PART 2

CHAPTER 7 — ENGINES AND APU

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PART 2

CHAPTER 7 — ENGINES AND APU

POWER PLANTS

General

1. Four Conway Mk 301 engines each developing 22,500 lb static thrust at sea level are installed in pairs on either side of the rear fuselage. Each engine is an axial-flow bypass turbo-jet, incorporating a twin spool compressor driven by turbines, and has a tubo-annular combustion chamber.

2. The drive shaft (N1) for the low-pressure compressor passes through the high-pressure compressor shaft (N2) and each compressor rotates independently of the other, and in the same direction.

3. The output of the LP compressor is divided. Part goes into the HP compressor to provide the necessary air for fuel combustion whence it is ejected rearwards to drive the turbines; the remainder is directed through the annular bypass duct, after which it joins the hot gas from the turbines and the total flow is ejected through a propelling nozzle to atmosphere.

4. The main units of the basic engine are:

a. Air intake casing and front bearing housing.

b. LP compressor and casing.

c. Compressor intermediate casing, which carries the internal and external wheel cases and the engine front mounting.

d. HP compressor and casing.

e. Compressor outlet casing.

f. Combustion section.

g. Nozzle-box and turbine assemblies; the nozzle-box carries the engine rear mounting.

h. Exhaust unit and tail bearing housing.

i. Bypass casing, which covers the engine to form an annular duct from the LP compressor stage four to the rear of the exhaust unit.

5. Internal cooling of the engine is obtained by feeding air bled from the engine compressors to the hot parts of the engine. In addition. cooling air is also used to pressurise the seals against oil or gas leakage.

6. Starting is by means of an air starter which turns the HP compressor-shaft; ignition is by high-energy igniter plugs.

7. Throttle levers at the pilots' and engineer's stations control the engines. A reverse thrust facility is provided on the outboard engines.

8. Indication of engine thrust measurement is provided by absolute pressure (P_7) gauges which function from probes in the engine tail pipes.

9. Failure of a low pressure shaft results in the associated HP cock automatically closing, thereby reducing the risk of further damage to the engine.

10. The inner nacelle side structure and the centre rib between the nacelles on each side, serve as fire walls, isolating the engines from the fuselage and from each other. An engine-mounted fire seal and fire-proof bulkhead aft of the torsion box (on which the engines are mounted) in each nacelle isolates the engine bay from the exhaust unit.

11. The engine bays are ventilated to prevent a dangerous concentration of fumes. Air enters through flush intakes in each nacelle upper and lower forward door, flows rearward around the engine and exhausts to atmosphere through louvred panels at the top of the nacelle, immediately forward of the fire-proof bulkhead.

11A. The HP and LP compressors can be immobilised, by the use of special equipment provided to cater for 3-engine ferry with a damaged engine.

Engine Limitations — Conway Mk 301

12. Engine limitations are contained in Part 1 of Pilot's Notes (Flying).

Compressors

13. The compressor assembly consists of:

a. LP compressor and casing.

b. Intermediate compressor and casing.

c. HP compressor and casing.

d. Compressor outlet casing.

14. The LP compressor consists of eight stages, the last four of which are intermediate stages. The whole assembly is driven by the two-stage turbine through an intermediate coupling shaft. The LP casing aft of the stage four rotor is the point at which the bypass air is initially divided from the main gas stream.

14A. The HP compressor consists of 9 stages and is driven by a single-stage turbine.

Combustion System

15. The combustion system is of the tubo-annular type. Ten interconnected circular flame tubes are housed in the annulus formed by the inner and outer casing between the HP compressor outlet casing and the nozzle-box. Ten duple burners, one for each flame tube, supply fuel to the combustion chamber.

Engine-Driven Accessories

16. Each engine has two external wheel cases which drive all the engine accessories except the LP shaft RPM generator and the cabin compressor. The right-hand wheel-case caters for:

Hydraulic pump
LP fuel backing pump
HP shaft RPM generator
Pneumatic starter.

The left-hand wheel-case caters for:

HP fuel pump
Main generator CSD
Engine oil pumps.

An internal wheel-case caters for:

Drives to left and right-hand wheel cases
The cabin compressor
LP shaft RPM generator.

17. *Controls and Indicators—Engines.* (See **Table 1**).

Throttle Controls

18. Two sets of interconnected throttle levers are provided, one set for the pilots at the forward end of the centre console and one set for the engineer at his station. Auxiliary levers on the pilots' outboard throttle levers control reverse thrust. A friction damper fitted to the pilots' throttle lever assembly is preset and is not adjustable in flight.

19. Thirteen microswitches are operated by the throttle levers at the engineer's station:

a. Eight microswitches for the autopilot bottom limit, which cut out the auto-throttles when the throttles are fully closed until such time as an 'increase speed' signal is received.

b. Four microswitches for the undercarriage warning horn, which sounds when any pair of throttles (one on each side of the aircraft) are retracted when the undercarriage is not locked down and the airspeed is below 155 ± 3 knots.

c. One microswitch for the take-off configuration warning horn, which sounds when all throttles are within the range of half-open to 80% open, and any of the flight controls are malfunctioning or not correctly set for take-off. (See Chapter 6, para 26.)

20. An auto-throttle control unit is incorporated in the base of the engineer's throttle pedestal.

HP Fuel Cock Controls

21. The four HP COCKS-RUN/START/SHUT levers are at the rear of the centre console. A microswitch, operated by each HP cock lever, forms part of the associated LP cock circuit when the LP cock switch is selected OPEN and the appropriate fire control handle is pulled.

22. When set to:

SHUT	HP cock is shut; no fuel to the engine
START	HP cock is partially open, fuel flow is restricted; fuel bypassed to pump inlet
RUN	HP cock is fully open.

23. Failure of an LP shaft results in the associated HP cock automatically closing. (See para 52.)

HP Fuel Pumps

24. Fuel from the aircraft supply is fed to each engine-driven dual type HP fuel pump via an engine-driven backing pump, and an LP filter; fuel delivery is limited to that required to maintain maximum HP RPM.

25. The pump output is passed to a fuel control unit where a metered flow suitable to the engine conditions is then delivered to the burners. If one pump fails, the other can meet full power demand at cruising altitudes or about 80% of full power demand at sea level.

ENGINE FUEL AND CONTROL

Fuel Control Unit

26. The fuel control unit (FCU) on each engine has manual controls for engine starting, speed regulation and stopping, and automatic controls to adjust the fuel flow, both to suit varying operating conditions and to avoid exceeding engine limitations. Most of the controlling units are housed in the fuel control unit. The maximum HP RPM governor is in the HP fuel pump.

27. Each unit controls the pump servo system according to signals received from the following:

Throttle valve
Altitude and ram air speed sensing unit
HP shaft governor
Acceleration control unit
Top temperature control
LP compressor speed
Compressor delivery pressure (P_3)
Idling speed governor. (Maintains minimum HP RPM.)

Table 1. Controls and Indicators — Engines

Item	*Location*	*Marking/Description*
Throttle levers (8)	Centre console (4) Engineer's station (4)	1, 2, 3, 4
HP cock levers (4)	Centre console	HP COCKS RUN/START/SHUT 1, 2, 3, 4
Reverse thrust levers (2)	Centre console, on 1 and 4 throttle levers	—
Reverse thrust warning lights (4)	Pilots' centre panel (2). Engineer's engine panel (2)	REVERSE (press-to-test, amber)
Auto-throttle switches (4)	Centre console	THROTTLES ON
Auto-throttle controller	Centre console	ENGAGE No. 1, No. 2
Power switch	Centre console	POWER ON
Speed selection knob	Centre console	SET KNOTS
Speed selection indicator	Centre console	Digital counter, hundreds, tens, units
Top temperature control switches (4)	Engineer's engine panel	TOP TEMP.-NORM/ISOL

Throttle Valve

28. The throttle valve on each engine consists of a fluted shaft in a sleeve. On opening the throttle the shaft is rotated, progressively uncovering a pattern of small holes in the sleeve, thus increasing the effective area.

29. By increasing the pump output to maintain the same pressure drop across the throttle valve, the fuel flow is increased. On closing, the effective area and pump output is reduced, thus maintaining the constant pressure drop.

30. A spill valve in the altitude sensing unit (ASU) varies the pump servo pressure according to throttle opening. The valve is controlled by a proportional flow which is a measure of the pressure drop across the throttle. This pressure drop is simulated across the proportioning flow restrictors by the proportioning valve, which is a plate valve mounted in a diaphragm. The top of the diaphragm is subjected to throttle down-stream pressure and the underside to throttle up-stream pressure which has passed through the proportioning restrictors.

31. Under stable running conditions, the proportional flow to the ASU creates sufficient pressure on the spill valve piston to hold the spill valve in a sensitive position, maintaining a constant pump stroke.

32. When the throttle is opened, the proportional flow to the ASU is reduced, the piston rises closing the spill valve, and the servo pressure rises increasing the pump stroke.

33. When the throttle is closed, the proportional flow is increased, the spill valve opens and the pump stroke is reduced.

34. Fuel flow is increased or decreased until the original pressure drop across the throttle is restored when, due to the proportional flow being restored, the spill valve in the ASU returns to the sensitive position.

35. As the engine RPM varies with the changing fuel flow, the pump stroke is altered to prevent excessive over-fuelling or under-fuelling.

36. The spill valve in the ASU is of the kinetic type, and is controlled by the proportional flow which, having passed through the restrictor, creates a pressure on the piston head to hold the interrupter against the spring.

Altitude and Ram Air Speed Sensing Unit

37. As altitude increases, an engine requires less fuel for a given RPM. In order to reduce the fuel flow without altering the throttle setting, the ASU spill valve reduces the pressure-drop across the throttle.

38. An evacuated capsule, subject to P1 pressure, exerts a third force on the spill valve lever. A reduction of air-intake pressure allows the capsule to expand, so compressing the spring, resulting in the spill valve opening wider, thus reducing the fuel flow.

39. As the proportional flow reduces, the pressure-drop across the ASU restrictor and piston decreases, restoring the spill valve to a sensitive position.

40. A variable restrictor (sensing valve) is used to maintain a pressure-drop when fuel flow is reduced with increasing altitude. It consists of a spring-loaded diaphragm in the centre of which is a hole around a fixed tapered needle. As the pressure drop varies, the diaphragm moves, altering the effective area of the hole.

HP-RPM Speed Control

41. The HP shaft maximum speed for each engine is controlled by a speed-sensitive governor within the associated HP fuel pump. As engine speed rises, centrifugal force acting on a rotating arm causes it to restrict the flow through a valve which is spilling fuel to the pump inlet from a drum. The drum is fed through a restrictor with fuel at pump outlet pressure. As engine speed rises, pressure in the drum (governor pressure) rises. Fuel at governor pressure is fed from the drum into a chamber where it acts against a pre-set spring force on a diaphragm. The governor pressure generated at maximum RPM is sufficient to move the diaphragm and thus open a bleed valve in the pump servo line to limit the pump output to that required to maintain the throttle position and air intake pressure. They are both sensed by the FCU, and act together to control servo pressure, pump stroke and pump output.

Acceleration Control

42. The acceleration control unit (ACU), by preventing excessive over-fuelling, enables the fastest possible acceleration without compressor surge to be obtained when required.

43. The ACU acts as an automatic throttle upstream of the throttle and only assumes control during rapid accelerations. If the throttle is opened suddenly, the pump output increases both the flow through the ACU plunger and the pressure drop across it. The increasing pressure drop is sensed by the ACU pressure drop control section, and is allowed to attain a maximum value, at which a kinetic servo valve begins to close to reduce pump output to the safe limit.

44. To allow the unit to control acceleration at all altitudes and engine speeds, the ACU plunger is tapered so that by altering its vertical position, the area of the orifice is changed. Since the orifice area determines the rate of flow at which the limiting pressure drop is reached, the maximum permitted fuel flow can be varied by changing the vertical position of the plunger. This is achieved by a subsidiary servo system under the influence of a controlling air pressure acting on the ACU capsule.

45. Because no single controlling pressure ensures rapid engine acceleration without surge under all conditions, two pressures are used; split P_3 which is a proportion of P_3, used at low compression ratios, and P_3 itself, used at high compression ratios. The change-over from one controlling pressure to the other is effected by an air switch in the air metering section which, sensing a proportion of P_3 against P_1, closes at the required compressor ratio. In this way a function of compressor delivery pressure controls the position of the ACU plunger which in turn controls the amount of over-fuelling permitted.

Top Temperature Control

46. Excessive gas temperatures are prevented by the top temperature control affecting the proportional flow. The system comprises:

a. A second proportional flow restrictor controlled by a pivoted trim lever, actuated by a solenoid.

b. A magnetic amplifier and parallel thermo-couple circuit.

47. The thermo-couple circuit supplies the amplifier with a current proportional to gas temperature, which is opposed by a datum current from the AC system.

48. When the gas temperature exceeds 595°C the thermo-couple current exceeds the datum current. The amplifier energises the solenoid so increasing the proportioning restrictor area. Proportional flow increases which decreases the servo pressure so that the pump stroke and fuel flow reduces, thus keeping the EGT within limits.

49. Four TOP TEMP. -NORM/ISOL switches, one for each engine on the engine panel at the engineer's station, are provided; when a switch is set to ISOL. the associated top temperature control and the LP shaft governor is overridden: when set to NORM. the top temperature control prevents an EGT of 595°C being exceeded.

LP-RPM Speed Control

50. At increasing altitudes, air intake temperature decreases and because of this the LP shaft speed increases relative to the HP shaft speed. Ultimately the LP shaft RPM reaches a value which must not be exceeded.

51. The output from the LP shaft RPM indicator generator is fed through the magnetic amplifier to the solenoid which controls the position of the trim lever used in top temperature control. This, as stated in paragraph 48 above, increases the effective area of one of the orifices in the proportional flow circuit. As the limiting LP-RPM is approached, a small increase in the proportional flow begins to reduce pump output, and in this way maximum LP-RPM is never exceeded.

LP Shaft Failure and HP Cock Interconnection

52. The LP shaft failure system automatically closes the HP cock on the engine if a failure occurs in the shaft connecting the LP turbine and LP compressor. Failure of the LP shaft results in the LP turbine speed rapidly increasing in relation to the speed of the LP compressor and this relative speed is utilised to operate a running nut which, through a series of pulleys, levers and a cable, closes the HP cock.

Control of Idling Fuel Flow

53. The fuel flow for idling conditions is controlled by:

The idling valve

The idling governor

The altitude idling valve.

54. *The Idling Valve.* This is a needle valve and restrictor through which fuel by-passes the throttle main flow area. The by-pass flow changes with the main flow under varying intake conditions.

55. *The Idling Governor*

a. The idling governor controls the idling RPM despite changes in the air off-takes and engine auxiliary load.

b. A pivoted lever actuated by a diaphragm and push-rod, forms a valve which controls the effective area of one proportional flow restrictor.

c. A speed signal in the form of a governor pressure acts on one side of the diaphragm opposing a spring tension. A decrease in pressure allows the spring to deflect the diaphragm reducing proportional flow.

d. As the pressure-drop across the sensing valve decreases, the ASU spill valve closes, increasing pump stroke and fuel flow, causing engine RPM and governor pressure to increase. Deflection of the idling governor restores the proportional flow.

56. *The Altitude Idling Valve*

a. The altitude idling valve ensures that sufficient fuel flow is maintained for efficient atomisation at all altitudes.

b. The unit consists of a spring-loaded plate valve and a flow restrictor. The plate valve maintains a constant pressure-drop across the restrictor and hence a constant flow. Thus flow is not affected by the ASU, consequently the idling RPM increases with altitude as engine fuel demand increases.

Power Limitation

57. Mass airflow and P_3 pressure increases more rapidly with lower intake temperatures, resulting in maximum permitted values being attained below normal take-off RPM. The power limiter controls the fuel flow to prevent a pre-determined P_3 pressure from being exceeded.

58. A pivoted lever is spring-loaded to close a spill valve connected to the ACU operating capsule chamber. A bellows attached to the lever senses P_3 pressure internally to oppose the spring force and open the valve.

59. With low intake temperature and P_3 increasing the capsule pressure eventually overcomes the spring, opening the spill valve, venting the capsule chamber to the engine bay. The ACU plunger is repositioned, limiting the fuel flow to the engine.

STARTING SYSTEMS

General

60. The engines are turned over for starting by air motors mounted on the engine right-hand wheel cases and geared to the engine HP compressor shafts. The air supply for the starter motors can be supplied either from a ground supply or the APU. Once an engine is started, the remaining engines can be started from it by cross-bleeding.

Starter Motors

61. Each engine is equipped with a pneumatic starter in the form of an air turbine, which is supplied with low pressure air via the pneumatic ducting of the anti-icing system on the engine via a start control valve. By connecting an external LP air supply into the main anti-icing duct, (which also serves the wing and tail anti-icing systems) and

closing the wing and tail stop valves, opening the pressure-reducing valves, temperature control valves and HP stop valves, each starter may be supplied with air by opening its associated start control valve.

62. A cut-out switch on the starter shuts off the air supply to the starter at 32-35% HP-RPM. The starter then automatically disengages from the engine. Failure of a starter to disengage results in a reverse torque ratchet operating to disengage the drive. If this occurs, the mechanism can only be reset on removal of the starter. Exhaust air from the starter is vented overboard.

63. Utilisation of the anti-icing manifold enables any running engine to supply air to start the remaining three. This is known as "cross-bleed starting".

Ignition

64. Two high-energy ignition units are fitted to each engine, both having a 28-volt DC supply. Each high-energy ignition unit operates an igniter; the igniters are fitted in combustion chambers 4 and 7. One igniter is supplied from No. 1 essential busbar, the other from No. 2 essential busbar. They are used for normal starting and relighting in the air. Operation of either stall protection system causes its associated igniter to function on all engines.

LP Starting System

65. To enable an external air supply, plugged into the main anti-icing ducting in the fuselage, to reach the engine starter, pressure reducing valves and the temperature control valves must be opened. The wing and tail stop valves also must be closed and the HP stop valves opened. The refrigerators must also be switched to ISOLATE.

Starting Controls

66. An engine starting panel is recessed into the engineer's table, adjacent to the duplicated set of throttle levers. All engine motoring and starting cycles are controlled from this panel. Since the starting system uses wing and tail de-icing ducting, the airframe anti-icing control panel must also be checked prior to starting.

NOTE: Although some valves are electrically selected, they may be pneumatically-operated and therefore, may not indicate correctly until duct pressure is available.

Engine Starting Panel

67. The engine starting panel comprises:

A rotary ALL OFF/IGNITERS OFF MOTORING/LP START—starter master selector switch.

Individual engine start switches marked START/OFF/RELIGHT, spring-loaded to OFF from START.

LP SHAFT ROTATION green press-to-test light.

IGNITERS ON double amber lights.

STARTER ON amber press-to-test light.

Starter Master Selector Switch

68. When set to:

ALL OFF	Ground starting systems are isolated.
IGNITERS OFF MOTORING ...	Ignition system is isolated. PRV's and temperature control valves are opened. Wing and tail stop valves are closed.
LP START	As above, except that igniters are available through individual engine start switches.

Engine Start Selector Switches

69. When set to:

START	Engine start valve is opened to supply air to starter; igniters operative.
OFF	Engine start valve is closed. Air supply to starter cut off; igniters inoperative.
RELIGHT	Igniters operative

Starting Indicators

70.

LP SHAFT ROTATION green light ...	When flashing, indicates that the LP compressor is rotating. Light goes out when start switch is released. Light does not function when starter master switch is at IGNITERS OFF MOTORING
STARTER ON amber light	Comes on when a starter control valve is open (engine start switch at START) and pressure is supplied to starter turbine.
IGNITERS ON double amber lights	Lights come on when igniters on selected engine are operative (one light for each set of igniters).

Associated Wing Anti-Icing Components

71. The following anti-icing system components are referred to during engine starting:

AIRFRAME ANTI-ICE DUCT pressure gauges (two)	Bulkhead panel C, at engineer's station.
HP STOP VALVE switches (four) ...	AIRFRAME ANTI-ICE panel at engineer's station. Magnetic indicators adjacent; normally set to NORMAL.
Pressure reducing valves switches (two)	AIRFRAME ANTI-ICE panel marked REDUCE VALVE. Magnetic indicators adjacent; normally set to NORMAL.
Wing and tail stop valves	AIRFRAME ANTI-ICE panel; normally SHUT.

Note: These valves (except the wing stop valves) are electrically-selected but pneumatically operated, and may not indicate correctly until duct pressure is applied.

THRUST REVERSERS

General

72. A thrust reverser at the rear of the outboard engines provide a means of reducing aircraft forward speed by reversing the direction of the exhaust gas flow and therefore engine thrust.

73. A reverser consists basically of two doors or eyelids, hinged about the horizontal axis, which form part of the jet pipe inner casing for normal forward thrust, and pivot rearwards to blank off the exit nozzle and uncover outlet ports at the top and bottom of the unit for reverse thrust. To prevent ingestion of hot gas or debris by the engines, the lower cascades of the thrust reversers are angled both forward and outward. The upper cascades are angled forward only.

Control of Thrust Reversers

74. Control is by individual reverse levers mounted on the outboard throttle levers. Rearward movement selects reverse thrust, the thrust increasing with further movement to a maximum of 93% HP RPM in ISA sea level conditions. An interconnection with the throttle lever ensures that reverse can only be selected if the throttle is at IDLE and, when reverse is selected, the throttles cannot be moved forward of IDLE until reverse has been cancelled.

Safety Devices

75. A cam and roller assembly on the thrust reverser provides for the following:

a. Power in reverse cannot be selected until the reverser doors are in the fully reverse setting.

b. If a thrust reverser is inadvertently moved into reverse, the throttle lever returns to IDLE, reducing power accordingly.

c. If during landing, a thrust reverser fails into forward thrust, the reverse lever returns to the baulk position, reducing power accordingly.

Operation of Thrust Reversers

76. When reverse is selected, the control valve on the thrust reverser is operated and P_3 air is directed to:

a. A lock plunger, unlocking it and then to,

b. Four double rams which open the reverser doors.

77. When reverse is cancelled, the doors are returned to their original setting (forward thrust) and the lock is re-engaged.

78. Amber warning lights on the pilots' centre instrument panel, and repeated on the engineer's engine panel, come on when their associated reverser lock is broken.

ENGINE OIL SYSTEM

Engine Oil System

79. Each engine has a self-contained oil system, with a combined sump and tank in the left-hand wheel-case and a fuel-cooled cooler fitted under the low pressure compressor casing. A pressure filling point is provided in the base of the sump and a gravity filling point for emergency use. Sump contents, in pints of usable oil, are indicated on a sight gauge on the sump. The oil capacity of the engine is 33 pints; the sump holds 24 pints of oil and has a usable capacity of 18 pints.

◀79A. A magnetic plug is fitted in the base of the sump; the plug can be removed for checking without loss of oil. ▶

80. A single pump in the sump circulates oil via the fuel-cooled oil cooler and a filter to a distribution gallery in the left-hand wheel-case. The gallery has a 50 PSI relief valve and tappings for the oil pressure transmitter and low pressure (12 PSI) warning light switch. A temperature bulb is provided to operate the associated temperature gauge on the engineer's panel.

81. Seven scavenge pumps return oil to the sump from various parts of the engine.

◀81A. Magnetic chip detectors are fitted in the LP and HP turbine bearing scavenge filters. Steel particles retained by the detectors reduce the electrical resistance between the detector and earth, facilitating their detection without removing the filters.

Engine Oil and Fuel Drains

82. An engine-mounted collector tank receives fuel, during engine shut-down and after wet starts, from the burner manifolds, combustion chambers, nozzle box and the bypass duct. Each collector tank is emptied, via a suction pipe in the jet pipe, when the engine is running. The tank capacity (9 pints) is sufficient to cater for one normal shut-down and two wet starts. Fluid from gland drains, on various engine components, is drained directly overboard through holes in the engine cowlings. ▶

ENGINE AIR SYSTEM AND SUPPLIES

Internal Cooling Air System

◀83. A small amount of engine compressor air is tapped off internally to cool the main bearings and to pressurise seals. Overheating of bearings, or, internal leakage of hot air, is detected by a temperature probe in the cooling air outlet duct. If the temperature of the cooling air reaches 430°C, the associated ENGINE O/HEAT light on the engineer's panel and the ENGINE FAIL light on the pilots' centre panel come on.

External Air System

84. Air from the engine compressors is used for various services. Since these off-takes affect engine thrust and fuel consumption, most of them are controlled by either undercarriage 'weight-on' switches or switches at the engineer's station. ▶

High Pressure Supplies

85. High pressure air supplies are taken from the hot air collector around the HP compressor outlet casing and passed through ducts, to the aircraft services pneumatic manifold on the lower left-hand side of the engine and to the engine anti-icing manifold on the upper right-hand side of the engine.

86. The left-hand tapping supplies air to a pneumatic manifold for:

Airframe ice protection
Cross-bleed starting.

87. The right-hand tapping supplies air for:

Engine and nose-cowl anti-icing
Fuel heating
Ground cooling for the generator and CSD oil cooler
The thrust reverser in the case of outboard engines.

Low Pressure Supplies

◀88. Low pressure air supplies are provided for:

The pressurisation of the CSDU oil tank
The airframe ice protection system
The cabin compressor oil cooler jet pump. ▶

ENGINE ICE-PROTECTION

Engine Ice-Protection

89. Parts of the engines and nacelles that can be supplied with hot air for ice-protection purposes are:

a. *Power Unit*
Intake casing
Inlet guide vanes
P_1 probe
Nose fairing.

b. *Nacelles*
Nose cap
Intake fairing
Nacelle strut leading edge
Cabin compressor intake.

In all cases a common source of high pressure air (P_8) is used.

90. The nacelle struts leading edges receive a supply of air from their associated inboard nacelle nose cap, but the cabin compressor intake can be supplied from either nacelle nose cap.

91. Engine and nacelle ice-protection is controlled by the four ANTI-ICING — ON/OFF switches at the engineer's station. Four ENGINE ANTI-ICE

pressure gauges, adjacent, indicate the pressure in each individual system. A full description of the engine ice protection system is contained in Chapter 12.

ENGINE INSTRUMENTS AND INDICATORS

92. *Engine Control Panel — at Engineer's Station.* (See **Table 2.**)

93. *Rear Roof Panel at Engineer's Station.* (See **Table 3.**)

94. *Pilots' Centre Panel.* (See **Table 4.**)

Engine Absolute Pressure Gauges (mean engine exhaust gas pressure (P_7))

95. Each engine absolute pressure gauge gives a direct reading of the absolute pressure in the associated tail pipe. This pressure, in conjunction with the pressure altitude and with various corrections applied, enables the thrust of each engine to be measured with a reasonable degree of accuracy. A direct comparison of engine power can be made by reference to the gauges which are calibrated in inches HG.

Engine Overheat Warning Lights

96. An engine overheat warning lights comes on when the temperature of the air passing through the associated LP cooling air outlet duct exceeds 430°C. When an ENGINE O/HEAT light comes on, the associated engine FAIL light on the pilots' centre panel also comes on. An ENGINE OVERHEAT-TEST/NORMAL switch is provided on panel EA; when held to TEST, the ENGINE O/HEAT and engine FAIL lights come on; when the switch is released to NORMAL the lights go out.

RPM Indicators and Synchroniser

97. Four HP compressor (N2) RPM indicators, one for each engine, are provided on the pilots' instrument panel and are duplicated at the engineer's station. They are calibrated in percentage RPM and are electrically-operated by a tachometer generator on the associated engine. Four LP compressor (N1) RPM indicators, one for each engine, which are similar in construction and operation, are also provided at the engineer's station.

98. The synchroniser system presents a visual indication of the synchronisation of the HP shafts of No 2, 3 and 4 engines, in relation to that of No 1 engine, on the synchroscope at the engineer's station. The function of the system enables all four engines to be run at a common HP RPM. Clockwise rotation of a pointer indicates that the speed of the associated engine should be decreased to achieve synchronism and vice versa. When a pointer is stationary the associated engine is synchronised with No 1 engine.

Low Oil Pressure Warning Lights

99. A low oil pressure warning light comes on when the associated engine oil pressure falls below 12 PSI; when an OIL LP light comes on the associated engine FAIL light also comes on.

Oil Pressure and Temperature Gauges

100. Each dual oil pressure and temperature gauge is controlled by a pressure transmitter and a temperature bulb on the engine; these are powered by a 115-volt supply from the associated generator busbar. A transformer within the instrument provides 26-volt AC for the pressure gauge circuit. A 12-volt DC supply for the temperature gauge circuit is also provided.

AUXILIARY POWER UNIT

Artouste Mk 121 or 123 — General Description

101. The APU is an Artouste Mk 121 or 123 gas-turbine engine, housed in its own bay, in the rear fuselage, aft of the rear pressure bulkhead. It provides AC electrical power and low pressure air for engine starting on the ground. An electrically-operated starter motor is fitted. The APU can be used during taxying. Maximum fuel consumption under full load is 300 lb/hour.

101A. The APU can be started only from the APU control panel on panel C, but can be shut-down from either panel C or the APU external control panel (para 111). The APU is shut-down when the undercarriage 'weight-on' switches are in the 'weight-off' condition.

101B. The APU fuel control unit contains an electrically-powered P_2 heater; the heater is supplied:

a. In flight, via the undercarriage 'weight-on' switches.

b. On the ground, via the APU P_2 HEATER switch on panel C. When the switch is selected ON, an amber light, adjacent to the switch, comes on.

Table 2 — Engine Control Panel — Engineer's Station

Item	*Marking/Description*
Reverse thrust indicator lights (two)	REVERSE (amber, press-to-test)
Engine absolute (P_7) pressure gauges	INS HG ABS
Engine overheat warning lights (four)	ENGINE O/HEAT (red)
HP RPM indicators (four)	HP PER CENT RPM
Top temperature control switches (four)	TOP TEMP CONT — NORM/ISOL
EGT gauges (four)	°C × 100
LP RPM indicators (four)	LP PER CENT RPM
Oil low pressure warning lights (four)	OIL LP (red)
Oil temperature gauges } (four dual	Minus 60°C to plus 120°C
Oil pressure gauges } gauges)	0 to 75 PSI
Generator busbar failure warning lights (four) ...	GEN BUS FAIL (red)
Synchroscope	SLOW/FAST — 2, 3, 4

Table 3 — Rear Roof Panel — Engineer's Station

Item	*Marking/Description*
Engine overheat warning lights test switch ...	ENGINE OVERHEAT — TEST/NORMAL (spring-loaded to NORMAL)

Table 4 — Pilots' Centre Panel

Item	*Marking/Description*
Reverse thrust indicator lights (two)	REVERSE (amber, press-to-test)
HP RPM indicators (four)	HP PER CENT RPM
Engine failure warning lights (four)	FAIL (red)

Note: The associated engine FAIL warning light on the pilots' centre panel comes on when a low oil pressure or overheat warning light on the engineer's panel comes on.

102. A gauze-covered air intake on the right-hand side of the aircraft tail end, forward of the front fireproof bulkhead, allows air to enter a plenum chamber formed by the fireproof bulkhead, fuselage skin, a structural floor and a forward bulkhead. Air from the plenum chamber is fed to the APU via two intake extensions.

103. No throttle control is provided, as the engine is designed to run at a constant speed. The airflow through the engine is in the axial direction from the plenum chamber to the exhaust duct. A proportion of the air is used for combustion whilst the remainder of the air mass can be diverted to the aircraft anti-icing/start ducting to provide a supply for starting the main engines by way of an air control delivery valve.

104. Fuel is supplied from the aircraft No 2 fuel tank downstream of the LP cock. Within the combustion chamber the fuel mixes with air and the mixture is burned continuously, the gases passing through a two-stage turbine to be exhausted from the engine through the exhaust duct.

104A. The fin tank ground isolation valve and the fin tank refuel/defuel valve are interconnected with both the APU start master switch and the APU fire control system. When either the APU start master switch is set ON or the APU fire warning light comes on, the refuel/defuel valve indicator shows cross-line and the ground isolation valve indicator shows SHUT. In the case of the ground isolation valve, closing it ensures that there is no fuel in that part of the fin tank overfuel pipe in the area of the APU. In the case of the refuel/defuel valve, closing it prevents refuelling of the fin tank when the APU is running.

105. If the APU fuel feed system is disconnected for any reason the feed line will need priming. A spring-return to off switch on panel V at fuselage station 1279 is provided so that the fuel pump and valves can be operated independently of APU control for priming purposes. Access to the switch is gained by opening the service door in the rear toilet. When priming the feed line, both the APU fuel pump and at least one booster-pump in No 2 tank should be switched on.

◀ 106. No APU engine instruments are provided at the engineer's station. A portable instrument panel with EPT, RPM and oil pressure gauges can be plugged into a test socket at the external air start panel. ▶

APU Limitations

107. APU limitations are contained in Part 1 of Pilots' Notes (Flying).

APU Oil System

◀ 108. A six pint capacity (OX-38) self-contained oil system is provided. The usable capacity is three pints and the maximum consumption rate 0·3 pints/hour. ▶

109. Oil is contained in two tanks which are integral with the air intake casing, and are interconnected by a balance pipe and, in effect, serve as one tank with a common pressure re-oiling point. The pressure re-oiling point is on the underside of the left-hand tank. A gravity re-oiling point is also provided.

110. Included as part of the pressure re-oiling point is a sight glass contents gauge. The oil level should be checked within 30 minutes of shutdown, otherwise a false indication may be given.

APU Controls and Indicators

◀ 111. Control of the APU is from the AUX POWER UNIT panel on panel C at the engineer's station. An external APU control panel at station 280 left, contains a 28-volt DC supply connector, a fire warning light, a circuit breaker and a SHUT DOWN/NORMAL switch. ▶

112. *Controls on APU Panel at Engineer's Station.* (See **Table 5.**)

113. *Controls on External APU Panel.* (See **Table 6.**)

114. *External LP Air Position.* (See **Table 7.**)

APU Control and Operation

115. *General.* Prior to starting the APU, both refrigeration master switches must be set to ISOLATE and the wing and tail anti-icing stop valves must be SHUT.

No 1 TRU must be set to ISOLATE.

All fuel booster-pumps must be OFF.

No 2 LP cock must be OPEN.

116. *Starting the APU*

Note: The P_2 heater should be switched on prior to starting the APU after prolonged cold-soak conditions either in the air or on the ground.

a. Starting is initiated by setting the MASTER STARTER switch ON and pressing the START PUSH switch. From this point the starting sequence (approx 35 seconds) is automatically controlled.

b. When the master starter switch is set to ON, a 28-volt DC supply from No 1 battery or the external 28-volt DC supply is made available at the START PUSH switch and the APU control relays.

c. Pressing the START PUSH switch:

(1) Energises the APU control relay which then supplies:

The fuel pump

The fuel valves

The start control relay

The electrical 'lock-on', to maintain APU control when the push switch is released.

◀ (2) Energises the start control relay which is then locked-on electrically until the start sequence is completed. During this period (8 to 15 seconds) the start warning light is on.

d. At a nominal 9500 RPM the start control relay is de-energised and the start light goes out. ▶

Table 5 — Controls on APU Panel — Engineer's Station

Item	*Marking/Description*
Shutdown control switch	NORMAL / SHUT DOWN (spring-loaded to NORMAL)
Starter push switch / Start cycle warning light } Combined	START PUSH (amber)
Starter master switch	START MASTER — ON/OFF
Fire control switch	FIRE SYSTEM — MANUAL/AUTO/TEST (spring-loaded from TEST to AUTO)
Fire warning light	Red
Generator control switch	GENERATOR — CLOSE / TRIP (spring-loaded to CLOSE)
APU running indicator	APU RUNNING (RUN or cross-hatch)
Fin tank ground isolation valve magnetic indicator	FIN TANK GRD ISOL (OPEN/SHUT)
LP fuel valve indicator	Magnetic indicator: LP FUEL VALVE (OPEN/SHUT)
Main engines air control start switch	START/OFF
Main engines air control valve warning light ...	AIR CONTROL VALVE — OPEN (amber — press-to-test)
Bottle fired indicator	EXTINGUISHER BOTTLE FIRED
Adjacent to APU Panel	
Elapsed time indicator	ETI. Records running time; resets to zero at 10,000 hours. A pointer indicates minutes and a drum-type counter indicates hours.
APU P_2 heater control switch	GROUND USE APU HEATER — ON/OFF
APU P_2 heater indicator light	GROUND USE APU HEATER — HEAT

Table 6 — Controls on APU External Panel

Item	*Marking/Description*
APU shutdown control switch	NORMAL / SHUT DOWN (spring-loaded to NORMAL)
Fire warning light	Red
24-volt DC external supply connector	—

Table 7 — External LP Air Position

Item	*Marking/Description*
APU test connector	—

e. At a nominal 32,200 RPM the APU governed speed relay is energised, this permits operation of:

(1) The air delivery valve

(2) The air bleed valve (anti-surge valve)

(3) The APU generator GCB.

It also causes the APU RUNNING magnetic indicator to show RUN, and changes the overheat datum from 700°C to 600°C above ambient, after a ten second time delay.

117. *Shutting Down the APU.* The APU is normally shut down by holding to SHUT DOWN the NORMAL/SHUT DOWN switch on the APU panel at the engineer's station or at the external APU panel. When the APU has shut down, the switch should be released.

118. *APU Fault Protection.* Protection is provided against:

Overspeeding
Overheating
Low oil pressure
Fire.

If one or more of these conditions arise, the APU is automatically shut-down.

119. *Fire Protection.* (See Chapter 8.)

APU Drains

120. All APU drains join a common exit in the APU left-hand door, aft of the fire-proof bulkhead.

121. The jet-pipe drain (wet start fuel and water) exit is through the right-hand door aft of the fire-proof bulkhead.

APU Ventilation

122. The APU chamber is ventilated through louvres in the APU compartment doors and in the structure aft of the fire-proof bulkhead.

Air Supply for Main Engine Starting

123. Air from the APU is fed into the main airframe anti-icing ducting, via the air control valve, for main engine starting. The delivery duct from the APU is waisted to form a venturi; a solenoid-operated, venturi controlled anti-surge valve automatically controls the flow of excess air to atmosphere to maintain pressure in response to system requirements.

124. Air is fed to the aircraft system via the air delivery valve which is controlled from the AIR CONTROL-START/OFF switch at the engineer's station (panel C). The valve is only operative when the APU is running at full rated speed.

125. A non-return valve in the air delivery line prevents air from the aircraft anti-icing/engine start ducting discharging to atmosphere through the APU, should the air delivery valve fail to close.

Starting a Main Engine from the APU

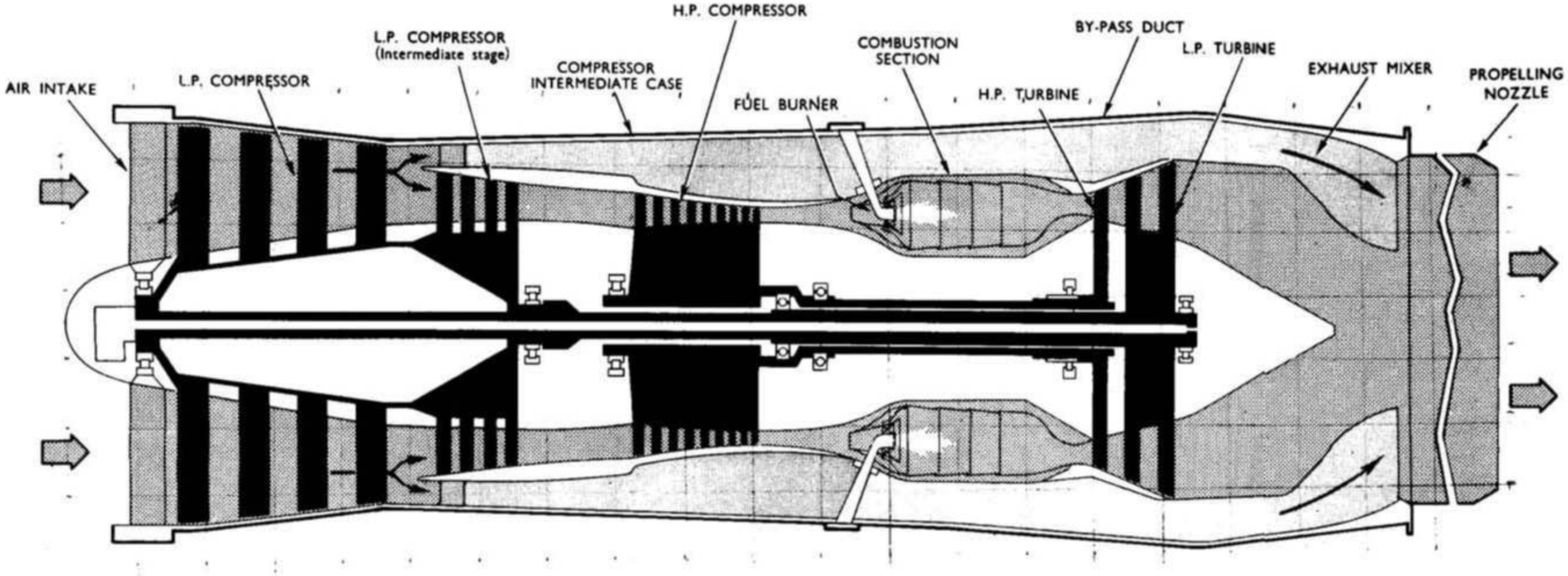
126. To start a main engine, the APU must be running at full rated speed and the AIR CONTROL VALVE switch set to START.

127. When the engine start master switch is set to LP START, the system valves are set to the correct position for starting and a supply is provided to the individual engine start switches.

128. When each engine start control switch is selected to START its start valve is opened, permitting air to flow to the starter motor. The flow of air through the APU venturi causes the anti-surge valve to move towards the closed position, reducing the bleed to atmosphere, so maintaining the flow of air to the starter motor.

129. When the start switch is released to OFF, or the starter cut-out switch operates, the start valve closes. The reduced airflow through the venturi causes the anti-surge valve to open, permitting excess air to flow to atmosphere.

130. The above sequence also applies when the engine is turned over with the starter master switch set to IGNITERS OFF MOTORING.



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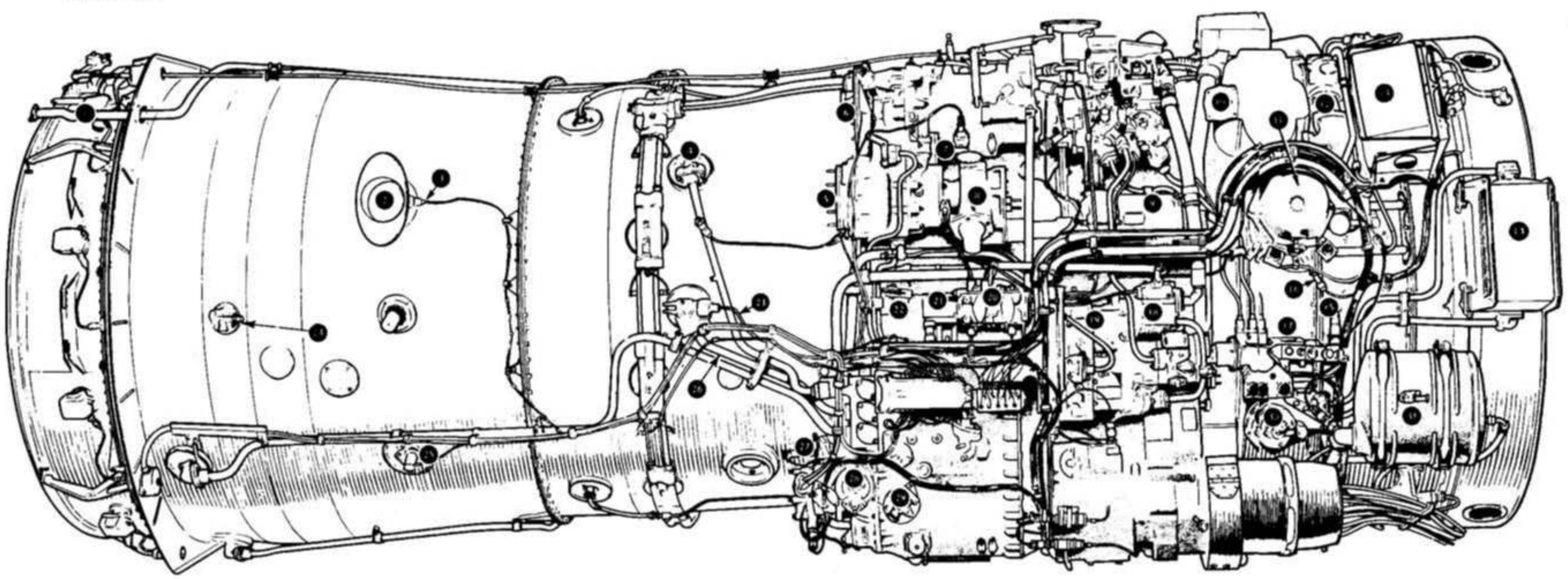
2–7 Fig 1 Gas Flow Through Engine



NOTE:- Engine shown is not to a specific Modification standard. For precise details refer to system and unit descriptions

1 Thrust reverser air supply pipes
2 LP cooling air outlet
3 LP cooling air overheat detector
4 Thrust bearing oil return pipe
5 Hydraulic pump mounting face
6 Air starter mounting face
7 HP RPM indicator generator
8 LP fuel pump (backing pump)
9 Engine oil cooler
10 Fuel heater air outlet
11 LP fuel filter
12 Fuel heater air valve and actuator
13 Temperature and LP RPM control signal amplifier
14 CSD oil cooler
15 LP fuel pressure transmitter
16 LP fuel temperature bulb
17 Fuel flowmeter mounting
18 HP fuel shut-off cock
19 HP fuel pump
20 Drains block
21 LP RPM indicator generator
22 LP shaft failure mechanism
23 Thrust bearing drain pipe
24 Combustion fuel drains
25 Vibration indicator mounting
26 HP turbine bearing oil return pipe
27 Oil temperature transmitter
28 Pressure oil filter
29 Oil sump drain valve
30 CSD oil filter
31 CSD oil tank drain

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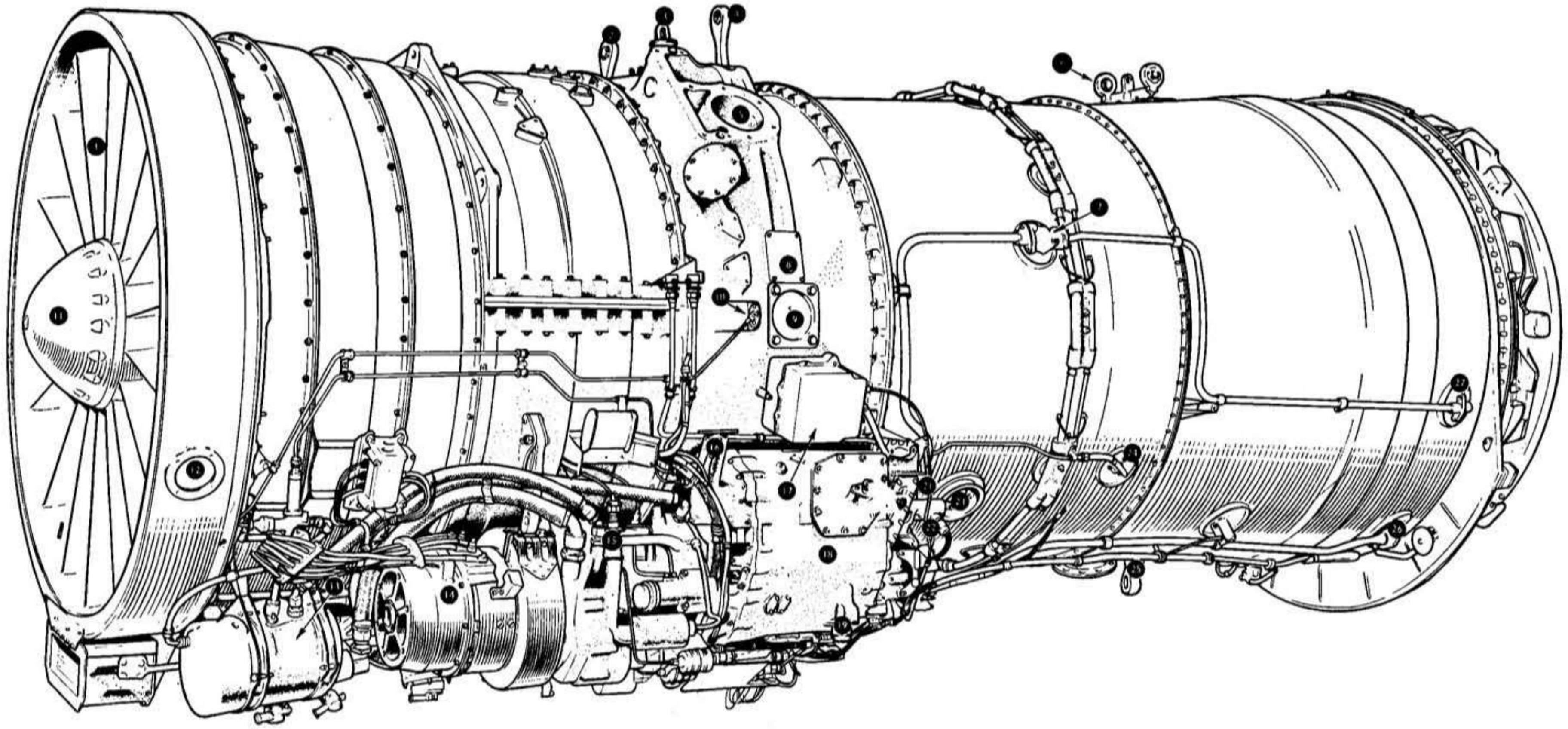
2–7 Fig 2 Underside View of Engine

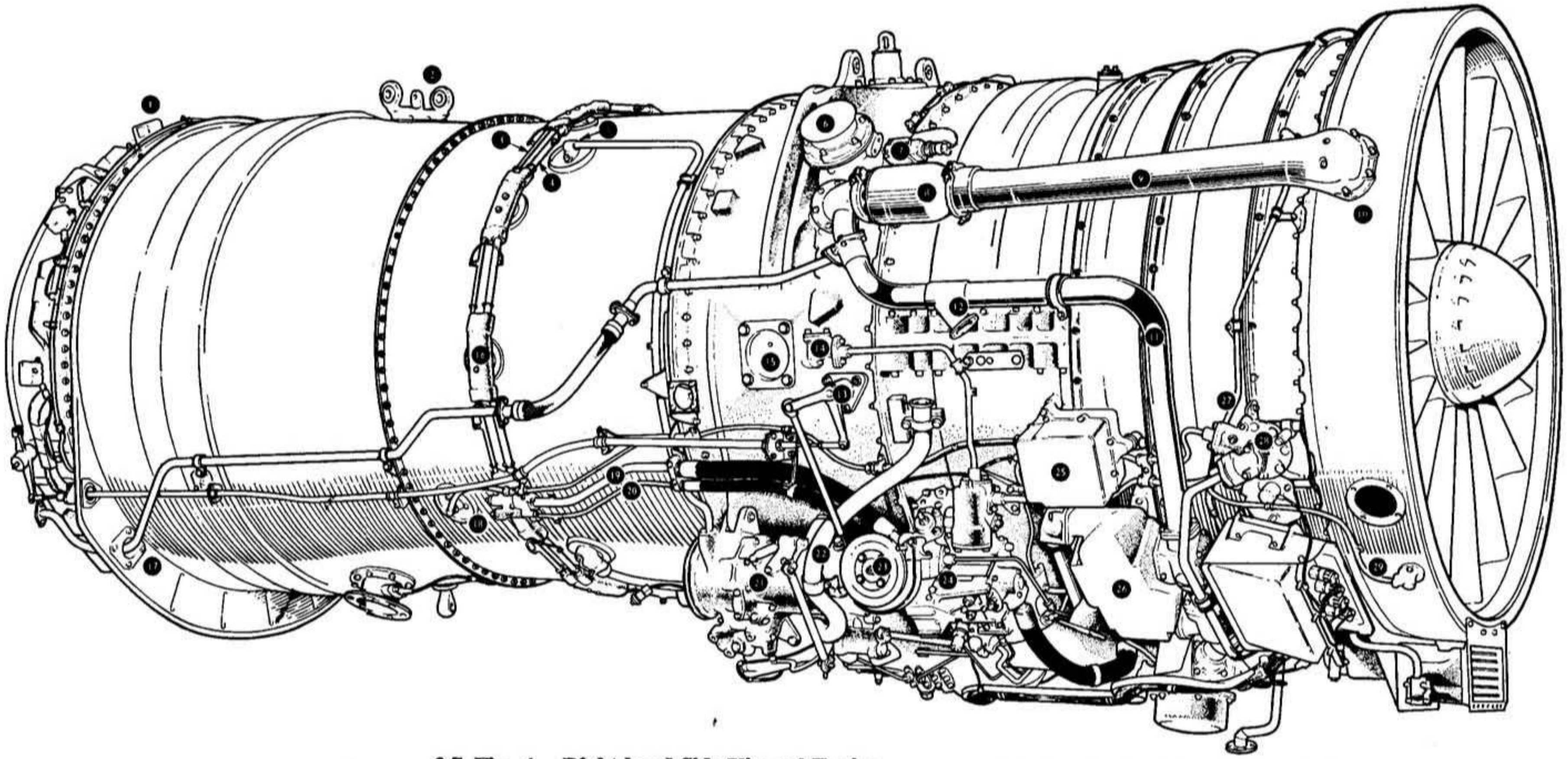
1 Air intake guide vanes
2 Forward mount—right-hand side
3 Forward lifting and locating spigot
4 Forward mount—left-hand side
5 Cabin blower gearbox mounting face
6 Rear suspension and slinging point
7 HP turbine bearing oil supply
8 Engine data plate
9 Handling trunnion point
10 CSD pressurising air tapping
11 Engine air intake nose cone
12 Engine anti-icing air exhaust
13 CSD oil tank
14 Generator
15 CSD unit
16 Centrifugal breather overboard vent pipe
17 HE ignition unit
18 Left-hand side wheelcase
19 Oil sump pressure filling connection
20 Oil level sight glass
21 Low oil pressure warning switch
22 Oil pressure transmitter
23 Aircraft de-icing HP air supply
24 HE igniter plug
25 Engine jacking point (strong point)
26 LP turbine bearing oil return pipe
27 LP turbine bearing, thrust bearings and LP compressor front bearing oil supply



NOTE:- Engine shown is not to a specific Modification standard. For precise details refer to system and unit descriptions

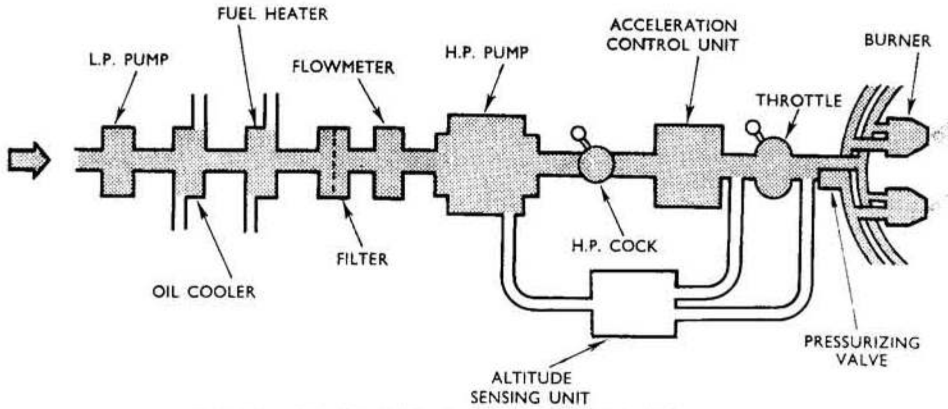
2.7 Fig. 3. Left-hand Side View of Engine

1 Thermocouples
2 Rear suspension and slinging point
3 Burner primary manifold
4 Burner main manifold
5 Thrust bearing vent pipe
6 Aircraft de-icing air supply
7 Anti-icing hot air valve actuator
8 Engine anti-icing hot air valve
9 Engine anti-icing hot air manifold
10 Engine air intake manifold
11 Fuel heater hot air supply pipe
12 Ground cooling air supply
13 Thrust reverser control lever
14 P3 air supply to FCU
15 Handling trunnion point
16 Fuel burner
17 Fireproof bulkhead
18 High energy igniter plug
19 Burner main fuel supply pipe
20 Burner primary fuel supply pipe
21 Right-hand side wheelcase
22 Main fuel supply
23 Throttle
24 FCU
25 High energy ignition unit
26 Fuel heater
27 Anti-icing pressure pipe
28 P1 transfer valve
29 P1 air supply to FCU

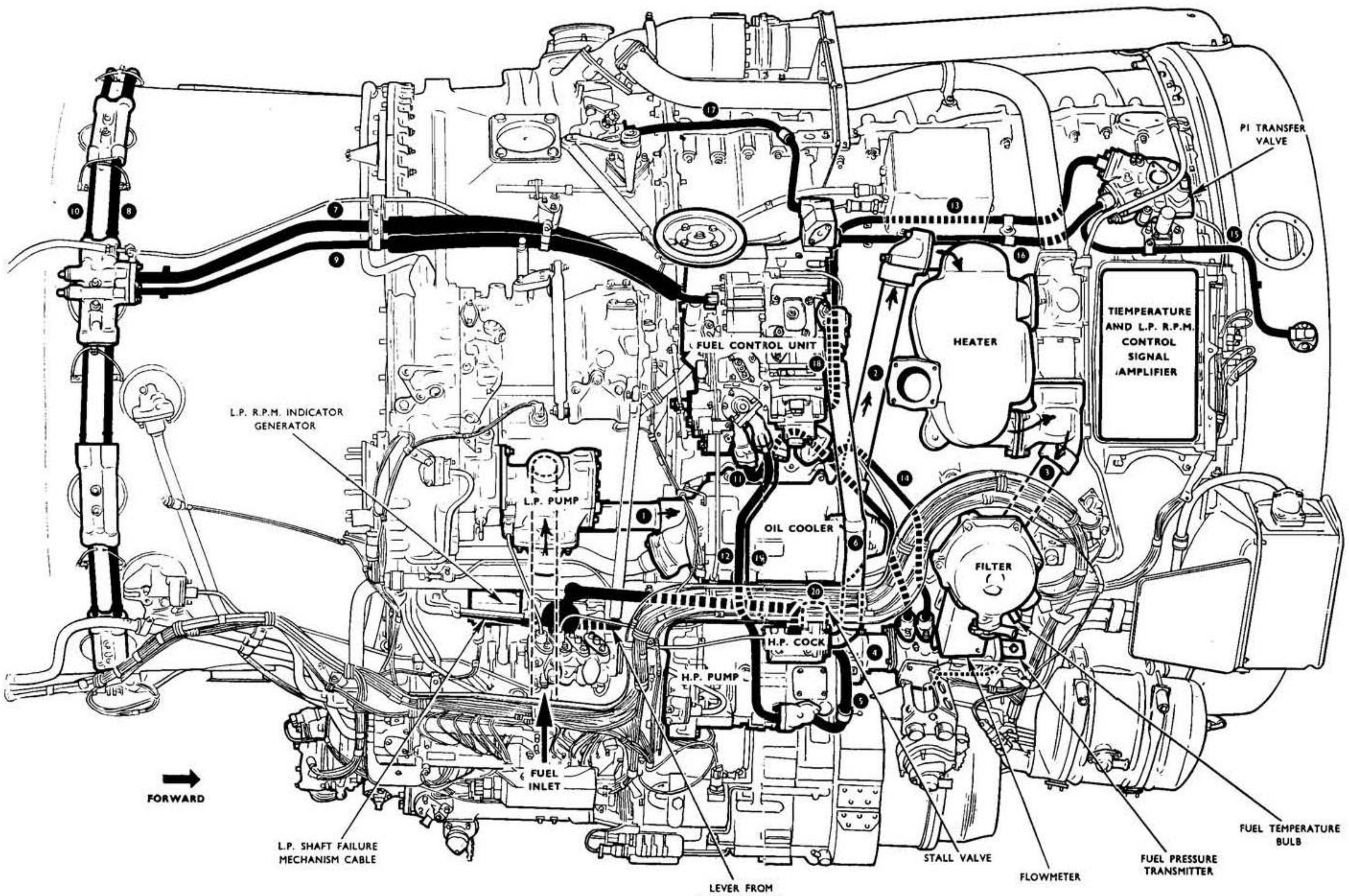


2.7 Fig. 4. Right-hand Side View of Engine

NOTE:- Engine shown is not to a specific Modification standard. For precise details refer to system and unit descriptions



2.7 Fig. 5. Fuel System — Simplified View



2.7 Fig. 6. Fuel System — External Pipes

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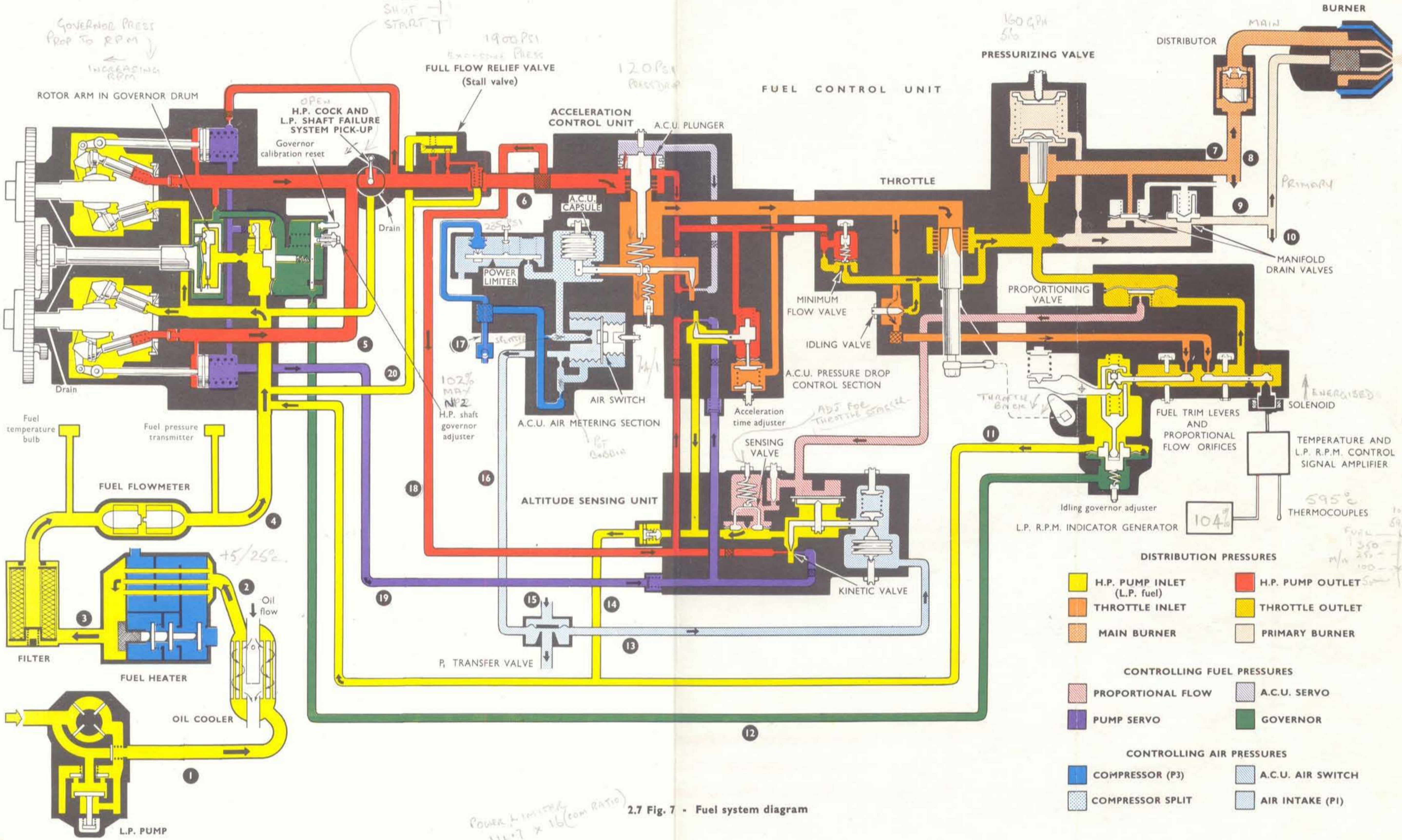

2.7 Fig. 7 - Fuel system diagram

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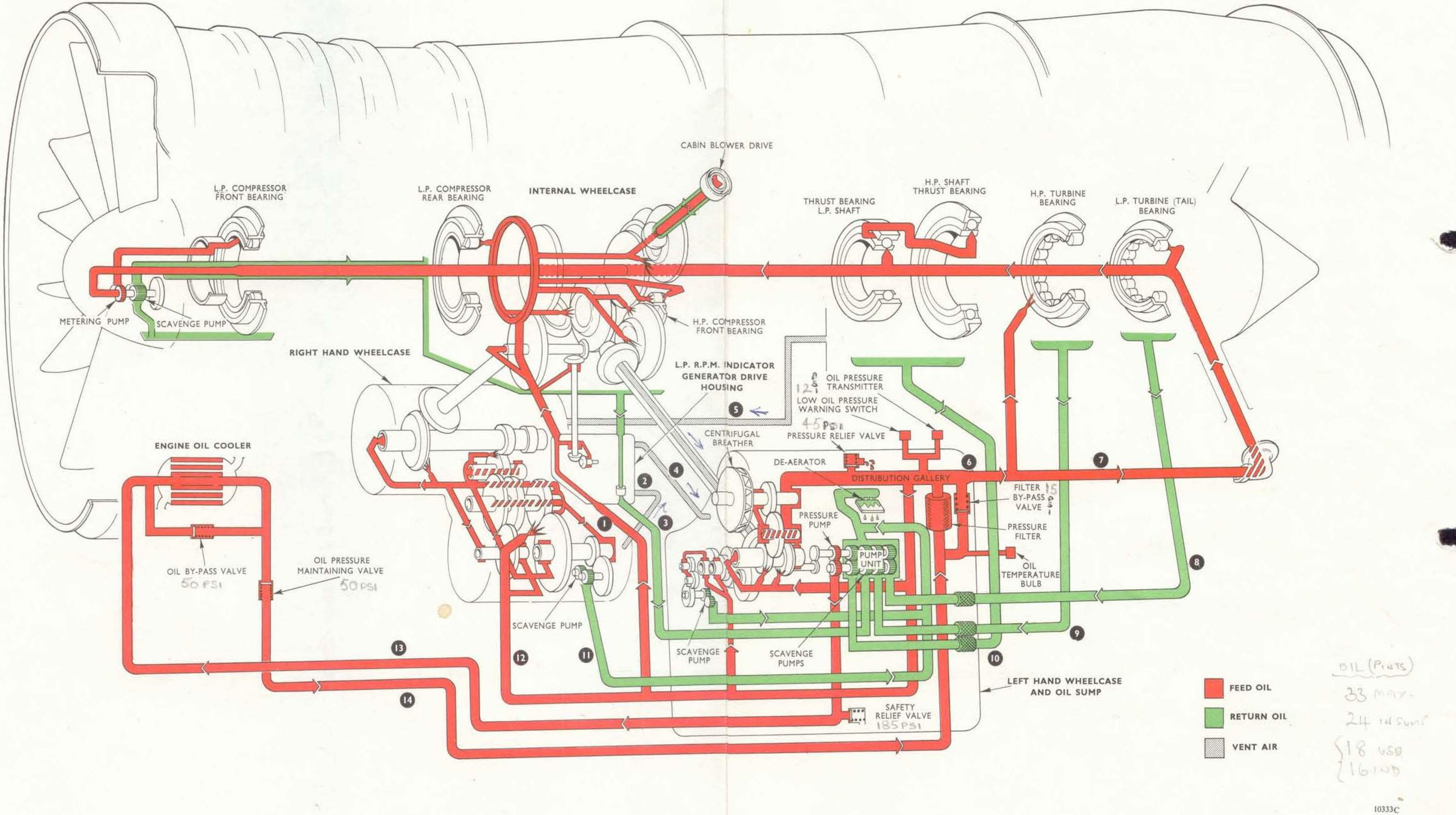
All external pipes are numbered for reference to location on engine (2.7 fig. 6)



All external pipes are numbered for reference to location on engine (2.7 fig. 9)

2.7 Fig. 8 - Oil systemdiagram

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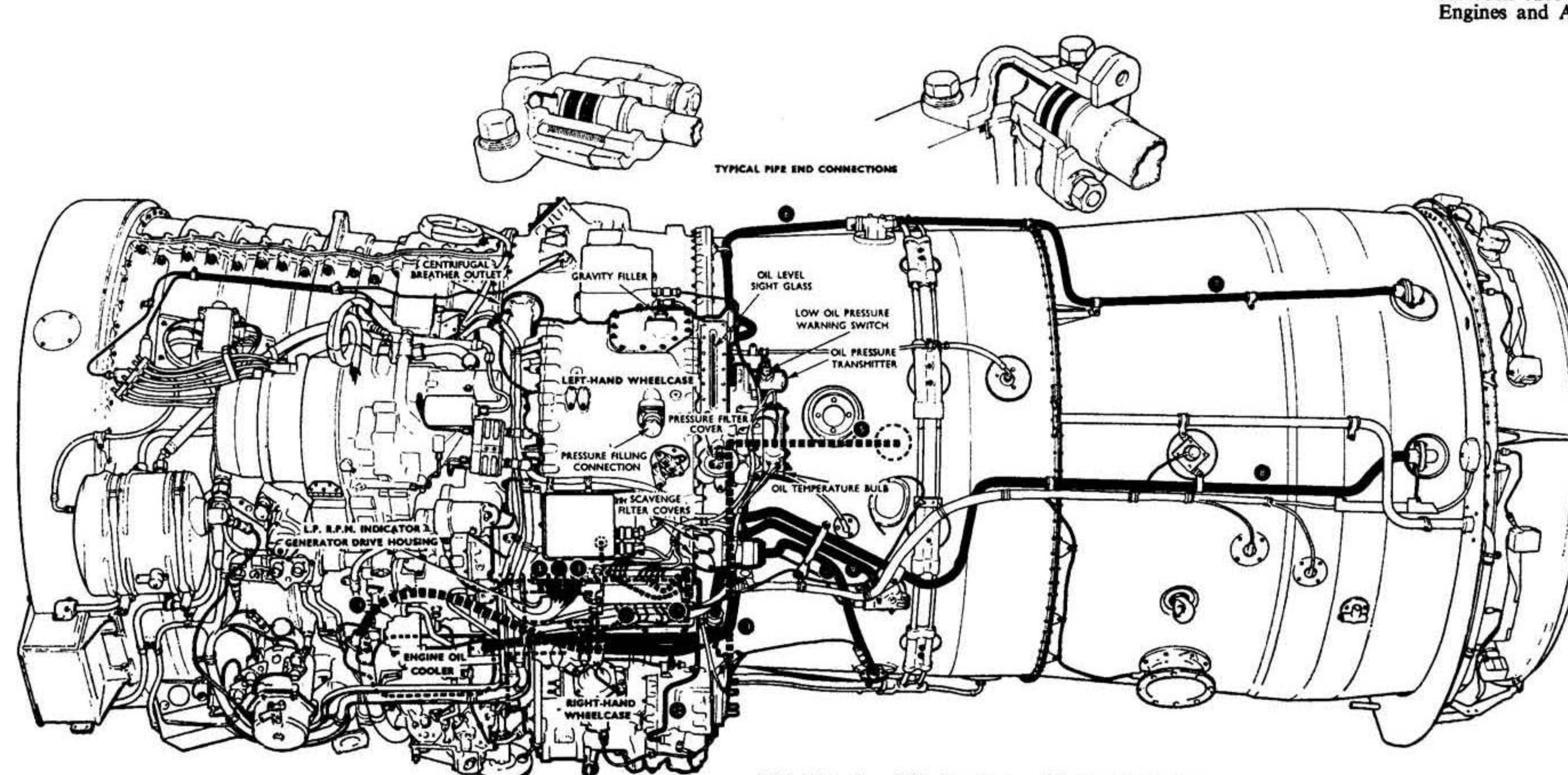

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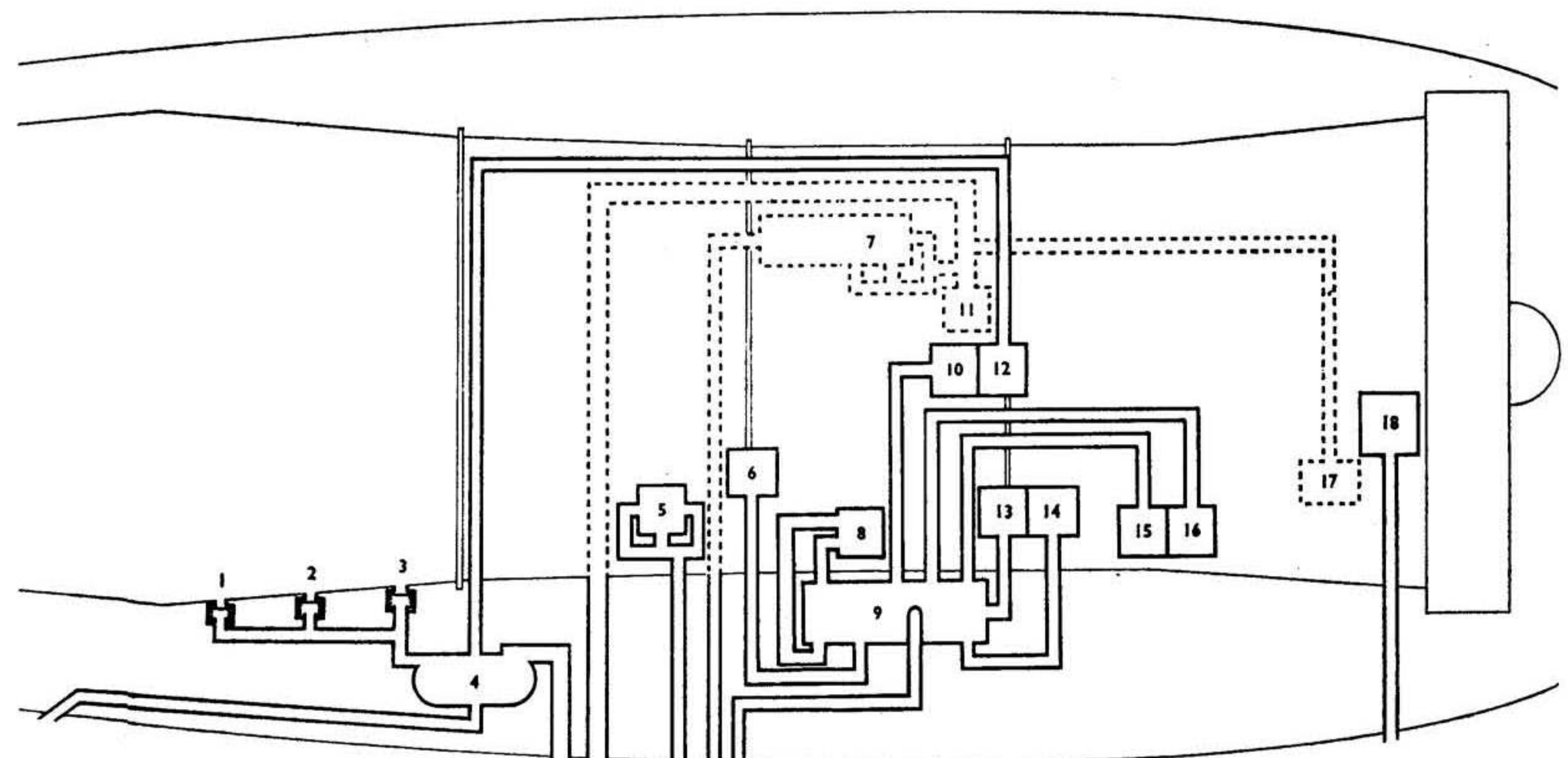
2.7 Fig. 9. Oil System — External Pipes

1 By-pass duct
2 Nozzle box
3 Combustion chamber
4 Drains tank
5 Hydraulic pump
6 HP shaft thrust bearing
7 Cabin compressor
8 LP fuel pump
9 Drains block
10 Throttle valve
11 Engine centrifugal breather
12 Burner manifold
13 HP fuel pump
14 HP cock
15 CSD unit (input and output shaft seal
16 CSD disconnect (output shaft seal)
17 CSD pressurising air
18 P1 transfer valve



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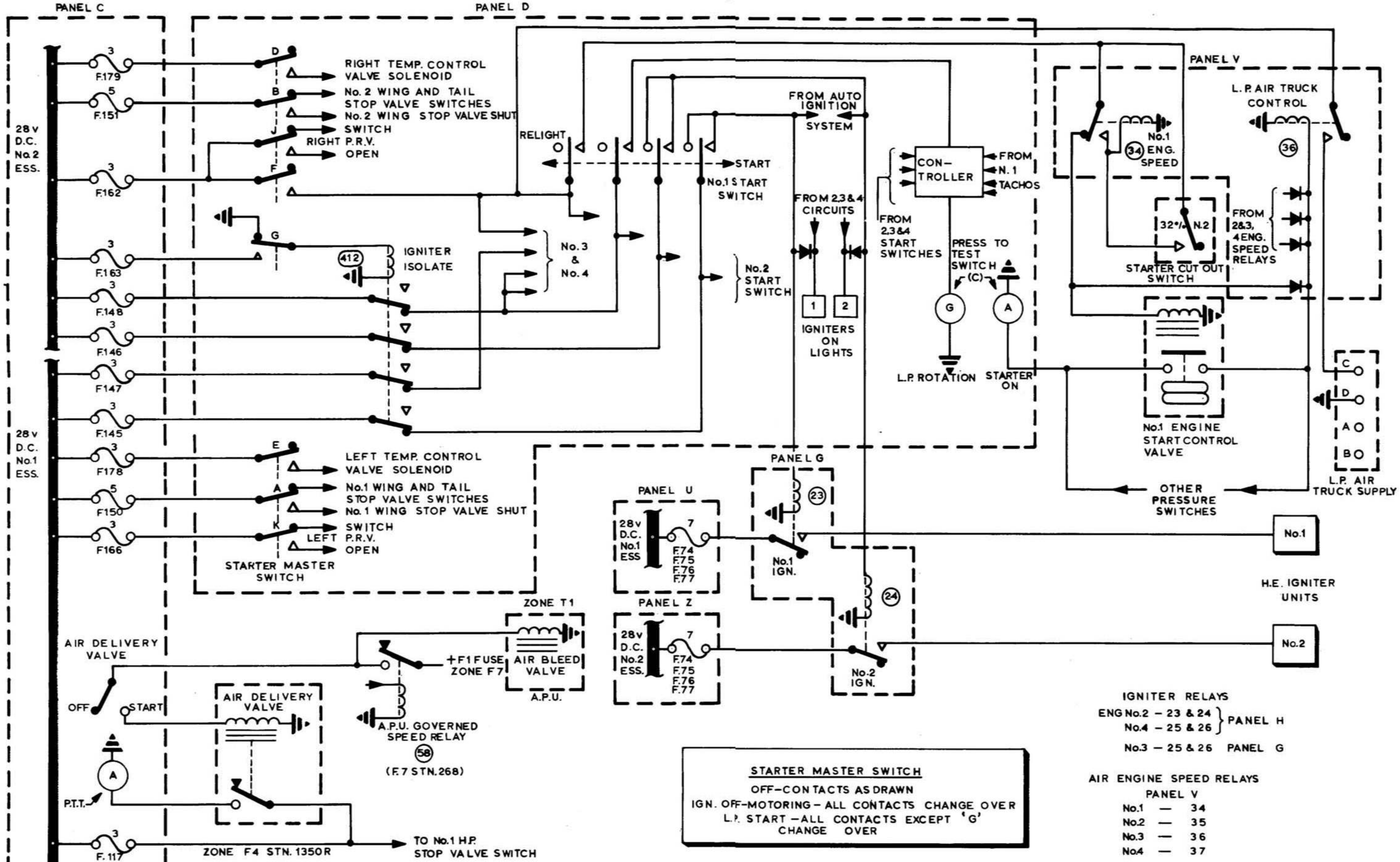
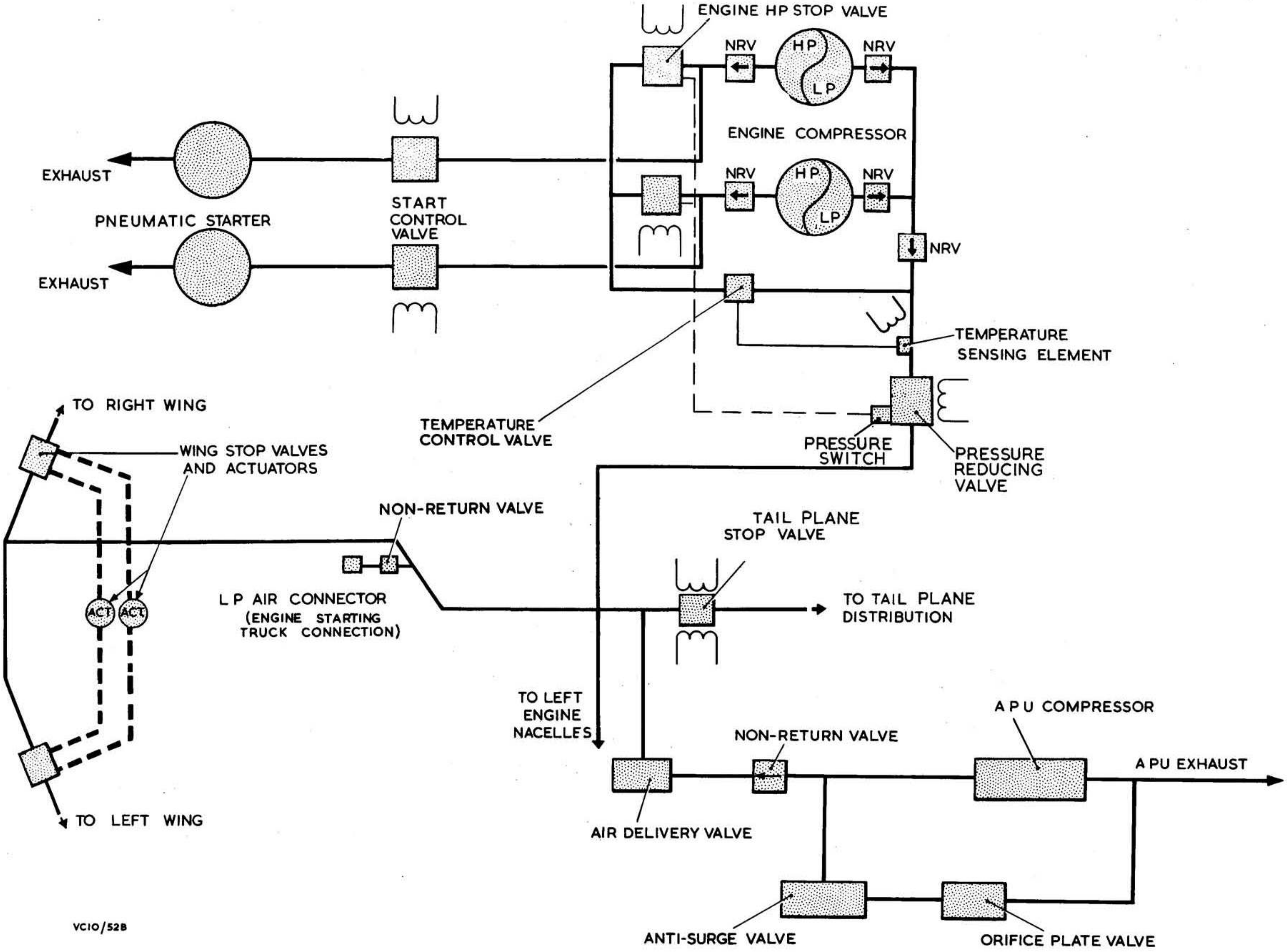
2.7 Fig. 10. Engine Drains

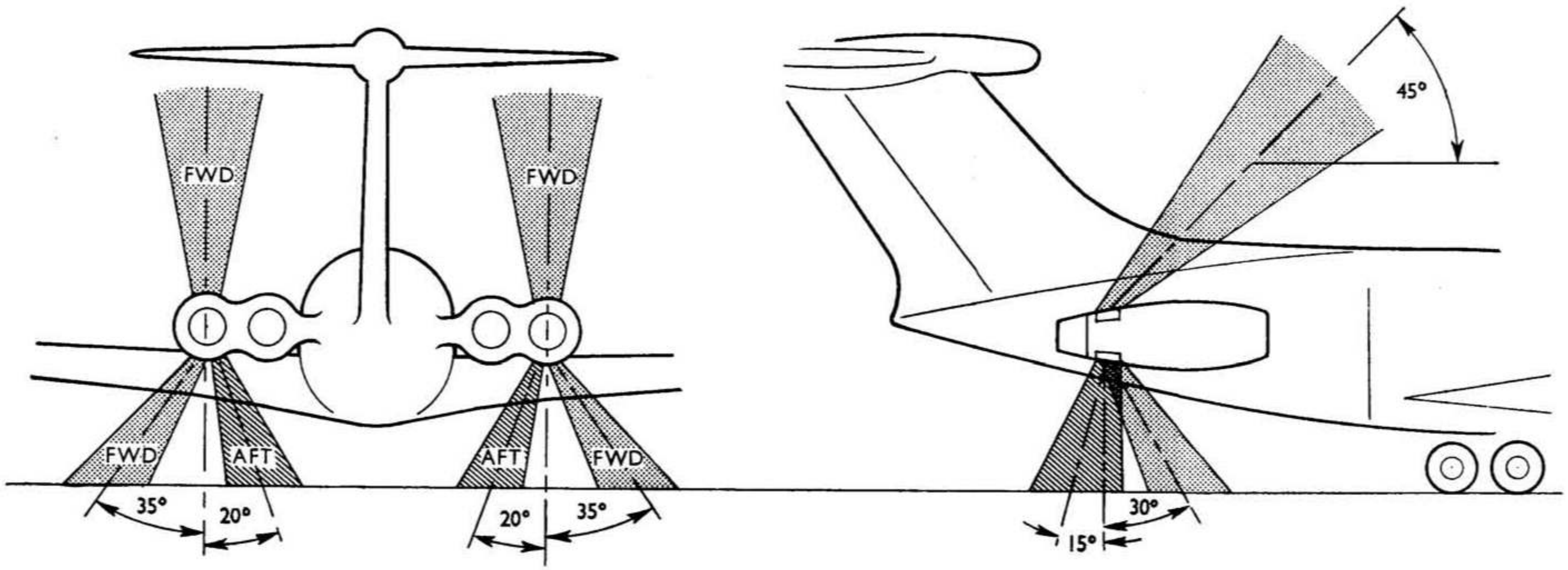


2.7 Fig. 11. Engine Starting Circuit

◀ *Revised Diagram* ▶



2.7 Fig. 12. Engine Starting System
◀ *NRV in APU Air Supply Line Reversed* ▶



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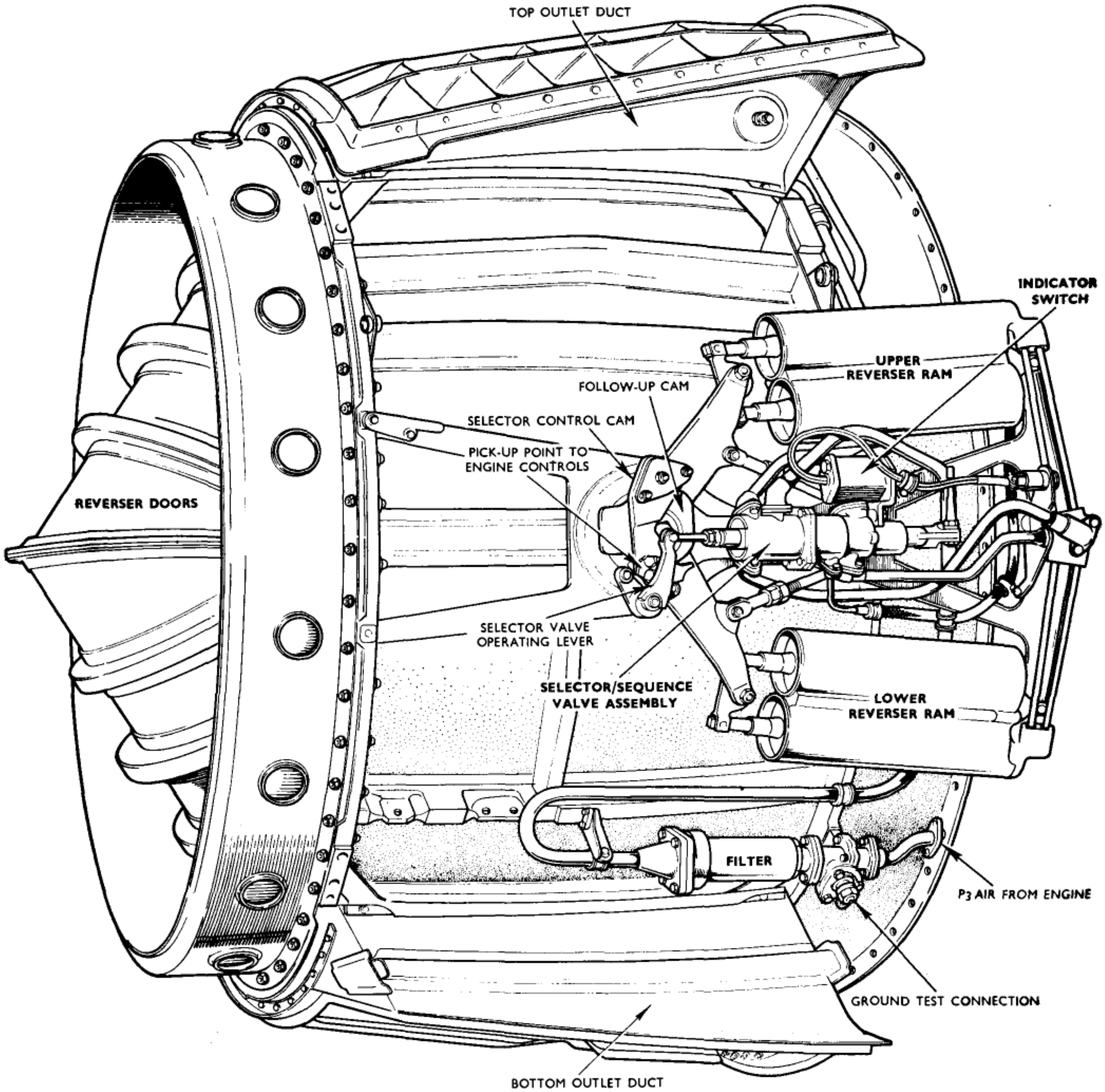
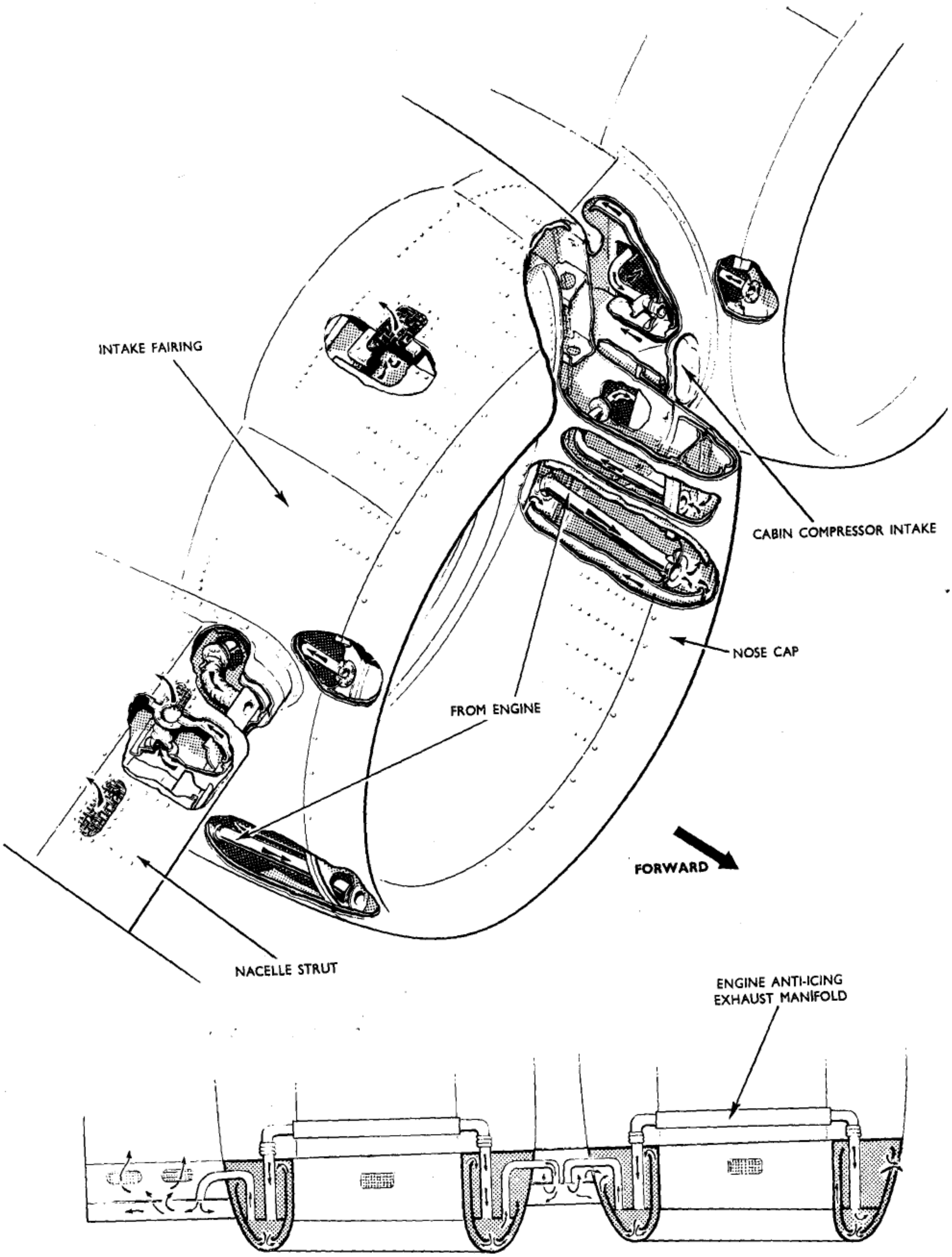
2.7 Fig. 13. Cascade Vane Gas Deflection

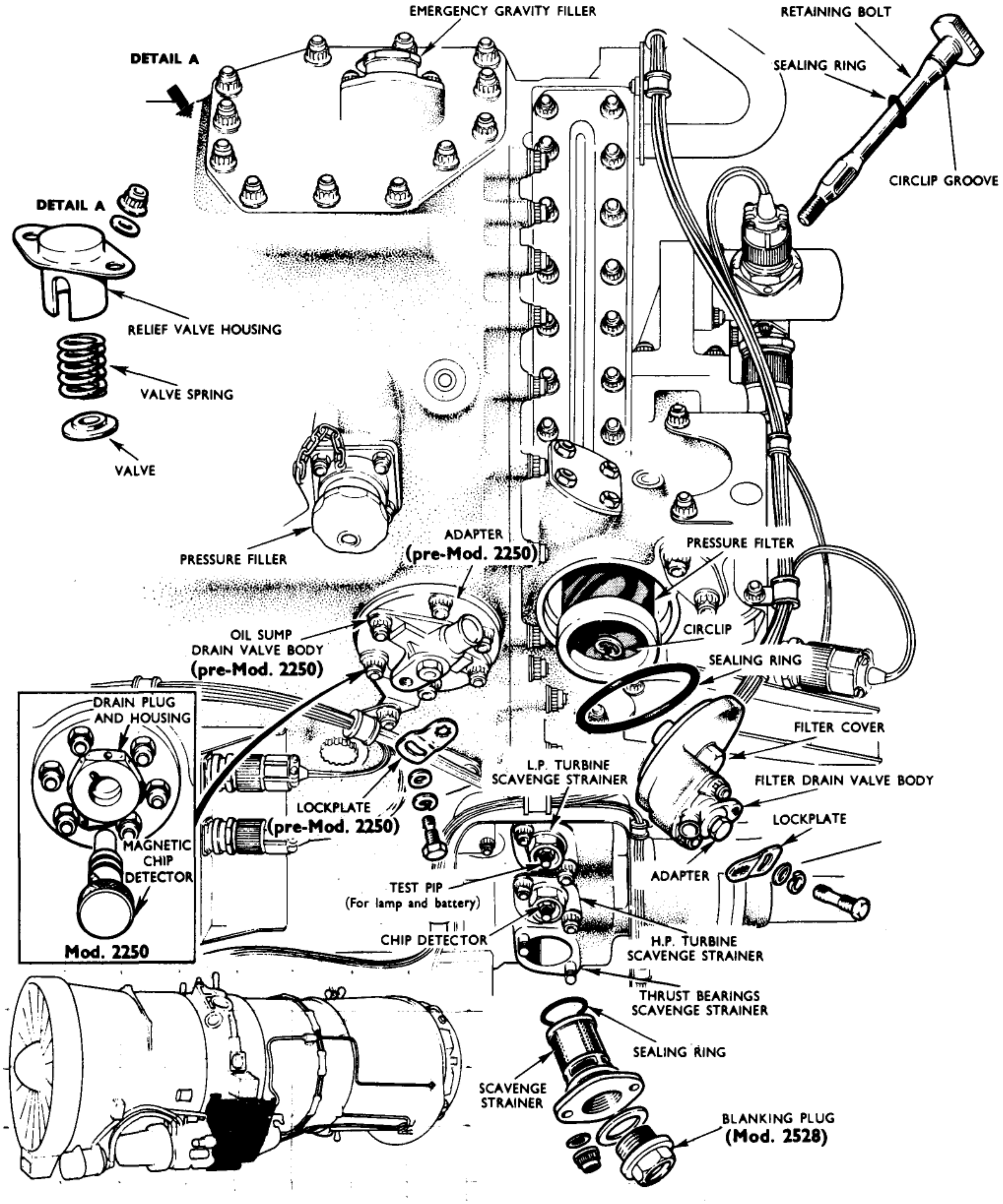


2.7 Fig. 14. Thrust Reverser Right-hand View



2.7 Fig. 15. Engine Air-intake Fairing

[redacted]



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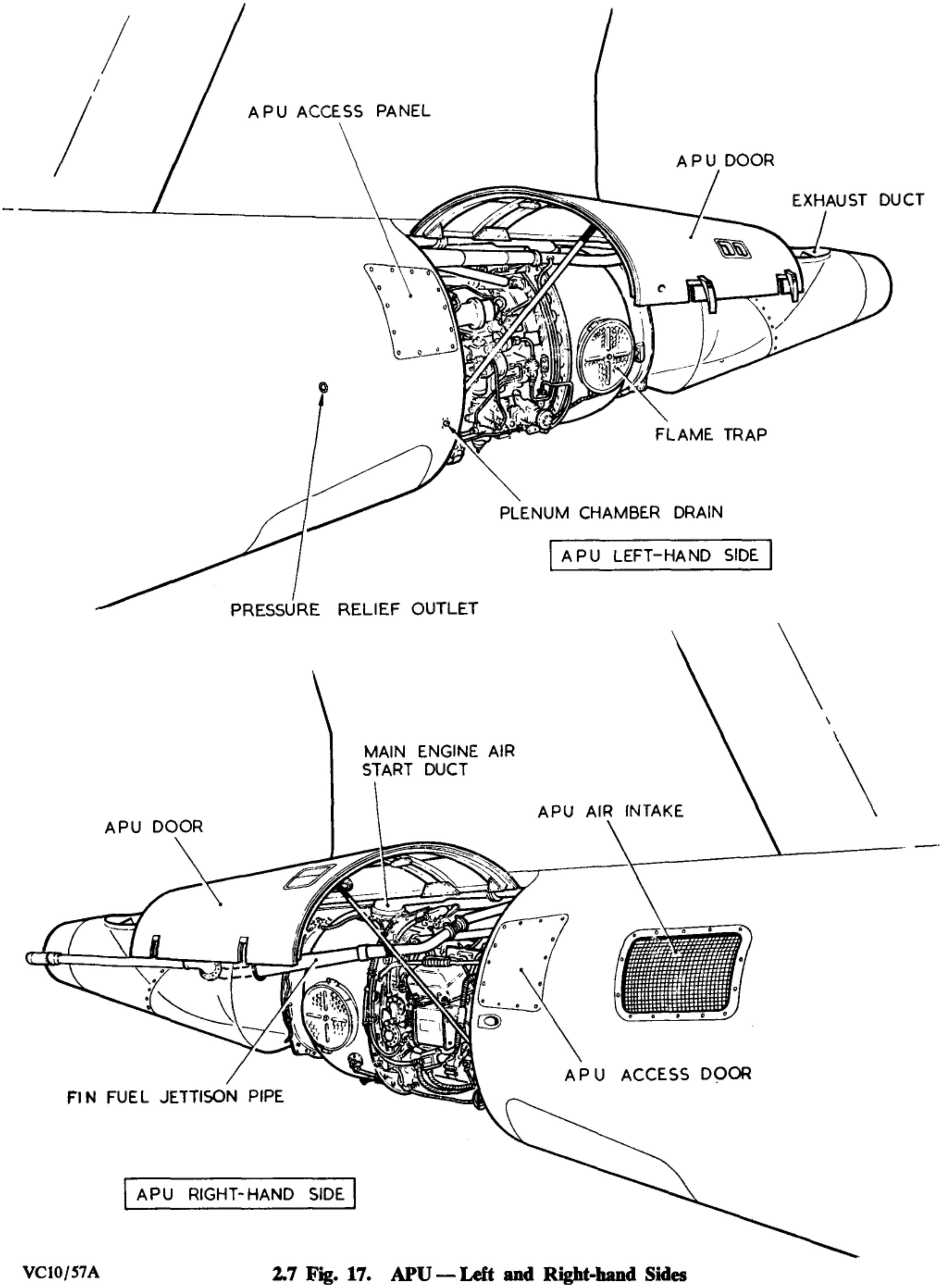
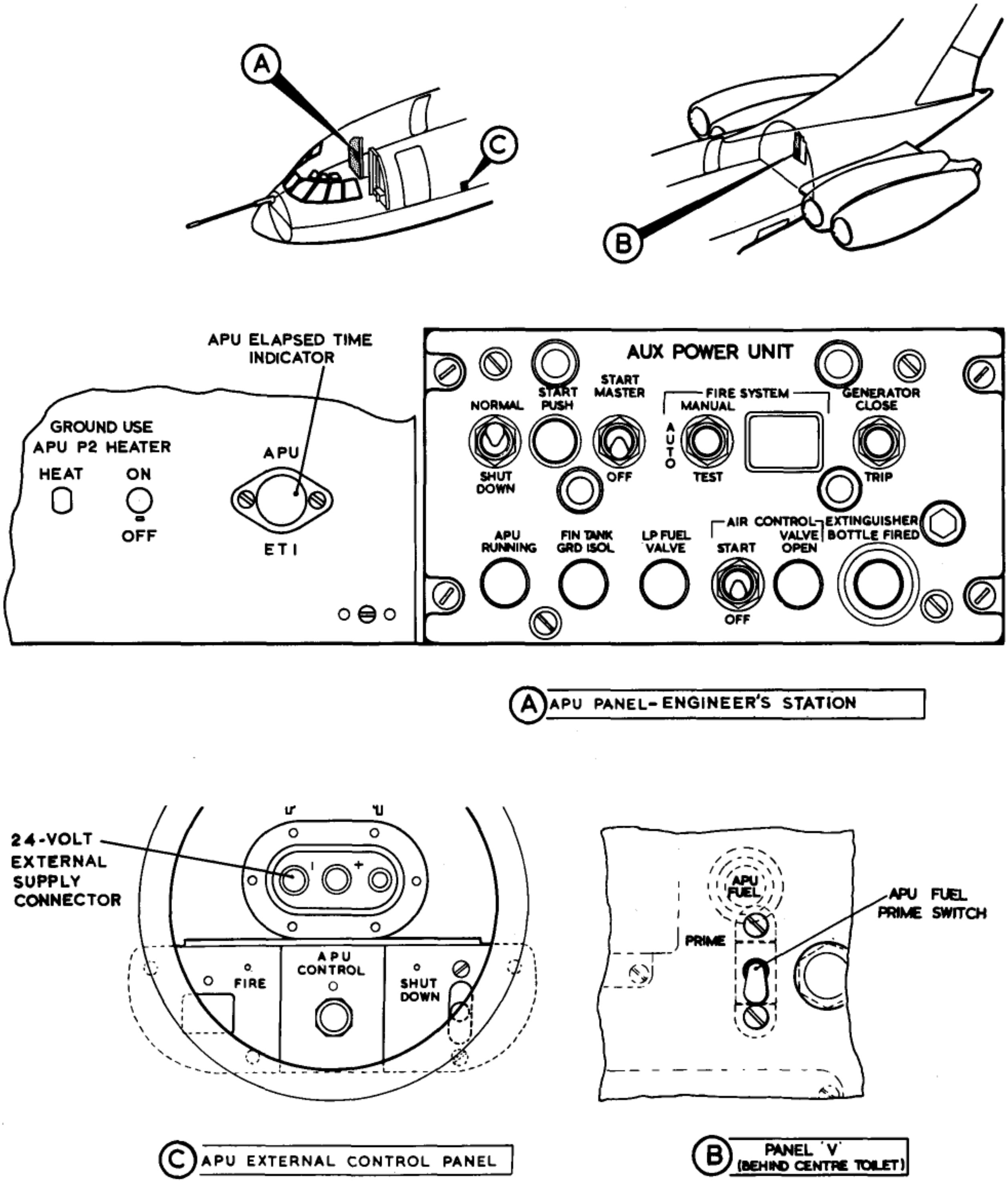
2.7 Fig. 16. Oil System — Maintenance Locations

◀ *Mod* 2528 *Included* ▶



2.7 Fig. 17. APU — Left and Right-hand Sides



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2—7 Fig 18 APU Control Panel and Indicators

◀ P_2 Heater Switch and Warning Light Added ▶


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