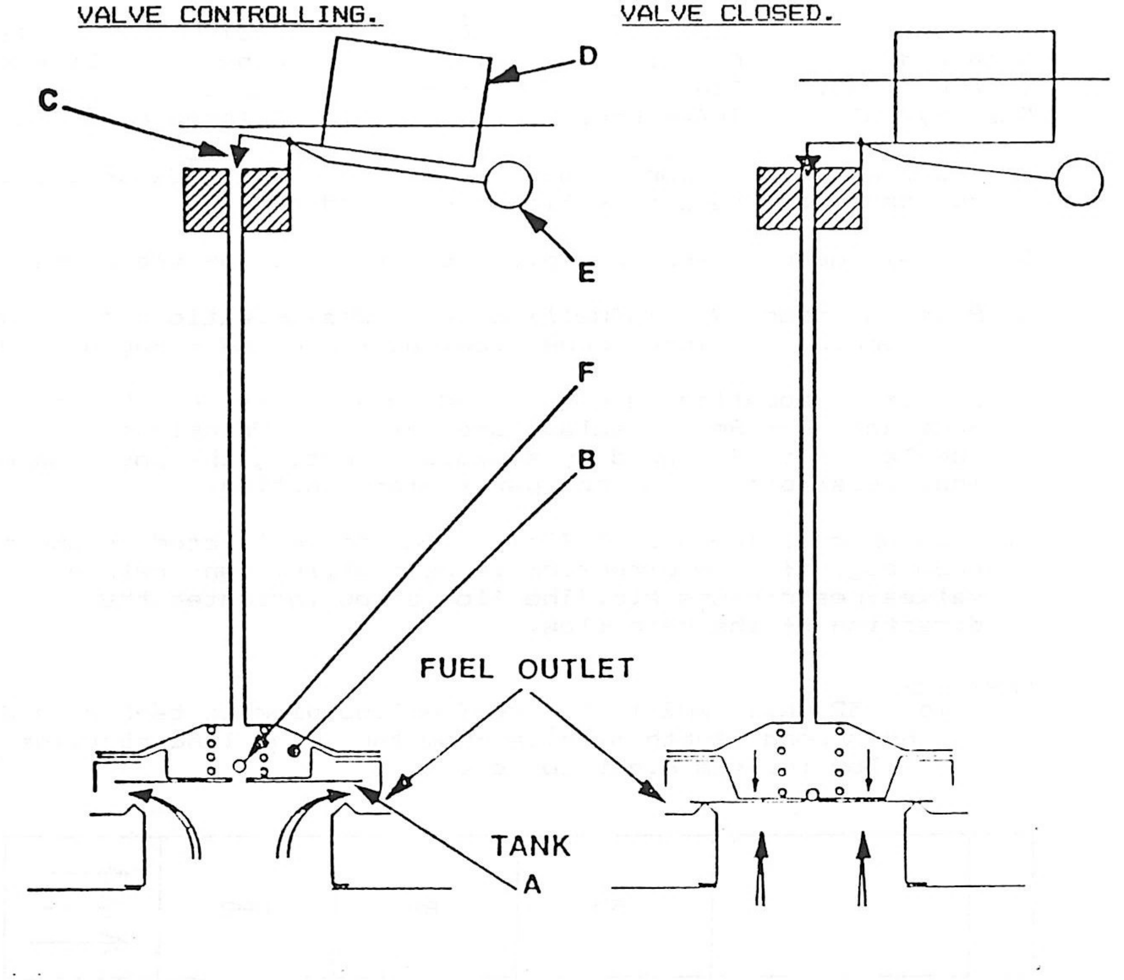
5. Float Switches.

There are high level,low level and mid level float switches in the system.Each float switch is basically similar in construction,comprising a tube enclosing two or more magnetically operated reed switches.An annular float assembly,carrying a permanent magnet,slides up and down the tube.As the float moves with the fuel level the magnet will operate the reed switches to give an indication of pre-determined levels.



FLOAT SWITCH.

6. <u>Float Valves.</u>
These are split into two parts,although operation is as one assembly,the two parts are referred to as:-
Float Valve Float Assembly,Float Valve Valve Assembly.



<u>Operation.</u>
When transfer commences fuel pressure opens valve 'A' and fuel enters chamber 'B' via ball valve 'F'.Fuel pressure in this chamber is controlled by float 'D' and valve 'C',positioned at the level required in the tank.As the level in the tank rises the float lifts and gradually closes off the bleed from 'C'. This causes pressure to rise in chamber 'B' thus starting to close valve 'A'.When the fuel is at the required level.float 'D' has fully closed valve 'C' preventing any further bleed from chamber 'B',the fuel pressure is now equal either side of valve 'A' which is closed by spring pressure.The hydraulic lock formed by the closure of valve 'C' prevents any further movement of valve 'A' until the fuel level falls allowing the float to drop and again open valve 'C'.During inverted fligh or negative 'G' conditions the counter weight 'E' closes valve 'C' by acting on the float.Valve 'A' is then held closed.

7. Fuel Pipes.

The fuel pipes are of various bores, dependent upon the function of the sub-system in which they are fitted. Each pipe has a functional marking on pre-printed bands of adhesive tape, the marking is as follows:-

(A)	(B)	(C)	(D)	(E)
Standard International Fuel Symbol.	Aircraft Fuel Reference.	Pipe Function.	Pipe Position Reference.	Direction of flow arrow, AS Required.

A. Standard International Fuel Symbol. Black diamonds around the periphery of the pipe, followed by a red band.

B. System Number..Each fuel pipe is identified by the number 52.

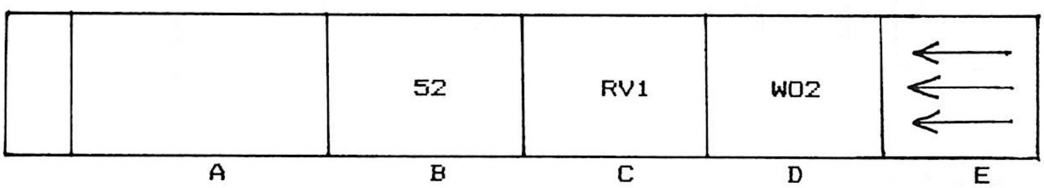
C. Pipe Function. R - Refuelling. P - Pressurisation. T - Transfer. PU - Drain. I - Interconnection. AL - Air. AR - Engine Supply.

D. Location. Location is designated by a letter: F - Centre fuselage. E - Rear fuselage and tail. W - Mainplane. The letter is followed by a number denoting the position of the individual pipe in of the particular function.

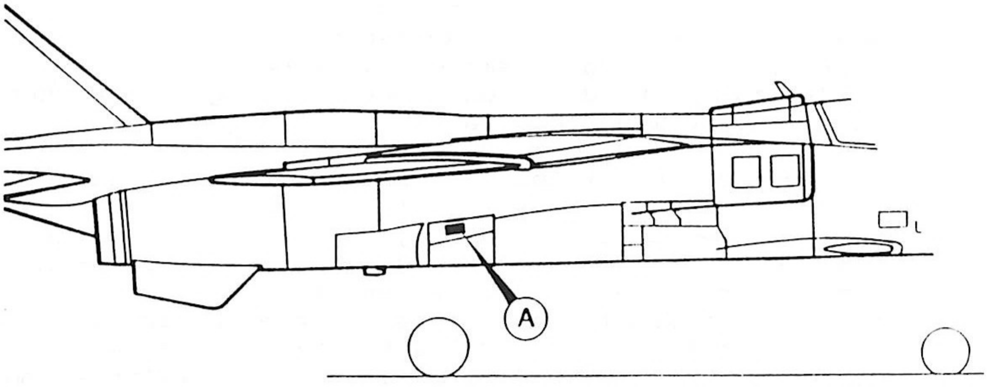
E. Flow Arrows. The use of flow arrows is restricted to where knowledge of flow direction is helpful, ie. non- return valves, restrictors etc. (The flow arrow indicates the direction of the main flow.

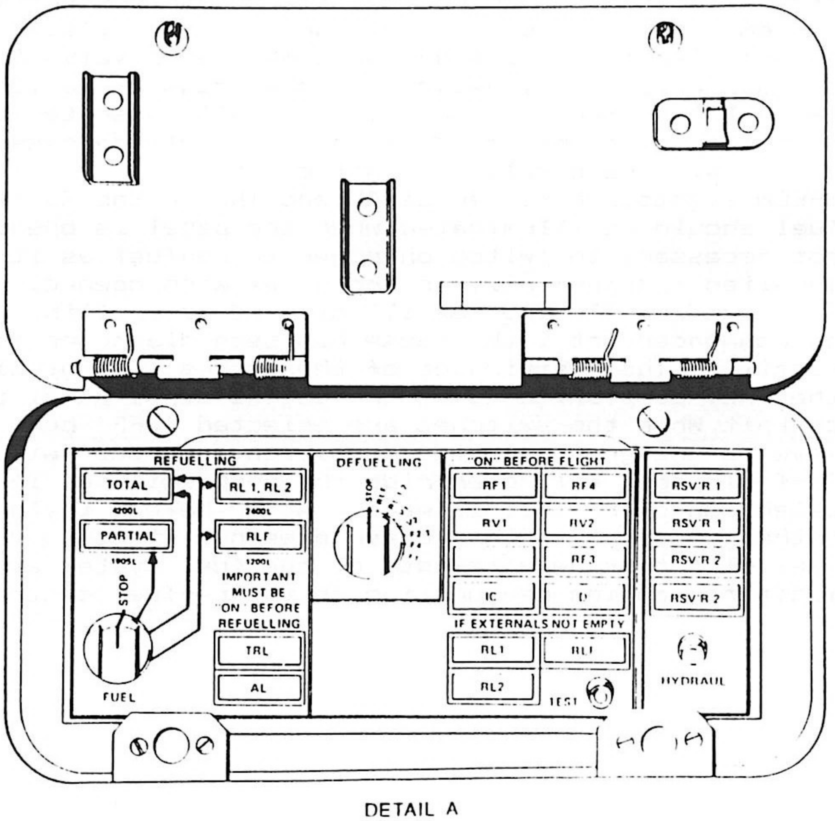
Example.

Symbol 52 RV1 W02 is the re-fuelling pipe to tank V1 and is the second length of pipe from the main plane root. The fuel flow is from right to left.



GROUND RE-FUELLING.





DETAIL A

GROUND RE-FUEL/DE-FUEL CONTROL PANEL.

8. <u>Ground Re-fuelling.</u>

General.
Two methods of re-fuelling are available Pressure and Gravity.Under normal circumstances the gravity method would only be used in emergency or under exercise conditions.A third method of re-fuelling can be used and this will be mentioned later.

The re-fuelling of the aircraft,using the pressure system requires certain conditions to be satisfied.These relate to the orientation of fuel system components prior to re-fuelling.All conditions are monitored by the Re-fuel/De-fuel control panel (see diagram) in the form of an illuminated display therefore the pre.re-fuelling check of the system is simplified.The position of valves AL and TRL is the main pre-requisite of the system. Valve AL must be in the de-pressurised position and Valve TRL must be closed.The reasons being that if the air pressurised system were not opened to atmosphere then difficulty would be experienced in filling the tanks,hence valve AL open to atmosphere.Secondly valve TRL is a transfer valve on the re-fuel transfer line and will normally operate at 5 psi. As bowser pressure is 50 psi.damage would be caused to the float valve were valve TRL not closed.
GREEN lights,identified as AL and TRL on the Re-fuel/De-fuel should be illuminated when the panel is opened.It is not necessary to switch on power to re-fuel as it is supplied independently to the panel when opened.
If AL and/or TRL are not illuminated re-fuelling <u>must</u> <u>not</u> be commenced until the cause has been diagnosed and rectified.The positioning of the valves is controlled by the fuel pump switches on the engine start panel in the cockpit.When the switches are selected 'OFF' both valves move to the ground re-fuel position.The FUEL switch on the Re-fuel panel will over-ride the pump switches if a selection of re-fuel is made,however before trying this method ensure that the bowser does not start to deliver fuel.All other requirements of the fuel system are monitored,during re-fuelling,on the re-fuel control panel.

Hot Re-fuelling.

This will be carried out with the pilot in the cockpit and the port engine running. In this situation the fuel pump switches will be selected 'ON' in the cockpit therefore AL and TRL will not be illuminated on opening the re-fuel/de-fuel panel. This can be overcome by the method mentioned in the last paragraph.

Indications.

Beneath the 'ON BEFORE FLIGHT' caption on the re-fuel/de-fuel panel are the lights for the individual tanks in the aircraft. Note: F2 is not indicated. Whilst re-fuelling the individual lights will be extinguished as the high level float switch in each tank closes the re-fuel valve. The last tank to fill will illuminate the appropriate light on the left of the panel ie. PARTIEL, TOTAL, RL1-RL2 and RLF. the light illuminated will depend on which fuel load has been selected.

The exception to this rule are the drop tank indicators on the bottom of the panel under the caption 'IF EXTERNALS NOT EMPTY'. These indicators will be 'ON' during a re-fuel and will go out as the tank is filled. As the same line is used for re-fuel and for transfer it will now be necessary to re-open the re-fuelling valve to allow transfer to take place. This is simply done by the action of selecting 'STOP' on the fuel switch, also the lights will now illuminate indicating the valves have re-opened.

Lights 'IC' and 'D' on the panel relate to the inter-connecting valve between N1 and N2 tanks and the jettison valve respectively, with the light 'ON' the valve is 'CLOSED'.

On the two-seater version an extra light can be seen indicating valve 'V'. The light should be 'ON' indicating 'CLOSED'. THe valve will open when the jettison switch is set to 'ON'.

Pressure Re-fuelling.

Three pressure re-fuelling programmes can be selected by the FUEL switch on the control panel. These selections allow for differing requirements of the aircraft. The programmes are as follows:-

Partial Re-fuel.

In this mode fuel tanks F1, N1, N2 and F4 (To the M2 level) are replenished. The total amount of fuel in the aircraft is:-

Single Seater.........approx.1160 Kgs.

Two Seater............approx.1595 Kgs.

Total Fuel Load.

Fuel tanks N1,N2,F1,F2-3,F4,V1 and V2 are replenished in this mode to atotal fuel load of 3200 Kgs.

Total Plus Load.

In addition to a total fuel load,either one,two or three drop tanks will be replenished in this mode,depending on the role fitment required.For the complete fuel load add 950 Kgs.for each drop tank to the total fuel load.

Gravity Re-fuelling.

Gravity re-fuelling is achieved by the use of re-fuelling caps in tanks F1 and V1,V2.Each re-fuelling point is complete with a filter assembly to protect the fuel system.All fuel must be passed through a filtration point before being put into the aircraft.A normal selection of 'TOTAL' must be made on the re-fuel/de-fuel panel to ensure that the re-fuelling valves open.To re-fuel the drop tanks each tank is provided with three filler caps.It will be found in practice that approx.85% of the total load will be accepted by the aircraft.This is due to difficulty of access without pressure being applied.

9. De-fuelling.

De-fuelling of the aircraft is controlled by the de-fuel switch on the re-fuel/de-fuel panel.Each fuel tank can be selected independently,remembering that F2-3 is considered as one tank.If external tanks are fitted they should be emptied first to maintain the C of G of the aircraft. When a tank selection is made on the De-fuel switch the relevant Re-fuel valve will open and the remainder closed. With bowser suction applied at the re-fuel connection the tank will empty.No air pressure or pump pressure is required to complete the operation.To completely de-fuel the aircraft the selector is moved to each tank in turn. NOTE:F4 is drained before F1 to prevent the aircraft becoming tail heavy.

On completion of the bowser de-fuel N1 and N2 tanks will contain approx.220 Kgs.of fuel.To complete the de-fuel these tanks are drained via the water drains.

Re-fuel Through the De-fuel Switch.

As seen during de-fuel the operation consists of opening the re-fuel valve.Therefore it follows if fuel can be taken out that way it can be put in the same way.However there are some points to observe.

i. As re-fuelling is to be carried out through only one valve,delivery pressure must be reduced.

ii. Whilst re-fuelling through the de-fuel switch the high level float switches will be in-operative,therefore certain tanks will vent to atmosphere,a hose must be connected to the external vent pipe and the overflow collected in a suitable container.

SYSTEM CONDITION \ INDICATOR	TRANS LIGHT	INTER LIGHT	N1 LIGHT No 1.(CWP)	N2 LIGHT No 2 (CWP)	LP1 LIGHT No 1	LP1 LIGHT No 2	BP1 LIGHT 1 (CWP)	BP2 LIGHT (CWP)	F3 PUMP	F3 PUMP	F4 PUMP	F4 PUMP	AIR PRESS	R.L.1.	R.L.2.	R.L.F.	V.1.	V.2.	OBSERVATIONS
INITIAL STATE	⊗	⊗	⊗	⊗	⊛	⊛	⊛	⊛	OFF	OFF	OFF	OFF	⊛	■	■	■	■	■	POWER ON AIRCRAFT AND NO SWITCHING MADE.
FUEL PUMP ON	⊗	⊗	⊗	⊗	⊗	⊗	⊛	⊛	OFF	OFF	ON	ON	⊛	■	■	■	■	■	STAGE 1 OF FUEL TRANS COMMENCED N1 AND N2 FILLED TO LEVEL 1 STATE.
ENGINES RUNNING AIR PRESSURE TO TANKS	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	OFF	OFF	ON	ON	⊗	■	■	■	■	■	RLF SHOWN TO HAVE TRANS FUEL TO F2 FUEL TANK RL1 OR RL2 COULD CHANGE.
STAGE 2 FUEL TRANS	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	ON	ON	OFF	OFF	⊗	▨	▨	▨	■	■	FUEL DRAWN FROM CENTRE GROUP AT THIS STAGE SUPPLIED BY EXTERNAL TANK
STAGE 2 FUEL TRANS	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	ON	ON	OFF	OFF	⊗	□	□	□	▨	▨	FUEL FROM CONTRE GROUP WING TANKS SUPPLYING FW &3. F2 & 3.
STAGE 3 FUEL TRANS	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	OFF	OFF	ON	ON	⊗	□	□	□	□	□	F1 AND F4 TRANS TO N1 AND N2 N1 AT LEVEL 3, N2 AT LEVEL 1
FINAL STAGE	⊛	⊛	⊛	⊛	⊗	⊗	⊗	⊗	OFF	OFF	OFF	OFF	⊗	□	□	□	□	□	F1 AND F4 EMPTY N1 AND N2 DECREASED TO LEVEL 4 STATE.

NOTE.
THE ABOVE INDICATIONS ASSUME THAT THE FUEL TRANSFER COMMENCES WITH ALL FUEL TANKS FULL AS PER A REFUELLING PROGRAMME TOTAL RL1, RL2 AND RLF.
DEFECTS INDICATIONS ARE NOT CONSIDERED.

⊗ — LIGHT NOT ON

⊛ — LIGHT ON

10. <u>Fuel Transfer Sequence.</u>

The fuel transfer is a fully automatic system controlled by float switches and float valves.Two methods of transfer are used as follows:-

Air pressure to transfer fuel from all drop tanks,V1,V2 wing tanks and F1 fuselage tank.

AC fuel pumps to transfer fuel from F4,F2-3 tanks to the collector tanks N1 and N2.

For the purpose of seeing the full transfer we will assume the aircraft to be fully loaded to total + with all three drop tanks fitted.

On entering the cockpit,with external power applied, the Fuel Management Panel indications will be:

External tank indicators.........Black.

Wing tank indicators.............Black.

F3 and F4 pump indicators........Off.

Trans and Inter lights...........Off.

Air pressure light...............On.

LP1/LP lights....................On.

All FMP switches.................Auto.

With the selection of LP pump switches to 'ON' in preparation to start the engines the following takes place:-

LP1 and LP2 lights...............Off.

F4 pump indicators...............On
(On AC 213 and 214 the F3
indicators show).................On.

Air light........................On.

All magnetic indicators..........Black.

Start both engines.

<u>Fuel Transfer Stage 1.</u>

After start and remembering that F2-3 tank is only filled to the level 2 position fuel under air pressure will be transferred from the drop tanks to fill F2-3 to the level 1 position.This transfer may be enough to change the magnetic indicator one one of the drop tanks from BLACK to CROSS-HATCHED.

Fuel from tank F4 will flow to the collector tanks to maintain them at a level 1 condition.As the level falls in F4 tank the quantity detector,receiving a signal from the gauge probes in the tank,will detect when the fuel has reached the M1 level.

M1 level on 'S' version.........400Kgs.+ or - 30Kgs.

200 and 203.....................780Kgs + or - 30Kgs.

There is no M1 level on 213 or 214.

At this point F3 pumps will be switched 'ON' and after a 3 second delay F4 pumps switched 'OFF'.The display on the FMP will go from REAR to CENTRE.

Fuel Transfer Stage 2.

As 213 and 214 started at this stage fuel transfer will be identical from this stage

Fuel will be transferred from F3 to the collector tanks to maintain level 1 conditions in those tanks.F2 will replenish F3 continuously by gravity feed via two pipe lines connecting the tanks together.As the level falls the level 1 float valve will open and allow transfer from RL1,RL2 and RLF.Transfer will continue from these tanks until they are empty.At this stage the low level float switch will:
Change the magnetic indicators to WHITE.

Close the re-fuel/transfer valves to prevent air reaching F2 tank.

Fuel will once again be transferred from the F2-3 tank until the level 3 float valve is reached,at this stage V1 and V2 will commence to feed to F2 via two non-return valves and the wing indicators will change from BLACK to CROSS-HATCHED.
Fuel will continue to transfer from the wings until they are empty,at this stage the low level float switch will change the magnetic indicators to WHITE.A fuel/no air valve will prevent air reaching F2.

To maintain aircraft Cof G.fuel will still be fed from F2-3 to the collector tanks.This feed will continue until the first part of the two part float switch is made.This is preparing the system for the final part of the transfer sequence.By studying the diagram it will be seen that if some provision is not made for F1 to feed to level 3 in N1 tank then that tank will be unable to transfer fuel.With F2-3 empty the second part of the float switch is made and this will switch ON F4 pumps and after a 3 second delay switch OFF F3 pumps,simultaneously valve 'N' will be closed.This action will prevent F4 from feeding N1 and so the level in that tank will fall.

The INTER light will not illuminate as the level 2 thermistor is exposed to air as this is part of the normal transfer sequence.When the level 3 float valve is reached fuel will flow from F1 to N1 under air pressure.Fuel in the two N tanks will be as Follows:
F4 maintaining N2 at level 1
F1 maintaining N1 at level 3.

At this stage,on the single seat aircraft only,there will be more fuel in F1 than F4 so therefore F4 will empty first.As the level drops in N2 the level 2 thermistor will illuminate the INTER light,at the same time a TRANS light will also come on,although indications are of a fault there is nothing wrong in the system.As the level further drops in N2,level 3 float valve will open and N2 will then also be fed from F1.

On both two-seat versions there will be more fuel in F4 than F1 therefore F1 will empty first,to allow F4 to feed both N1 and N2 the low level float switch in tank F1 will re-open valve N,also at this stage a TRANS light will be illuminated indicating the end of the transfer sequence.

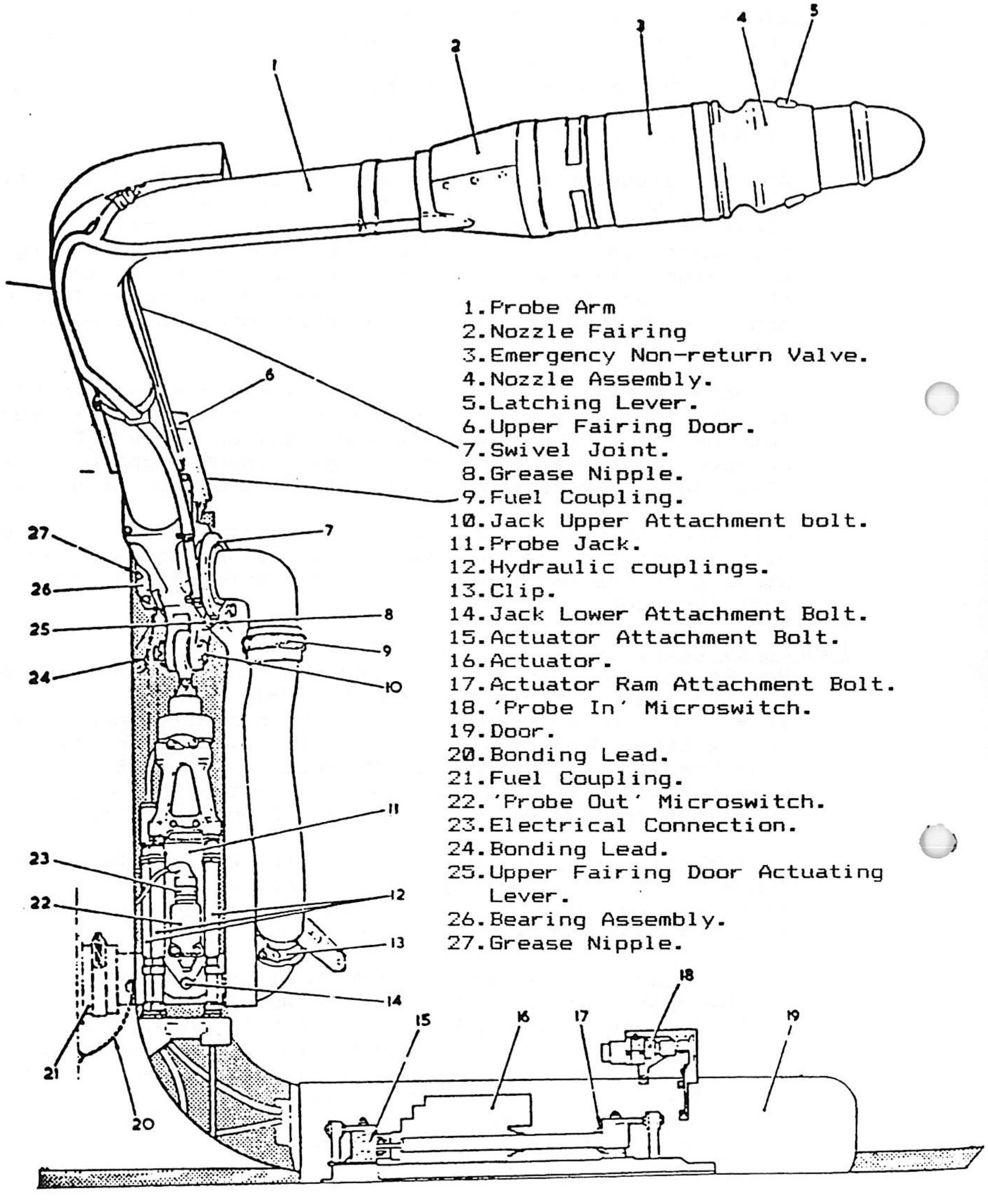
With fuel only in N1 and N2,when the level drops to level 4,the thermistor at this level will illuminate a N1/N2 warning on the CWP indicating there is less than 100Kgs of fuel per tank.

Emergency Selections.

Providing that both air pressure and pumps are available all the fuel in the system can be used.
If fuel cannot be transferred in the normal manner from V1 and V2,Level 3 float valve stuck closed,Selection of the wing transfer switch on the FMP from AUTO to OPEN will open the wing re-fuelling valves and allow the wing fuel to pass through them and to valve TRL and to F2 tank.

If fuel cannot be transferred from the drop tanks,Valve TRL stuck in the closed position, once again select wing transfer from auto to open and this time the fuel will flow via the wing feed lines to F2.

If fuel cannot be transferred from F1 tank,Valve N stuck in the open position,select Centre,Auto,Rear switch to Centre and the N1,N2 Auto/Open switch to Open,this action will start the centre pumps and open valve IC and also F1 and F3 re-fuelling valves.This will allow fuel to flow from F1 to F3 and thence be pumped to N1 and N2.In this situation care must be taken to monitor the C of G.in case of the aircraft becoming tail heavy.



1. Probe Arm
2. Nozzle Fairing
3. Emergency Non-return Valve.
4. Nozzle Assembly.
5. Latching Lever.
6. Upper Fairing Door.
7. Swivel Joint.
8. Grease Nipple.
9. Fuel Coupling.
10. Jack Upper Attachment bolt.
11. Probe Jack.
12. Hydraulic couplings.
13. Clip.
14. Jack Lower Attachment Bolt.
15. Actuator Attachment Bolt.
16. Actuator.
17. Actuator Ram Attachment Bolt.
18. 'Probe In' Microswitch.
19. Door.
20. Bonding Lead.
21. Fuel Coupling.
22. 'Probe Out' Microswitch.
23. Electrical Connection.
24. Bonding Lead.
25. Upper Fairing Door Actuating Lever.
26. Bearing Assembly.
27. Grease Nipple.

FLIGHT RE-FUELLING PROBE.

11. Flight Re-fuelling.

General.

Flight re-fuelling is carried out,on a single seat aircraft,via a hydraulically extended and retracted probe,located on the starboard side of the fuselage at frame 8.On the later two seater version aircraft re-fuelling is carried out through a permanently extended probe in the position of the main pitot tube.Both re-fuelling connectors are identical.

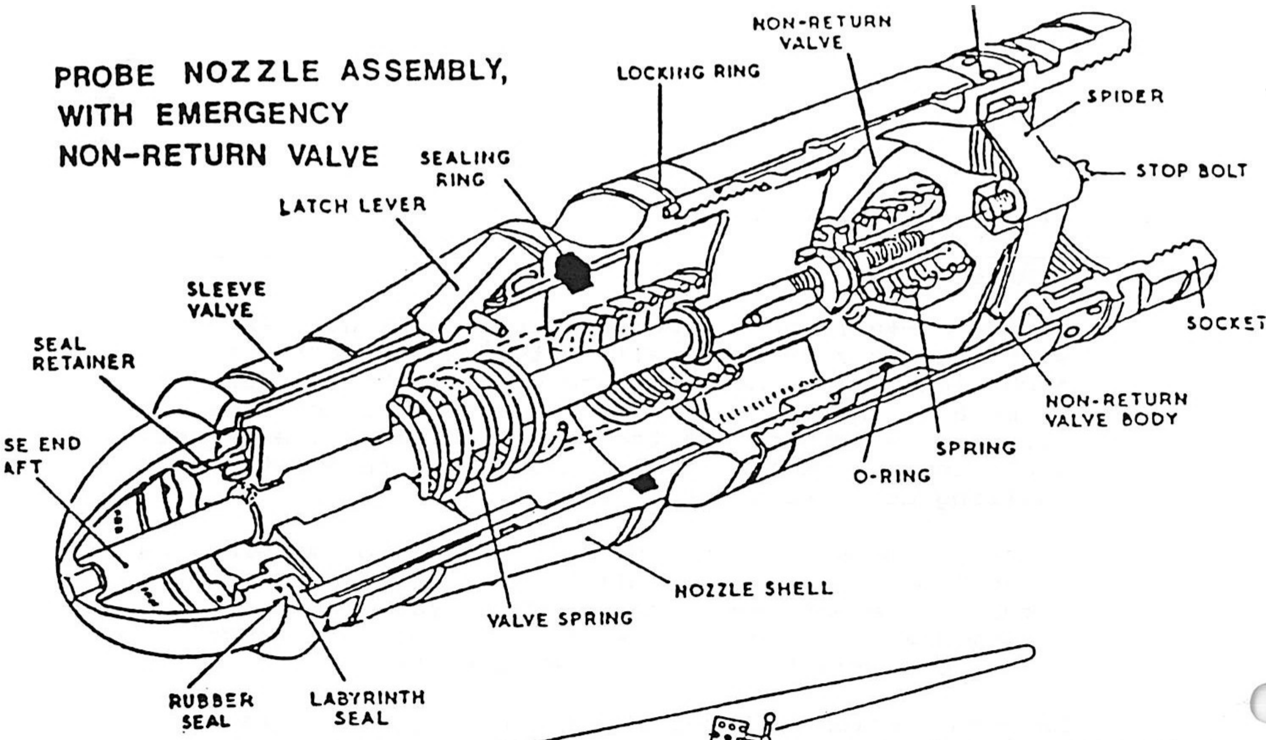
Hydraulic power for extending the probe,'S' version, is taken from the No.1 hydraulic system,in emergency the probe can be extended from the No.2 hydraulic system,however this is extension only and the probe cannot be retracted using the No.2 system.

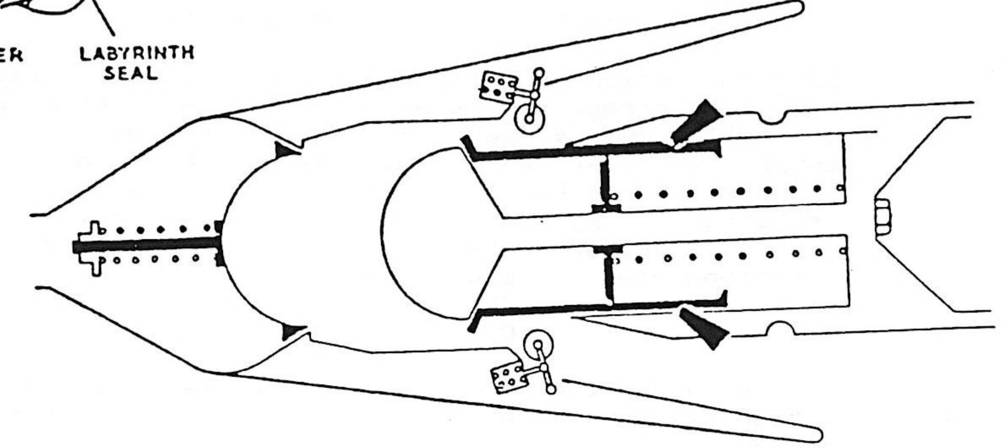
On both versions the flight re-fuelling system is connected directly to the ground re-fuel system and is controlled by a flight re-fuel selector switch.
On the single seater the control switch is on the upper part of the starboard forward console,under the coaming,and comprises a four position switch,which should be depreesed to operate,the four selectable positions are:- EMERGENCY.
IN.
OUT.
REFUEL.
On the two seater the control is in the same position but on the port forward console,the three positions are:- REFUEL.
DRY.
OFF.
Each selection operates the probe and the re-fuelling system according to the requirement selected.

Operation of the System.

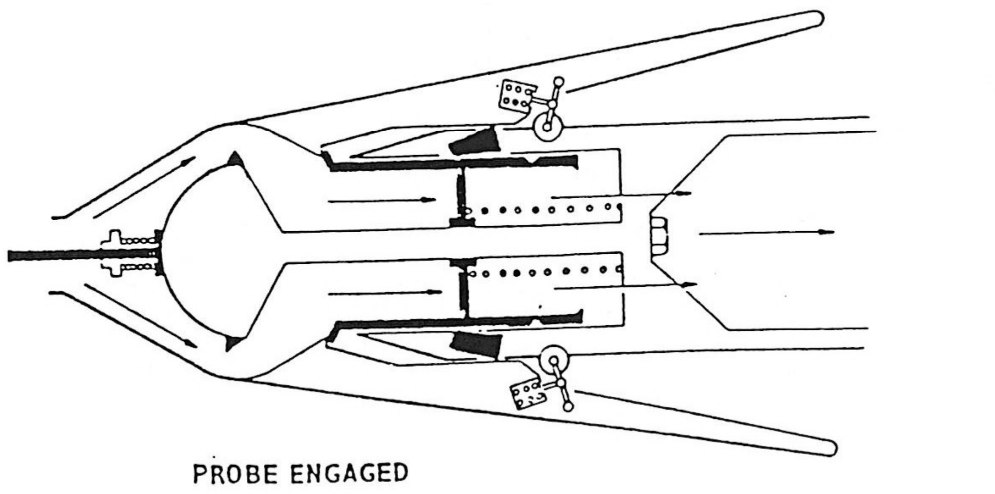
Re-fuel Selected.
When re-fuel is selected on the single seater version an electrical supply is placed on the door actuator.Immediately the door begins to move a RED 'Probe in Motion' lamp will illuminate,when the door is fully open the probe extend hydraulic actuator will be energised and the probe will move to the fully open position.As it begins to open a probe light will illuminate to give the pilot visibility of the probe in poor light conditions.When the probe is fully extended the door will close and the 'Probe in Motion' light will go out.

PROBE NOZZLE ASSEMBLY, WITH EMERGENCY NON-RETURN VALVE





PROBE DISENGAGED



PROBE ENGAGED

PROBE FUNCTIONAL DIAGRAM.

It will be appreciated that as the probe is extending the fuel system is being 'set up' to the flight re-fuel mode.This will occur on both versions of the aircraft.

The fuel system will be de-pressurised by the movement of valve AL,air light will come on on the FMP.

Valve TRL will close to prevent fuel entering F2 tank.

Valve IC will open to connect N1 and N2 tanks.

All re-fuelling valves will motor to open.

On completion of these operations a GREEN 'Ready to Re-fuel' light will illuminate,informing the pilot that he may now accept fuel.

On completion of re-fuel a selectiom of IN (S.Version) or OFF (B.Version) will return all components to their normal configuration.The movement of the probe will be a reversal of the extension.

Out or Dry Selection.

The OUT (S.Version) or DRY (B.Version) selection is a facility provided for training in flight re-fuel procedures
As the tanker hose is fully primed certain precautions must be taken to prevent inadvertent damage through fuel acceptance.To prevent this if external tanks are fitted the re-fuelling valves to the tanks will be closed.Valve TRL will be closed to prevent fuel entering F2.To prevent surges in the system and damage occurring re-fuelling valve RF4 will be opened on a 'S' version and RF3 on the 'B' version.
An IN or OFF selection returns the system to normal.

Emergency Selection.(S.Version Only).
The operation of the probe door,probe and fuel system components will follow the same pattern as a normal REFUEL selection.The main difference being that the emergency hydraulic selector valve will be used to extend the probe and hydraulic supply will be from the No.2 hydraulic system.
During an IN selection the probe will remain extended but the fuel system will return to its normal configuration.On IN selection the probe door will open and remain open therefore the starboard gun is made inoperative.
A switch indicating F1-F4/OFF is located on the port forward console,this switch will be used during flight re-fuel operations to control the C of G of the aircraft in case of failure of either F1 or F4 re-fuelling valve.Movement to OFF will close the other valve.

12. <u>Fuel Jettison.</u>

Jettison is controlled by a switch on the port forward console and will operate valve D in the system.The selection of 'Jettison' will open valve D and fuel will be jettisoned via the dump line to the vent line.The transfer system now acts as a jettison system and fuel is pumped overboard in the transfer sequence until switched OFF or a pre-determined level in F4 is reached.N1 and N2 each receive fuel as normal from the fuel transfer system.

Automatic Cancel Levels are as follows:-

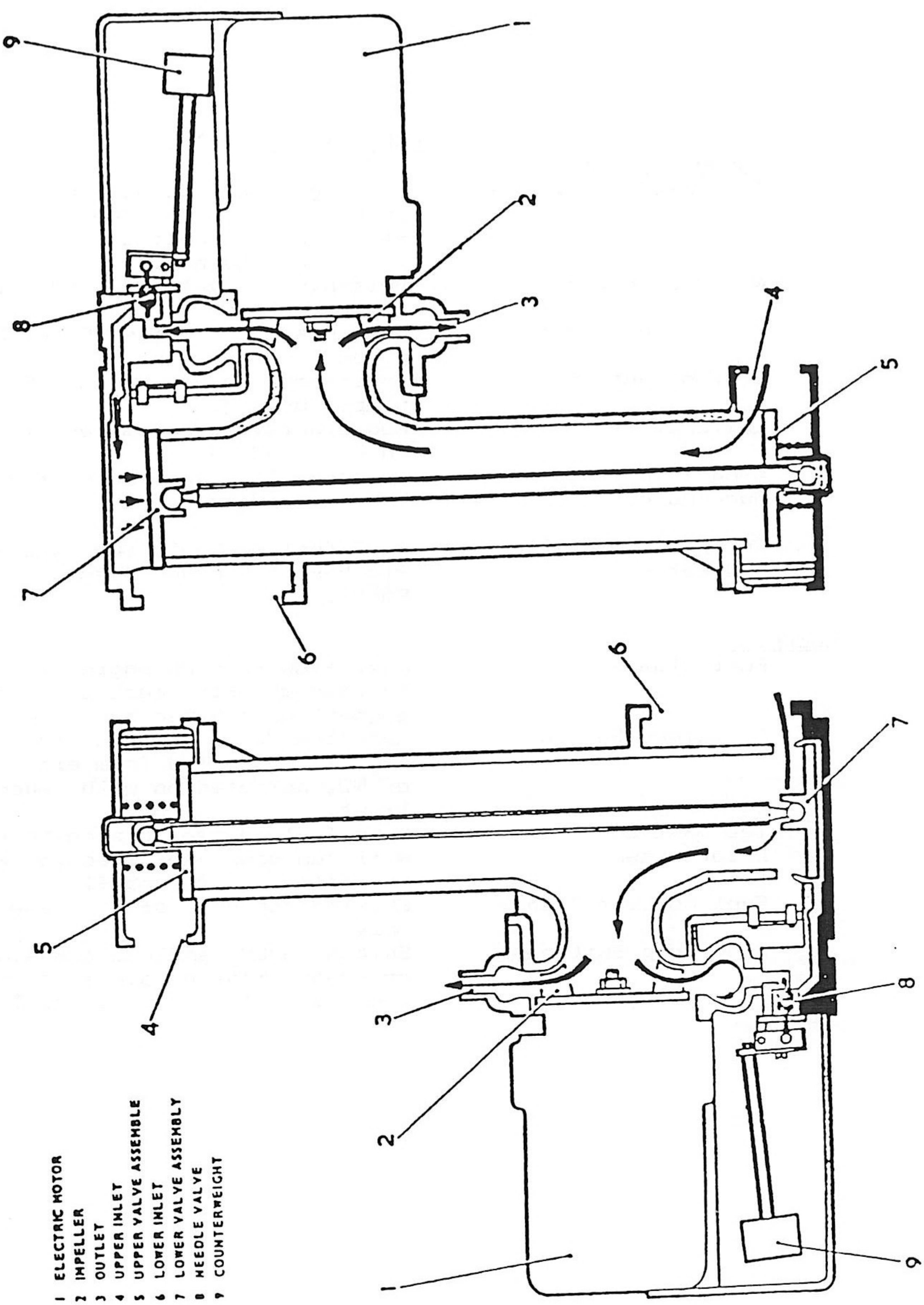
All ~S~ version aircraft...............310Kgs.
Aircraft 213 and 214...................840Kgs.
Aircraft 200 and 203...................730Kgs.

It can be seen from the fuel system diagram that it is not possible to jettison from F1 tank because it is not connected to the jettison line.

<u>N1 and N2 Fuel Pumps.</u>

As no recuperators are fitted to the aircraft it is necessary for the N1 and N2 pumps to function in the normal and inverted positions.

Under normal conditions fuel enters the pump at 6 into the impeller 2 and out to the engines at 3.
The float counter-weight 9 holding the needle valve 8 in the closed position.On inverting the aircraft the counter-weight 9 drops and the needle valve 8 is opened allowing fuel from the impeller to be felt behind the lower valve assembly 7.This pressure overcomes the spring moving the valve assembly and closing off inlet 6 as this happens another inlet 4 is opened and fuel can then flow via the impeller to the outlet 3,thus the inlet of the pump is kept in fuel at all times.



N1 AND N2 LP FUEL PUMP.

COCKPIT CONTROLS AND INDICATIONS.

Fuel Management Panel.

Air Pressure Light.	Red Light,indicating tank pressurisation failure.
Trans.Light.	Red Light,indicating incorrect transfer sequence.
N1/N2 Open/Auto.	Switch,opens valve IC and N if closed.
Centre/Auto/Rear.	Switch,selects either F3 or F4 pumps.
Off/On Captions.	Indicators,showing either F3 or F4 pumps running.
LP1,LP2.	Red Lights,indicates pump failure in N1 or N2 tank.
Wing Transfer, Open/Auto.	Switch,will open wing re-fuel valves in Open.
Port/Stbd.Magnetic Indicators.	Wing fuel contents indicators Black-Full,Striped-Feeding,White-Empty.

Cockpit.

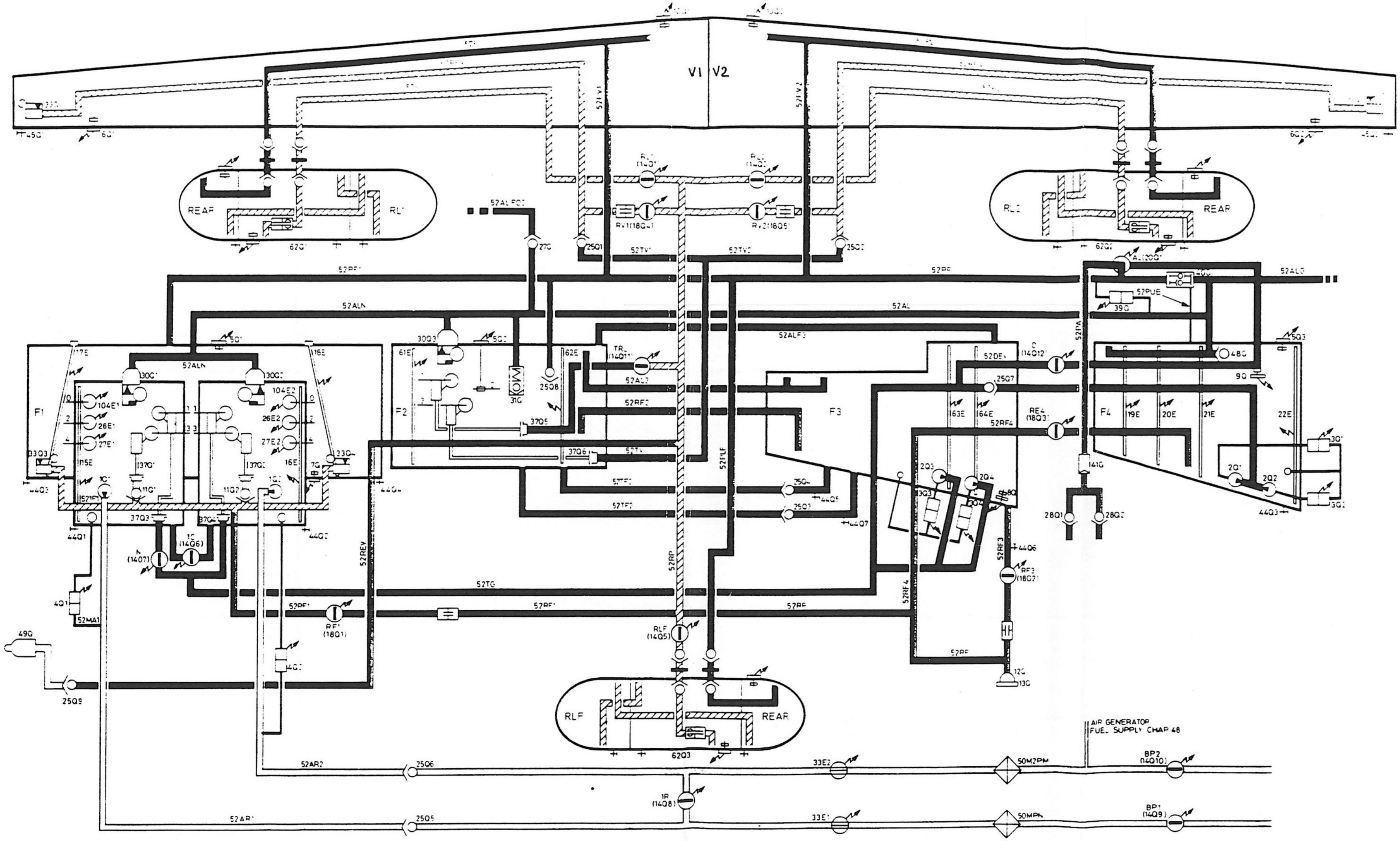
Fuel Flowmeter.	Fuel flow to each engine in Kgs.per min.Flow must be in orange segment with after-burner on.
Crossfeed Switch.	Operates Valve IR,allowing both engines to be fed from either N1 or N2,indicated on with amber light.
Test Button.	Runs fuel gauges to zero to test.
Detotaliser.	Will run down fuel load in 10 Kg.increments during flight.
Fuel Content Gauges.	Showing contents of fuselage tanks only.
Fuel Pump Switches.	Switch on LP1 and LP2 pumps,also relevant transfer pumps.Controls operation of Valves AL and TRL.

Air/No Fuel Valve.

Three air/no fuel valves are fitted in the venting system,one each in the top of tanks N1,N2 and F2. Each valve connects the respective tank to the vent gallery. The air/no fuel valve opens whenever the pressure inside the tank is lower than the pressure outside and during normal flight when the float is not immersed. The valve closes when the pressure inside the tank is higher than the pressure outside,during inverted flight and during normal flight if the float is immersed.

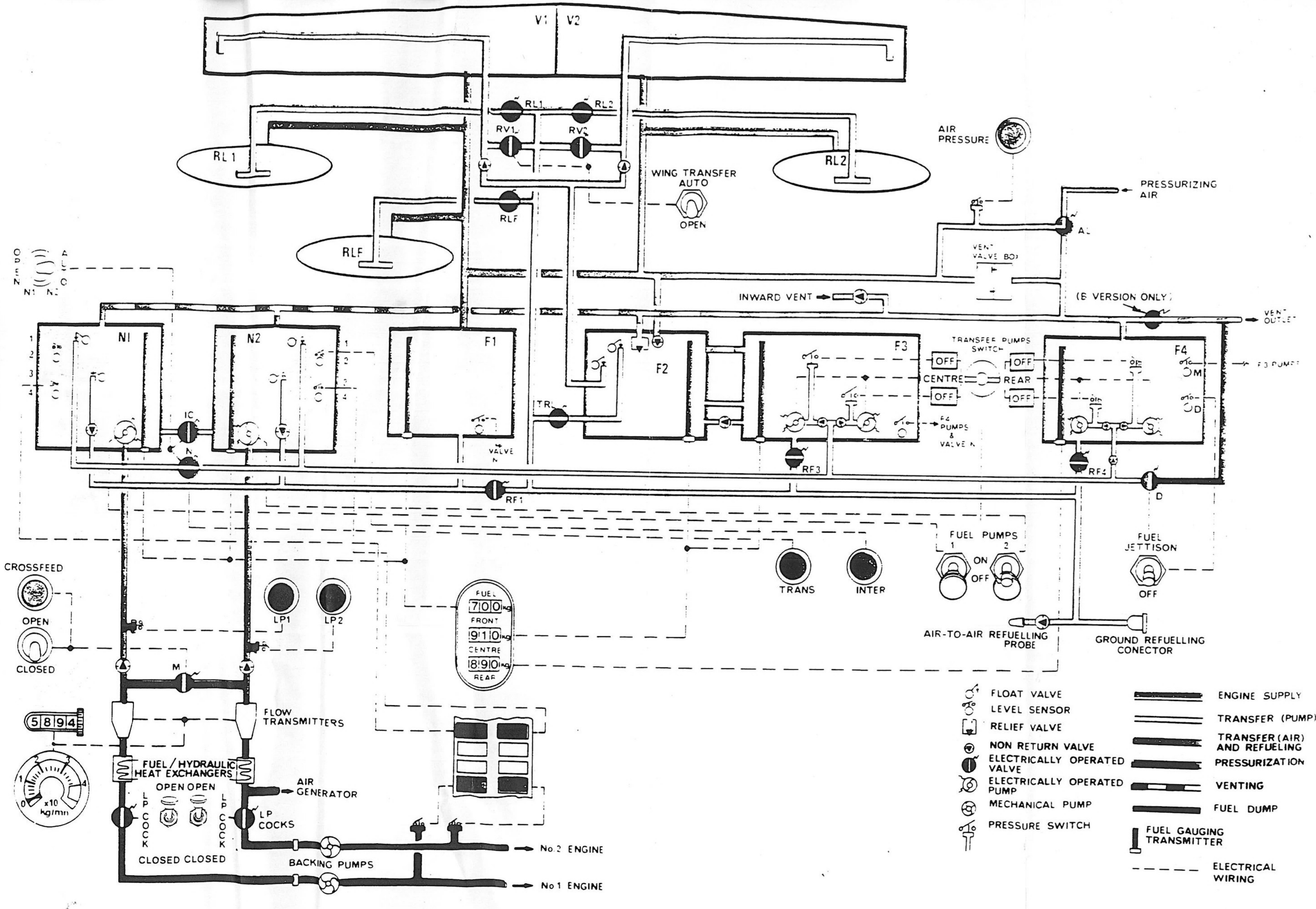
Fuel/No Air Valve.

Four fuel/no air valves are fitted,one in each wing tank and one on each side of F1 tank.These valves are fitted in the system to prevent air from the pressurisation system entering non-pressurised tanks when V1,V2 and F1 are empty.



TRANSFER
REFUELLING
PRESSURIZATION
ENGINE SUPPLY
AIR VENT
COMMON REFUEL/TRANSFER LINE

Fuel system – general arrangement



Fuel System Schematic