Part I

Chapter 1—Electrical System

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Description

1 Normal MV supplies

(*a*) The electrical power supply to the aircraft's bus-bars is obtained from four engine-driven alternators, each having a 3-phase 50 KVA output at 200 volts 400 CPS.

A hydraulically-operated constant-speed drive unit is interposed between the engine and the alternator to ensure constant frequency output.

(*b*) Each alternator output is fed via a circuit breaker ("A" breaker) to its own bus-bar, thus providing four independent generating systems. Two synchronising bus-bars are also provided, one to

parallel the outputs of Nos. 1 and 2 alternators and the other to parallel the outputs of Nos. 3 and 4 alternators. These outputs are fed to the synchronising bus-bars via synchronising circuit breakers (" S " breakers).

(*c*) Provision is also made to connect the port and starboard synchronising bus-bars, via a paralleling contactor, should this become necessary.

2 Standby MV supplies

(*a*) The standby supply for the main generating system is provided by an airborne auxiliary power plant (AAPP) which is a Blackburn " Artouste " gas turbine driving a 3-phase 40 KVA, 200 volt 400 C/S alternator. The frequency in this case is kept constant by governing the speed of the gas turbine, to which the alternator is directly coupled by step down gearing.

(*b*) The output from the AAPP alternator is connected to the starboard synchronising bus-bar via a relay which can only be closed if the starboard synchronising bus-bar is dead. The supply can also be fed to the port synchronising bus-bar if the paralleling contactor is closed. The supply to the four bus-bars is then completed via the " S " breakers, if the main alternators have failed.

(*c*) The AAPP can also be used to provide electrical power for ground servicing, air pressure for starting the engines and air supplies for the jet pump.

3 Additional standby MV supplies (PFCU)

(*a*) To provide emergency MV supplies for the PFCU's two, ram air turbine (RAT) 15 KVA alternators are fitted in the rear fuselage. The port RAT supplies the No. 1 power control sub-units and the starboard RAT supplies the No. 2 PFCU's. Additionally the port RAT also supplies the No. 1 TRU and the No. 2 3-phase 115 volt 400 C/S transformer.

(*b*) The scoops for the RAT's are situated on top of the rear fuselage In flight they are normally held closed by hydraulic jacks, but should the speed of both engines on one side fall below 52% RPM the appropriate scoop opens and the turbine runs up to operating speed. As the speed of the engines falls still further the main alternator drive underspeed switches operate and the flying control power unit motors are transferred from the main bus-bars to the outputs of the RAT alternators. The scoops are normally open on the ground when the engines are not running or are operating at lower RPM than 52%.

(*c*) Provision is also made for manual switching at both the pilot's station and AEO's station.

4 Normal LV supplies

(*a*) To provide the 28 volt DC supplies necessary for control switching and actuators etc. two transformer/rectifier units (TRU's) are provided. The TRU input is normally derived from No. 1 and No. 4 200 volt bus-bars but provision is made for supplying No. 1 TRU from the port RAT.

(*b*) The output from the TRU's feed No. 1 and No. 2 LV bus-bars respectively and additionally the special feeder circuits.

(*c*) Provision is made for paralleling Nos. 1 and 2 LV bus-bars via a contactor.

5 Standby LV supplies

(*a*) Each LV bus-bar has a 24 volt 25 amp. hr. battery connected to it which will back up the output of the associated TRU.

(*b*) When the alternators are operating and the batteries and TRU's are connected to their bus-bars, as stated in para. 4(*b*), the special feeder circuits are fed from the TRU's but if the batteries are disconnected from the bus-bars for any reason, the special feeder circuits are fed by the batteries.

6 MV and LV ground supplies

(*a*) Three ground supply plugs are provided for 200 MV, 28 LV and 115v supplies (fuel gauges only).

(*b*) The MV supply is connected, via a circuit breaker to the port synchronising bus-bar and to the starboard synchronising bus-bar by the automatic closing of the paralleling contactor. The circuit breaker and the contactor will only close if the respective bus-bars are dead. From the synchronising bus-bars the supply to the main bus-bars is completed via the respective " S " breakers.

(*c*) The LV supply is connected via a contactor to No. 1 LV bus-bar and by the automatic closing of the paralleling contactor to No. 2 LV bus-bar. Post-Mod. 3636 the RPU heater switch on panel BF must be at NORMAL. To connect the ground supply to the special feeder circuits Nos. 1 and 2 batteries must be switched on.

(*d*) The 115v external supply is used during fuelling operations and, when connected, transfers the fuel gauge amplifiers from the aircraft main MV bus bars to the 115v external supply, provided that a 28v ground supply is in use. Thus no 200v MV supply is required during refuelling operations.

7 115 volt AC supplies

(*a*) 115 *volt* 3-*phase* 400 C/S *supplies*

Four transformers supplied from the main bus-bars and referred to as Nos. 1, 2, 3 and 4, 115 volt 400 C/S supplies, are provided. Nos. 1 and 2 transformers are normally supplied from No. 1 bus-bar and Nos. 3 and 4 transformers from Nos. 3 and 4 bus-bars respectively. Additionally No. 2 transformer can be supplied from the port ram air turbine.

(*b*) 115 *volt single-phase* 1600 C/S *supplies*

Two frequency changers are provided and referred to as 115 volt 1600 C/S supply No. 1 and supply No. 2. No. 1 supply is obtained from No. 1 bus-bar and No. 2 supply from No. 3 bus-bar.

(*c*) The 115 volt supplies are used as follows:

Supply	*From bus-bar*	*Equipment supplied*
115 volt, 400 c/s 3 phase		
No. 1 Transformer . .	1	Green Satin only
No. 2 Transformer . .	1, or Port RAT	1st Pilot's MFS, standby yaw damper, Mk. 22 altimeter. Additionally, via a change-over relay, the circuits normally supplied by No. 3 Transformer
No. 3 Transformer . .	3	NBS, IBS, RPU, standby horizon, TAS unit. Standby for 1st Pilot's MFS (post-Mod. 3334)
No. 4 Transformer . .	4	2nd Pilot's MFS, auto-pilot ▶◀
115 volt, 1600 c/s 1 phase		
No. 1 Frequency changer .	1	Either supplies NBS, RPU and radio altimeter Mk. 6
No. 2 Frequency changer .	3	

Controls and Indicators

8 Main generating system control panel

(*a*) The main generating system control panel is panel BF at the AEO's station. The panel is laid out to represent a simple line diagram of the system, with indicators in positions occupied by circuit breakers or contactors in the system. These magnetic indicators are designed to provide line indications of circuits being made or broken.

(*b*) The panel illumination is by submerged lights, the routing lines and annotations thus being trans-illuminated for night flying.

9 Alternator controls and indicators

(*a*) Each alternator has a four-position ON—OFF—RESET—ISOLATE switch, a POWER FAILURE warning light, a COOLING FAILURE warning light and a KW/KVAR meter.

(*b*) An alternator commences generating as soon as the engine is running; however with the control switch at OFF the power is not connected to its bus-bar. When ON is selected, provided the constant speed drive unit oil pressure is sufficient, the " S " breaker opens and the "A" breaker closes ; its indicator shows in line and the power failure light goes out.

(*c*) The RESET position is used to reset the exciter relay of the alternator.

(*d*) The ISOLATE position is used to disconnect an alternator from the synchronising bus-bar, whilst leaving it connected to its own bus-bar.

(*e*) A switch, labelled KW-KVAR is between each pair of KW-KVAR meters to enable the desired selection to be made.

(*f*) The cooling failure warning lights come on if the cock controlling the blast air from the engine compressors closes for any reason.

NOTE: This air supply is for engine bay cooling only.

10 Alternator synchronising controls and indicators

(*a*) Between each pair of A breaker indicators is a No. 1 (No. 3)—BUSBAR—No. 2 (No. 4) three position switch, below which is a SYNCHRONISING PUSH AND LIGHT. On either side of the panel is an AC voltmeter and a frequency meter.

(*b*) Setting the selector switch to No. 1 (or No. 3) or No. 2 (or No. 4) enables the volt and frequency meters to show the existing conditions of the alternator.

(*c*) Pressing the synchronising push causes the output of the relevant alternator to come on to the synchronising bus-bar via the " S " breaker, the indicator for which will show in-line. The selector switch, when selected to other alternator then causes the light in the synchronising push to blink, if the frequency of the second alternator is not in phase with that of the first alternator. When the light is out, pressing the synchronising push brings the second alternator on to the synchronising bus-bar via its " S " breaker. The second " S " breaker indicator will now show in line. It is not possible to bring any alternator on to its sync. bar if the paralleling circuit breaker is closed.

(*d*) Once two alternators are running in parallel, should either one fail or be selected OFF, both " S " breakers will remain closed and the remaining alternator will supply both bus-bars.

11 MV bus-bar paralleling control and indicators

(*a*) If it is necessary to parallel the two synchronising bus-bars, the outputs must first be compared on the two sets of meters. The phase relationship of the two outputs is shown by the BUS-BAR PARALLELING SYNCHRONISING LIGHT, which when pressed, will show an intermittent light whenever the phases are not in harmony. When the light is out, setting the MV PARALLELING, NORMAL—PARALLEL switch to PARALLEL causes the paralleling circuit breaker to close and the magnetic indicator above the switch to show in line. A guard over the switch prevents inadvertent operation.

(*b*) The synchronising bus-bars are automatically paralleled when a ground supply is plugged in.

12 Ram air turbine controls and indicators

(*a*) Control of the RAT's is normally fully automatic (see para. 3(*b*)).

(*b*) Manual control of the RAT scoops can be effected by the pilots and by the AEO. A double-pole NORMAL—START switch on panel AL controls the opening of both scoops. If the switch is set

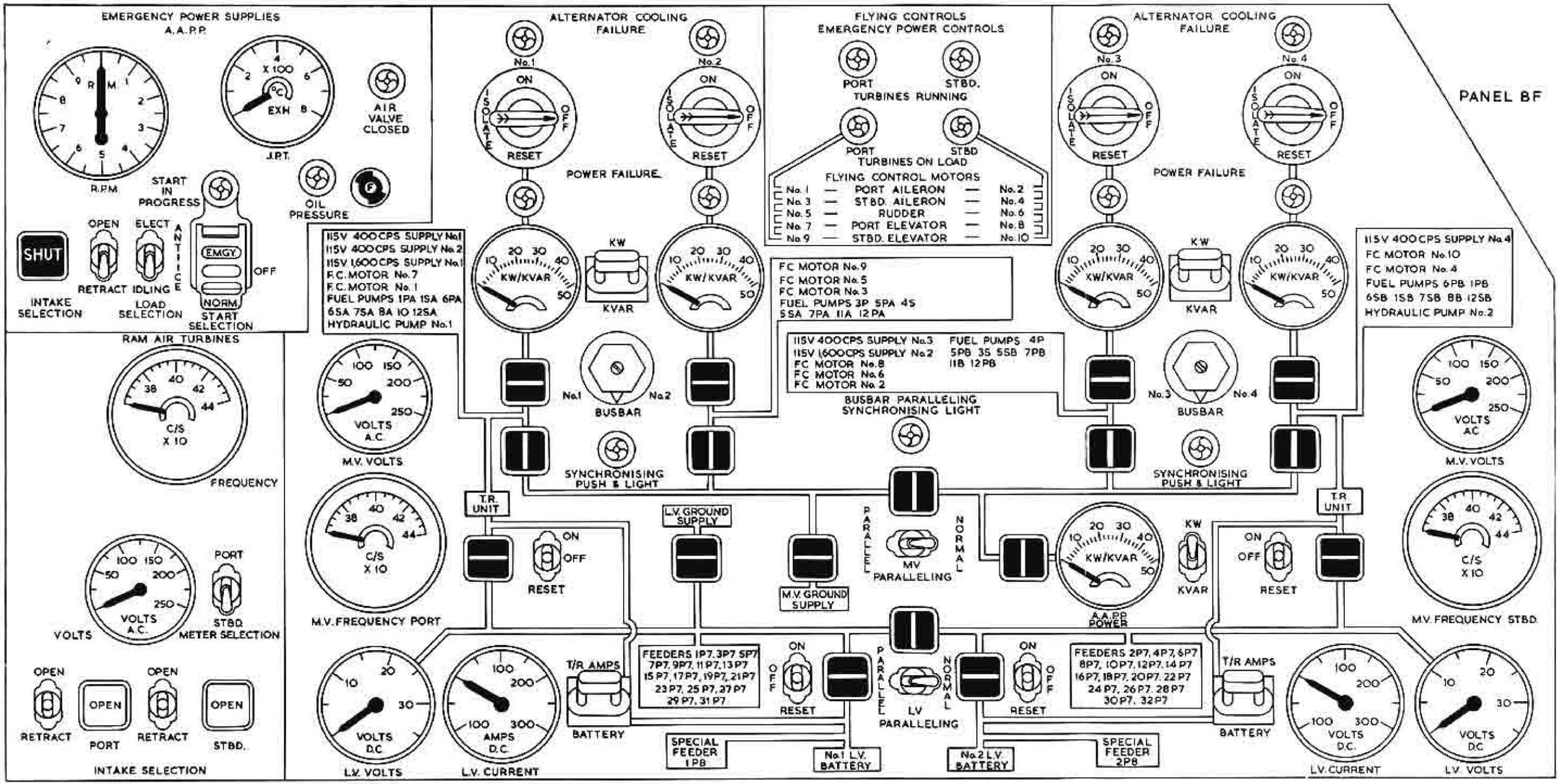

Fig. 1 Generating system, controls and indicators (Pre-Mod. 3904)

◀ NOTE: Mod. 3904 revised electrical supplies to the booster-pumps and therefore the relevant labelling on Panel BF. (See Chap. 2 para. 10(*h*)) ▶

to START, both scoops open and remain open until control is returned to the AEO by setting the switch to NORMAL and a retract selection made by the AEO.

(*c*) At the bottom left-hand corner of the AEO's panel BF are two OPEN-Off—RETRACT switches and two OPEN—striped—SHUT magnetic indicators. Provided that the pilots' switch is at NORMAL the AEO has full control of the scoops. The magnetic indicators show striped when the scoops are in an intermediate position.

(*d*) Above the AEO's control switches are a frequency meter and a voltmeter; also a PORT-STBD., METER SELECTION switch by which the output of the appropriate RAT alternator can be checked.

(*e*) At the top of panel BF is a sub-panel labelled FLYING CONTROLS, EMERGENCY POWER CONTROLS. Four lights are provided, two TURBINES RUNNING lights and two TURBINES ON LOAD lights. The first pair come on when the alternator outputs have built up following opening of the scoops. The second pair come on either together or individually, only when one or more flying controls sub-unit motors are connected to the RAT bus-bars and the scoops are fully open.

13 RAT test switches and warning lights

(*a*) Four test push switches, each with an integral warning light are at the top left-hand corner of the navigator's panel CA and labelled RAM AIR TURBINES TEST, PO, PI. SI, SO. The contacts of the pushes are connected to the respective engine signalling units and when the push is operated it simulates flame-out conditions, thereby causing the light to come on.

(*b*) The appropriate light will also come on in flight if the engine flames out or electrical supply to the signalling unit fails.

(*c*) Should both pushes on one side be operated simultaneously the scoop controlled by those signalling units will open.

14 AAPP alternator supply to MV bus-bars controls

(*a*) The AAPP alternator can only be effective if the frequency output is 400 ± 20 c/s. The alternator can be used to supply the main bus-bars in flight and on the ground.

(*b*) The LOAD SELECTION switch on panel BF must be set to ELECT to connect the AAPP alternator output to the starboard synchronising bus-bar via the AAPP relay, the magnetic indicator of which will show in line only if the bus-bar is dead.

(*c*) Adjacent to the magnetic indicator is a KW/KVAR meter which registers at all times when loads are being supplied. A KW/KVAR selection switch is alongside the meter.

15 LV bus-bars controls and indicators

(*a*) The two LV bus-bars are supplied by the two TRU's. When either ON—OFF—RESET switch is set to ON a relay is closed and a magnetic indicator adjacent to the switch shows in-line.

(*b*) The RESET position is for use should the reverse current cause the relay to trip. This position should not be used in flight.

(*c*) A voltmeter is provided for each LV bus-bar and gives a constant indication.

(*d*) An ammeter is also provided to indicate the TRU output current or battery current. An adjacent selector switch, T/R AMPS—BATTERY enables either to be read.

16 LV bus-bars paralleling control and indicator

(*a*) A single pole, LV PARALLELING, NORMAL-PARALLEL switch is provided to enable the LV bus-bars to be paralleled. A magnetic indicator above the switch shows in-line when this has occurred. A guard over the switch prevents inadvertent operation.

(*b*) The LV bus-bars are automatically paralleled when an LV ground supply is plugged in or the AAPP start selector switch is selected to START and will remain so until the AAPP is running above 6,000 RPM.

17 Special feeders controls and indicators

(*a*) Two special feeder switches, NORMAL 1P8—OFF—1P8 EMERGENCY and NORMAL 2P8—OFF—2P8 EMERGENCY are on the forward face of the AEO's table. Two indicators on panel BB give ON—OFF indications.

(*b*) A direct supply is taken from No. 1 LV battery to the NORMAL 1P8 switch setting and to the 2P8 EMERGENCY switch setting. Similarly a direct supply is taken from No. 2 LV battery to the 1P8 EMERGENCY and NORMAL 2P8 settings of the switches.

18 LV battery controls and indicators

(*a*) The batteries are connected to the LV bus-bars by two ON—OFF—RESET switches on either side of the LV paralleling switch. The RESET position is for use should the reverse current coil disconnect a battery from its bus-bar and must *not* be used in flight. The special feeder switches must be on before these switches are operative.

(*b*) Adjacent to each switch is a magnetic indicator which shows in-line when a battery is connected to its bus-bar.

19 Internal lighting

(*a*) The internal lighting arrangements comprise four high intensity amber thunderstorm lights and six cabin lamps for general illumination. A system of combined pillar and bridge, panel, strip and floodlights are used for illumination of instruments and switches. In general, lamps are fitted to give duplicated illumination for each component.

(*b*) The following switches control the lights as follows:

Lights	*Control*
High intensity cockpit	Two switches on panel AZ
Cabin lights	Master switch on panel BB
Console AE red floods Oxygen regulator panel Plasteck & pillar lights on AC & AAF	Dimmer on console AE
Visual B/A control unit red floods Oxygen regulator panel Pillar lights on AR	Dimmer on visual B/A switch panel
Console AF red floods Oxygen regulator panel Lights on AD and AAJ	Dimmer on console AF
Pilots' coaming panels striplights Lights on panel AW & AZ	Dimmer on panel AB
P12 compass light Lights on AL	Dimmer on panel AL
Chartboard lamp at AEO's position	Type R dimmer on panel BB
Chartboard lamp at Nav./Plotter's position	Type R dimmer on panel CAG
Chartboard lamp at Nav./Radar position	Type R dimmer on oxygen reg. panel
Striplights on panel CAG	Dimmer on panel CAG
Panel BB amber floods	Dimmer on panel BB
Panel BF lights	Dimmer on panel BCA
Panel AT lights	Dimmer on panel AT

(*c*) *Emergency lamps*
Two lamps are installed in the cabin roof and are automatically switched on, if a crash landing occurs, by the action of an inertia switch integral with each lamp. The power supply is from two independent dry batteries. The lamps may be tested by means of a TEST switch embodied in each. Each lamp also has a RESET switch by means of which the inertia switch can be reset.

20 External lighting

(*a*) *External lights master switch.* This switch, on panel AC, controls the supply to the individual lamp switches for the port and starboard landing lamps, flashing beacon and navigation lights. The extension and retraction of the landing lamps is by a separate supply controlled from the IN-TAXY-LAND switch on panel AC.
(*b*) Navigation lights ON-OFF switch is mounted on panel AC.
(*c*) Flashing beacon STEADY-OFF-FLASHING switch is mounted on panel AC. The switch is marked ON/OFF when the Grimes light is fitted (Mod. 4042).
(*d*) Landing lights ON—OFF switches on panel AC, control their respective port or starboard lamp filaments. In addition, there are two master circuit breakers on panel BA.
(*e*) Thirty-one lamps and nine two-pin sockets are provided for servicing use. The DC supply to the lamps and sockets is from an external socket type G fitted on board FE, together with a SERVICE LIGHTS MASTER, ON/OFF switch and a 20 amp fuse. With the master switch ON the supply is directed to a switch incorporated in each lamp.

Normal Management of the System

21 Before starting main engines

(*a*) *Special feeder and* LV *battery checks*
(i) On entering the aircraft and before connecting any external supplies, check that both LV batteries are switched OFF, AAPP start switch OFF and the required LV circuit breakers are made. Select No. 1 P.8 and No. 2P.8 special feeder switches to EMERGENCY and NORMAL in turn, checking that the indicators show ON. Leave both switches selected to NORMAL. Switch ON both LV batteries, check that the indicators show vertical, and after switching both LV ammeter switches to BATTERY, check that the battery voltages are not below 24 volts and that both LV ammeters are reading. Press the STOP buttons of both No. 1 and No. 2 frequency changers before connecting any MV supply.
(ii) If the charge state of the batteries is in doubt they may be checked when an MV supply is available and the TRU's switched ON. Switch the ammeter switch to BATTERY and check that the battery is charging at not more than 20 amps. This rate should fall to 10 amps within 1 minute, and to a maximum of 3 amps before taxying. If the charging rate is excessive it indicates that the batteries have been discharged and should be changed.

(*b*) *Use of external* MV *supply for functional checks*
(i) On completion of the above checks ensure that the MV paralleling switch is NORMAL. An external 200 volt 3-phase 400 cycles external supply may then be connected to provide power for functional checks of equipment.
(ii) Check that the MV GROUND SUPPLY indicator shows vertical, that the MV PARALLELING indicator shows horizontal (automatic parelleling) and that the MV bus-bar voltage and frequency indications are normal. Select both LV ammeter switches to T/R AMPS and switch ON No. 1 TRU, checking that its indicator shows vertical. Check that the port LV voltmeter and ammeter readings are normal, then select the LV PARALLELING switch to PARALLEL and check that the starboard voltmeter and ammeter readings are normal.
(iii) Return the LV PARALLELING switch to NORMAL, switch on No. 2 TRU and again check that the starboard voltmeter and ammeter readings are normal. The frequency changers may then be started if required and functional checks of equipment carried out in accordance with the aircraft check list.
(iv) On completion of the functional checks, and before starting the engines, press the STOP buttons of the frequency changers. Switch all alternator control switches to RESET and then OFF, and switch all KW/KVAR switches to KW. The engines may then be started as required.

(c) *Use of* AAPP *power for functional checks*

(i) On completion of the checks at (a) the AAPP may be started to supply electrical power for functional checks of equipment.

(ii) Check that the MV PARALLELING switch is at NORMAL and its indicator vertical.

(iii) When cleared with the crew chief start the AAPP (see para. 24(a)) using either the aircraft LV batteries or an external 28 volt supply. When the AAPP is running normally set the AAPP LOAD SELECTION switch to ELECT. The RPM should increase to 33,200—35,200 RPM and the indicator beside the AAPP POWER gauge should show horizontal.

(iv) Check that the port MV synchronising bus-bar volts and frequency read zero. Then select the MV PARALLELING switch to PARALLEL, check that its indicator shows horizontal and that the port MV voltage and frequency indicators read AAPP volts and frequency. If an external 28 volts supply has been used, this should now be removed.

(v) Check that the LV GROUND SUPPLY indicator shows horizontal and that the LV PARALLELING indicator shows vertical. Switch both LV ammeter switches to T/R AMPS and switch ON No. 1 TRU. Check that the port LV voltmeter and ammeter readings are normal, switch the LV PARALLELING switch to PARALLEL and check that the starboard LV voltmeter and ammeter readings are normal. Return the LV PARALLELING switch to NORMAL, switch ON No. 2 TRU and again check that the starboard LV voltmeter and ammeter readings are normal.

(vi) The frequency changers may then be started if required and the functional checks of equipment carried out in accordance with the Flight Reference Cards.

(vii) On completion of the functional checks and before starting the engines, press the STOP buttons of the frequency changers. Switch all alternator switches to RESET and then OFF, and switch all KW/KVAR switches to KW. The engines may then be started as required.

22 Alternator control

NOTE: During engine starting with the appropriate synchronising selector meter switch set to the required alternator position, definite indications of alternator power output should be noticeable by the time the JPT is indicated. If no alternator output is indicated before the engine starter push-button springs out, the engine must be closed down immediately to avoid damage to the alternator drive mechanism. The engine may be restarted after a delay of two minutes but, should the alternator still fail to indicate power output, the engine must again be closed down and the CSDU oil system checked.

(a) *Bringing an alternator on to line*

When an engine is running with the alternator control switch set to OFF, the ALTERNATOR COOLING FAILURE warning light should be out, but the POWER FAILURE warning light should stay on until the alternator is brought on to line. Set the appropriate synchronising selector meter switch to the required alternator position and check on the MV VOLTS and MV FREQUENCY meters that the alternator output is normal (200 ± 5 volts and 400 ± 4 CPS). Select the alternator control switch to ON, check that the POWER FAILURE warning light goes out, that the appropriate "A" breaker indicator shows vertical (closed) and the appropriate "S" breaker indicator shows horizontal (open). The alternator's individual bus-bar will now be live and may be loaded as required.

(b) *Synchronising of alternators*

NOTE: The following procedure for synchronising the two port alternators is similar to the procedure for synchronising the two starboard alternators.

(i) Before connecting an engine-driven alternator to a synchronising bus-bar, any other supply from either the AAPP alternator or the MV ground supply must be disconnected, and the MV PARALLELING switch must be selected to NORMAL.

(ii) Select the port synchronising selector and meter switch to the No. 1 position; the output of No. 1 alternator will now be indicated on the port MV VOLTS and MV FREQUENCY meters. If output is normal, press the port SYNCHRONISING

PUSH and LIGHT to close No. 1 " S " breaker and connect the alternator to the port synchronising bus-bar. Check that the pushbutton does not stay in when released. Select the synchronising selector meter switch to the No. 2 position and check that the voltage and frequency outputs of No. 2 alternator are similar to those of No. 1 alternator.

(iii) The synchronising light will now be connected between the two alternators and will provide an indication of their phase relationship by flashing on and off slowly. The period during which the alternator outputs are in phase will be indicated by the light being off, and it is during this period that the SYNCHRONISING PUSH and LIGHT should be pressed to synchronise the alternators. Pressing the light when it is on may result in one or both alternators coming off line, damage to the alternator drive mechanism or the rupturing of the 100 amp synchronising bus-bar protection fuses which are inaccessible from the cabin. Should the light remain on or off continuously, vary engine RPM or switch on a load to disturb the synchronism of the alternators. If the light flashes more than twice per second no attempt must be made to synchronise the alternators until the flashing rate decreases.

(iv) When the alternators are synchronised the synchronising selector and meter switch should be selected to BUS-BAR so that the voltage and frequency available at the synchronising bus-bar may be read from the gauges. Check that the KW/KVAR meters indicate that two alternators are on load ; under low load conditions variation in load sharing may be expected.

(v) If, after synchronising the alternators, any one of them should fail or be manually switched OFF, both " S " breakers will remain closed and the other alternator will supply the loads on both bus-bars.

(vi) To isolate an alternator and its individual bus-bar from the synchronising bus-bar, select the alternator control, switch to ISOLATE (for not more than 5 seconds) check that the " S " breaker opens and then select ON.

(*c*) MV *bus-bar paralleling procedure*

Provision is made for connecting the port and starboard synchronising bus-bars in parallel whilst the alternators are connected to them. Check that the voltages and frequencies of both synchronising bus-bars are normal. Press the BUS-BAR PARALLELING SYNCHRONISING LIGHT. The light will now be connected between the two synchronising bus-bars and will provide an indication of the phase relationship by flashing on and off. The outputs on both sides will be in phase when the light is out, and it is at this time that the MV PARALLELING switch should be selected to PARALLEL. If it is subsequently desired to separate the bus-bars, select the MV PARALLELING switch to NORMAL.

WARNING. Selection of the MV PARALLELING switch to PARALLEL when the BUS-BAR PARALLELING SYNCHRONISING LIGHT is illuminated may cause rupturing of the 100 amp bus-bar paralleling protection fuses which are not accessible from the cabin.

(*d*) *Normal synchronising and paralleling procedure*

Under normal conditions Nos. 1 and 2 alternators and Nos. 3 and 4 alternators should be synchronised as separate pairs. MV bus-bar paralleling should not normally be carried out when engine-driven alternators are connected to the synchronising bus-bars because of the risk of transferring a fault from one pair of alternators to the other pair.

23 Secondary supplies control

(*a*) 115 *volt* 3-*phase* 400 CPS *transformers*

The number 2, 3 and 4 transformers providing 115 volt 3-phase 400 CPS supplies operate automatically when the MV bus-bars are live. The No. 1 transformer is controlled by the Green Satin ON/OFF switch. The only indication of transformer serviceability is the normal operation of the associated equipment, which may be switched on as required.

(*b*) 115 *volt single-phase* 1600 CPS *frequency changers*

To prevent possible rupture of the frequency changer supply fuses, press the Nos. 1 and 2 frequency changer STOP buttons before any MV supply is connected to the main bus-bars. The NBS equipment must also be switched off. When MV supply is connected, select No. 1 position on the LOAD TRANSFER switch before pressing the NO. 2 START button, then move the LOAD TRANSFER switch to the No. 2 position and press the No. 1 START button. Check that the appropriate neon lights illuminate. Both frequency changers should normally be kept running during flight but, because the LOAD TRANSFER switch also controls the distribution of some loads between No. 2 and No. 3 transformers, the No. 2 position should normally be selected to assist even distribution of the transformer loads. If, for any reason, it is necessary to transfer the loads between frequency changers, provided that the other frequency changer is running with its neon light on, the LOAD TRANSFER switch may be operated without switching off the loads. However, should the MV input supply to the frequency changers be interrupted or removed for any reason, no matter how short the period of interruption, the frequency changer STOP buttons must be pressed before replacing the MV supply. If the frequency changers are used when the bus-bars are supplied by the AAPP or the MV ground supply, they must be switched OFF before the alternators are switched ON. Failure to take this precaution may result in rupture of the frequency changer input fuses.

NOTE: If at any time during flight the frequency changer LOAD–TRANSFER switch is moved to the No. 1 position, the captain should be informed that the 1st pilot's MFS and the standby artificial horizon will both be supplied from No. 2 transformer and both will be affected by any interruption in power supply.

24 Control and use of the AAPP

(*a*) *Ground starting of the* AAPP

(i) Electrical power for ground starting of the AAPP may be obtained from the aircraft LV batteries, or an external 200v supply providing 28-volts through an aircraft TRU, or an external 28-volt supply.

(ii) Before starting the AAPP on the ground check with the crew chief that the external area is clear, check that the scoop opens and retracts when the appropriate selections are made, and that the OPEN and SHUT indications are correct.

(iii) Test the AAPP fire detection, start in progress and oil pressure indications.

(iv) Select the INTAKE SELECTION switch to OPEN, the LOAD SELECTION switch to IDLE and the START SELECTION switch to NORMAL. The START IN PROGRESS light should illuminate and the LV bus-bar automatically parallel until 6,000 to 8,000 RPM. Check JPT not above 700°C, OIL PRESSURE light out and fire warning light out. The RPM should build up and idle at 23,000-25,000 RPM.

(v) When the AAPP is idling correctly, if electrical loading is required select ELECT, note that RPM increase to 33,200-35,200 RPM and the JPT falls below 500°C. Provided that no other supply is connected to the starboard synchronising bus-bar, the AAPP alternator output will be connected automatically to it and voltage and frequency output may be checked. Before paralleling the MV bus-bars ensure that no supply is connected to the port synchronising bus-bar.

(*b*) *In-flight starting of the* AAPP

(i) In-flight starting of the AAPP is certain up to 10,000 feet and ability to start at considerably greater altitude is also highly probable. The scoop must not be opened or closed at airspeeds in excess of 250 knots, but when the scoop is fully open speed may be increased to a maximum of 330 knots.

(ii) Before starting, test the fire warning detection system and check that the LOAD SELECTION switch is selected to ELECT. (On no account must IDLING be selected in flight as this will cause failure to light or flame extinction). Simultaneously select OPEN on the INTAKE SELECTION switch and EMERGENCY on the START SELECTION switch.

WARNING. *It is essential to check that the INTAKE SELECTION indicator changes from SHUT to striped indication within 5 seconds and that it indicates scoop fully OPEN within 45 seconds of selection. Should it fail to do so, the start selection must be cancelled immediately.*

(iii) Check that the START IN PROGRESS light illuminates, that the fire warning light does not illuminate and that the LV bus-bar is automatically paralleled. The engine windmilling speed will increase rapidly to above 20,000 RPM; light is indicated by a rise in JPT. The maximum JPT during starting is 700°C.

(iv) The START SELECTION switch must be left at EMERGENCY after starting and whilst the engine is running; ignition and oxygen enrichment will be switched off automatically at 30,000 RPM. In all cases if the AAPP fails to light-up before reaching 25,000 RPM or within 1 minute of selection, switch the START SELECTION switch to OFF, retract the scoop, and make a further attempt at a lower altitude if possible.

(v) If the AAPP starts normally, check that the amber START IN PROGRESS light goes out and LV bus-bars deparallel at 6,000 to 8,000 RPM and that the green OIL PRESSURE indicator light goes out by 23,000 RPM. RPM should increase steadily to the normal operating speed of 33,200-35,200 RPM, varying slightly with changes in aircraft speed and altitude. Provided that no other supply is connected to the starboard MV synchronising bus-bar, the AAPP alternator will automatically be connected to it and the voltage and frequency outputs may be checked.

(*c*) *Stopping the* AAPP

Before stopping the AAPP check that alternative electrical supplies are available if required. Select the START SELECTION switch to OFF. Before retracting the scoop ensure that speed is below 250 knots.

25 Ram air turbine scoop and alternator control

(*a*) Whilst no facility exists for checking the operation and output of the ram air turbine alternators on the ground, the system indications and operation of the scoop controls should be checked as follows before flight.

(*b*) (i) The green TURBINE ON LOAD lights should be illuminated when the special feeders are switched on and one or more of the appropriate PFCU's is switched off and the scoop is fully open.

(ii) The amber RAM AIR TURBINE TEST lights above the navigator's position should be illuminated when the appropriate engines are stopped or operating below 52% RPM. Check that the INTAKE SELECTION indicators show OPEN when any pair of lights is on.

(iii) After the engines are started, have each engine accelerated and check that the RAM AIR TURBINE TEST lights extinguish when the appropriate engine exceeds 52% RPM. Have the crew chief confirm all scoop movements. Select the INTAKE SELECTION switches to RETRACT and check that the indicators show SHUT 2-3 seconds after selection. Select START on the RAM AIR TURBINE SELECTOR SWITCH (at the pilot's panel AL), check that the indicators indicate OPEN 1-1½ seconds after selection, then return the switch to NORMAL.

(iv) Again select AEO's INTAKE SELECTION switches to RETRACT. Throttle back the engines, check that the RAM AIR TURBINE TEST lights illuminate as each engine reduces below 52% RPM, and that the intakes open and indicate OPEN as the second of each pair of lights illuminates. Throughout the checks note that the green TURBINE ON LOAD lights extinguish whenever the appropriate turbine intake moves from the fully open position.

(*c*) The RAT scoops should be selected to OPEN whenever the aircraft is on the ground and during take-off to prevent inadvertent opening caused by relay bounce interrupting the hold-in signal. By running the RAT during take-off, any moisture which may have

collected will be shed from the blades. The RAT scoops should be selected to RETRACT during the after take-off checks.

(*d*) During flight the scoops may be selected OPEN at the captain's discretion in order to carry out RAT alternator voltage and frequency checks at altitude. At 220 knots these should be approximately 185 volts and 370 CPS and will vary with changes in height and airspeed. During flight in inclement weather conditions, such as sandstorms or hailstorms, the scoop intake should be selected to RETRACT and, if necessary, held in during landing.

(*e*) When a RAT is in use, dutch rolling and side-slipping should be avoided, otherwise the changing air flow entering the turbine intake may cause variations of turbine speed with consequent fluctuations of alternator output.

26 Normal in-flight operation

(*a*) In order to cater for possible failure of electrical supplies to the pilots' instruments during a critical stage of flight shortly after take-off, and to make best use of the alternative supplies it is recommended that prior to take-off the AAPP is started and selected to ELECT, the engine-driven alternators are isolated from the synchronising bus-bars, and the AAPP alternator is connected to both synchronising bus-bars by paralleling. This will provide immediate and automatic take-over by the alternative supply in the case of total loss of MV supplies to either side (e.g. two-engine flame-out). On completion of the after take-off checks, the AAPP should be closed down, the synchronising bus-bars de-paralleled and the engine-driven alternators synchronised.

(*b*) During flight the voltages and frequencies of the MV bus-bars, the load sharing of the synchronised alternators, the voltages of the LV bus-bars, and all indicators and warning lights should be monitored frequently. If any malfunctions of the system occur, appropriate action should be taken as described in the subsequent paragraphs.

(*c*) The AAPP should be started prior to landing. At the captain's discretion the engine-driven alternators may be isolated from the synchronising bus-bars, and the synchronising bus-bars paralleled. The AAPP may be kept running whilst taxying to provide an air supply for the jet pump until the Blue Steel is closed down and when closing down the main engines. The AAPP alternator must, however, be disconnected from the synchronising bus-bar if an external power supply is to be connected.

(*d*) Prior to closing down the engines, close down Blue Steel, switch off all heavy MV loads except fuel pumps. Having closed down the engines, switch off the alternators and booster pumps. Switch off the LV batteries and when the engines have stopped turning and the engine LP cocks are closed, switch off the special feeders.

Malfunctioning of the System

27 Alternator load sharing malfunction

In flight if the load sharing between two synchronised alternators differs by more than 8 KW/KVAR, with each alternator supplying load, the alternators should be isolated and the individual voltages and frequencies checked. Switch OFF the appropriate frequency changer, after transposing if necessary. If one alternator is found to be operating outside its limits, the other alternator should be reconnected to the synchronising bus-bar before the faulty alternator is switched OFF. If both alternators are found to be operating within their limits they may be resynchronised provided that neither alternator is overloaded ; restart the frequency changer. Under low-load conditions when the total load on two alternators is less than 10 KW the load sharing control circuits may not operate at their maximum efficiency and variation in load sharing may be expected.

28 Single alternator failures

(*a*) *Electrical faults*

If an alternator fails because of an electrical fault, this will be indicated by illumination of the appropriate POWER FAILURE warning light and opening of its "A" breaker. Select the appropriate RAT intake OPEN. Switch the alternator to RESET and then OFF. Stop any frequency changer supplied by the alternator. Check the voltage and frequency outputs. If the voltage and frequency are not within the normal limits, leave the control switch

at OFF. Check the loading of the serviceable alternator and reduce loads if necessary. The RAT should be selected in again when the failure has been investigated.

NOTE: The alternator control switch must *not* remain at RESET for more than five seconds.

(b) Alternator drive failure

If the drive mechanism of an alternator fails, the POWER FAILURE warning light does not come on if the alternator is synchronised but failure will be indicated by complete out-of-balance of KW load sharing ▶◀ and possible deviation of bus-bar frequency from 400 CPS. Select the appropriate RAT intake OPEN and STOP any frequency changer supplied by the alternator. If a POWER FAILURE warning light illuminates, switch the alternator OFF, check its voltage and frequency, and check the loading of the serviceable alternator. If no POWER FAILURE warning light illuminates, check the frequency at the synchronising bus-bar. If this is low, switch OFF the alternator carrying zero KW load. If the frequency is higher than normal, switch OFF the alternator carrying all the KW load. Check the loading of the serviceable alternator and reduce loads if necessary. The RAT should be selected in again when the failure has been investigated.

(c) High CSDU *temperature*

(i) The normal CSDU temperature is 40°-60°C. Any increase in temperature up to the maximum continuous operating limit of 95°C indicates a possible fault.

(ii) Should 95°C be reached, select the appropriate RAT intake open, if necessary transpose the loads and stop the appropriate frequency changer. Load shed or switch off the appropriate alternator and monitor its temperature. When the temperature returns within limits, reload or switch on the alternator and close the RAT intake.

(iii) If this action does not result in the temperature remaining at or below 95°C the engine should be flamed out as soon as practicable to minimise the fire risk and/or CSDU damage. If an electrical emergency exists or arises a CSDU oil temperature of 120°C may be accepted for up to 2 hours.

(iv) Operation of CSDU's at temperatures above 95°C results in a shorter life and must be reported on landing.

29 Double alternator failure on one side

NOTE: When both RAT's are extended the drag factor is such that range is cut by approximately 7%.

(a) Electrical faults on both alternators

(i) If two alternators on one system fail because of electrical faults, both POWER FAILURE warning lights will illuminate. The appropriate RAT scoop will open automatically and the opposite RAT should be selected open as a precautionary measure. The PFCU's supplied from the failed side will transfer to the RAT as its scoop opens, thus probably preventing it from running up to provide a useful output and resulting in the loss of use of these PFCU's. Check the voltage and current output of the LV battery on the failed side; if these are normal parallel the LV bus-bars to prevent excessive discharge.

(ii) In the event of failure of Nos. 1 and 2 alternators check that the frequency changer LOAD TRANSFER switch is on the No. 2 position and that the Standby Artificial Horizon supply is maintained. Switch the failed alternators to RESET and then OFF and check their individual outputs. If these are normal shed all switchable MV loads (e.g. hydraulic pump motors, fuel booster-pumps, frequency changer, ECM) before switching ON again. Reload as required, but do not re-synchronise.

(iii) If, on switching on again, one alternator re-trips, switch OFF and do not connect the serviceable alternator to the synchronising bus-bar. Re-load the serviceable alternator. Should one alternator show a fault condition on the voltage and frequency check, switch ON only the serviceable alternator, connect it to the synchronising bus-bar and re-load.

(iv) If both alternators show fault conditions leave their control switches selected to OFF. As soon as possible, descend to 20,000 feet, light the AAPP with the load selector selected to ELECT and connect to the bus-bars as required.

(v) The RAT's should be selected in again when the failure has been investigated.

(*b*) *Failure of two adjacent engines*

(i) If two adjacent engines fail, the appropriate RAT will open automatically as both engines decelerate below 52% RPM. However, if possible the RAT scoop should be manually selected open as a precautionary measure. The PFCU's will automatically be transferred to the RAT alternator bus-bar when the engine driven alternators come off line.

(ii) If the two port engines fail, the No. 1 T/R unit and No. 2 transformer will automatically be supplied from the port RAT alternator. Shed the appropriate switchable MV loads (e.g. frequency changer, hydraulic pump motors, fuel booster pumps, ECM, etc.) and, when the POWER FAILURE warning lights illuminate, switch off both the alternators.

(iii) If the two starboard engines have failed, the output of the starboard LV battery should be checked and the LV bus-bar paralleled.

(iv) If one or both engines are subsequently relit, switch ON the alternator(s), when the output is normal, reload as required and deparallel the LV bus-bars. Close the RAT intake as required.

(v) If neither is successfully relit, descend as soon as possible to a height at which the AAPP can be started. Start the AAPP with the load selector at ELECT, connect to the bus-bars as required.

(*c*) RAT *output*

The performance of the RAT's under their full electrical load is such that they will take over and support five PFCU's, one TRU and one 1 KVA transformer at the following altitudes and speeds:

165 knots at 55,000 ft.
170 knots at 50,000 ft.
175 knots at 45,000 ft.
190 knots at 30,000 ft.

NOTE: The starboard RAT solely supports five PFCU's.

30 Failure of four alternators

(*a*) The chance of four-alternator failure is considered remote, and the RAT alternators are not designed to cater for such a failure if it is caused by electrical faults. If a four engine flame out occurs the alternators will eventually come off line in underspeed regardless of aircraft speed. However, they may be kept on line for a limited period by descending at the highest practicable IAS/MN.

(*b*) (i) On warning of engine flame-out, immediately select both RAT intakes OPEN. Check that the TURBINE RUNNING lights illuminate and that the voltage and frequency outputs are normal (185v 370 CPS). Select main yaw damper to STANDBY, and the standby yaw damper ON if required.

(ii) Shed all non-essential electrical loads, in particular the LV loads of STR18, NBS and the VHF box not in use.

(iii) As the alternator POWER FAILURE warning lights illuminate, check that the RAT TURBINES ON LOAD lights illuminate and the voltage and frequency outputs are normal. Switch OFF the alternators.

(iv) If immediate attempts to relight the engines are unsuccessfull check load shedding of No. 2 T/R unit, ECM, hydraulic pump motors, frequency changers, NBS, Green Satin, fuel booster pumps, auto-pilot and all other non-essential loads.

(v) If the main engines are relit above maximum AAPP lighting altitude, switch on the appropriate alternators when output is normal, and check that the TURBINES ON LOAD lights go out. Switch on MV and LV loads and retract RAT intakes as required.

(vi) If the engines cannot be started above maximum AAPP lighting altitude, start the AAPP, check that its alternator output is normal and that the starboard TURBINES ON LOAD light goes out when the AAPP power magnetic indicator is horizontal. Switch on No. 2 T/R unit, fuel booster pumps as required and No. 2 hydraulic pump motor.

(vii) If a main engine or engines are subsequently relit switch ON the appropriate alternator(s) when the output is normal. Check the MV PARALLELING switch is at NORMAL, synchronise alternators and switch on MV and LV loads as required. Select standby YAW DAMPER to STANDBY and main yaw damper ON. Retract RAT scoops as required.

31 Failure of 115-volt 3-phase 400 CPS supplies

Failure of Nos. 1 and 3 transformers will only be indicated by failure of their associated equipment. Nos. 1, 2 and 4 transformers have no standby supplies. If No. 3 transformer fails, its loads may be transferred to No. 2 transformer by selecting the frequency changer LOAD TRANSFER switch to the No. 1 position. (Before doing so ensure that No. 1 frequency changer is running and its neon light illuminated.) If No. 2 or 4 transformers fail, the MFS at the appropriate pilot's position will fail, the MFS power failure warning light will illuminate and both attitude fail flags will come down.

32 Failure of a frequency changer

Failure of a frequency changer will be indicated by a failure of its neon indicator light and, if the LOAD TRANSFER switch is selected to the failed frequency changer, by failure of its associated equipment. Check that the other frequency changer is running and its neon indicator light is illuminated, or if necessary START the other frequency changer. Then select the LOAD TRANSFER switch to the other position. No. 2 frequency changer is normally in use (with No. 1 standing by). Selection of the LOAD TRANSFER switch to the No. 1 position will also cause the loads of No. 3 transformer to be transferred to No. 2 transformer. The pilots should be informed that both the 1st pilot's MFS and standby horizon are now being fed from No. 2 transformer.

33 Failure of a T/R unit

Failure of a T/R unit will be indicated by the voltage of the associated LV bus-bar falling to 24 volts or less and by the battery showing a discharge. The T/R unit magnetic indicator may be horizontal or vertical. If the indicator is horizontal switch OFF the T/R unit, check that battery voltage and amperage are consistent with its loads and select the LV PARALLELING switch to PARALLEL. Change the T/R unit control fuse and switch on. If the indicator remains horizontal switch OFF the T/R unit and leave it off. If the indicator returns to vertical, deparallel the LV bus-bar, switch ON the T/R unit and check its output is normal. If, when the failure occurred, the magnetic indicator was vertical, switch OFF the T/R unit, check that the battery output is normal and switch the LV PARALLELING switch to PARALLEL. For No. 1 TRU only, check fuse K1/CD to RAT supply c/o switch.

34 Failure of a special feeder

(*a*) Failure of a special feeder will be indicated by a number of the indicators on the generating panel BF changing to the striped indication. The appropriate special feeder indicator will show OFF and the associated LV VOLTS and LV CURRENT meters will read zero and the TRU and LV magnetic indicators will show cross-line. The appropriate RAT indicator will show a striped indication and the RAT scoop will extend automatically. Check the special feeder circuit breaker. If this is tripped switch OFF the associated LV battery and T/R unit. Switch off the affected services befor re-introducing the power supplies. Then reclose the circuit breaker. If the circuit breaker remains closed, the indicators should revert to their normal indications. Switch ON the battery and the T/R unit and switch on the services required. Select the RAT intake switch to

RETRACT. However, if the 1P8 circuit breaker trips a second time, select the LV PARALLELING switch to PARALLEL and switch on loads as required. If the 2P8 circuit breaker trips a second time no LV paralleling action can be carried out.

(*b*) Under these conditions the inoperative indicators will remain striped, the POWER FAILURE warning lights of the two associated alternators will be inoperative and two engine fire-warning lights and fire-extinguisher systems will be inoperative.

(*c*) If the special feeder circuit breaker was found to be closed reduce loads and switch the special feeder control switch to EMERGENCY. This should make the indicators on panel BF operative, and the special feeder indicator should read ON. Check the appropriate battery indicator and LV voltmeter. If the battery indicator is vertical and the LV voltage low or zero. switch off the battery and T/R unit and retract the RAT intake. Do not parallel the LV bus-bars as a bus-bar fault is indicated. Should the battery indicator be horizontal and the LV voltage normal when checked, a battery or battery-lead fault is indicated. The battery should be switched off and the RAT intake retracted.

35 LV battery fault

An LV battery fault will be indicated by the associated magnetic indicator showing horizontal. Select the appropriate special feeder to EMERGENCY and switch OFF the failed battery. Change the battery control fuse (No. 1—AJ/L10, No. 2—AJ/L16) and switch the battery ON. If the battery indicator shows vertical return the special feeder switch to NORMAL. If the battery indicator remains horizontal, switch the battery OFF and leave OFF.