Part I

Chapter 6—Engines

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Power Plants—Description and Controls

1 General

(*a*) Four Conway Mk. 201 engines are installed, two in each wing adjacent to the fuselage. Each engine is an axial-flow by-pass turbo-jet incorporating a twin-spool compressor driven by turbines and has a turbo-annular combustion chamber.

(*b*) The drive shaft for the low-pressure compressor passes through the high-pressure compressor shaft and each compressor rotates independently of the other, and in the same direction. Provision is made for the HP shaft to drive ancillary units. The only drive from the LP shaft is for the LP shaft tachometer.

(*c*) The output from the LP compressor is divided. Part goes to 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 by-pass duct, after which, it joins the hot gases from the turbines and the total flow is ejected through a propelling nozzle to atmosphere.

2 HP fuel pumps

(*a*) Fuel from the aircraft supply is fed through an engine-driven backing pump, through an LP filter to an engine-driven dual type HP fuel pump, the fuel delivery of which is limited to that required to maintain max shaft RPM.

(*b*) The pump output is passed through a fuel-cooled oil cooler into a fuel control unit. A metered flow suitable to the engine conditions is then delivered to the burners.

3 Fuel control units

Each unit contains the following features to provide a correct flow of fuel to the engine.

(*a*) A steady running control system comprising a combined throttle valve and HP cock and an altitude sensing unit.

(*b*) A top temperature control, limiting exhaust gas temperature for take-off, climb and cruise.

(*c*) An LP shaft top-speed governor.

(*d*) An acceleration control.

(*e*) An idle speed governor.

(*f*) A maximum thrust governor.

4 By-pass duct bleed valve

(*a*) Each engine has an air bleed valve fitted in the by-pass duct casing in order to reduce the tendency for the LP compressor blades to stall at low RPM, thus leading to compressor surge.

(*b*) The bleed valve consists of a shuttle which operates a butterfly valve. Air tapped from the engine anti-icing supplies and controlled by a solenoid is used to operate the shuttle. The valve is open up to a given RPM to allow surplus air to escape from the by-pass duct; a P3 switch affects the fixed opening above 40000 ft. Above HP RPM of $88\pm1\%$ on the ground and $86{\cdot}5\pm1{\cdot}5\%$ at 52,000 ft. and 0·86M the valve is closed thereby improving compressor efficiency with a resultant lower specific fuel consumption.

(*c*) Mod. 3736 provides four magnetic indicators on the co-pilot's instrument panel to show the position of the bleed valve on each engine.

5 Anti-icing system

To prevent ice formation on the LP compressor, hot air is bled from the HP compressor, via twin feeds, to the intake guide vane assembly, first row of stators. Two air regulator valves automatically prevent excess pressures developing in the system. Hot air is bled from the LP compressor to heat the articulated duct.

6 Fuel heater system

(*a*) Protection against fuel filter icing is provided by a hot air fuel heater just upstream of the main LP filter. The system is fully automatic and is operated by a pressure differential switch across the LP filter.

(*b*) On the 2nd pilot's console AF are four FUEL FILTER DE-ICING ISOLATION, AUTO/OFF/MAN switches, together with four ON (valve open)/OFF (valve closed) indicators. The system is normally operated with the switches at AUTO, the OFF and MAN positions are for after flight and flight-override purposes, respectively (see para. 19).

(*c*) Four test buttons are at the aft end of console AF.

7 Throttle/HP cock controls

(*a*) Two throttle boxes are provided, one for each pilot on the appropriate console. Each throttle lever can be moved freely from IDLING to FULLY OPEN and may be held in any selected position by operating the friction lock lever.

(*b*) At the IDLING position on the 1st pilot's throttle box is a gate mechanism which acts as the idling stop for the throttle levers. When the gate is disengaged the throttles may be moved back to the SHUT OFF position, at which position the throttle valves are fully closed and act as HP cocks.

(*c*) The idling gate may be disengaged by either pilot. A switch on the 1st pilot's throttle box operates the gate mechanism. A second switch on the 2nd pilot's throttle box is connected to a rotary solenoid on the gate mechanism; when the switch is operated the gate is disengaged. When the switch is released the gate is returned to its normal position under spring pressure.

(*d*) The gate mechanism must be operated before the throttles can be moved out of the SHUT OFF position or returned to that position from IDLING.

(*e*) Mod. 4020 introduces a visual indicator for the throttle gate lever. A white knob replaces the black knob on the lever and a second knob is provided at the inner face of the sleeve guard. When aligned the knobs provide visual and feel indication to the 1st pilot that the gate is engaged.

8 Top temperature controls

Four JET PIPE TEMPERATURE ISOLATION, NORMAL/ISOLATE switches are on 1st pilot's side panel. A three position CRUISE/CLIMB/TAKE-OFF switch is on panel AZ.

9 Anti-icing system controls

Four ENGINE ANTI-ICING-ON/OFF control switches are on 2nd pilot's panel AD, one for each engine.

10 LP turbine overspeed warning lights

Four OVERSPEED WARNING lights one for each engine, are on panel A. The appropriate light comes on if an LP turbine over speeds, in which case RPM should be reduced to the point where the light is extinguished.

11 Fuel heating control and indicator

(*a*) Although the system is designed for automatic operation, an AUTO/OFF/MAN override switch is provided on panel AF.

(*b*) With the switch set to AUTO the system operates automatically and a thermal switch prevents overheating. With the switch set to MAN the heater is under the pilot's control and no overheat protection is provided.

(*c*) The setting of the hot air valve is shown by an ON-OFF magnetic indicator also on panel AF.

12 Engine starting controls

(*a*) The engines are turned over for starting by air motors mounted on the engine starboard wheelcases and geared to the engine HP compressor shafts.

(*b*) The air supply to the starter motors can be supplied either from a ground supply or from the AAPP. All engines can be started from the AAPP supply; once any one engine is started the remaining three engines can be started from it. For rapid engine starting fuel/air combustors are fitted. (See para. 13).

(*c*) All engine starting control switches are on panel AL in the cockpit roof. These switches are:

(i) A starter master GROUND/FLIGHT/COMBUSTOR/AAPP switch.

(ii) Four separate ENGINE SELECTOR switches by means of which individual engines may be selected for starting.

(iii) STARTER PUSH switch which completes the interconnection between the main engine start circuits and air supply sources. The button locks in until the selected engine reaches self-sustaining speed.

(iv) Four START IN PROGRESS/LP STALL WARNING lights, one for each engine and which come on as soon as the associated LP compressor rotates. The light extinguishes as soon the starter button throws out. The light indicates that the LP compressor is turning; if no indication is given the start must be discontinued. The light operates within 180° of compressor rotation.

(v) IGNITION ISOLATION switch which completes the circuit to the HE igniter units of the engine being started. After all engines are started the switch must be set OFF. It should also be OFF when motoring an engine after a wet start.

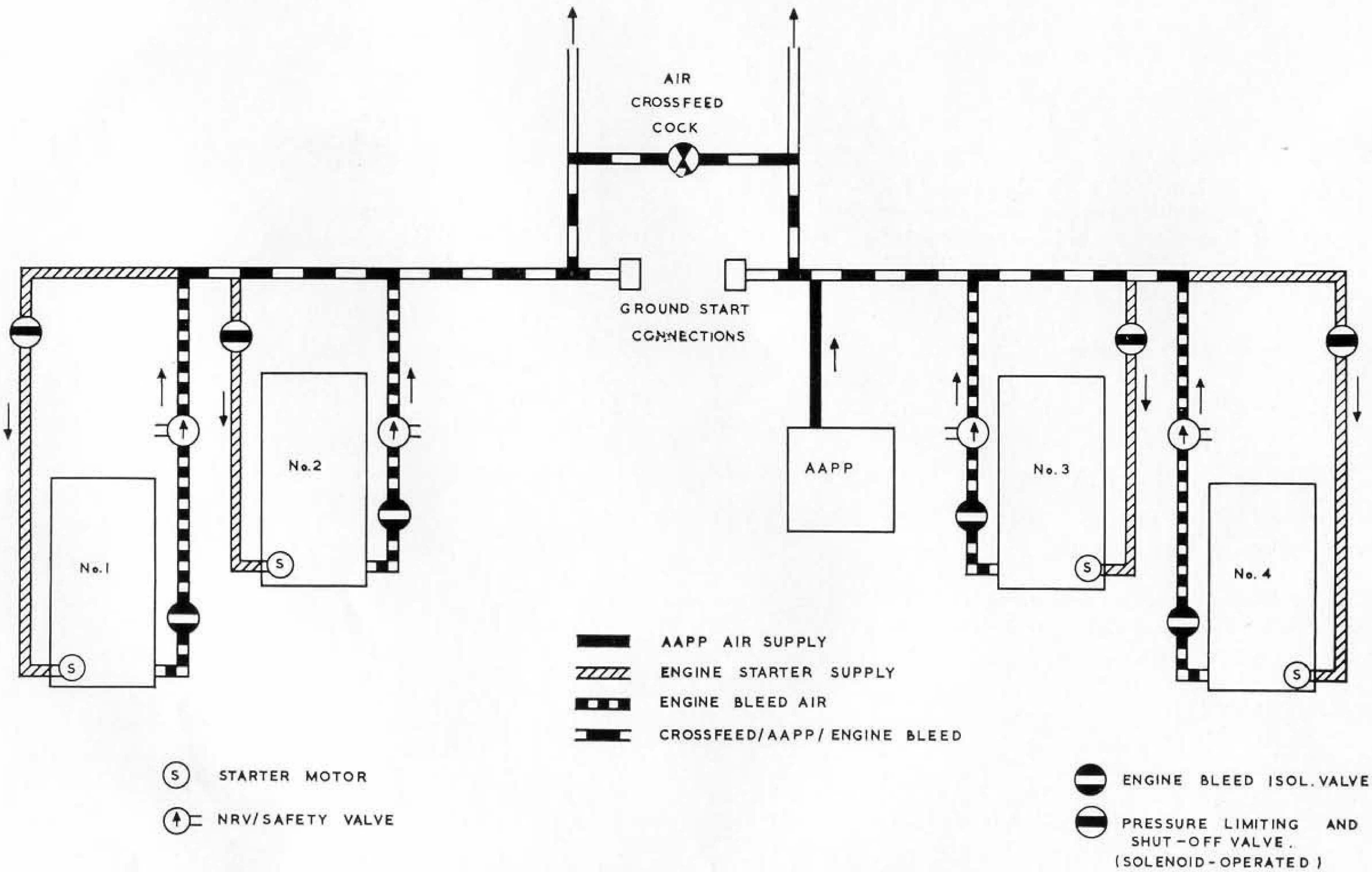

Fig. 1 Normal engine starting system

(vi) CROSSFEED COCK, OPEN-CLOSE switch which controls the crossfeed cock between the port and starboard high pressure air starting systems so that when any engine has been started, air may be crossfed to the other engines. An amber warning light indicates when the cock is open.

(*d*) The RELIGHT buttons for starting an engine in the air are in the tops of the throttle levers, on each pilot's throttle box.

13 Rapid engine starting

(*a*) *Introduction*

(i) In order that more than one engine can be started at one time a fuel/air combustor starting system is provided.

(ii) A combustor mounted on the underside of each engine provides low pressure air for the associated starter motor when the engine start selection is made. This is achieved by burning fuel, taken from the fuel tanks, with air from storage bottles, and directing the gaseous products from the combustor to the turbo starter motor.

(*b*) *Air supplies*

Five air storage bottles carried in each mainplane supply high pressure air at 3,300 PSI for the combustors in the associated wing. Sufficient air is contained in the bottles for two engine starts per side provided that the bottles are initially fully charged.

The air from the five storage bottles is collected in a common manifold and fed via a charging point and gauge to the combustors in that wing. Control of the air is achieved by an On/Off valve and a pressure reducing valve in each combustor supply line. On opening the On/Off valve the high pressure air flows through the pressure reducing valve which controls the air supply to the combustor at 240 PSI. This air pressurises the fuel reservoir in the combustor and also mixes with the spray from the atomiser in the combustor, assisting ignition.

(*c*) *On/Off valve*

This is an electrically operated differential pressure type valve and is used to control the air supplies to the combustor. The unit consists of a main piston valve which is subjected to inlet pressures. A small drilling through the valve allows inlet pressures to the back of the valve, this in conjunction with a bias spring holds the valve on its seat isolating the air supplies. A solenoid operated bleed valve at the back of the main piston valve, when energised vents the back of the valve to atmosphere such that the inlet pressure felt on the head of the valve forces the valve off its seat allowing air to the pressure reducing valve and combustor. When the bleed valve closes, a pressure build up at the back of the main piston valve in conjunction with the spring, forces the valve back onto its seat so isolating the air supplies.

(*d*) *Pressure reducing valve*

This valve is fitted immediately upstream of the combustor and reduces the air supply pressure from 3,300 PSI to 240 $^{+2}_{-3}$ PSI. A bursting disc assembled on the valve protects the combustor against high supply pressure should the PRV fail in the open position.

(*e*) *Fuel/air combustor*

The combustor assembly consists basically of a steel cylinder divided by a web at its approximate mid-position to form two chambers, one a combustion chamber, containing an igniter plug and pressure switch, and the other a fuel reservoir.

(i) *Combustion chamber*

Mounted on the web and extending into the combustion chamber is a cylindrical flame tube. This tube forms an annular cavity between itself and the cylinder that forms the combustor casing, so protecting the area around the combustor from radiant heat. A burner head mounted on the web, carries a diffuser plug which atomises the incoming fuel for ignition. To complete the combustion chamber a conical tube, carried on the exhaust outlet, extends into the flame tube forming a flame trap so protecting the ducting against a naked flame.

An air inlet is provided on the combustion chamber close to the web, and directs a portion of the incoming air through drillings in the web, into the reservoir on one side of the floating piston.

(ii) *Igniter plug*

An igniter plug, mounted on the wall of the combustion chamber, extends into the flame tube to ignite the atomised fuel when an engine start selection is being made.

(iii) *Pressure switch*

A pressure switch carried on the wall of the combustion chamber and sensitive to combustion pressures locks in the starting cycle when ignition has taken place.

(iv) *Fuel reservoir*

The reservoir comprises an annular chamber which contains a fully floating piston. A fuel transfer tube is located in the reservoir and passes down its axis through the floating piston to make its attachment on one end of the web, while the other end picks up with a drilling on the end wall of the reservoir. The end wall of the reservoir provides the fuel inlet which incorporates an NRV to the reservoir, a drilling to connect the stored fuel to the transfer tube, and a bleed screw, that permits initial priming of the reservoir.

(*f*) *Operation*

(i) On initiating a rapid engine start, high pressure air passes through the ON/OFF valve and pressure reducing valve to the combustor. A proportion of this air is fed into the reservoir and impinges on the separator piston, pressurising the fuel. The fuel now passes out of the reservoir into the transfer tube, off seating the delivery valve, and to the atomiser mounted in the burner ring in the combustion chamber. An NRV located in the fuel inlet feed line prevents fuel from the reservoir back tracking to the aircraft fuel system. The remainder of the air passing to the combustor is directed into the combustion chamber to mix with the fuel spray from the atomiser. At the time of the engine start selection, a time switch is set to function the igniter mounted in the combustor chamber and control the time of combustor operation.

(ii) The igniter is functioned for a period of 2 seconds to fire the mixture in the combustion chamber, while the pressure switch sensitive to combustor pressures operates and locks in the starting cycles. Heated gases at a pressure of 36 PSI and at a temperature of 1,000°C now pass into the starter and are brought to impinge on the turbine wheel in the starter motor to rotate the engine rapidly to engine self-sustaining speed.

(iii) Incorporated in the starter is a speed sensitive device which will terminate the starting cycle when the engine reaches a predetermined speed. This is achieved by breaking the electrical supplies to the on/off valve so shutting the valve and isolating the air supply from the combustor.

(iv) In the event of the engine not starting first time, the starting cycle is automatically stopped by the time switch after 15 seconds.

(v) A second attempt to start an engine can be made after 30 minutes. The combustor reservoir contains 400 CC of fuel catering for approximately 200 CC of fuel to be used per start before it is subsequently recharged in flight for further engine starts.

(*g*) *Combustion fuel supplies*

Fuel is taken from the engine's fuel system just upstream of the backing pumps. The combustor reservoir, once primed, is subsequently charged during flight under booster pump pressure.

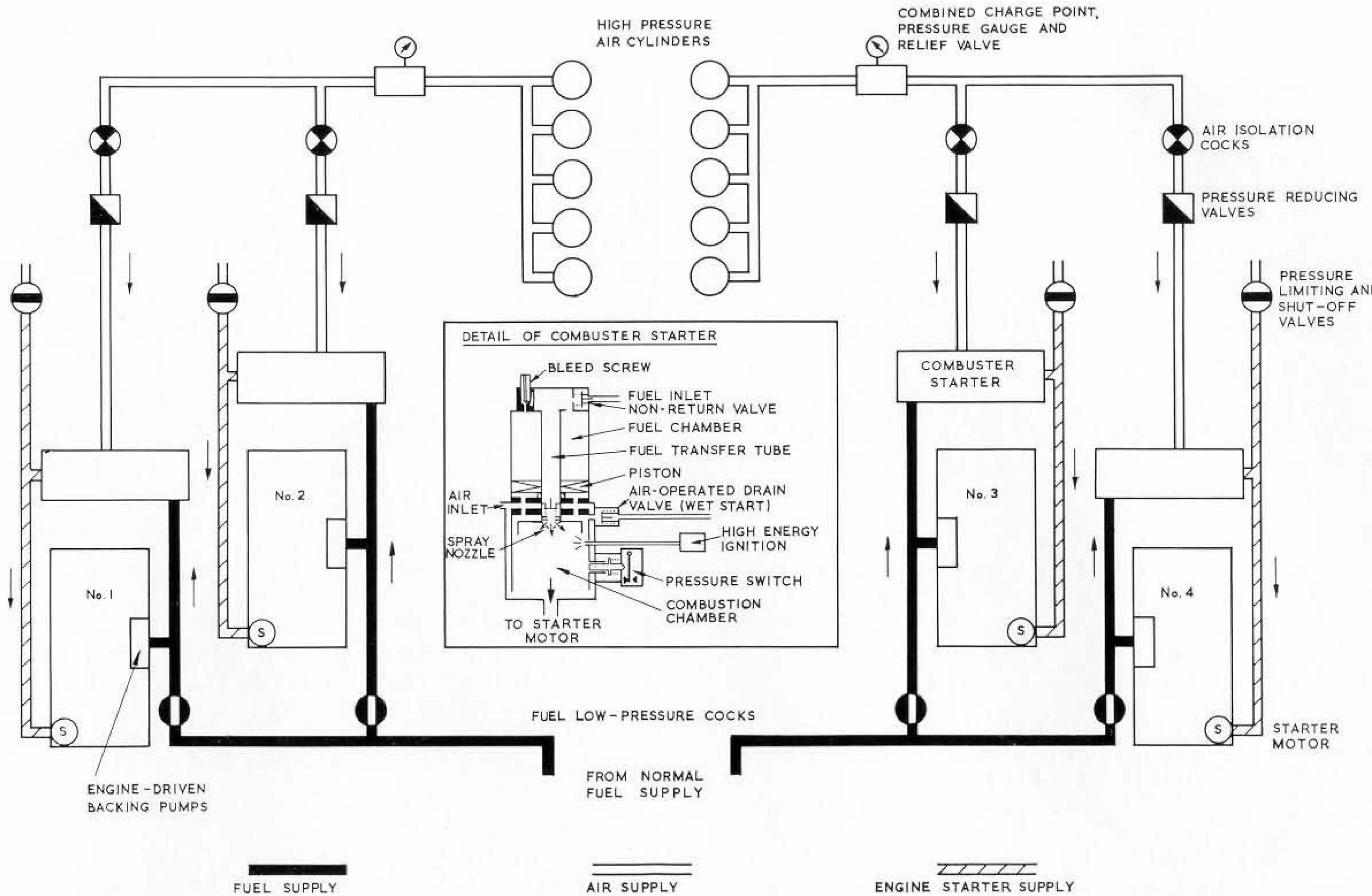

Fig. 2 Rapid start system

14 Engine instruments

(*a*) EGT *gauges*

Four EXHaust gas temperature (EGT) gauges, one for each engine, are on panel A.

Each measures the temperature of the gases in the exhaust unit of its associated engine. The exhaust unit is upstream of the junction of the by-pass flow and the gas stream.

(*b*) HP RPM *indicators*

Four percentage-calibrated RPM indicators are on panel A and each is driven by a tachometer generator on its respective engine.

(*c*) *Oil pressure indicators*

Four oil pressure indicators are on panel A. The required 200 volt 400 c/s single phase AC is from the 200 volt bus-bars and is fed to individual auto-transformers which step the voltage down to 26 volts.

(*d*) CSDU *oil temperature gauge*

A temperature gauge is fitted on AEO's panel BC. An adjacent selector switch enables the oil temperature of any constant speed drive unit to be obtained. Electrical supplies are from feeder 12P7.

15 Fuel LP warning lights

Four warning lights, one for each engine, are on panel A. Each gives an indication of low fuel pressure as it leaves the backing pump of the associated engine and also indicate low fuel pressure at the inlet to the engine backing pump ; two lights on one side illuminating while using wing groups will indicate a proportioner failure on that side. All four lights illuminating while the fuselage group only is in use will indicate a fuselage proportioner failure. The lights are of the press-to-test type, and the electrical supplies are from feeder 3P7 for the port lights and 2P7 for the starboard lights.

Airborne Auxiliary Power Plant (AAPP) Description and Controls

16 AAPP—general

(*a*) The AAPP is a gas-turbine engine, housed in the lower section of the starboard wing root, Air for the operation of the engine is ducted into the unit via a forward-facing retractable intake.

(*b*) The AAPP drives a 200-volt 3-phase 400 c/s 40 KVA alternator, which can supply the electrical system, up to an altitude of 45,000 feet. It also provides low pressure air for starting the engines and for ground running of the Blue Steel vapour cooling pack.

(*c*) A self-contained oil system is provided of 5 pint capacity.

17 AAPP controls and indicators

(*a*) All controls are on the AEO's panel BF.

(*b*) *Intake control*

This is operated by an INTAKE SELECTION OPEN-CLOSED switch with an adjacent magnetic indicator which shows SHUT in white-on-black, OPEN in black-on-white and striped when the intake is in an intermediate position, or electrical supply is lacking.

(*c*) *Electrical load control*

The distribution of electrical power is controlled by a LOAD SELECTION, IDLING-ELECT switch. The IDLING position causes the AAPP to run at idling RPM except when main engine starting is in progress. The ELECT position is used when electrical supplies to the main bus-bars and/or Blue Steel ground cooling are required.

(*d*) AAPP *starting controls*

(i) AAPP starting is controlled by a START SELECTOR, NORMAL-OFF-EMERGENCY switch. Adjacent to the switch are an RPM indicator, a JPT gauge, an oil pressure light, a start in progress warning light and a combined fire extinguisher push-button and warning light.

(ii) When the start selector switch is set to NORMAL the AAPP starter motor is energised, the booster pump in tank 10 starts up, the ignition system operates and the start in progress light comes on. As RPM build up the oil pressure light should go out. When the AAPP reaches 6,000 to 8,000 RPM the starting system is de-energised and the start in progress light goes out. The starter switch should be left at NORMAL.

NOTE: NORMAL starting should not be attempted unless the intake is fully open.

(iii) An EMERGENCY start can be made in the air before the intake is fully open.

(iv) An OFF selection should only be made to stop the AAPP.

Normal Management of the Engine Systems

18 Management of engine anti-icing system

(*a*) If icing is encountered in flight, the engine anti-icing system must be switched on immediately and the aircraft should be climbed or descended out of icing as quickly as possible.

(*b*) Anti-icing may be used for take-off, but the aircraft should be climbed out of icing as quickly as possible.

(*c*) On the ground at air temperatures below + 8°C and in conditions of high humidity such as fog or mist reducing the visibility to less than 1,000 yards, anti-icing must be used on take-off.

(*d*) The affect of engine anti-icing is:

(i) The air flow through the combustion chamber and turbines is reduced, giving decreased thrust for a given EGT.

(ii) The air entering the intake is heated slightly causing a decrease in air density and a further decrease in thrust.

(*e*) To maintain engine thrust during anti-icing operation the engine RPM may be increased, if necessary, to give greater air flow through the engine.

19 Management of the engine fuel filter de-icing system

NOTE: When fuel with an anti-icing additive is used the system is rendered inoperative by removal of the fuses. Before flight using fuel without an anti-icing additive the system is to be ground serviced and used as described in the following paragraphs.

(*a*) If, prior to starting the engines, the settings of the de-ice selector switches and indicators disagree, this should be disregarded until the post start-up checks have been performed. Since the de-icing control valve is servo-operated, it can only function when the engine is running; thus, if the switches are set at OFF, the indicators should change to OFF during start-up.

(*b*) During the after take-off checks select the FUEL FILTER DE-ICING ISOLATION switches for each engine system to AUTO. Check that the associated magnetic indicator shows OFF (valve closed).

(*c*) During flight the four magnetic indicators must be monitored frequently and in any case at intervals of not more than 30 minutes. If an indicator shows ON (valve open) for a period in excess of 3 minutes (i.e. de-ice period plus time switch run-down) it signifies possible malfunction of the system and the appropriate selector switch must be set to OFF. The flight may continue. If the ON indication persists the engine should function normally for up to 10 hours. However, if any signs of engine malfunction occur, the engine should be shut down as soon as possible.

(*d*) If, with the switches set at AUTO, two or three indicators show ON, the switches of the other systems should be set to MAN for 2 minutes and then returned to AUTO. This is because it is unlikely that icing conditions will occur at one filter and not at another; failure of an indicator to show ON in these circumstances indicates possible failure of the automatic side of the system.

(*e*) During descent from a flight where the systems have been used, operate the test facility or set the selector switches of serviceable systems to MAN for a period of 2 minutes and then return them to AUTO. This procedure should be carried out before reaching the check height (where opening of the throttles will demand the higher fuel flow rates) and if possible should be completed not more than 5 minutes before landing.