

**PART 1**  
**CHAPTER 1—ELECTRICAL POWER SYSTEM**

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**CONTROLS AND INDICATORS**

1. Details of the controls and indicators of the electrical system are listed in Table 1 for the F Mk 3

and F Mk 6; see Table 2 for the T Mk 5. Table 3 deals with supply failure warnings. Fig 1 and 2 illustrate the positions of the controls and indicators in the single-seat aircraft and the T Mk 5 respectively.

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Table 1 — Electrical System Controls and Indicators — F Mk 3 and F Mk 6

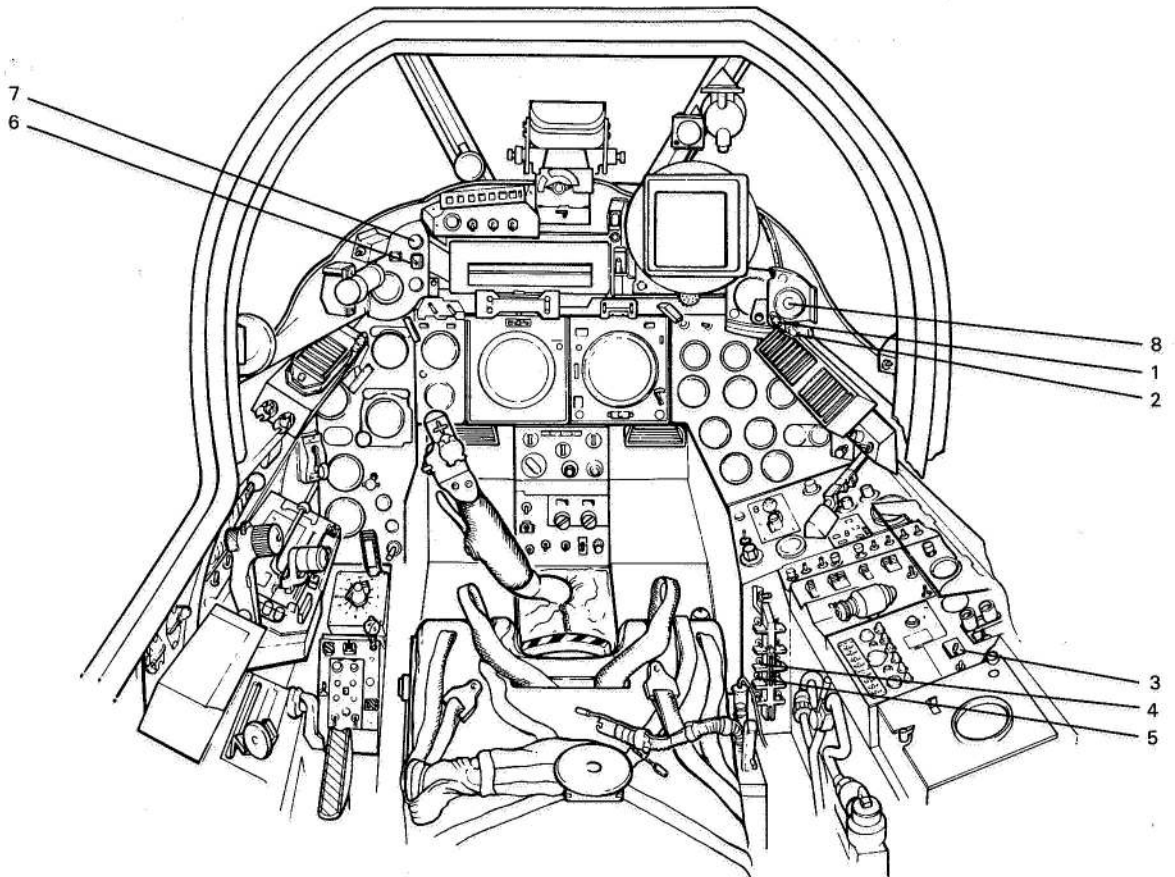
<i>Item No</i>	<i>Item</i>	<i>Markings</i>	<i>Remarks</i>
1	AC reset button	AC	—
2	DC reset button	GEN	—
3	Generator control switch	NORMAL/STBY/LIFT FOR EMERG	Guarded away from EMERG position
4	Battery switch	BATTERY	Up for on
5	Instrument master switch	INST MASTER	Up for on
6	Standby inverter switch	NORMAL/STANDBY INVERTER	—
7	Standby inverter MI	Black/ON	—
8	Voltmeter	See text	—

Table 2 — Electrical System Controls and Indicators — T Mk 5

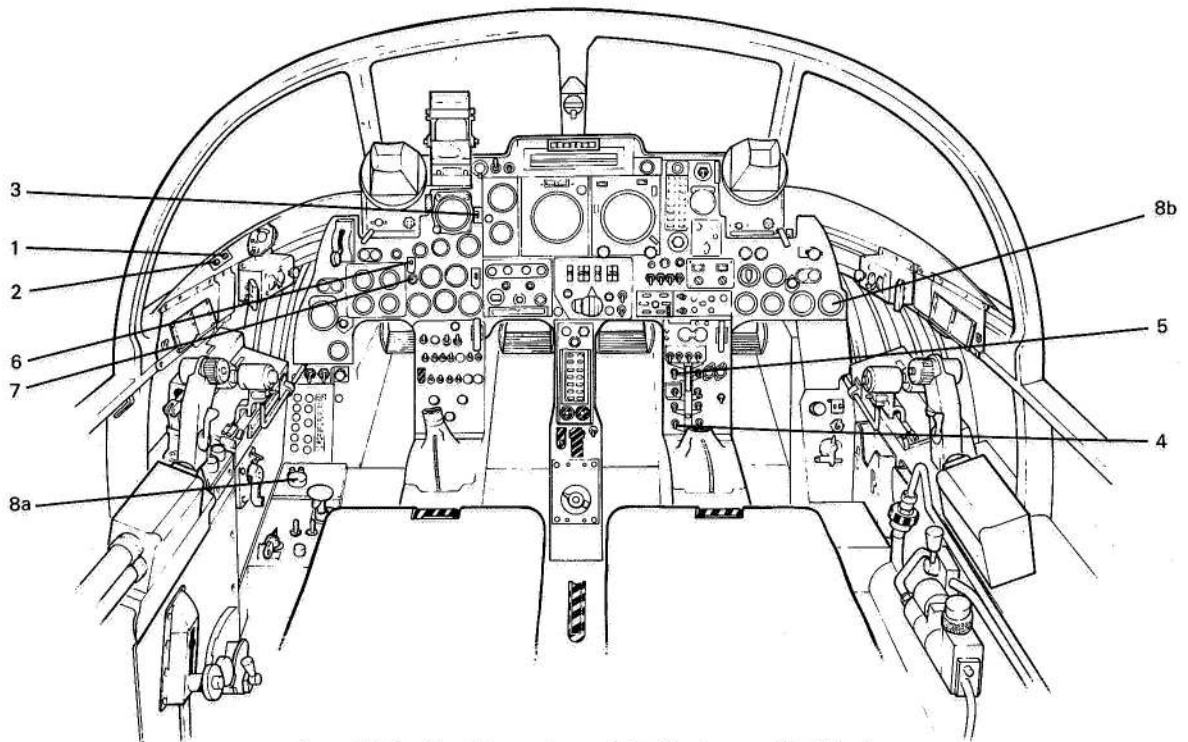
<i>Item No</i>	<i>Item</i>	<i>Markings</i>	<i>Remarks</i>
1	AC reset button	AC RESET — AC	—
2	DC reset button	RESET GEN — GEN	—
3	Generator control switch	GEN — NORMAL/STBY/EMERGY	Guarded away from EMERGY position
4	Battery switch	BATTERY — ON	—
5	Instrument master switch	INSTRUMENT MASTER — ON/OFF	—
6	Standby inverter switch	NORMAL/STANDBY INV	—
7	Standby inverter MI	Black/ON	—
8	Voltmeters	See text	Two indicators: a. Pupil b. Instructor

Table 3 — Supply Failure Warning Captions

<i>SWP</i>	<i>AWP</i>	<i>Effect of Indication</i>
GEN	GEN	Both generators off line
—	GEN	Main generator off line Standby generator on line
AP	AC	Alternator off line
AP	AC and TURB	Alternator main contactor tripped owing either to underspeeding of turbine or operation of nozzle stall switch
AP	AC, TURB, GEN	As for AC and TURB. Generator output reduced below 25.5 volts
GEN, AP	AC, TURB, GEN	Failure of main turbine and standby generator also off line or not selected



1-1 Fig 1 Controls and Indicators — F Mk 3 and F Mk 6



1-1 Fig 2 Controls and Indicators — T Mk 5

## DESCRIPTION OF THE SYSTEM

## General

2. The primary power supplies are provided by an alternator and a generator which are mounted on an air turbine motor driven by air tapped from the engine compressors. The alternator produces 200 volts, 3-phase, 400 Hz current to the AC busbar; the generator supplies 28 volts DC to the DC busbar.
3. A standby generator supplies 28 volts DC to the DC busbar when switched into service. It is driven by its own air turbine motor using air tapped from either or both engine compressors.
4. In the F Mk 3 and F Mk 6 a 24-volt, 18 amp hour battery is fitted; in the T Mk 5 the battery is also 24-volt but has a 35 amp hour life. In all three aircraft the battery is connected to the DC busbar by the BATTERY switch relay and it is charged by whichever generator is running providing the BATTERY switch is on. It provides standby power for all DC services and, via the DC busbar and an inverter, AC for certain AC-operated instruments and services. In the T Mk 5, control equipment automatically switches the battery out of the charging circuit at a given temperature until normal working temperatures prevail; however, if both generators fail with the battery off line, it is automatically restored to the DC busbar provided the BATTERY switch is on.
5. In the F Mk 3 and F Mk 6, a 24-volt, 0.4 amp hour emergency battery supplies emergency cockpit lighting (see Part 1, Chapter 9). In the T Mk 5 a 22.8-volt, 7 amp hour emergency battery supplies cockpit lighting, standby UHF radio power, and the standby artificial horizon and direction indicator when all other power sources have failed (see Part 1, Chapters 7 and 13). The emergency batteries are not connected to the DC busbar and are not charged from the aircraft system.
6. Switching for both AC and DC operated services is 28-volt DC controlled.

## Air Turbine Motor

7. The air turbine motor is supplied with high pressure bleed air from a duct fed by the 15th stage of both engine compressors. When the air supply is sufficient, motor speed is controlled by an integral governor so that alternator output is maintained at a constant frequency. The motor incorporates three automatic switches:

- a. *Overspeed Switch.* If turbine speed becomes excessive, the overspeed switch operates to close the

main turbine shut-off cock which takes the main generator and alternator off line. The shut-off cock can only be reset on the ground (see Fig 4).

- b. *Nozzle Stall Switch.* If bleed air pressure falls below the minimum value to maintain turbine speed, the nozzle stall switch operates to bring on the TURB caption on the AWP and open the alternator contactor (AC caption on AWP). The switch resets and AC can be restored when bleed air pressure increases.

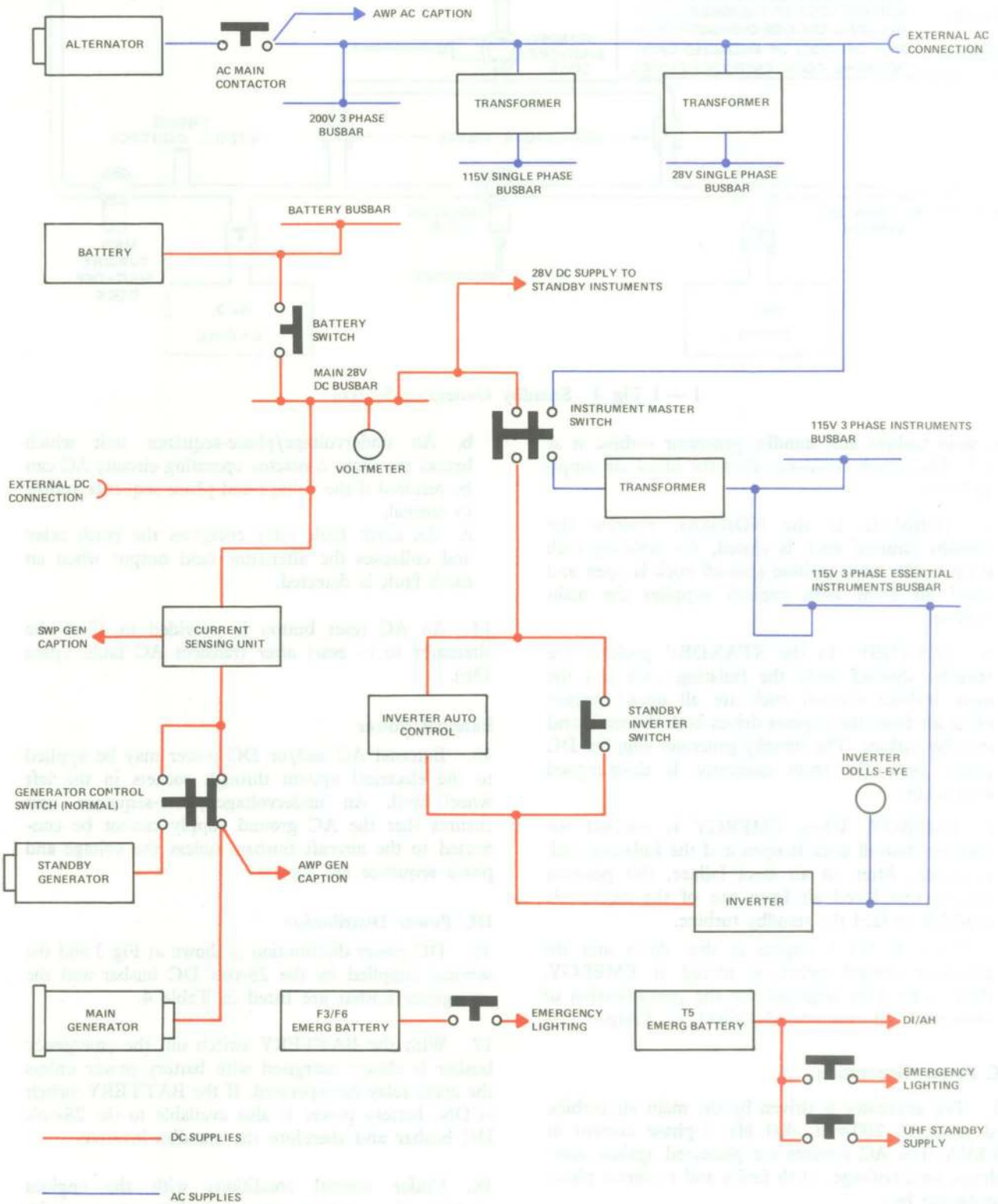
- c. *Underspeed Switch.* If the nozzle stall switch fails to operate as turbine speed decreases, the underspeed switch acts to disconnect the alternator and bring on the TURB caption. AC power can be reset when the turbine speed is at a correct value.

## DC Power Generation — Main Generator

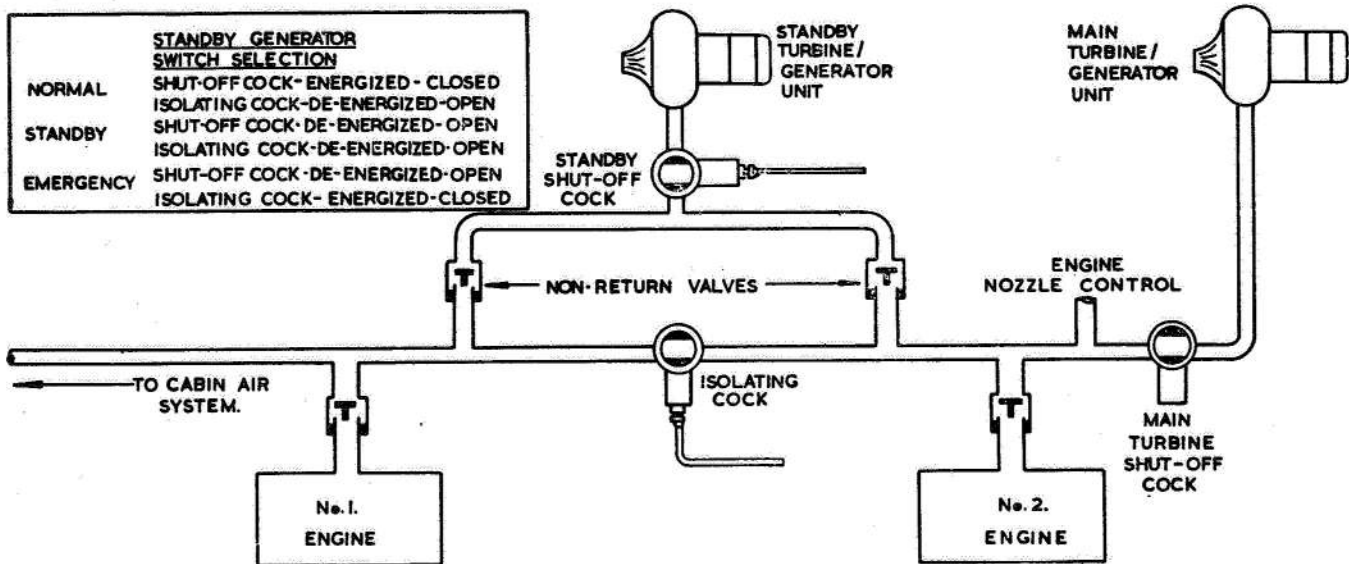
8. The primary source of DC power is the brushless main generator which produces  $28 \pm 0.5$  volts, 200 amp current for the DC busbar. Its output is automatically monitored by a control and protection unit (CPU). A fuse provides further protection.
9. The CPU incorporates overvoltage and undervoltage protection circuits. If the turbine is running at normal speed and the voltage rises above  $30.5 \pm 0.5$  volts, or if the voltage produced drops below  $25.5 \pm 0.5$  volts, the generator is shut down. If an undervoltage is caused by the turbine underspeeding, the CPU lights the GEN caption on the AWP but does not shut down the generator immediately. Pressing the DC reset button resets the generator after a transient failure.
10. The generator comes on line automatically when an engine is accelerated through approximately 40% RPM and it achieves full output at about 50% RPM. When the RPM of both engines falls below approximately 35% the generator is taken off line as the turbine underspeeds.

## DC Power Generation — Standby Generator

11. The standby generator supplies a maximum output of 2.8 kW (100 amp) at 28 volts to the DC busbar. Its operation is controlled by the generator control switch.
12. Selecting the 3-position generator control switch from NORMAL to STANDBY or EMERGENCY de-energises the main generator contactor and the main generator is disconnected from the DC busbar. A diagram showing the routing of the air supplies to



1-1 Fig 3 Electrical Power Distribution



1-1 Fig 4 Standby Generator System

the main turbine and standby generator turbine is at Fig 4. The switch positions affect the bleed air supply as follows:

a. **NORMAL.** In the **NORMAL** position the standby shut-off cock is closed, the isolating cock is open, the main turbine shut-off cock is open and bleed air from both engines supplies the main turbine.

b. **STANDBY.** In the **STANDBY** position the standby shut-off cock, the isolating cock and the main turbine shut-off cock are all open: engine bleed air from the engines drives both the main and standby turbine. The standby generator supplies DC power since the main generator is de-energised electrically.

c. **EMERGY.** When **EMERGY** is selected the standby shut-off cock is open and the isolating cock is closed. After an air duct failure, this position ensures that bleed air from one of the engines is available to feed the standby turbine.

Note: If No 1 engine is shut down and the generator control switch is placed at **EMERGY**, there is no 15th stage air for the pressurisation or associated air systems described in Chapter 10.

### AC Power Generation

13. The alternator is driven by the main air turbine and produces 200-volt, 400 Hz, 3-phase current at 20 kVA. The AC systems are protected against over-voltage, undervoltage, earth faults and incorrect phase sequencing by:

a. An overvoltage relay which de-energises the alternator field. This relay can only be reset by shutting down the main air turbine.

b. An undervoltage/phase-sequence unit which breaks the main contactor operating circuit; AC can be restored if the voltage and phase sequence return to normal.

c. An earth fault relay energises the crash relay and collapses the alternator field output when an earth fault is detected.

14. An AC reset button is provided to allow the alternator to be reset after transient AC faults (para 13b).

### External Power

15. External AC and/or DC power may be applied to the electrical system through sockets in the left wheel well. An undervoltage/phase-sequence unit ensures that the AC ground supply cannot be connected to the aircraft busbars unless the voltage and phase sequence are correct.

### DC Power Distribution

16. DC power distribution is shown at Fig 3 and the services supplied by the 28-volt DC busbar and the emergency busbar are listed in Table 4.

17. With the **BATTERY** switch off, the emergency busbar is always energised with battery power unless the crash relay has operated. If the **BATTERY** switch is ON, battery power is also available to the 28-volt DC busbar and therefore the standby inverter.

18. Under normal conditions with the engines running, the main generator supplies power to the 28-volt DC busbar and, providing the **BATTERY** switch is ON, to the emergency busbar, thus charging the battery. When the generator control switch is

selected away from NORMAL to STANDBY or EMERGENCY, the main generator is electrically disconnected and the standby generator supplies power to the system in the same way as the main generator.

#### AC Power Distribution

19. AC power distribution is shown in Fig 3. Alternator or external 200-volt, 3-phase current is fed direct to a busbar for services requiring that power. 115-volt, single-phase and 28-volt, single-phase transformers supply separate busbars. A 115-volt, 3-phase transformer supplies two busbars through the INSTRUMENT MASTER switch, one of which is protected after AC failure by an inverter connected to the 28-volt DC busbar. The standby inverter starts automatically when 115-volt, 3-phase power fails or when the standby inverter switch is moved from NORMAL to STANDBY providing the INSTRUMENT MASTER switch is ON. The services associated with the five AC busbars are listed in Table 5.

#### Voltmeters

20. In the F Mk 3 and F Mk 6 a voltmeter is fitted to the right cockpit shroud. In the T Mk 5 two voltmeters are fitted, one on panel A2 and the other on the right of panel A1. The voltmeters show 28-volt DC busbar voltage. Each indicator is divided into a red sector for voltages of 15 to 22 volts, an amber sector for voltages between 22 and 25, a white sector for voltages between 25 and 29 and a further red sector for voltages above 30 volts.

#### Inertia Crash Switches

21. Two inertia crash switches are fitted, connected in series. When both inertia switches operate the following automatic events occur:

Battery isolation	} field circuits interrupted
Main generator	
Standby generator	
Alternator	
Both fire extinguishers operate	

### MANAGEMENT OF THE SYSTEM

#### Starting

22. Before starting, the generator control switch is to be set at NORMAL. Normally, both AC and DC external power is connected for starting.

23. Prior to starting, the external AC supply may be used to warm up the AI equipment, which requires a total of five minutes on external and/or internal power before becoming operational. If the AC power

supply is broken during the 5-minute warm-up period the cycle must be recommenced.

24. With a ground DC supply connected, the GEN caption on the AWP goes out when the main contactor closes but the GEN warning on the SWP may remain lit depending on the relative outputs of the aircraft and ground supply; if the SWP warning remains on, it goes out when the external supply is removed.

25. Up to 70% RPM may be required to extinguish the TURB and AC captions. Thereafter run No 2 engine at 58% RPM or above to maintain AC supplies, except during the standby generator check.

26. If an external DC supply is not connected, the battery supports all the DC loads, including the engine starting and standby inverter loads. After starting, the GEN caption on the SWP goes out when the generator output is between 15 and 25 amps, followed by the GEN caption on the AWP when the voltage increases to 25.5 volts, indicating that the generator has accepted the load.

27. With no external AC supply, the standby inverter automatically starts up when the BATTERY and INSTRUMENT MASTER switches are selected ON. See Part 1, Chapter 7 regarding MRG starting in this situation.

28. When both engines have been started and the external supply disconnected, check the function of the standby generator as follows:

a. On the first sortie of the day set the No 1 and No 2 engines at 65% and 50% RPM respectively (on subsequent sorties set idle/fast idle). Check TURB, AC and both GEN warnings are out.

b. Select the generator control switch to STBY. The GEN caption on the AWP comes on indicating that the main generator has gone off line. The GEN warning on the SWP comes on momentarily, the voltmeter records a slight fall and the attention-getter and audio warning operate prior to the standby generator coming on line, when the SWP GEN caption goes out. Check the voltmeter reads 28 volts.

Note: If the SWP GEN caption does not come on momentarily after selecting STBY, the standby generator was operating prior to the selection.

c. Reselect the generator control switch to NORMAL and check both GEN warnings are out and the voltmeter reads 28 volts.

d. Increase No 2 engine to 58% RPM and then return No 1 engine to idle.

**In Flight**

29. The air turbine maintains sufficient speed to hold the alternator on line and develop full generator output at or above 58% RPM, which corresponds to idling RPM at approximately 250 knots at 15,000 feet. At idle RPM below this altitude, the air turbine speed reduces, the alternator drops off line and the GEN warning appears on the AWP.

30. To prevent oil starvation in the air turbine gearbox, negative g flight is not to be sustained for longer than 15 seconds.

31. Periodically during flight, check that the voltmeter pointer indicates in the white sector.

32. Owing to limited equipment cooling, the standby generator is not to be used unless the main generator fails.

**After Landing**

33. During the **Checks after Landing**, select the No 2 engine to fast idle (58% RPM) to keep the AC on line during single-engine taxiing. In dispersal switch OFF the MRG before shutting down the No 2 engine and then ensure that all electrical services are off before switching off the BATTERY. The items listed in Table 4 under the heading Battery Busbar are on line with the engines shut down and the battery switch off.

**MALFUNCTIONS OF THE SYSTEM****AC Failure**

34. *Indications.* AC failure is indicated by the AC warning on the AWP and the AP warning on the SWP; the standby inverter MI shows ON and most of the AC services listed in Table 5 are lost.

35. *Actions.* Cancel reheat and press the AC reset button; further attempts may be made at 2- to 3-minute intervals if the first is unsuccessful. If AC power cannot be restored, land as soon as practicable. The standby inverter supplies the Essential Instrument services listed in Table 5 and the standby artificial horizon and direction indicator continue to run on DC power, but all other AC services are lost. The full drill is to be found in FRC.

36. *Intermittent AC Failure.* If intermittent AC failure occurs, an output surge from the JPT controllers may occur at engine temperatures above 550°C, resulting in a reduction of fuel flow to the engines and a consequent transient loss of thrust. Therefore, if the AC supply becomes intermittent or

if repeated operation of the AC reset button is necessary, switch OFF the JPT controllers and maintain the engine within limits manually.

**Generator Failure**

37. *Indications.* Failure of the main generator is indicated by the GEN captions on the SWP and AWP; the voltmeter indicates battery voltage.

38. *Actions.* Attempt to regain the main generator by pressing the DC reset button. If this is not successful, select STBY on the generator control switch. When the standby generator comes on line, the GEN caption on the SWP goes out and all DC services are normal. The GEN caption on the AWP remains on. Monitor the voltmeter. Land as soon as practicable.

**Double Generator Failure**

39. If the standby generator fails to come on line, both GEN captions remain lit. All DC services are borne by the battery, which may be relied upon to provide normal DC services whilst the voltmeter reads above 22 volts. Once below 22 volts the battery discharges rapidly. When the battery fails, all AC and DC services are lost except those supplied by the emergency battery. The drill is given in the FRC.

40. *Load Shedding.* A guide to load-shedding is also given in the FRC. It is important to switch off the DC pumps and to leave them off, and to select the UHF and UHF power to STANDBY and the main set OFF. When load-shedding is complete, minimise the use of the remaining services, eg, restrict radio transmissions to a minimum and avoid constant/instinctive use of trim; consideration should be given to switching OFF the pitot heaters if conditions permit. Do not use the ILS unless essential.

41. *Recovery and Landing.* If range is not critical, descend to VMC below cloud. If range is critical, cruise at optimum altitude until the voltmeter reads 23 volts and then descend. With the DC pumps switched OFF there is a danger of fuel starvation; increase attitude to 7° nose up for 15 seconds half-way down the descent and maintain a nose-up attitude whenever possible once at low altitude. Approximately 100 lb/side of gauged fuel is unusable with the DC pumps OFF. If practicable lower the flaps, and the undercarriage on the normal system, before the voltage drops below 22 volts. (The undercarriage can always be lowered on the emergency system but there are no undercarriage position indications if the battery has failed.) Land as soon as possible.

42. *Battery Failure.* When the battery fails, all electrical flight instruments are lost except in the T Mk 5, where the emergency battery supplies the standby

artificial horizon and the direction indicator. In all marks, emergency lighting is also available until the standby battery fails. The major electrical services lost are listed in the FRC. However, in VMC the aircraft may still be landed after lowering the undercarriage on the emergency system; flaps and airbrakes are not available unless previously extended but the braking parachute and wheelbrakes operate.

#### Generator Overvolting

43. If the main generator produces more than  $30.5 \pm 0.5$  volts, it is taken off line automatically. However, if a sustained voltage of 30 volts or more is indicated and the CPU fails to take the main generator off line, select STBY on the generator control switch and check that the voltage settles at 28 volts as the standby generator takes over. The GEN caption appears on the AWP. No DC services are lost. Monitor the voltmeter.

44. If, subsequently, the standby generator should also overvolt, return the generator control switch to NORMAL and isolate the battery from the overvoltage from the main generator by selecting the BATTERY switch off. The GEN caption on the AWP goes out. Put the BATTERY switch on again in the circuit prior to landing.

45. If, with the BATTERY switch off to protect the battery from overvolting, the main generator is switched out by the CPU, the standby shut-off cock automatically opens because there is no power to hold it closed with the battery off, and the standby generator runs up. When the standby generator comes on line, the standby shut-off cock is energised closed, the standby generator runs down and comes off line. The standby generator cycles on- and off-line every two seconds giving symptoms of electrical oscillations or power surges. Selecting the generator control switch to STBY holds the standby shut-off cock open when power is next applied to the DC busbar and the standby generator stays on line.

#### Main Air Turbine Malfunctions

46. Illumination of the TURB caption on the AWP indicates either that the turbine is underspeeding or that it has failed completely. In the latter case the failure may have been caused by an automatic shut-down after an overspeed condition or by mechanical failure. However, the TURB caption does not come on in isolation and the additional indications show the nature of the turbine failure. The indications and remedial actions are as follows:

a. *Underspeed.* The turbine underspeeds when insufficient bleed air is available to maintain the necessary turbine RPM. As the turbine speed falls

through a critical value, the TURB and AC captions on the AWP and the AP caption on the SWP come on and AC failure is experienced. The audio warning and attention-getter operate. If the turbine speed reduces further, the generator undervolt relay acts to bring on the GEN caption on the AWP and the battery is discharging. Increasing the engine power restores the turbine to its correct operating speed and the warnings go out.

b. *Overspeed or Turbine Failure.* If the turbine fails, or if it overspeeds and is automatically shut down, the TURB, AC and GEN captions on the AWP, and the GEN and AP captions on the SWP all come on, together with the audio warning and attention-getter. Selecting the generator control switch to STBY starts the standby generator (SWP GEN caption out) and restores DC to normal, but all AC services are lost except those served by the standby inverter via the Essential Instruments busbar (Table 5). The standby artificial horizon and direction indicator continue to run on DC power. The drill for recovery and landing is given in the FRC. After an overspeed and automatic shut-down, the main turbine cannot be restarted in the air.

#### Burst Air Duct

47. A rupture of the air duct carrying bleed air to the main turbine is indicated by the TURB, GEN and AC captions on the AWP and the GEN and AP captions on the SWP together with audio warning and attention-getter (identical to warnings given for a turbine overspeed or failure). However, with a burst air duct, pressurisation is lost (and the CPR caption on the AWP comes on at altitude), loss of jet pipe nozzle control may occur and hot air leaking from the duct may trigger the fire warnings. Nevertheless, the failure may also manifest itself simply by a loss of thrust without the attendant warnings.

48. If the nozzles are at the fully open position and loss of thrust has occurred, ensure that both engines are running and then select EMERGENCY on the generator control switch. The isolating cock in the air duct between No 1 and No 2 engine closes (see Fig 4), the standby shut-off cock opens, and the standby generator comes on line to restore DC electrical supplies.

49. The position of the rupture in the air duct can now be identified by reference to Fig 4:

a. *Rupture on No 1 Engine Side.* If the burst has occurred on No 1 engine side of the isolating cock, pressurisation failure remains but nozzle control is regained; the main turbine speeds up and the TURB caption goes out if a minimum of approximately 65% RPM is maintained on No 2 engine.

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AC power is available from the alternator, and the standby generator continues to provide DC power. Leave the generator control switch at the EMERGENCY position to maintain the isolated situation. Note that if No 2 engine is shut down complete electrical failure occurs and nozzle control is lost on No 1 engine.

b. *Rupture on No 2 Engine Side.* If the burst is on No 2 engine side of the isolating cock, nozzle control is lost and the alternator cannot be regained. Experience suggests that the nozzles can be expected to remain in the position they were at the time of the failure of the air supply. However, there is a remote possibility that they may blow open under exhaust gas pressure.

Table 4 — DC Distribution

28V DC Busbar	
Airbrake control and indication	LFS
Armament circuits	Lighting:
AI circuits	Cockpit and anti-dazzle
Artificial horizon (standby power)	4-volt IFIS control
Auxiliary warning system	Navigation
Brake parachute jettison	Anti-collision
Brake pressure gauge	Taxy
Camera and AI recorder control	Missile telemetry switching (Mk 5)
Cockpit air control	Nozzle position indicator
Cockpit temperature control (manual)	Overwing tank fuel dumping
Direction indicator (standby power)	Oxygen air-mix valve (Mk 5)
Engine and duct anti-icing	Oxygen contents and flow
Engine starting and relighting	Radar altimeter (Mk 3 and Mk 6)
Feel cut-out	Radio
Flap control and indication	Radio compass (if fitted)
Flight control system	Rain dispersal control
Fuel:	Reheat system
Transfer pumps	Seat height adjustment
LP cocks	Standard warning system
Gauge tests	Standby generator control
AAR	Tacan
Heaters:	Trims:
Pitot and Vent Valve control	Control and indication
Pitot (standby)	Tailplane auto trim
Ice warning system (inoperative)	Undercarriage:
IFF	Control (normal)
ILS	Indication
Inverter supply and control	Ventral emergency transfer (Mk 6)

24/28V DC Emergency (Battery) Busbar

Canopy:	Missile jettison
Operation	Refuelling
Audible warning	Telebriefing
Fire extinguishers	
Inertia crash switches	

Table 5 — AC Distribution

<i>200V, 3-Phase AC Busbar</i>	
AI 23	Spraymat
Canopy blower motor	Ventral fuel pump (Mk 6)
Data link	Windscreen heaters (centre and side)
Missile supply	
<i>115V, 3-Phase AC Instrument Supply</i>	
Note: These services are <i>not</i> transferred to the standby inverter after AC failure; however, the DI and standby artificial horizon have alternative DC sources.	
Air data computer:	Direction indicator (DI)
Height	FCS control
Strip speed	JPT
Vertical speed	Standby artificial horizon
<i>115V, 3-Phase AC Essential Instruments Busbar</i>	
Note: These services are transferred to the standby inverter after AC failure.	
Cockpit temperature control (auto)	Fuel contents
Fire detection	MRG (attitude and navigation display)
<i>115V, Single-Phase AC Busbar</i>	
IFF	Spraymat (auto)
Radar altimeter (Mk 3 and Mk 6)	Tacan
<i>28V, Single-Phase AC Busbar</i>	
Heaters:	Services pressure gauge
Pitot (main and standby) (normal)	
Vent valves (normal)	

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